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ul. Kawęczyńska 36, 03-772 Warszawa,
wsm.warszawa.pl, tel. 22 59 00 700,
e-mail: ptps@mac.edu.pl

Warsaw Management University
36 Kawęczyńska St., 03-772 Warsaw, Poland,
wsm.warszawa.pl, phone: +48 22 59 00 700,
e-mail: ptps@mac.edu.pl

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Adres redakcji

03-772 Warszawa

ul. Kawęczyńska 36
pok. A 306

tel. 22 59 00 828

fax: 22 59 00 774

e-mail: ptps@mac.edu.pl

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TECHNOLOGICAL PROGRES IN FOOD PROCESSING

Komunikat
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Czasopismo recenzowane
Wyższej Szkoły Menedżerskiej w Warszawie

Uzyskanie recenzji uznanych specjalistów krajowych
i zagranicznych dofinansował Wydawca

Founded in 1992 / Istnieje od 1992 r.

Until 2003 it was published by Institute of Food Machines / Do 2003 r. wydawane przez Instytut Maszyn Spożywczych

It is a scientific journal presenting international studies of progress in the food industry, including research articles, development studies, implementations, as well as review articles, including the area of food engineering, organization and technology of production, development, construction, exploitation of food machines, as well as food processing management.

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OD REDAKCJI

Przed nami lato, urlopy i nadzieja na lepsze jutro.

Za nami sześćdziesiąty numer „Postępów Techniki Przetwórstwa Spożywczego".

Ponad trzydzieści lat działamy na rynku naukowych wydawnictw periodycznych, promując postęp techniczno-technologiczny w przetwórstwie spożywczym. Publikujemy jedynie oryginalne, podwójnie recenzowane artykuły naukowo-badawcze, badawczo-rozwojowe i analityczno-przeglądowe. Recenzje w większości zostały uzyskane od naukowców zagranicznych.

Dotychczas opublikowaliśmy ponad 1200 artykułów. W bieżącym numerze znajdą Państwo 25 artykułów. Trudno jest omówić każdy z nich, choć wszystkie są interesujące, dlatego sygnalizuję tylko niektóre.

Z badań audytowych przeprowadzonych w polskich zakładach mięsnych przez pracowników Instytutu Nauk o Żywieniu Człowieka SGGW w Warszawie wynika, że dostawcy przypraw zaopatrują zakłady mięsne w produkty bezpieczne, wytworzone w odpowiednich warunkach i przy pełnej kontroli procesu produkcyjnego.

Pracownicy Instytutu Nauk o Żywności SGGW w Warszawie w wyniku badań otrzymali folie jadalne na bazie wytłoków jabłkowych oraz pektyny jabłkowej w połączeniu z puree z warzyw pochodzących z mrożonego wysortu warzywnego z kalafiora, brokułu, żółtej i zielonej fasolki szparagowej. Wytworzone folie warzywne mogą znaleźć zastosowanie w projektowaniu nowych produktów m. in. jako bezglutenowe przekąski warzywne lub powłoki funkcjonalne do batonów owocowo-warzywnych.

Doświadczenie badawcze przeprowadzone w Instytucie Nauk o Żywieniu Człowieka SGGW w Warszawie pozwoliło na wybranie spośród 5 szczepów probiotycznych i potencjalnie probiotycznych – szczepu *Lactobacillus plantorum 299v*, który umożliwia uzyskanie deseru kokosowego o najwyższych notach w ocenie sensorycznej.

Na podstawie analizy badań zamieszczonych w literaturze Instytut Nauk o Żywności SGGW w Warszawie stwierdził, że dodatek proszku z suszonych wytłoków owocowych kształtuje jakość produktów piekarsko-ciastkarskich, mlecznych i mięsnych, ze szczególnym uwzględnieniem wartości odżywczej, tekstury oraz aspektu środowiskowego liofilizowanych przekąsek.

Świeże mleko oraz uzyskane z niego mleczne napoje fermentowane, poprzez zawarte w nich bogate niezbędne składniki odżywcze, korzystnie oddziaływują na zdrowe kości, obniżają ciśnienie krwi, a także zapobiegają chorom metabolicznym – twierdzi pracownik Instytutu Nauk o Żywieniu Człowieka SGGW w Warszawie po przeprowadzeniu analizy odstępnych materiałów badawczych.

O korzyściach i zagrożeniach wynikających z zastosowania w przemyśle spożywczym i gospodarstwach domowych ogrzewania mikrofalowego informują pracownicy Instytutu Nauk o Żywieniu Człowieka SGGW w Warszawie.

Nowe substancje słodzące zalecane Rozporządzeniem Parlamentu Europejskiego i Rady (EU) 2015/2283 w sprawie nowej żywności, nie podnoszące szybko poziomu glukozy we krwi i powodujące mniejsze wydzielanie insuliny w porównaniu z glukozą to: izomaltuloza, D-tagatoza, trehaloza i sukromalt, czytamy w kolejnym artykule pracowników SGGW w Warszawie.

O możliwości funkcjonowania przetwórni spożywczych jako uczestników Klastrów Spożywczych dowiadujemy się z lektury artykułu pracownika Wyższej Szkoły Menedżerskiej w Warszawie.

Zachęcam do lektury wszystkich artykułów.

Dziękujemy Autorom krajowym i zagranicznym, Recenzentom, Członkom Rady Redakcyjno-Programowej oraz Zespołowi Redakcyjnemu i zachęcam zarówno Ich, jak też nowych Autorów i Recenzentów do współpracy z naszym Czasopismem.

REDAKTOR NACZELNY

Mgr inż. Katarzyna JAKUBOWSKA-GAWLIK[1]
Mgr Surya S. NAIR[1,2]
Mgr Aparna P. MURALI[1,3]
Prof. dr hab. Ewa CZARNIECKA-SKUBINA[1]
Dr hab. Joanna TRAFIAŁEK, prof. SGGW[1]
[1]Zakład Technologii Gastronomicznej i Chemii Żywności
Katedra Technologii Gastronomicznej i Higieny Żywności
Instytut Nauk o Żywieniu Człowieka
Szkoła Główna Gospodarstwa Wiejskiego w Warszawie – SGGW, Polska
[1]Chair of Food Gastronomy and Food Chemistry
Department of Food Gastronomy and Food Hygiene
Institute of Human Nutrition Sciences
Warsaw University of Life Sciences – WULS, Poland
[2]Malayalam Exports South Vellarappilly P.O. Sreemoolanagaram, Aluva
Ernakulam District, 683580, Kerala, India
[3]Future tech foods India Pvt Ltd.,
202, Phatak Park Apartments, Behind Kalyan Jewellers, Nal Stop,
Karve Road, Pune, Maharashtra India 411004

EVALUATING OF SPICES SUPPLIERS FOR MEAT PRODUCTION PLANTS®

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Key words: meat plants, spices supplier, suppliers evaluation.

The aim of the study presented in the article was to verify whether the suppliers of spices for the production of meat products meet all food safety requirements. For this purpose, 10 audits of spice suppliers were carried out using the audit method with a plant-specific questions checklist. It was found that monitoring the quality management system of suppliers allows for their good control and obtaining the appropriate quality, safe raw material for production. Based on the conducted audits, it was found that the suppliers of spices provide the meat plant with a safe products, produced in appropriate conditions and with full control of the production process. The research carried out in functioning meat plants is presented which have big implication importance to the theory and practice as well as for future studies.

Słowa kluczowe: zakłady mięsne, dostawcy przypraw, ocena dostawców.

Celem badań przedstawionych w artykule było sprawdzenie czy dostawcy przypraw do produkcji wyrobów mięsnych przestrzegają wszystkich wymogów bezpieczeństwa żywności. W tym celu przeprowadzono 10 audytów u dostawców przypraw, wykorzystując metodę audytu z opracowaną do specyfiki zakładu listą kontrolną pytań. Stwierdzono, że monitorowanie systemu zarządzania jakością dostawców pozwala na ich dobrą kontrolę i uzyskanie właściwej jakości, bezpiecznego surowca do produkcji. Na podstawie przeprowadzonych audytów stwierdzono, że dostawcy przypraw dostarczają do zakładu mięsnego produkty bezpieczne, wytworzone w odpowiednich warunkach i przy pełnej kontroli procesu produkcyjnego.

Przedstawione badania przeprowadzone w funkcjonujących zakładach mięsnych mają duże znaczenie dla teorii i praktyki oraz przyszłych badań.

INTRODUCTION

Despite the many beneficial properties of spices, they can pose a threat to human health. Spices as a product of agricultural practice can carry high numbers of microorganisms as well as mycotoxins. Microorganisms detected in herbs and spices have the potential to cause human illnesses. Among the most important microorganisms are *Bacillus cereus*, *Clostridium perfringens*, *Escherichia coli*, *Salmonella* spp., *Listeria monocytogenes, Staphylococcus aureus* and bacilli of the family *Enterobacteriaceae* [5,10,11,15,30,32,36]. The most common fungi detected in spices are *Fusarium, Rhizopus, Penicillium, Aspergillus* (e.g. Aspergillus spp.), and bacteria of the genus *Bacillus* [25], and *Cronobacter* species bacteria [15].

The degree of contamination of spices depends on factors such as: growing, harvesting, storage and transport conditions.

Corresponding author – Adres do korespondencji: Joanna Trafiałek, Warsaw University of Life Sciences, Institute of Human Nutrition Sciences, 02-787 Warsaw, str. Nowoursynowska 166, Poland; e-mail: joanna_trafialek@sggw.edu.pl; https://orcid.org/0000-0001-5839-1786; phone: +48 22 593 70 82

Based on research results, it is known that contaminated spices have been the causes of certain food-borne illnesses and food spoilage [2]. Poor quality of spices causes a variety of food hazards, including pathogens, chemical contaminants, and pests [1, 33, 38, 50, 51].

Prevention of microbial contamination in dried herbs and spices lies in the application of good hygiene practices during production cycle i.e. growing, harvesting and processing from farm to fork, and effective decontamination [35]. Effective control and knowledge about the methods of quality assurance at the producers and suppliers of spices and about the quality management systems used by them is a prerequisite for the use of spices in the food sector [31]. Spice producers have to ensure food safety [34], and also have certified quality management systems such as ISO 9001, ISO 22000, BRC, IFS. Whereas, the recipients of spices, e.g. meat plants, monitor the quality of the spices supplied, and the quality management systems used in their production. Supplier monitoring is a requirement of the standards they have implemented [7, 17, 19, 20]. Various methods of supplier evaluation are described in the literature, and the most frequently used method is audit [21, 46, 52].

The aim of the study was to verify whether the suppliers of spices for the production of meat products meet all food safety requirements.

MATERIAL AND METHODS

The study examined the results of audits carried out in 2021 by one of the largest meat processing plants in Poland. The audit methodology was based on the guidelines given in ISO 19011 [18] and the plant's own internal audit procedure. The research is a continuation of the evaluation of spice suppliers in terms of the assessment of compliance with food safety requirements in the years 2007–2019 [22].

The analysis of the monitoring results showed that not all requirements were fully met. In the previous research, a forecast was calculated that indicated that all the requirements of supplied spices would be met in 2021. The authors

Table 1. Checklist of spices suppliers audit

Tabela 1. Lista kontrolna audytu dostawców przypraw

No.	Question	Abbreviation	Score (1-4)
1	Is a qualifying questionnaire employed and is the information so obtained verified and monitored?	Supplier assessment	
2	Is there an established organisational policy and a process of continuous improvement?	Organisational policy	
3	Are the (GMP, GHP, HACCP) principles understood, and are the relevant procedures, internal audits, training programmes established, implemented and functioned?	HACCP	
4	Is monitoring of raw material purchasing (quality, delivery, origin) taking place?	Purchasing	
5	Is the specification of products (ingredients, recipe, packaging) checked and controlled?	Specification of products	
6	Is product design and development taking place and does this result in product and process modification?	Product design and development	
7	Is the release of the products is carried out properly?	Product release	
8	Are proper procedures in place to ensure traceability, particularly of allergens and GMO?	Traceability	
9	Are corrective actions and correction undertaken; occurrences of non-compliance managed and non-compliant products processed?	Corrective actions	
10	Is the location and immediate environment of the plant appropriate?	Location	
11	Is the layout of the plant, and workflow appropriate?	Plant layout	
12	Is the equipment in production and storage areas kept in a good state?	Equipment	
13	Are measuring and monitoring devices maintained, repaired, calibrated and controlled?	Monitoring devices	
14	Are utilities (water, ice, air, gases, and other services) professionally procured and controlled?	Utilities	
15	Is equipment for personnel hygiene provided and are suitable social facilities available?	Personnel hygiene facilities	
16	Are appropriate hygiene practices, medical examinations, procedures for infectious diseases and work injuries in place?	Personnel hygiene procedures	
17	Is protective clothing for the use of personnel and visitors available and appropriate?	Protective clothing	
18	Is hygiene maintained in the plant and immediate surroundings; are appropriate processes in place for washing, disinfection, waste management, and pest control?	Plant hygiene	
19	Is the production process properly carried out, and are all the necessary parameters monitored and controlled?	Production	
20	Are supplies properly stored with rotation and control of stock?	Storage	
21	Is shipment and transport properly organised and controlled; is product delivery properly supervised?	Shipment and transport	
22	Is adequate control of the product during processing and after completion properly undertaken?	Product control	
23	Are allergens under supervision?	Managing allergens	
24	Is monitoring and control of foreign body contamination in place?	Foreign body contamination	
25	Is plant access controlled and are suitable supervision and monitoring procedures implemented?	Food defence	

Source: [22]

Źródło: [22]

of this study set themselves the goal of verifying whether the forecast has come true. For this purpose, two years after the previous research, ten audits of spice suppliers were carried out in 2021. The same methodology was used in this study. The audits were carried out based on a checklist with 25 audit questions (Table 1). All audits were performed by the same auditor as in the previous work, i.e. the first author of the paper.

Each requirement was assessed a score of four, three, two, one, or zero points depending on the degree of the supplier's compliance with the requirements, according to the following rules: 4 points – full compliance, 3 points – one minor noncompliance, 2 points – two minor non-compliance, 1 point – three minor non-compliances, 0 points – more than three minor non-compliances or one major non-compliance. The points obtained influenced the audit result. The total number of points that could be scored was 100 [22].

DATA ANALYSIS

Descriptive statistics were used to characterize the obtained results, i.e. mean, median, minimum, maximum and standard deviation. To compare the results of the audits from 2021 and 2019, the student's T-test was calculated [26]. The calculations were performed using Statistica 13.3 software (StatSoft, Inc., Krakow, Poland). Significance was identified when p £0.05.

A forecast to when the spice suppliers achieve 100% compliance was calculated using the third order polynomial [41]. The probability of meeting the forecast was determined by the coefficient of determination R^2. The coefficient of determination R^2 was calculated using Excel Microsoft Office Professional v.2016 in order to predict the year in which full compliance with food quality and food safety standards will be achieved.

RESULTS

As a result of audits carried out in 2021, it was found that the average score was 97.7 points (97.70% compliance with requirements). This result was significantly higher than the average number of points obtained in the previous study in 2019, i.e. 95.40% (Table 2).

Table 2. Comparison of the average results of spice producers' audits (2019 and 2021)

Tabela 2. Porównanie średnich wyników audytów u producentów przypraw (rok 2019 i 2021)

Year	2019	2021	T-student p value
Average audit result	95.40	97.70	0.020
Degree of compliance with the requirements	95.40%	97.70%	–

Source: Own study

Źródło: Badania własne

In 2021, the implementation of 17 out of 25 audit questions received the highest score, i.e. 4.0 (median 4.0) (Table 3). The rating of 4 was the maximum rating for the audit question. Regarding the answers to the remaining 8 questions, full compliance with requirements was not achieved and they were scored slightly lower, i.e. 3.40 – 3.80 (Table 3). The lowest average score was obtained for the equipment (mean = 3.40, median 3.00, question 12) and plant hygiene (mean = 3.60, median 4.00, question 18). The lowest minimum rating was 2.0 and it was awarded for answers regarding monitoring devices (question 13) and plant hygiene (question 18). The results of answers to these audit questions had the highest SD values, which proves the greatest diversification of the degree of their fulfillment in the audited plants.

Table 3. Audit assessment results for spice suppliers in 2021

Tabela 3. Wyniki oceny pytań audytowych u dostawców przypraw w roku 2021

No	Audit question	Mean ± SD	Median	Min.	Max.
1.	Supplier assessment	4.00 ± 0.00	4.00	4.00	4.00
2.	Organisational policy	4.00 ± 0.00	4.00	4.00	4.00
3.	HACCP	4.00 ± 0.00	4.00	4.00	4.00
4.	Purchasing	4.00 ± 0.00	4.00	4.00	4.00
5.	Specification of products	4.00 ± 0.00	4.00	4.00	4.00
6.	Product design and development	4.00 ± 0.00	4.00	4.00	4.00
7.	Product release	4.00 ± 0.00	4.00	4.00	4.00
8.	Traceability	4.00 ± 0.00	4.00	4.00	4.00
9.	Corrective actions	4.00 ± 0.00	4.00	4.00	4.00
10.	Location	3.80 ± 0.42	4.00	3.00	4.00
11.	Plant layout	4.00 ± 0.00	4.00	4.00	4.00
12.	Equipment	3.40 ± 0.52	3.00	3.00	4.00
13.	Monitoring devices	3.70 ± 0.67	4.00	2.00	4.00
14.	Utilities	4.00 ± 0.00	4.00	4.00	4.00
15.	Personnel hygiene facilities	3.70 ± 0.48	4.00	3.00	4.00
16.	Personnel hygiene procedures	4.00 ± 0.00	4.00	4.00	4.00
17.	Protective clothing	3.80 ± 0.42	4.00	3.00	4.00
18.	Plant hygiene	3.60 ± 0.70	4.00	2.00	4.00
19.	Production	4.00 ± 0.00	4.00	4.00	4.00
20.	Storage	4.00 ± 0.00	4.00	4.00	4.00
21.	Shipment and transport	3.90 ± 0.32	4.00	3.00	4.00
22.	Product control	4.00 ± 0.00	4.00	4.00	4.00
23.	Managing allergens	4.00 ± 0.00	4.00	4.00	4.00
24.	Foreign body contamination	3.80 ± 0.42	4.00	3.00	4.00
25.	Food defence	4.00 ± 0.00	4.00	4.00	4.00

Source: Own study

Źródło: Badania własne

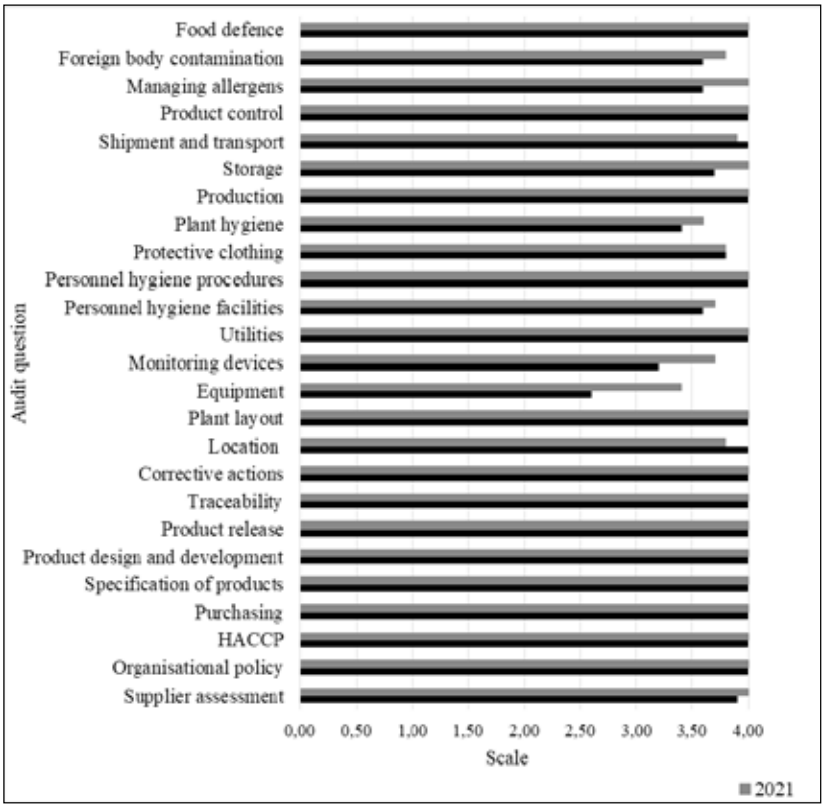

Fig. 1. Comparison of compliance with audit requirements at spice producers (2019 and 2021).

Rys. 1. Porównanie spełnienia wymagań audytowych u producentów przypraw (rok 2019 i 2021).

Source: Own study

Źródło: Badania własne

Differences and similarities in the implementation of audit requirements between 2019 and 2021 were shown (Fig. 1). In 2021, the implementation of 17 out of 25 audit questions received the highest average score (4.0), which represents 100% compliance with the requirements, while in 2019 it concerned 16 questions.

In the case of 8 audit questions, a significant improvement in compliance with audit requirements was found. They were: Q1 – Supplier assessment (T – student p value, p = 0.330), Q12 – Equipment (p = 0.159), Q13 – Monitoring devices (p = 0.216), Q15 – Personnel hygiene facilities (p = 0.660), Q18– Plant hygiene (p = 0.323), Q20 – Storage (p = 0.176), Q23 – Managing allergens (p = 0.330), Q24 – Foreign body contamination (p = 0.355). At the same time, in the case of two requirements, a slight and statistically insignificant deterioration of the implementation of the requirements was observed. These were requirements such as Location (Q10) and Shipment and transport (Q21).

The study verified the forecast of compliance with all requirements in 2021, calculated based on the results of audits carried out in 2007–2019 [22]. Audits carried out in 2021 revealed non-compliance with audit requirements that were not fully complied with, as predicted in the previous study. Therefore, the forecast of compliance with all requirements was re-calculated, supplementing the previous data with the results of audits from 2021 (Fig. 2). According to the forecast, spice suppliers will achieve the expected maximum points in 2024. The probability of meeting the forecast is at the level of approximately 57% (R^2 = 0.5722).

DISCUSSION

As the researchers [3, 4],. point out, the selection of suppliers is a multi-criteria decision problem in which criteria have different relative importance, and in practice, many input information is not exactly known. Therefore, despite the selection of suppliers, it is important to further improve the supplier evaluation system to better manage costs, quality, and service, including delivery time performance and after sales performance of the supply chain. Many authors [8, 12, 16, 23, 29] propose complicated models of supporting the decision-making process for various types of producers. In this paper, we propose, based on the experience of meat plants, supplier assessment audits, which can be easily modified when situations changed in the food market, e.g. during a pandemic.

The use of audits made it possible to assess the application of the requirements of quality management systems by suppliers of spices to meat industry plants. This method was the most frequently chosen method of supplier evaluation declared by 85% of meat industry companies [21]. The popularity of the audit is due to the fact that it can be used to evaluate many processes, such as: customer service, research and development, processes, product quality, quality system management, packaging, shipping, etc. [43]. During audits, attention is also paid to the documents used and the safety of work places [46]. The quality of the raw materials supplied to the meat industry is very important for the safety of meat products and therefore was often used in the evaluation of suppliers [37, 39].

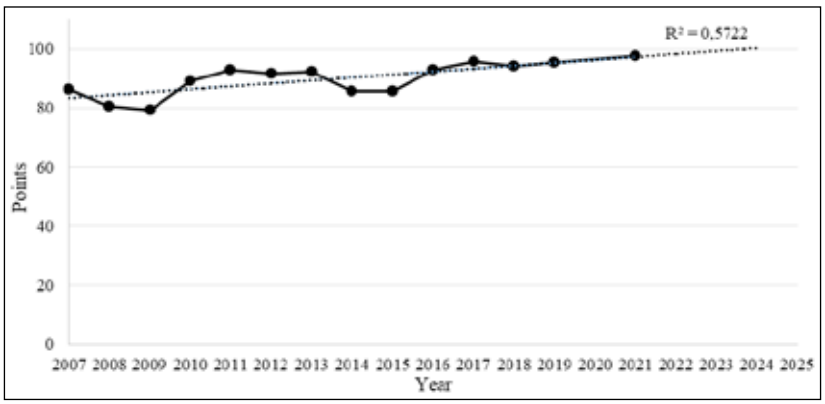

Fig. 2. Forecast of compliance with the audit requirements by spice producers.

Rys. 2. Prognoza spełnienia wymagań audytowych przez producentów przypraw.

Source: Own study

Źródło: Badania własne

Supplier's activities monitoring is a requirement of management systems and is essential to the quality of meat products. If non-compliances are identified during supplier audits, the results may indicate needed areas of improvement for suppliers. The audits carried out revealed non-compliances that were already indicated in the literature on the subject, such as plant hygiene, staff hygiene, foreign body contamination, allergen management and plant equipment [6, 14, 24, 26, 42, 44, 48,].

There has been a significant improvement in fulfilling the requirements of food safety management systems compared to previous studies [22], although the calculated forecast for 2021 has not been met. The reasons can be found in the pandemic SARS-Cov-19, which changed the situation on the food market, limited the frequency of internal audits, the employment of specialists, and made it necessary to deal with various economic and financial problems [13, 27]. The implementation of the forecast has been postponed by 3 years until 2024. It is worth emphasizing that the obtained average number of points 97.70 out of 100 possible to be scored turned out to be very satisfactory. Therefore, despite the failure to meet the previously calculated forecast, it is necessary to positively emphasize the activities of spice producers to improve the functioning of food safety management systems in their plants. Efforts of spices suppliers regarding the areas indicated in previous studies as sources of non-compliance deserve a positive emphasis. For example, many non-compliances were identified in traceability operations, HACCP, product release, corrective action, product specification, plant layout [9, 28, 40, 41, 45, 47, 49]. In the current research, they have been assessed as maximum points.

The presented study has some limitations. They concern the conduct of audits among suppliers of one large meat processing plant in Poland. Suppliers of other or smaller plants, as well as in other countries may meet the food safety requirements at different levels.

CONCLUSIONS

The authors want draw attention to monitoring of suppliers quality management system. It is important to guarantee the appropriate quality of raw materials and semi-finished products used in the production, in the discussed case of the production of meat and its products. These are the key elements to obtain high-quality and food safety industry products.

Supplier evaluation by means of an audit has proved to be a useful tool for assessing compliance with the requirements of quality and food safety management systems in the supervision of spice suppliers. In 2021, there was a significant improvement in the audit compliance with the producer's requirements compared to the previous research conducted among spice suppliers in 2019. However, the calculated forecast of meeting all, i.e. 100%, requirements of the food quality and safety management system has not been met. The forecast calculated in previous studies was to come true in 2021. Most likely, the forecast was not fulfilled due to the SARS-CoV-2 pandemic, and the new calculations point to 2024. However, the significant improvement in the implementation of audit requirements and the achieved result are fully satisfactory. Spice suppliers can be considered to deliver a safe product to the meat processing plant, produced under appropriate conditions and with full control of the production process.

WNIOSKI

Autorzy publikacji chcą zwrócić uwagę na monitorowanie systemu zarządzania jakością dostawców. Istotne jest, aby zagwarantować odpowiednią jakość surowców oraz półproduktów wykorzystywanych w produkcji, w omawianym przypadku, produkcji mięsa i jego przetworów. Są to kluczowe elementy do uzyskania wysokiej jakości i bezpieczeństwa produktów przemysłu spożywczego.

Ocena dostawców za pomocą audytu okazała się użytecznym narzędziem do oceny spełnienia wymagań systemów zarządzania jakością i bezpieczeństwem żywności w zakresie nadzoru nad dostawcami przypraw. W roku 2021 nastąpiła istotna poprawa spełnienia wymagań audytowych w porównaniu do poprzednich badań wykonanych wśród dostawców przypraw w roku 2019. Nie spełniła się jednakże obliczona prognoza spełnienia wszystkich, tj. 100% wymagań systemu zarządzania jakością i bezpieczeństwem żywności. Obliczona w poprzednich badaniach prognoza miała spełnić się w roku 2021. Najprawdopodobniej nie została ona zrealizowana z powodu pandemii SARS-CoV-2, a nowe obliczenia wskazują rok 2024. Istotna poprawa realizacji wymagań audytowych i osiągnięty wynik są jednak w pełni satysfakcjonujące. Można uznać, że dostawcy przypraw dostarczają do zakładu mięsnego produkt bezpieczny, wytworzony w odpowiednich warunkach i przy pełnej kontroli procesu produkcyjnego.

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Mgr inż. Paulina Luiza WIZA
Department of Economics and Economic Policy in Agribusiness
University of Life Sciences in Poznan, Poland
Katedra Ekonomii i Polityki Gospodarczej w Agrobiznesie
Uniwersytet Przyrodniczy w Poznaniu, Polska

REGIONAL VARIATION OF MILK PRODUCTION IN POLAND IN THE YEARS 1998–2019®

Zróżnicowanie regionalne produkcji mleka w Polsce w latach 1998–2019®

Key words: regional variation, milk production, dairy sector, Poland.

The aim of the research was to identify the most important changes that occurred in the Polish dairy sector in the years 1998–2019, in terms of milk production in regional terms. The research included data for the years 1998–2019. The time interval used in the analyses was determined by the administrative reform carried out in 1998 and the availability of regional data on milk production in the Central Statistical Office database. The material used in the study came from unpublished and published Agricultural Statistical Yearbooks for the years 1998-2019. The material for the study also included literature on the subject which contributed to characterizing the definition of a region, indicating the classification of regions occurring in Poland, taking into account the specificity of milk production, and determining the determinants shaping regional differentiation of milk production in Poland. In order to show changes in a regional perspective in the dairy sector the following were analysed: the state of the cow stock, milk production, milk productivity of cows, prices and purchase of milk. Descriptive and cause-effect methods were applied in the presentation of research results. On the basis of performed research analyses and review of literature, it was demonstrated that under conditions of market economy, production of milk was reduced faster in those voivodeships where it is difficult to rationalise production, reduce production costs due to excessive fragmentation or less favourable natural conditions. In consequence, it was observed that the increase in milk production increases more dynamically in voivodships where natural and economic conditions are favourable for effective milk production, i.e. from the south of Poland to the north.

Słowa kluczowe: regionalizacja, produkcja mleka, sektor mleczarski, Polska.

Celem badań było wyodrębnienie najważniejszych zmian, jakie zaszły w polskim sektorze mleczarskim w latach 1998–2019, pod względem produkcji mleka w ujęciu regionalnym. Badania obejmowały dane za lata 1998–2019. Przedział czasowy wykorzystany w analizach był determinowany reformą administracyjną przeprowadzoną w 1998 roku oraz dostępnością danych w ujęciu regionalnym z zakresu produkcji mleka w bazie Głównego Urzędu Statystycznego. W pracy wykorzystano materiał pochodzący z niepublikowanych oraz publikowanych Roczników Statystycznych Rolnictwa za lata 1998-2019. Materiał do badań obejmował również literaturę przedmiotu, która przyczyniła się do scharakteryzowania definicji regionu, wskazania klasyfikacji regionów występujących w Polsce, z uwzględnieniem specyfiki produkcji mleka oraz określenia determinant kształtujących zróżnicowanie regionalne produkcji mleka w Polsce. W celu ukazania zmian w ujęciu regionalnym w sektorze mleczarskim zbadano: stan pogłowia krów, produkcję mleka, wydajność mleczną krów, ceny i skup mleka. Przy prezentacji wyników badań zastosowano metodę opisową oraz przyczynowo-skutkową. W oparciu o przeprowadzone analizy badawcze oraz przegląd literatury wykazano, że w warunkach gospodarki rynkowej produkcja mleka była ograniczana szybciej w tych województwach, gdzie trudno jest racjonalizować produkcję, obniżać koszty produkcji ze względu na nadmierne rozdrobnienie lub mniej sprzyjające warunki przyrodnicze. W konsekwencji obserwowano, że wzrost produkcji mleka dynamiczniej zwiększa się w województwach, gdzie warunki przyrodnicze oraz gospodarcze są korzystne dla efektywnej produkcji mleka, czyli z południa Polski na północ.

INTRODUCTION

In economic sciences, it is crucial to define a region correctly. In economic terms, a region is understood as „an area with a specific economic specialization, which is a consequence of endo- and exogenous determinants of development" [13, 14]. According to Z. Domański [2] and K. Kuciński [10] the scope of the concept of region should be extended. Resources of a given area, i.e. local community (social capital), environment and capital can be classified as important criteria of a region's development. The mentioned criteria were used to develop a classification of development factors, among others in relation to spatial economy [13]. Agriculture (including agribusiness) is an important link of the national economy, which is connected with the concept of an agricultural region,

Adres do korespondencji – Corresponding author: Paulina Luiza Wiza, Uniwersytet Przyrodniczy w Poznaniu, Wydział Ekonomiczny, Katedra Ekonomii i Polityki Gospodarczej w Agrobiznesie, ul. Wojska Polskiego 28, 60-637 Poznań, e-mail: paulina.wiza@up.poznan.pl

defined in the literature as „separate areas having a set of specific features relating to agriculture, differentiating it from other areas". [1, 13, 14]. Features of a selected agricultural area are connected with types of agricultural holdings which occur in a specific area and with economic and natural criteria occurring in the area. W. Stola and R. Szczęsny [17] distinguished 10 agricultural regions diversified in terms of natural and internal factors of agriculture (types of agricultural holdings and directions of production). Among 10 regions W. Stola and R. Szczęsny [17] distinguished the following agricultural regions occurring in Poland:

- Zachodniopomorski region – with lakeside landscape, with large share of state-owned land, dominated by market and mixed agriculture,
- Masuria region – with lakeside landscape, not very favourable agro-ecological conditions, with a large share of land belonging to the State Treasury, with subsistence agriculture,
- Wielkopolskie-Pomorskie region – with favourable agro-ecological conditions and commodity agriculture of a relatively high level of development,
- Lower Silesia region – with favourable agro-ecological conditions and commodity agriculture on a diversified level of development,
- Central region – with diversified natural conditions and market-oriented to self-supply agriculture,
- Upper Silesia region – with a lot of land devoted to industry and urbanisation,
- North-eastern region – with less favourable natural conditions for agriculture, characterised by agriculture of various types, from traditional to market-oriented,
- Lesser Poland (Małopolska) region – with diverse natural conditions, where small-scale farming prevails and commodity crop production occurs on small areas,
- the Carpathian region – with unfavourable natural conditions, dominated by traditional and semi-subsistence agriculture, while on small areas commercial animal production prevails,

  Sudeten region – similar to the Carpathian region in terms of natural conditions. This region has low-intensive and small-scale agriculture [13, 17].

In the literature there can be indicated other divisions of occurring agricultural regions in Poland. An example is the division of Poland into 9 agricultural regions proposed by W. Kamiński [9] (differing from the above-mentioned one), taking the need of food economy planning as the division criterion [13]. Another example of distinguishing agricultural regions in Poland is the division proposed in the publication „Cohesive structural policy of rural and agricultural development", which was accepted by the Council of Ministers in 1999 [12]. In the adopted document agricultural regions were distinguished due to the agrarian structure and condition of farms. According to this criterion, three macro-regions were indicated, which were additionally divided into sub-regions:

- Macroregion I (the South of Poland) – characterised by the dominance of small farms. In this macro-region two sub-regions (Śląskie and Małopolskie) were indicated, which are differentiated in terms of the number of jobs for non-agricultural work. According to W. Michna [11], the following provinces can be classified in macroregion I: Podkarpackie, Małopolskie, Śląskie and Świętokrzyskie.
- Macroregion II (north and west of Poland) – within this macroregion large-area farms dominate, which are characterised by underinvestment, disorderly ownership and cereal monoculture. According to W. Michna [11], the following voivodships can be classified in macroregion II: Warmińsko-Mazurskie, Pomorskie, Zachodniopomorskie, Lubuskie, Dolnośląskie, Opolskie.
- Macroregion III (the centre and east of Poland) – within this macroregion there dominate farms with an average area characterised by a weak evolution of changes which await state impulses for production activation as well as structural transformations. W. Michna [11] qualified the following voivodships to macro-region III: Wielkopolskie, Kujawsko-pomorskie, Łódzkie, Mazowieckie, Podlaskie, Lubelskie [1, 11, 13].

The division of Poland into agricultural regions was also proposed by the Institute of Agricultural and Food Economics of the National Research Institute (IERiGŻ-PIB), dividing Poland into four agricultural regions, taking as a criterion for division seven statistical indicators which made it possible to determine production effects of agricultural holdings. These indicators included: the area of arable land in an average individual agricultural holding, the percentage share of permanent grassland in the total arable land, the number of milking cows in an average individual agricultural holding, the total number of pigs in an average individual agricultural holding, cereal yields in the whole agriculture, annual milk production from 1 cow and NPK consumption in kg per 1 ha of total arable land. On the basis of performed analyses of deviations of the indicated indicators it has been determined that lines of division for distinguishing agricultural regions will run along borders of NUTS 2 regions, i.e. voivodships, and each of the regions will cover 4 NUTS 2 regions (i.e. four voivodships each). Thus, in the classification of Polish FADN there are four agricultural regions:

- the Pomerania and Masuria region comprising the Warmińsko-Mazurskie, Pomorskie, Zachodniopomorskie and Lubuskie provinces,
- Wielkopolska and Silesia region comprising the provinces of Kujawsko-Pomorskie, Wielkopolskie, Dolnośląskie and Opolskie,
- the Mazovia and Podlasie region comprising the following provinces Podlaskie, Mazowieckie, Lubelskie and Łódzkie,
- Małopolska and Pogórze region covering the provinces of Świętokrzyskie, Śląskie, Małopolskie and Podkarpackie [13, 20].

The above indicated and described criteria aimed at division of Poland into agricultural regions, as well as functioning divisions of Poland into agricultural regions do not fully exhaust this issue. Various methods of distinguishing agricultural regions indicate application of different approaches, which is connected with variable features of agriculture and various indicators (measures) used in

distinguishing agricultural regions. According to J. Bański [1] there are no coherent and homogeneous agricultural regions with universal features which could be universally accepted by the environment that deals with this issue [13].

In Polish literature on the subject one can distinguish the publication of J. Seremak-Bulge, K. Hryszko, A. Zalewski from 2006 entitled „Regional diversification of dairy farming". In Polish literature we can distinguish the publication of J. Seremak-Bulge, K. Hryszko, A. Zalewski from 2006 „Regional diversification of dairying" which refers to the subject of regionalisation of cattle farming and milk production. In this publication authors indicate three areas of milk production in Poland, where the criterion of division was conditioned by data on milk purchase at the level of voivodships:

- area I – showing well developed commodity production, with a minimum 70% share of purchases in milk production. Area I includes six voivodships, i.e.: Podlaskie, Kujawsko-pomorskie, Wielkopolskie, Dolnośląskie, Mazowieckie and Opolskie,
- area II – having an average commerciality of milk production, within the range from 40 to 70% of purchase share in milk production. Seven voivodships may be classified in area II, i.e. Lubelskie, Lubuskie, Łódzkie, Pomorskie, Śląskie, Warmińsko-Mazurskie and Zachodniopomorskie,
- area III – having low commerciality of milk production, below 40% share of purchase in milk production. Three provinces - Małopolskie, Podkarpackie and Świętokrzyskie - can be classified in area III [16].

While conducting research on occurring regional changes in milk production in Poland it is crucial to look for an answer to the question: What determinants determine the process of polarization of regions in cattle rearing and milk production concentration? In the new institutional economics the category of specific resources is important, i.e. resources occurring only in a given area and not anywhere else [19]. In order to determine conditions enabling development or stagnation of milk production, also taking into account assumptions of the new institutional economics, A. Parzonko [13] carried out research (using an interview questionnaire) in which he asked employees of communes dealing with agriculture what, in their opinion, conditions milk production in Poland. Conducted research enabled A. Parzonko [13] to distinguish determinants which, according to municipalities employees, contributed to the development of farms specializing in milk production and a category of factors which contributed to stagnation or limitation of milk production in given regions of Poland. To the category of determinants shaping the development of dairy farms A. Parzonko [13], on the basis of conducted research, qualified:

- favourable historical conditions – an example is Podlaskie Voivodship, where milk production is a key activity, as a result of which farms specialising in milk production could undertake investment activities, i.e. building barns for cows using loans. These actions contributed to the development of milk production in Podlaskie Voivodship and in those regions of Poland where historical conditions were also favourable,
- the lack of opportunities for other agricultural or economic activities – in regions of Poland where poor soil quality prevailed, the lack of outlets for agricultural products, the lack of jobs outside of farming contributed to the continuation of milk production by farmers despite the unfavourable economic situation for milk. This phenomenon was visible after the marketisation of the economy, i.e. at the beginning of the 1990s, when a fall in the price of milk at the point of purchase was observed. As a result, there was a decline in the stock of cows, but in some regions in Poland milk production was developed regardless of unfavourable economic conditions,
- support measures on the part of local dairy companies – after the marketisation of the economy, dairy companies took initiatives aimed at increasing milk production in farms specialising in milk production. Actions taken by dairy companies to increase milk production include: providing low interest loans to farmers to buy milk cooling tanks and milking machines, started supplying farmers with udder disinfectants, ointments and balms used to prevent udder diseases, etc., started training among farmers financed by dairies to create awareness among farmers about the importance of animal welfare in agricultural production. Besides, dairy companies introduced price calculation for milk depending on the quality and quantity of milk delivered by the farmer to the dairy, which is still in force today,
- favourable economic situation for milk after Poland's accession to the EU, including the possibility of benefiting from the EU structural funds – Poland's accession to the EU in 2004 made it possible for farms specialising in milk production which carried out commercial milk production to develop their activities using the available financial support from EU funds. Farmers allocated the funds received to modernising their farms and machinery stock, which made it possible to adapt milk production to EU requirements. Further development of milk production was possible due to a favourable economic situation for milk [14].

On the other hand, A. Parzonko [13], on the basis of conducted research, qualified the factors limiting the development of dairy farms as the following:

- unfavourable historical conditions – in regions of Poland, e.g. in the Małopolskie voivodship, where milk production was a secondary activity, unfavourable historical conditions were demonstrated, due to which farms specialising in milk production had limited opportunities to undertake investment activities, which was associated with the small area of such farms and the small fodder area of the farms. These activities contributed to the inhibition of milk production in these regions of Poland,
- increasing quality requirements for purchased milk – in order to meet the growing quality requirements for purchased milk observed in the years 2003–2007, the key task for farmers was to guarantee optimal conditions for keeping cows and storing milk. In order to meet the milk quality requirements of dairy companies, farmers were forced to invest in the purchase of milk cooling tanks. In case of lack of capital and small scale milk production,

investment activities were limited or economically disadvantageous,

- low production potential/low scale of milk production – in the case of small farms which obtain a production volume below the profitability level, the farmer's activity does not provide him with an income enabling him to support his family and accumulate funds for the development of his activity, which, in consequence, may lead to the abandonment of milk production,
- high capital intensity of milk production – in order for holdings specialising in milk production to develop, it is necessary to invest in their activities, which is associated with a high demand for capital. In the period of transformation and preparations related to Poland's accession to the EU, farmers did not have their own funds, while obtaining funds from outside was difficult, which contributed to the reduction of milk production in Poland,
- lack of advice from dairy companies as well as scientists and experts on determining the desired directions for the development of farms specialising in milk production,
- EU structural funds, calculation of direct payments – some programmes introduced by the EU were not favourable to the development of milk production, among others, according to farmers, agri-environmental programmes were not adjusted to the local conditions of milk production, which in consequence limited milk production in those regions of Poland where there were unfavourable natural conditions and a small number of modernised high-yield farms [14].

The aim of the study was to isolate the most important changes that occurred in the Polish dairy sector in 1998–2019 in terms of milk production by region. Due to the important role of the dairy sector in Poland, it was selected purposively.

METHODS AND MATERIALS

The research included data for the years 1998–2019. The time interval used in the analyses was determined by two factors. Firstly, the administrative reform carried out in 1998, which contributed to the functioning of 16 voivodships in Poland. Secondly, availability of regional data on milk production in the Central Statistical Office (GUS) database. The paper uses material from unpublished and published Agricultural Statistical Yearbooks for the years 1998–2019, as well as publications entitled „The physical dimensions of livestock production". „Physical dimensions of livestock production" for 1998–2019 authored by GUS. The research material also included literature on the subject which contributed to characterizing the definition of a region, indicating the classification of regions occurring in Poland taking into account the specificity of milk production and determining the determinants shaping regional differentiation of milk production in Poland. In order to show regional changes in dairy sector the following issues were examined: state of cow stock, milk production, milk yields of cows, prices and purchase of milk. The paper presents the following research problem: Under conditions of market economy, production of milk was reduced faster in those voivodships where it is difficult to rationalize production, reduce production costs due to excessive fragmentation or less favourable natural conditions. Descriptive and cause-effect methods were applied in the presentation of research results.

RESULTS AND DISCUSSION

Table 1 presents changes taking place in milk production, stock and milk yield of cows in the years 1998–2019. The length of the period of comparisons included in Table 1 is connected with the availability of data conditioned by the administrative reform carried out in 1998. Based on the data presented in Table 1, it was found that milk production in Poland is regionally differentiated. In the years 1998–2019 milk production in Poland increased by 15%. In regional terms, milk production in 1998–2019 increased in 6 voivodeships, which at the same time are characterised by high commoditisation at the level from 15% to 35% (Table 3.19). In the examined period milk production increased in the following provinces: Łódzkie by 11%, Kujawsko-Pomorskie by 43%, Warmińsko-Mazurskie by 51%, Wielkopolskie by 60%, Mazowieckie by 70% and Podlaskie, where milk production increased by 135% (Table 3.19). A decrease in milk production in the analysed period was observed in 10 voivodships, in which the level of decrease ranged from 15% to 79%. Reduction in milk production in the years 1998–2019 was recorded in the following voivodships: Opolskie by 15%, Pomorskie by 17%, Lubelskie by 34%, Dolnośląskie by 46%, Lubuskie by 47%, Zachodniopomorskie by 50%, Śląskie, Świętokrzyskie by 64%, Małopolskie by 65% and Podkarpackie by 79% (Table 1). The structural transformations taking place in agriculture and the dairy industry resulted in 6 voivodships (i.e. Łódzkie, Kujawsko-Pomorskie, Warmińsko-Mazurskie, Wielkopolskie, Mazowieckie and Podlaskie) producing a total of 80% of raw milk production in 2019, and their total share in procurement was 81% (Table 1, Table 3). Changes in milk production are determined, among others, by changes in the number and milk yield of cows [3, 15, 18].

In 1998–2019, there was a 31% reduction in the cow population, with a simultaneous 66% increase in milk yield (Table 1). In all voivodeships except Podlaskie and Warmińsko-Mazurskie the cow population was reduced in the analysed years. Only in Podlaskie and Warmińsko-Mazurskie Voivodeships, milk production was increased as a result of simultaneous improvement of milk yields (in Podlaskie Voivodeship, during the analysed period, milk yields increased by 84%, while in Warmińsko-Mazurskie Voivodeship – by 43%), as well as an increase in stock (by 27% in Podlaskie Voivodeship, and in Warmińsko-Mazurskie Voivodeship – by 2%) (Table 1). In voivodeships with high production growth and characterised by high commodity production, the decrease in the cow herd in the analysed period was at the level of approximately 10%, i.e. the Mazowieckie Voivodeship, which recorded a decrease in the cow herd by 9%, the Wielkopolskie Voivodeship, which recorded a decrease by 12%, and the Kujawsko-Pomorskie Voivodeship, which recorded a decrease in the cow herd by 14% (Table 1. In the years 1998-2019, the highest decrease in the cow stock at the level of 57–83% was observed in the provinces with the most fragmented agrarian structure, i.e. in the following provinces: Śląskie by 57%, Lubelskie by 59%, Małopolskie by 69%, Świętokrzyskie

by 72% and Podkarpackie by 83% (Table 1). A decrease in the number of cows in the years 1998–2019 at the level of 36–55% was recorded in the western and northern provinces, where a significant role is played by state-owned farms, i.e. in the following provinces: Łódzkie province a decrease in the number of cows was recorded by 36%, Pomorskie province by 40%, Opolskie province by 44%, Zachodniopomorskie province by 48%, Dolnośląskie province by 55% (Table 3.19). In the analysed period the highest increase in milk yield was recorded in the voivodship: Kujawsko-pomorskie by 73%, Łódzkie by 78%, Wielkopolskie by 80%, Podlaskie by 84% and Mazowieckie by 90%. On the other hand, in the zachodniopomorskie and lubskie voivodships a decrease in cows' milk yields was recorded in the analysed period, by 5% and 39%, respectively (Table 1).

In order to deepen analyses concerning occurring changes in regional differentiation of milk production, Table 2 presents changes in milk production, stock and milk yields of cows, distinguishing two periods. The first period covered the years 1998-2004, called the pre-accession period, in which changes in milk production related to adaptation to EU requirements were observed. The second period covered the years 2004-2019, called the post-accession period, in which changes in milk production connected with Poland's functioning on the European market were observed. It was shown that in the pre-accession period the region with the strongest regression in cow stock was the south-eastern region of Poland where a decrease in stock by 40% was recorded (from 45% in the Świętokrzyskie and Podkarpackie Voivodeships to 36% in the Śląskie Voivodeship and 35% in the Małopolskie Voivodeship, with the country average decrease by 21%). On the other hand, the decrease in milk production in the indicated region was observed at the level of 31% (from 39% in Podkarpackie to 25% in Małopolskie), where the average decrease in the country amounted to 6% (Table 2). In the post-accession period the regression in cow rearing and milk production in the south-eastern region of Poland deepened. Cow stock decreased by 51% (in the Podkarpackie voivodeship it decreased by 70%, in the Małopolskie voivodeship by 52%, in the Świętokrzyskie voivodeship by 50%, and in the Śląskie voivodeship by 33%), while on the national scale a decrease in cow stock by 12% was recorded. In the south-eastern region of Poland, both in the pre-accession and post-accession periods, a slight increase in milk yield was observed at the level of 13% in the pre-accession period, while in the post-accession period, at the level of 11% (Table 2). In the post-accession period in the analysed region there was a decrease in production by 45% (in Podkarpackie by 65%, Małopolskie by 54%, Świętokrzyskie by 50%, Śląskie by 12%), while in Poland there was an increase in milk production by 23% (Table 2). A decrease in the stock of cows and milk production, with a slight increase in the milk yield of cows was also recorded in the Lublin Province, where there is an unfavourable area structure of farms specialising in cow rearing and milk production (Table 2). Significant

Table 1. Differentiation of milk production by region in 1998-2019

Tabela 1. Zróżnicowanie produkcji mleka w ujęciu regionalnym w latach 1998-2019

	Milk production [million l].			Total number of cows [in thousands].			Average annual milk yield from 1 cow [in l]		
	1998	2004	2019	1998	2004	2019	1998	2004	2019
POLAND	**12229**	**11477,6**	**14089,9**	**3541,7**	**2796**	**2461**	**3491**	**4082**	**5803**
dolnośląskie	337,4	232,4	180,7	93,9	55,7	42,6	3558	4228	4311
kujawsko-pomorskie	737,9	674,4	1055,1	195,5	160,7	168,6	3800	4178	6561
lubelskie	1230,1	931,9	807,8	344,9	233,4	141,8	3593	3901	5758
lubuskie	159,3	130,8	84,9	35,4	28,9	31,6	4396	4525	2678
łódzkie	991,5	1012,4	1096,4	296,1	235,8	189,3	3309	4152	5898
małopolskie	820,4	614,9	285	262,3	170,2	80,9	3140	3539	3533
mazowieckie	1939,8	2043,7	3301,8	612,8	565,7	558,8	3253	3666	6192
opolskie	327,9	283,6	277,4	75,7	51,2	42,4	4370	5391	6413
podkarpackie	755,8	459,7	160,9	234,1	129,5	38,7	3216	3534	4080
podlaskie	1201,2	1618,2	2822,9	359,3	376,9	457,2	3328	4240	6134
pomorskie	446,1	349,8	371,8	120	78,6	71,6	3873	4463	5119
śląskie	440,9	307	270,2	109,7	70,5	47,4	4133	4558	5714
świętokrzyskie	603,9	432,8	217,7	191,1	105,8	53,4	3329	4006	4071
warmińsko-mazurskie	684,4	853,7	1031,4	196	183	200,4	3522	4708	5050
wielkopolskie	**1228,1**	**1311,5**	**1963,7**	**333**	**305,8**	**294,2**	**3735**	**4259**	**6760**
zachodniopomorskie	324,3	220,8	162,2	81,9	44,3	42,2	4014	4885	3800

Source: Own study based on [4, 5, 6, 7, 8]

Źródło: Opracowanie własne na podstawie [4, 5, 6, 7, 8]

decrease in cow stock and continuing decrease in production in this region is caused, among others, by the occurrence of small area farms which usually keep herds of 1 or 2 cows, which determines low commerciality of milk produced in this region [3, 18]. Additionally, the regression in the number of cows was conditioned by the policy of dairy companies reducing milk purchase from farms with low profitability and having difficulties in guaranteeing high milk quality [3].

In the period of intensive system transformations, the former central-eastern region of Poland, which in the new administrative division subtracted the Podlaskie, Mazowieckie and Warmińsko-Mazurskie Voivodeships, was characterised by the lowest cow stock decline. In the pre-accession period the decrease in the cow stock in that region amounted to 3% (with an increase in the Podlaskie Voivodeship by 5%) (Table 2). The voivodships which in the pre-accession period showed a low decrease in the cow stock, i.e. below the national average of 21%, were the Wielkopolskie voivodship, where a decrease in the stock by 8% was recorded, the Kujawsko-Pomorskie voivodship with a decrease by 18% and the Łódzkie voivodship with a decrease at the level of 20% (Table 2). In the pre-accession period in the Central-North-Eastern region of Poland there was observed a decrease in the number of cows at the level of 9% and increase in milk yields of cows by 21%, what caused an increase in milk production in that region by 11% (the most in Podlaskie by 35% and in Warmińsko-Mazurskie by 25%) (Table 2). In the post-accession period in the central north-eastern region of Poland there was an increase in the number of cows by 2% (with the highest increase in the number of cows recorded in Podlaskie Voivodeship by 21%), and production increased by 45% (with the highest increase in milk production recorded in Podlaskie Voivodeship by 74% and Mazowieckie Voivodeship by 62%). In the post-accession period in the analysed region there was also an increase in milk yields by 46.5% (where the highest increase was recorded in the Mazowieckie Voivodship by 69% and in the Wielkopolskie Voivodship by 59%) (Table 2). Dominance of 6 voivodships in milk production in Poland is conditioned by specialisation of farms keeping cows, manifested by a large increase in the share of farms keeping larger and larger herds of cows and obtaining favourable results in improvement of cow herds. This process was possible because in the described region the structure of farms keeping cows according to the area size of the farms was favourable, which made it possible to significantly increase the size of maintained cow herds [3].

In the pre-accession period in the western and north-western region of Poland, which includes the following voivodships: Dolnośląskie, Opolskie, Lubuskie, Zachodniopomorskie and Pomorskie, a decrease in livestock by 34% (from 18% in Lubuskie to 46% in Zachodniopomorskie), and milk production by 23% (from 14% in Opolskie to 32% in Zachodniopomorskie) was recorded. In the final phase of

Table 2. change in milk production, livestock and total cow milk yield by region from 1998 to 2019

Tabela 2. Zmiana produkcji mleka, pogłowia oraz mleczności krów ogółem w ujęciu regionalnym w latach 1998–2019

	Milk production [million l]		Total number of cows [in thousands]		Average annual milk yield from 1 cow [in l]	
	amendment 2004/1998	amendment 2019/2004	amendment 2004/1998	amendment 2019/2004	amendment 2004/1998	amendment 2019/2004
POLAND	**0,94**	**1,23**	**0,79**	**0,88**	**1,17**	**1,42**
dolnośląskie	0,69	0,78	0,59	0,76	1,19	1,02
kujawsko-pomorskie	0,91	1,56	0,82	1,05	1,10	1,57
lubelskie	0,76	0,87	0,68	0,61	1,09	1,48
lubuskie	0,82	0,65	0,82	1,09	1,03	0,59
łódzkie	1,02	1,08	0,80	0,80	1,25	1,42
małopolskie	0,75	0,46	0,65	0,48	1,13	1,00
mazowieckie	1,05	1,62	0,92	0,99	1,13	1,69
opolskie	0,86	0,98	0,68	0,83	1,23	1,19
podkarpackie	0,61	0,35	0,55	0,30	1,10	1,15
podlaskie	1,35	1,74	1,05	1,21	1,27	1,45
pomorskie	0,78	1,06	0,66	0,91	1,15	1,15
śląskie	0,70	0,88	0,64	0,67	1,10	1,25
świętokrzyskie	0,72	0,50	0,55	0,50	1,20	1,02
warmińsko-mazurskie	1,25	1,21	0,93	1,10	1,34	1,07
wielkopolskie	**1,07**	**1,50**	**0,92**	**0,96**	**1,14**	**1,59**
zachodniopomorskie	0,68	0,73	0,54	0,95	1,22	0,78

Source: Own study based on [4, 5, 6, 7, 8]

Źródło: Opracowanie własne na podstawie [4, 5, 6, 7, 8]

the pre-accession period and in the initial phase of the post-accession period a revival was observed in this region in cow rearing, first of all in high-yield farms (usually post-state farms keeping dairy cows), connected with striving to reach the highest possible limits of milk production [3]. As a consequence, in the post-accession period in the western and north-western regions of Poland, along with stabilization of ownership and organizational structure of farms established after liquidation of state farms, the dynamics of decrease in cow stock and milk production decreased significantly [3]. In the post-accession period there was recorded a decrease in cow stock by 9% (from 5% in the West Pomeranian Province to 24% in the Lower Silesian Province), and in milk production by 16% (from 2% in the Opole Province to 35% in the Lubusz Province) (Table 2). The decrease in milk production was determined by the decrease in milk production in self-supplied holdings and those which fall out of the dynamically shrinking group of commercial farms (milk suppliers to dairy companies) [3].

Changes occurring in the prices of purchased milk also had an important impact on the course of regionalisation of milk production in Poland. Table 3 presents changes in the purchase of milk and milk purchase prices in the years 1999–2019. The time interval 1999–2019 was adopted as the research period, which was conditioned by the availability of data in the GUS database. In the years 1999–2019 an increase in the purchase of milk in Poland by 82% was observed. The changes in the purchase of milk in the examined period took place dynamically in the central – north-eastern region of Poland, which was connected with dynamic development of milk production in that region. In the Zachodniopomorskie and Małopolskie voivodships, a decrease in milk purchase was recorded in the analysed period, by 8% and 22% respectively (Table 3). Along with changes in milk procurement, changes in milk procurement prices were recorded in the years 1999–2019. The highest increase in milk procurement prices in the analysed period was recorded in Podlaskie Province where the procurement price of cow's milk for 1 l of milk in 2019

Table 3. Changes in the purchase of milk [in thousand l] and in the purchase prices of cow's milk [in PLN per 1 hl] by regions in the years 1999-2019

Tabela 3. Zmiany skupu mleka [w tys. l] oraz cen skupu mleka krowiego [w zł za 1 hl] w ujęciu regionalnym w latach 1999-2019

	1999		2004		2019		change in milk collection 2019/1999	change in milk prices 2019/1999
	milk procurement [in thousand l]*	purchase price of cow's milk [in PLN per 1 hl]	milk procurement [in thousand l]*	purchase price of cow's milk [in PLN per 1 hl]	milk procurement [in thousand l]*	purchase price of cow's milk [in PLN per 1 hl]		
POLAND	**6486415**	**61**	**7 770 084**	**87**	**11827566**	**139**	**1,82**	**2,28**
dolnośląskie	143085,4	63	164 872	87	164734	139	1,15	2,21
kujawsko-pomorskie	446195	60	549 112	86	830018	133	1,86	2,21
lubelskie	552595,8	60	583 967	80	573439	140	1,04	2,33
lubuskie	75129,6	62	87 480	89	77894	139	1,04	2,24
łódzkie	653272	59	698 440	84	845414	127	1,29	2,15
małopolskie	172578,9	60	161 860	73	134941	124	0,78	2,06
mazowieckie	1190618	59	1 515 510	85	2581097	138	2,17	2,35
opolskie	171936	68	198 656	90	260802	139	1,52	2,04
podkarpackie	113283,5	53	126 651	71	119080	134	1,05	2,53
podlaskie	1033975,4	66	1 506 846	99	2605126	147	2,52	2,22
pomorskie	184062,4	59	196 972	85	329074	140	1,79	2,38
śląskie	167249,4	61	175 545	81	252784	138	1,51	2,26
świętokrzyskie	171266,2	54	172 666	76	179851	130	1,05	2,40
warmińsko-mazurskie	482361,6	58	510 021	91	926048	145	1,92	2,50
wielkopolskie	**782562,5**	**63**	**981 312**	**87**	**1814626**	**137**	**2,32**	**2,18**
zachodniopomorskie	145728,8	59	139 368	91	133690	140	0,92	2,38

* milk procurement [in thousand l] was calculated by multiplying the procurement of cow's milk per 1 sensitive head [in litres] and the total cow's population expressed [in thousands].

Source: Own study based on [4, 5, 6, 7, 8]

Źródło: Opracowanie własne na podstawie [4, 5, 6, 7, 8]

amounted to 1.47 PLN and was by 122% higher than the price offered in procurement in 1999 (0.66 PLN/l) (Table 3). High prices offered in Podlaskie Voivodeship for cow's milk purchase in the analysed period were conditioned by good financial and economic situation of large dairy enterprises located, in this voivodeship, high quality of milk produced by farmers and relatively large scale of production [15].

SUMMARY

On the basis of review of the literature on the subject and performed research analysis in the scope of determining changes in the Polish dairy sector taking place in the years 1998-2019 in the regional aspect of milk production in Poland it was stated that:

- Dynamic development of milk production was observed in the central-northeastern region of Poland, to which 6 voivodships were classified, i.e. Podlaskie, Warmińsko-Mazurskie, Mazowieckie, Wielkopolskie, Kujawsko-Pomorskie and Łódzkie. The factors determining the production growth in this region included: favourable natural conditions, agrarian structure, tradition and agricultural culture, which contributed to the concentration of herds and production of cheap roughage.
- On the other hand, the south-eastern region of Poland, which includes the Podkarpackie, Świętokrzyskie, Śląskie and Małopolskie voivodships, in the analysed period was characterised by the highest decrease in production, which was related to the fragmented agrarian structure, as well as the mountainous relief of this region.
- In the western and north-western region of Poland, which includes Dolnośląskie, Opolskie, Lubuskie and Zachodniopomorskie voivodeships, a decrease in production was also observed, which was a consequence of the lack of tradition in dairy cattle farming, while farms owned by legal persons, which were established on the basis of bankrupt state farms, continued to limit animal production, running mainly zero-inventory farms. Besides, the western and north-western region of Poland dominates in crop production [15, 18].

On the basis of the above analyses and the literature review, it was shown that under the conditions of market economy, milk production was reduced faster in those voivodeships where it is difficult to rationalise production, reduce production costs due to excessive fragmentation or less favourable natural conditions. Consequently, it was observed that the growth of milk production increases more dynamically in provinces where natural and economic conditions are favourable for effective milk production, i.e. from the south of Poland to the north [15, 18].

PODSUMOWANIE

W oparciu o przegląd literatury przedmiotu oraz przeprowadzone analizy badawcze w zakresie określenia zachodzących w polskim sektorze mleczarskim w latach 1998–2019 zmian w ujęciu regionalnym w zakresie produkcji mleka w Polsce stwierdzono, że:

- dynamiczny rozwój produkcji mleka obserwowany był w regionie centralno-północno-wschodnim Polski, do którego zakwalifikowano 6 województw, tj. podlaskie, warmińsko-mazurskie, mazowieckie, wielkopolskie, kujawsko-pomorskie i łódzkie. Do czynników determinujących wzrost produkcji w tym regionie zakwalifikowano: korzystne warunki przyrodnicze, strukturę agrarną, tradycję oraz kulturę rolną, co przyczyniło się do koncentracji stad oraz produkcji tanich pasz objętościowych.
- Region południowo-wschodni Polski, do którego można zaliczyć województwo: podkarpackie, świętokrzyskie, śląskie i małopolskie w analizowanym okresie cechował się najwyższym spadkiem produkcji, co było związane z rozdrobnioną strukturą agrarną, a także górskim ukształtowaniem tego regionu.
- W regionie zachodnim i północno-zachodnim Polski, do którego zaliczono województwo: dolnośląskie, opolskie, lubuskie, zachodniopomorskie i lubuskie, również obserwowano spadek produkcji, co było konsekwencją braku tradycji chowu bydła mlecznego, zaś gospodarstwa należące do osób prawnych, które powstały w oparciu o upadłe gospodarstwa państwowe nadal ograniczają produkcję zwierzęcą, prowadząc przede wszystkim gospodarstwa bezinwentarzowe. Poza tym region zachodni i północno-zachodni Polski dominuje w produkcji roślinnej [15, 18].

W oparciu o powyższe analizy oraz przegląd literatury wykazano, że w warunkach gospodarki rynkowej produkcja mleka była ograniczana szybciej w tych województwach, gdzie trudno jest racjonalizować produkcję, obniżać koszty produkcji ze względu na nadmierne rozdrobnienie lub mniej sprzyjające warunki przyrodnicze. W konsekwencji obserwowano, że wzrost produkcji mleka dynamiczniej zwiększa się w województwach, gdzie warunki przyrodnicze oraz gospodarcze są korzystne dla efektywnej produkcji mleka, czyli z południa Polski na północ [15,18].

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Dr hab. inż. Katarzyna SZWEDZIAK, Prof. PO[1]
[1]Department of Biosystems Engineering, Faculty of Production Engineering and Logistics
Opole University of Technology, Poland
Prof. dr hab. inż. Petr DOLEŽAL[2]
[2]Department of Animal Nutrition and Forage Production (FA), Mendel University in Brno, Czech Republic
Mgr inż Agnieszka KRUK

THE USE OF REGRESSION MODELLING TO DESCRIBE CHANGES TAKING PLACE ON THE AGRICULTURAL MARKET IN POLAND®

Wykorzystanie modelowania regresji do opisu zmian zachodzących na rynku rolnym w Polsce®

Key words: agricultural market, non-linear regression analysis, modelling, milk production, wholesale supplier.

The article presents a way of the application of regression analysis model to describe the phenomenon of the changing number of wholesale milk deliveries with respect to the number of wholesale suppliers on the agricultural market. In the process of mathematical regression, non-linear functions were used, where the independent variable was time. The data collected from the institution governing the milk production quota mechanism clearly shows that, during its operation, the national milk quota increased while the number of both wholesale and direct suppliers decreased. This situation resulted in an increased average individual quota per supplier. These results reflect the decreasing number of Polish farms maintaining dairy cattle in the country as a result of the shift from milk production in small farms to commercial production in farms developing in this sector. It should also be noted that the changes in the concentration of production are also linked to an increase in the quality of the raw material and final product. This tendency supports the fact that the dairy industry is becoming an increasingly specialized and forward-looking industry, as can already be seen from the consumer's perspective on the food products market today.
Although many authors have addressed the economic implications of the existing dairy price support scheme, few have explicitly considered the relationship between risk aversion, capital investment, milk production and price support policy in this process.

Słowa kluczowe: rynek rolny, analiza regresji nieliniowej, modelowanie, produkcja mleka, dostawca hurtowy.

W artykule przedstawiono sposób zastosowania modelu analizy regresji do opisu zjawiska zmiany liczby dostaw mleka w hurcie w stosunku do liczby dostawców hurtowych na rynku rolnym. W procesie regresji matematycznej wykorzystano funkcje nieliniowe, gdzie zmienną niezależną był czas. Z danych zebranych od instytucji rządzącej mechanizmem kwotowania produkcji mleka jasno wynika, że w trakcie jego funkcjonowania wzrosła krajowa kwota mleczna, a zmniejszyła się liczba zarówno hurtowych, jak i bezpośrednich dostawców. Sytuacja ta spowodowała wzrost średniej kwoty indywidualnej na dostawcę. Wyniki te odzwierciedlają zmniejszającą się liczbę polskich gospodarstw utrzymujących bydło mleczne w kraju w wyniku przejścia od produkcji mleka w gospodarstwach małych, do produkcji towarowej w gospodarstwach rozwijających się w tym sektorze. Należy również zauważyć, że zmiany w koncentracji produkcji są również związane ze wzrostem jakości surowca i produktu końcowego. Tendencja ta potwierdza fakt, że branża mleczarska staje się coraz bardziej wyspecjalizowaną i przyszłościową branżą, co widać już z perspektywy konsumenta na dzisiejszym rynku produktów spożywczych. Chociaż wielu autorów odniosło się do ekonomicznych implikacji istniejącego programu wsparcia cen mleka, niewielu wyraźnie rozważyło związek między awersją do ryzyka, inwestycjami kapitałowymi, produkcją mleka i polityką wspierania cen w tym procesie.

INTRODUCTION

The role of the European Union's common economic policy, based on the implementation of its respective policies, is to enhance its competitiveness in the global economy. It is therefore the aim and interest of the EU as a global player in the economy to increase the competitiveness of EU members in, among other things, agricultural production in relation to the marketing of these goods. Competitiveness is essential to maintain productivity growth and raise living standards, especially in small open economies that rely on international trade and are highly dependent on foreign direct investment [1, 11, 12].

Forecasting the production of agricultural products is an important theoretical and practical element. In 2008

Adres do korespondencji – Corresponding author: Katarzyna Szwedziak, Opole University of Technology, Faculty of Production Engineering and Logistics, Departament of Biosystem Engineering and Chemical Processes, ul. Mikołajczyka 5, 45-271 Opole, e-mail:k.szwedziak@po.edu.pl

a sudden increase in product prices was observed. These prices fell in following years. However, since around year 2000, an increasing trend in agricultural product prices could be observed. This can be clearly seen when analyzing the IMF (International Monetary Fund) food price index, including cereals, meat, seafood, sugar, bananas and oranges [20]. The factors influencing the prices of agricultural products are also discussed. In this context it is justified to take into account natural conditions such as weather conditions. Of course, prices are largely influenced by factors such as unforeseen droughts, floods and diseases. Therefore, forecasting prices of agricultural products is a difficult subject, as the above mentioned factors should be taken into account in modelling [23].

One of the key differences between research aimed at assessing the factors influencing structural change in agriculture is the use of data in macro or micro scale. Analyses using information on the structure of the agricultural market (e.g. number of entities) at regional or national level, try to explain the dynamics of development over a certain period of time [9, 18]. Meanwhile, studies based on micro scale data use information at the level of agricultural commercial entities to explain structural changes e.g. changes connected to an increase in the number of such entities [8, 39].

The assessment of the impact of purchase and wholesale of milk on the agricultural market, which significantly affects the competitiveness of the country, is a very important element. It should be noted that there are no perfect, universally accepted tools to analyze the impact of purchase and wholesale of milk on the prices of milk on the market. The literature contains opinions of experts who do not consider this indicator to be important for assessing economic competitiveness. Such studies include Krugman, Dicken, Baldwin [4], who emphasize that the basic measure of economic competitiveness between countries is labor productivity, arguing that the increase in living standards is essentially equal to national productivity growth rates [4, 15, 27]. In studies on the influence of various factors on the condition of the agricultural market, the *Dynamic Stochastic General Equilibrium* (DSGE) models are popular [6]. The use of models of this type offers a chance for a relatively accurate picture of the correlations existing in the economy. These models can also simulate the effects of different driving forces, including economic policy instruments [40, 42]. Market equilibrium assumes a balance between supply and demand. For example, an increase in supply affects the equilibrium point, causing prices to fall. When there is an increase in the volume of supply (excess of goods), a fall in prices occurs, which in turn makes the market return to the situation where the original volume of supplied goods is sufficient [7, 21]. Therefore, it was decided to find another way of modelling change in the volume of wholesale deliveries of milk affecting its price in order to describe this phenomenon accurately. Bapna and others [5] have used regression modelling in their research on price dynamics at Internet auctions. Wohlgenant and others [44] introduced a new model of retail price range, which takes into account both changes in supply of produce and retail demand. They applied this model to beef prices. The aim of Popescu's work [33] was to select the best regression model to evaluate milk production. The study used milk production as a dependent variable of Y and dairy cattle population as an independent variable X. Two polynomial regression models were tested: linear regression and square regression.

Structural changes in agriculture are complex processes influenced by many factors external and internal with respect to the farm. Their source of these factors is the changes taking place in the allocation of resources, i.e. labor, land and capital. One of the factors influencing structural change is agricultural policy. It is a form of planned interference of state institutions in the economic system resulting from the belief in market imperfection. The Common Agricultural Policy (CAP) is an example of action whereby changes in the agri-food sector and rural areas are stimulated with public funds [43].

According to the models of attraction to a given agricultural specialization used in the literature, three different model specifications can be distinguished: simple effects, differential effects and a fully extended model. A simple effect model assumes the same effect of a given explanatory variable on market share of all considered groups of farms. For example, the price of cereals has the same marginal impact on the share of dairy and cereal farms. The differential model allows for the influence of explanatory variables to be different depending on market shares of groups of farms. For example, the price of cereals may have a different influence on shares of dairy farms than on shares of cereal farms. In the fully extended model, the effects of explanatory variables on the own farm group and cross-farm group may differ between equations for the farm share. This approach allows to analyze the influence of explanatory variables e.g. the number of entities observed in one group of farms on the shares of other groups of farms e.g. dairy farms, farms with permanent crops [10, 30].

The specificity of the agricultural market, similarly to the housing market, makes it difficult to choose appropriate models to describe the market. In the case of the housing market customer preferences should be measured using the hedonic method [46].

Agricultural economics supports the decision-making process in agricultural policy-making by providing concepts, procedures and data to decision makers. The aim of quantitative analysis of agricultural policy is to examine its impact on a range of indicators at different levels of scale. For example, income, prices, farm size, productivity, factor allocation, production, welfare on a global, national, sectoral, regional or agricultural scale. An example that clearly shows the need for agricultural policy analysis and decision support is the 2003 reform of the European Union's Common Agricultural Policy. The Common Agricultural Policy is characterized by a significant change in the production support system [3, 14]. For this purpose, statistical techniques of designing experiments and modelling are used [24, 28]. This particular approach allows to systematically carry out simulation experiments with different collections of input parameters in order to discover the relationship between the model input data and the corresponding output data. The input data reflect the key factors of structural changes, including technological changes and macroeconomic framework conditions [25, 26].

The aim of this work is to analyze trends in order to obtain characteristics of changes in the volume of deliveries and the number of wholesale suppliers of milk within a few years from the introduction of the common agricultural policy.

MATERIALS AND METHODS

The analysis was performed by means of regression modelling using non-linear functions. The results of milk production from the years 2004–2011 were used in the research. The scope of the work included obtaining and proper grouping of the results, analysis of the obtained results by means of regression modelling, selection of an optimal model of the regression function, analysis of the generated models and interpretation of the results. The data for the research were obtained from the body governing the milk production quota mechanism. Data from 2004–2011 were used for the research. The number of producers (wholesale suppliers) and the volume of milk delivered by them to purchasing entities in the years 2004–2011 were used for the research. Data from each region in Poland were used for the research, taking into account the national average. In total, data from 16 voivodeships were used for the analysis. Then a comparative analysis of individual voivodeships to the national average was made. After analysis, empirical data were grouped and averaged. The analysis of the volume of wholesale sales by wholesale suppliers to purchasing entities was performed.

The obtained and grouped data were subjected to statistical analysis, during which the arithmetic mean, variance and standard deviation were determined. The data were then subjected to regression using exponential and power functions to determine the upward and downward trend and its character. The regression process was carried out in the MATLAB environment using the "fit" function, which uses the function of least squares to calculate the regression model parameters. The least squares method (LSM) is one of the most popular calculation methods used in statistics. It consists in determining the regression line, also called the trend line for the collected data – observable data, also called empirical data. The LSM method can be used to estimate both linear and non-linear relationships, however, in our case, non-linear relationships were used. In particular, four models of mathematical functions were used in the regression process: 1. $Fexp_1$ (1), which consists of the product of an exponential function with the exponent being the product of the parameter b and the independent variable (time t) and parameter a, which defines the amplitude; 2. $Fexp_2$ (2), which consists of the sum of two $Fexp_1$ functions, while the parameters of these functions being the regression coefficients determined in the regression process; 3. $Fpower_1$ (3), which is the product of the power function whose base is the independent variable i.e. time t and exponent is parameter b, and parameter a which defines the amplitude; $Fpower_2$ (4), which consists of the sum of the Fpower1 function and parameter c.

$$Fexp_1 = a * exp^{(bt)} \quad (1)$$

$$Fexp_2 = a * exp^{(bt)} + c * exp^{(dt)} \quad (2)$$

$$Fpower_1 = a * t^{(b)} \quad (3)$$

$$Fpower_2 = a * t^{(b)} + c \quad (4)$$

Where: a, b, c, d – are model parameters (regression coefficients),

t – independent variable [time].

The LSM method is designed to fit to the observable data collected, the pairs of results obtained for the applied correlations that are best matched to them (by calculation). The mathematical models were selected in such a way that it was possible to match their parameters with empirical data. The parameters of the model (a, b, c, d) were fitted in the regression process in such a way as to obtain possibly small fitting errors. The quality of the matching of measurement (empirical) data with the model (regression function) was determined by the size of the coefficient of determination R^2 (7) SSE sum of squared errors (5) root mean square error RMSE (8). It should be noted that an ideal match occurs when the value of R^2 is 1, while the values of SSE and RMSE are 0.

$$SSE = \sum_{i=1}^{n}(y_i - \hat{y}_i)^2 \quad (5)$$

$$SST = \sum_{i=1}^{n}(y_i - \bar{y})^2 \quad (6)$$

gdzie: n – is the number of observations,

y_i – i-th observation,

$\hat{y}_i$ – i-th prediction (calculated value),

$\bar{y}$ – mean over observations.

$$R^2 = 1 - \frac{SSE}{SST} \quad (7)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}} \quad (8)$$

The mean number of milk producers (wholesale suppliers) in the years 2004–2011 was used as observation data (dependent variable), which are summarized in Table 1. Subsequent years were used as an independent variable (time t).

Table 1. Mean number of wholesale milk suppliers and volume of wholesale milk deliveries in Poland in 2004–2011

Tabela 1. Średnia liczba hurtowych dostawców mleka i wielkość hurtowych dostaw mleka w Polsce w latach 2004–2011

Years	Number of wholesale milk suppliers	Wholesale supplies (kg)
2004	355246	8 346 602 807
2005	294468	8 931 767 093
2006	279257	8 967 395 692
2007	246720	8 878 812 386
2008	200995	9 316 352 490
2009	182836	9 087 608 502
2010	170106	9 108 491 821
2011	157684	9 499 434 521

Source: Own study

Źródło: Opracowanie własne

ANALYSIS AND DISCUSSION OF RESULTS

On the basis of the obtained results, comparative graphs of the number of suppliers and the volume of wholesale milk deliveries in Poland in the years 2004–2011 have been drawn up, which are presented in Figure 1. From the inclination of

the trend in the figure at the top one can observe an exponentially decreasing number of wholesale suppliers in the years 2004–2011. At the same time the figure at the bottom shows an inversely correlated power increase of wholesale deliveries in the country.

Figure 2 shows the changes in the number of wholesale suppliers in subsequent years with the result of fitting four regression models. From the inclination of the trend in the figure we can observe an almost linear decline of wholesale suppliers in the country.

A summary report of the quality assessment of the fitting of mathematical models for the whole country is presented in Fig. 3. The model selection was based on three quality assessment measures: R^2, SSE and RMSE. For all the models, high values of R^2 were obtained, with values below 0.98 only for Fpower1. RMSE and SSE values for Fexp1, Fexp2 and Fpower2 models show values at a similar level, i.e. RMSE in the range from 10.0 to 10.5 and SSE in the range from 445 to 605, whereas for Fpower1 the RMSE value is almost twice as high and SSE value five times as high. On the basis of the data presented in Figure 3, it can be concluded that the best fitting to empirical data was obtained for the Fexp2 model.

Figure 4 shows the values of quality assessment coefficients for model fitting obtained for individual regions. On the basis of the bars whose colors correspond to the individual regions, it can be concluded that the regression models used do not achieve a good fit for all cases. In particular, when considering SSE values, significant differences in the results obtained for data from individual regions are visible. Especially for the Fpower1 model the mean value of an SSE is 29.42, while the median value is 2.27, which is due to the many times higher value of SSE for Lublin and Warsaw regions. Similarly, for the RMSE ratio the values for

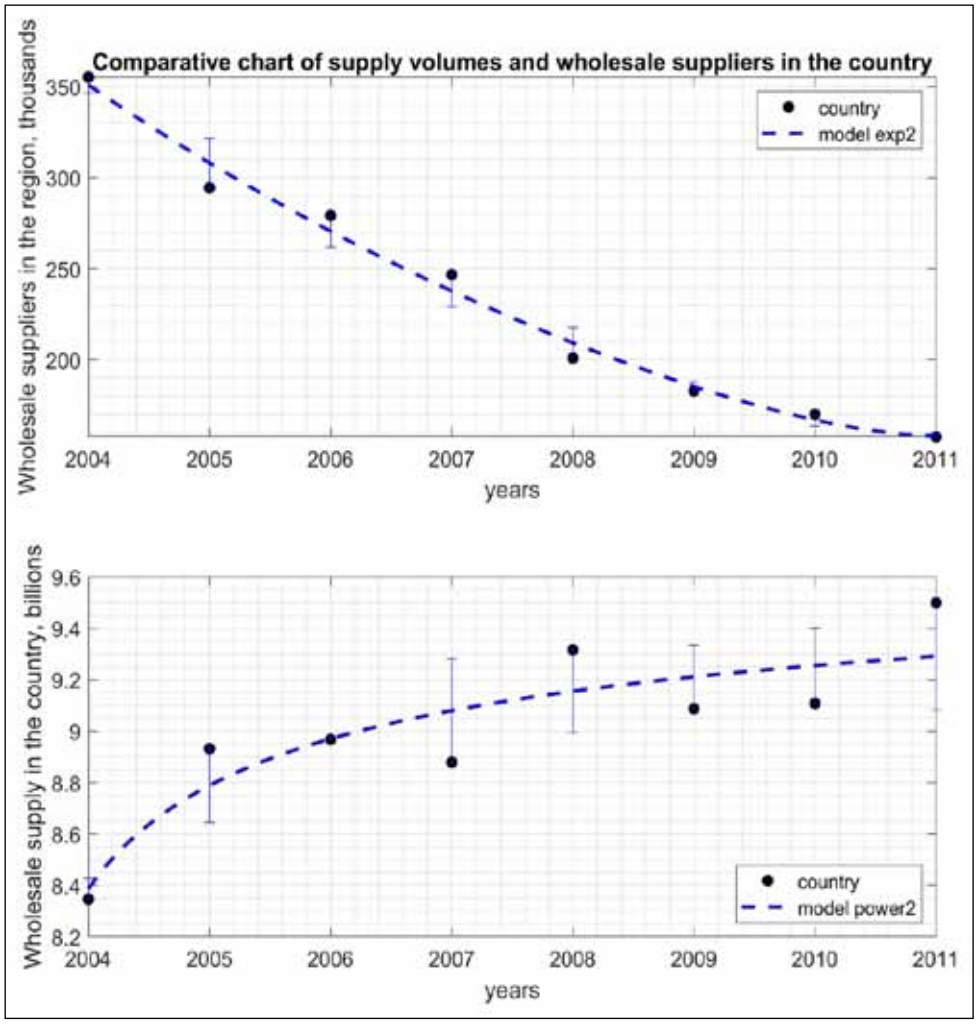

Fig. 1. Comparative graphs of suppliers and wholesale supplies in the country.
Rys. 1. Wykresy porównawcze dostawców i dostaw hurtowych w kraju.
Source: Own study
Źródło: Opracowanie własne

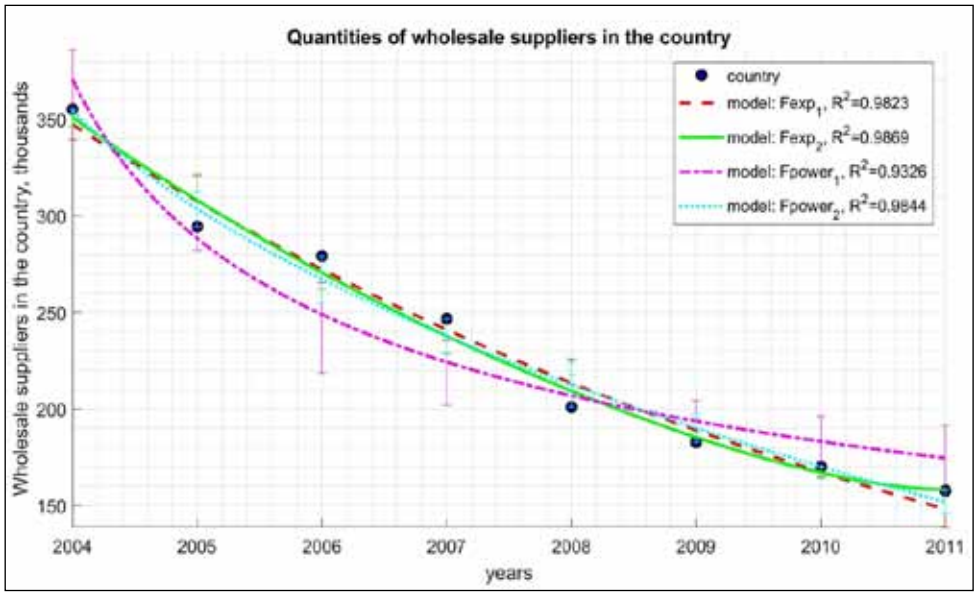

Fig. 2. Changes in the number of wholesale suppliers in the country.
Rys. 2. Zmiany w ilości hurtowych dostawców w kraju.
Source: Own study
Źródło: Opracowanie własne

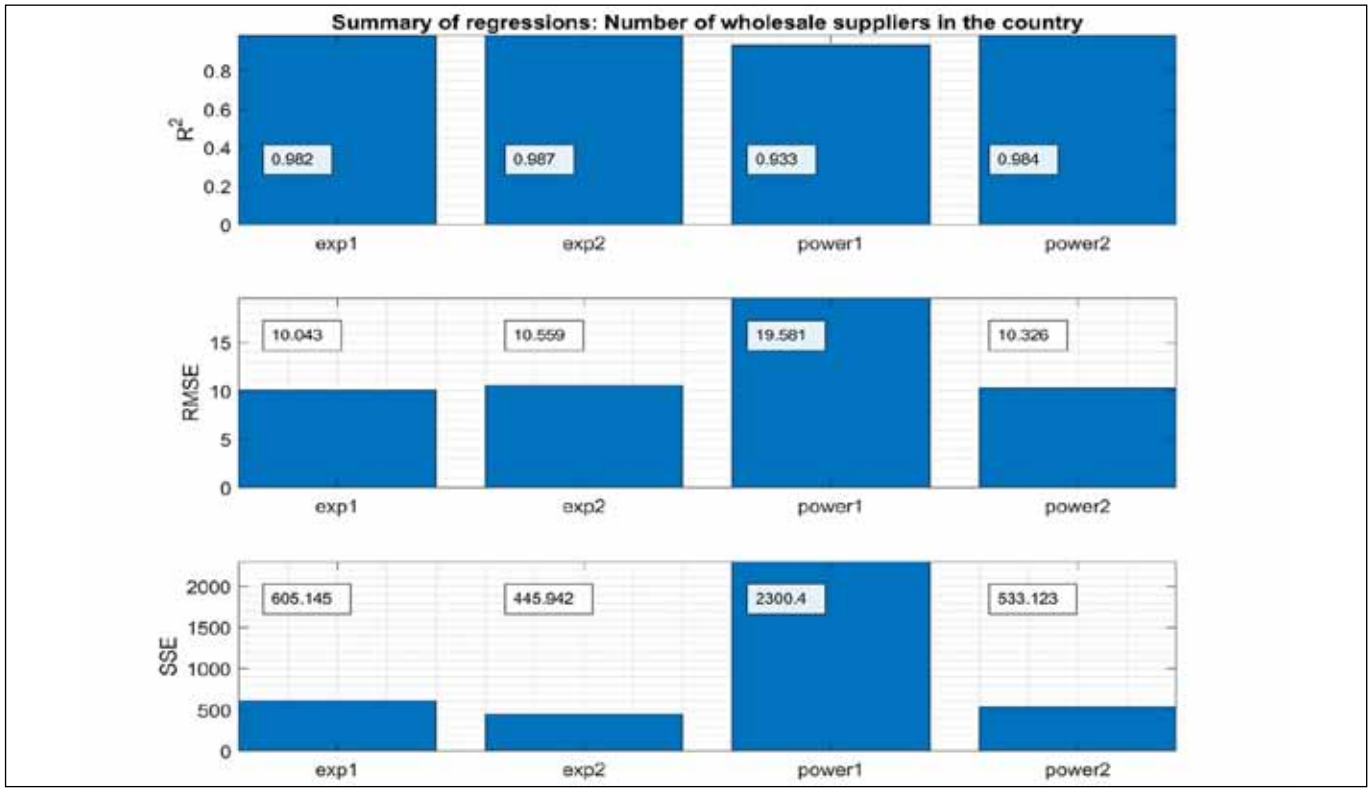

Fig. 3. Summary of the quality assessment of the fitting of the number of wholesale suppliers in the country.
Rys. 3. Podsumowanie oceny jakości dopasowania liczby dostawców hurtowych w kraju.

Source: Own study

Źródło: Opracowanie własne

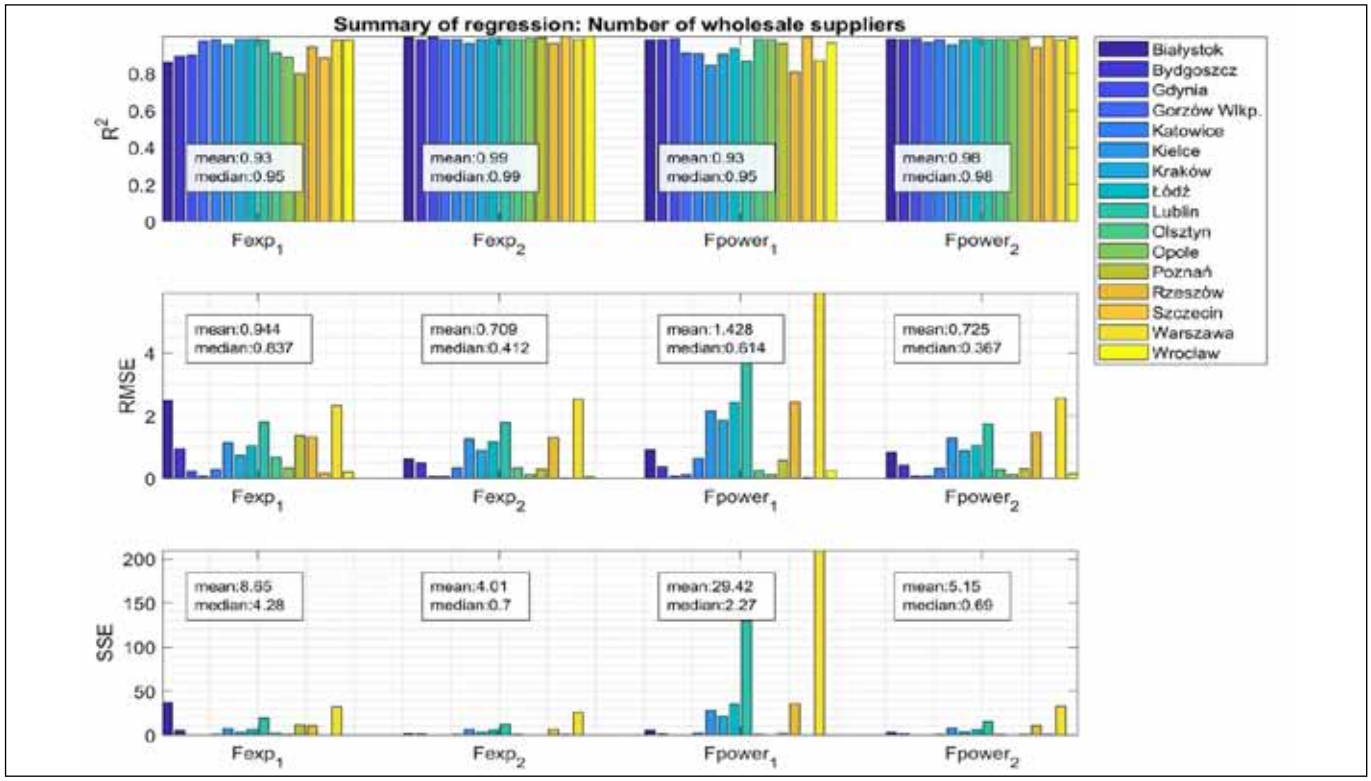

Fig. 4. Summary of the results of the quality assessment analysis of the fitting of the number of wholesale suppliers in all regions, where colors symbolize data corresponding to individual regions.
Rys. 4. Podsumowanie wyników analizy oceny jakości dopasowania liczby dostawców hurtowych we wszystkich regionach, gdzie kolory symbolizują dane odpowiadające poszczególnym regionom.

Source: Own study

Źródło: Opracowanie własne

these two regions are significantly higher. However, the analysis of R^2 values shows a high similarity in the quality of fit of the second order model, both power and exponential model, for which R^2 exceeds 0.98, both for the mean and median values. The other two models obtain slightly worse values of R^2, which exceed 0.9. Taking into account all values of calculated coefficients it can be concluded that the best fit was obtained for Fexp2 model.

Figure 5 shows the changes in the volume of wholesale deliveries in subsequent years with the result of fitting of four regression models. Unlike the number of wholesale suppliers, the volume of wholesale supplies in the country increased exponentially, which was confirmed by the fact that the best matching of observed data and the regression curve is for the Fpower2 model.

Figure 6 presents a summary of the results of the quality assessment analysis of the fitting of regression models for the whole country. The model was selected on the basis of three quality assessment measures: R^2, SSE and RMSE. For all models similar values of R^2 were obtained in the range from 0.691 to 0.793, SSE in the range from 0.169 to 0.251, RMSE in the range from 0.173 to 0.239. The second order power model, Fpower2, had the highest value of the R^2 coefficient and the lowest value of the SSE coefficient. It should be noted that for the first order power model, Fpower1, slightly better RMSE values were obtained compared to the second order power model.

Figure 7 shows the values of quality assessment coefficients for model fitting obtained for particular regions. On the basis of the bars whose colors correspond to the individual regions, it can be concluded that the regression models used do not achieve a good fit for all cases. In particular, for the regions of Gdynia, Gorzów, Katowice, Łódź, Opole and Szczecin, R2 values were obtained at the level below 0.6

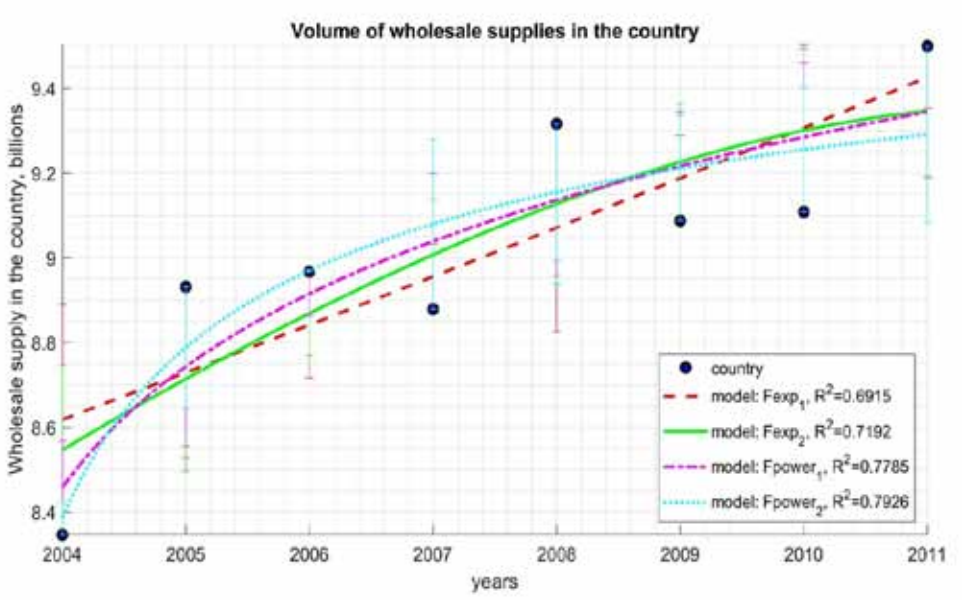

Fig. 5. Changes in the volume of wholesale supplies in the country.
Rys. 5. Zmiany wielkości dostaw hurtowych w kraju.
Source: Own study
Źródło: Opracowanie własne

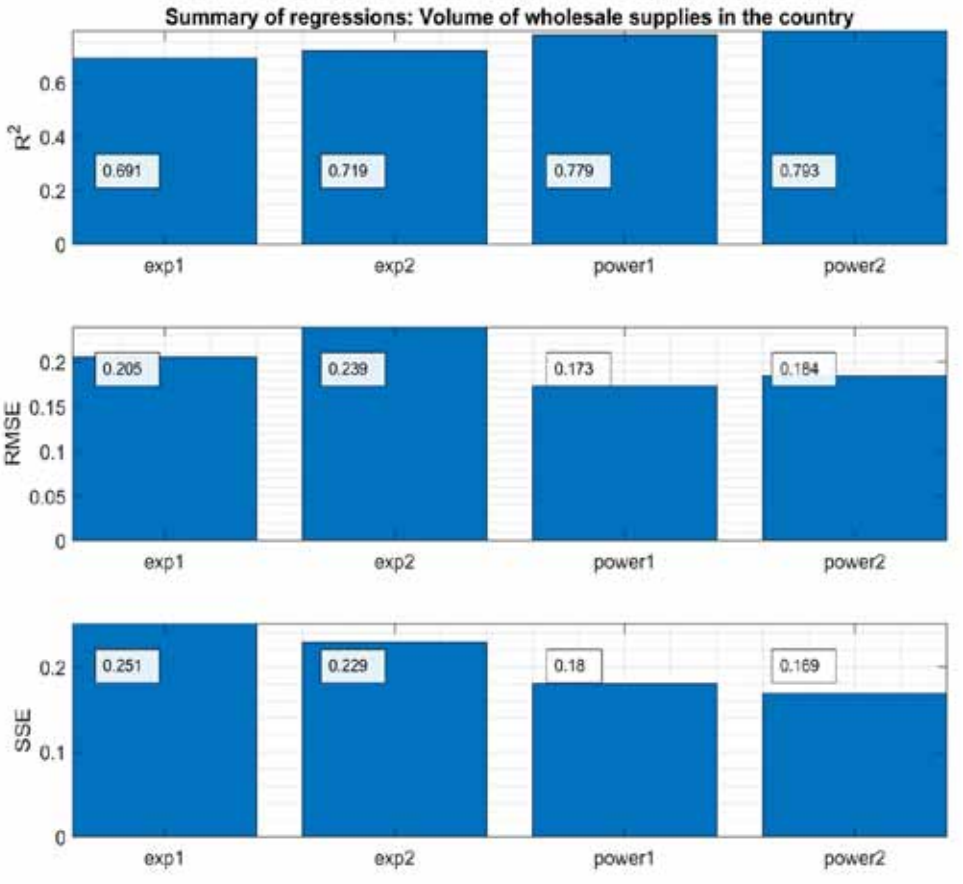

Fig. 6. Summary of the results of the quality assessment analysis of fitting the volume of wholesale supplies in the country.
Rys. 6. Podsumowanie wyników analizy oceny jakości dopasowania wielkości dostaw hurtowych w kraju.
Source: Own study
Źródło: Opracowanie własne

regardless of the model, with the exception of the Szczecin region, for which only for the Fexp2 model higher values were obtained, indicating a good fit. For the regions of Białystok, Bydgoszcz, Rzeszów, Kielce, Kraków and Poznań values of R^2 above 0.8 were obtained regardless of the model, except for the Fpower1 model, for which lower values of R^2 were obtained. The analysis of SSE coefficient values allowed to indicate differences in the fitting of regression models for data obtained in particular regions, especially differences for Warsaw region. However, it should also be noted that these differences are at the level of one thousandth of a fraction, which indicates that they are not significant. Based on the data presented in Figure 7, it can also be shown that higher values of R^2 do not always correlate with low values of SSE and RMSE, so it seems important to consider the quality of model matching on the basis of all three accuracy measures.

Popescu [33] in his research indicated the importance of comparative analysis of the standard error of different regression models, and finally decided to choose the type of regression whose standard error is the smallest, because the standard error is a measure of forecast accuracy. Authors managed to obtain a positive correlation of r = 0.884, the standard error of regression was smaller for linear regression, σest = 2 286.028830 than for square regression, σest = 2 336.915726, just in this case linear regression proved to fit the data better [33]. When describing the phenomenon of change in the volume of milk production depending on wholesale milk suppliers in particular regions of Poland, non-linear functions worked best. A satisfactory fit was obtained for power model of the second order, Fpower2, which was characterized by the best fit of R^2 = 0.987; RMSE = 10.559; and SSE = 445.942. In the modeling describing the volume of milk wholesale deliveries in the country, also the best fit was obtained for the power model of second order which was characterized by the quality factor: R^2 at 0.793; RMSE = 0.184 and SSE = 0.169. Empirical modelling (EM) is a useful approach to analyze different problems in many areas. As it is known, this type of modelling is particularly helpful when parametric models cannot be formulated for various reasons. Based on different methods and approaches (e.g. the least squares method), it provides a preliminary understanding of the relationships that exist between different variables belonging to a particular system or process [19]. The least squares method also allowed to obtain satisfactory results allowing to describe changes of production quantities and wholesale suppliers of milk on the agricultural market in Poland. In the research conducted by

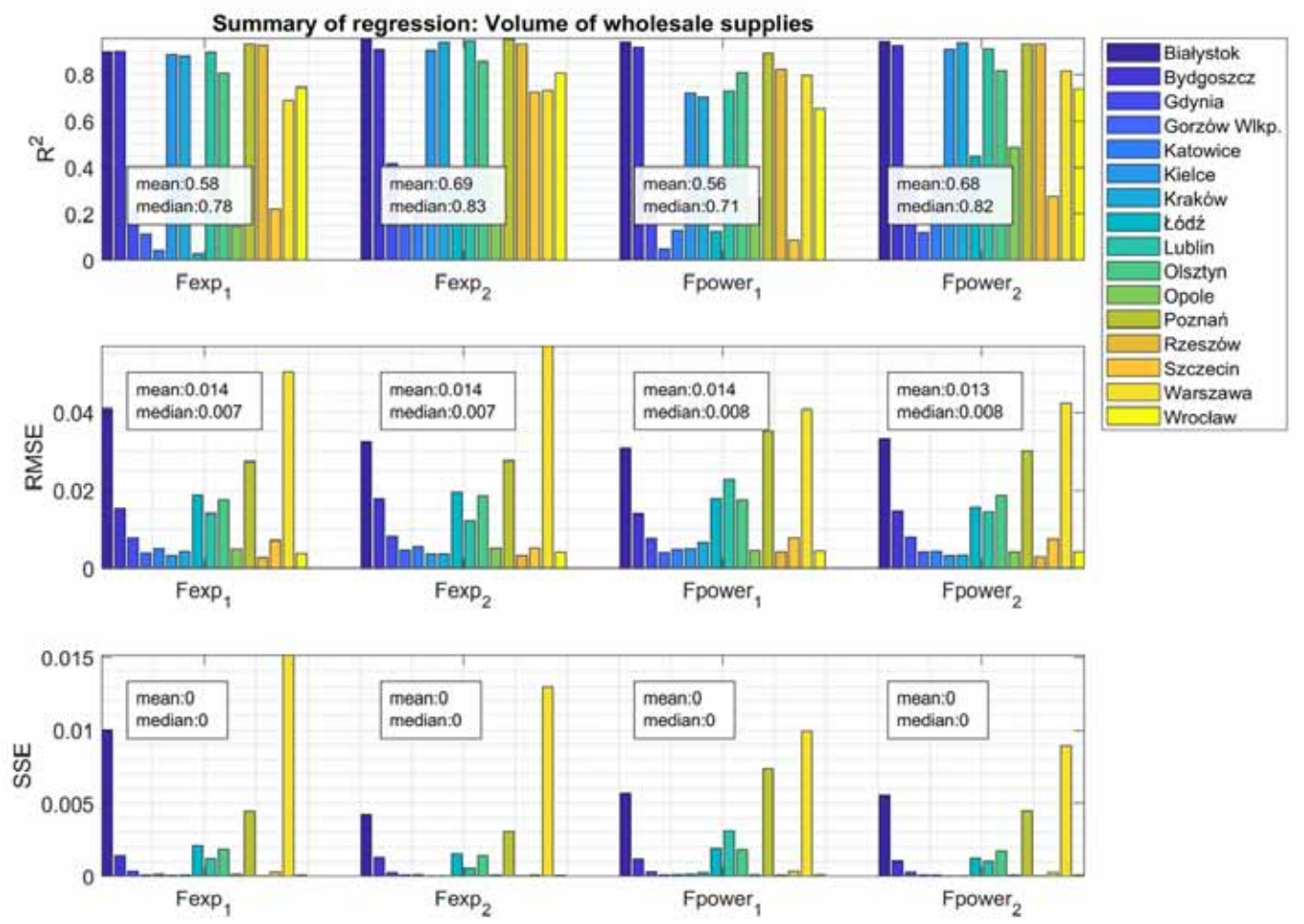

Fig. 7. Summary of the results of the quality assessment analysis of wholesale supply fitting in all regions, where colors symbolize data corresponding to individual regions.

Rys. 7. Podsumowanie wyników analizy oceny jakości dopasowania zaopatrzenia hurtowego we wszystkich regionach, gdzie kolory symbolizują dane odpowiadające poszczególnym regionom.

Source: Own study

Źródło: Opracowanie własne

Jaliliva et al. [22] a two-stage approach to the least squares analysis was applied to estimate the impact of contextual variables on rice production. Many scientific papers have proposed and studied the use of a partially adaptive estimation technique to improve the reliability of conclusions drawn from multiple regression models when the dependent variable is not a normal distribution [17, 41]. These results confirm the assumption that the application regression techniques in the description of changes in production volume and wholesale suppliers of milk on the agricultural market is justified, as proved by the revision of the proposed models by comparing the R^2 factor. The usefulness of this technique for agricultural economics research is assessed using Monte Carlo simulations and two main applications: time series analysis and empirical model [44]. Ramirez et al. [34] found that the least-squares method allows in practice for more precise conclusions about the magnitude of the influence of independent variables on the dependent variable of interest. Moreover, this technique generates confidence intervals for forecasts of dependent variables, which are more efficient and consistent with the observed data [18, 20]. Non-linear regression models are important tools, because many processes in agriculture are better represented by non-linear than linear models. The fitting of non-linear models is not a one-stage procedure, but a complex process that requires careful examination of each individual stage. Depending on the purpose and field of application, different priorities are set when fitting non-linear models; these include obtaining acceptable estimates of parameters and a good model fit while meeting the standard assumptions of statistical models [2]. The aim of the studies by Daud et al. [13] was to identify sources of risk that may occur in the existing milk supply chain and their impact on the production chain behavior. Agricultural production is in fact a business of risk. Risks exist at each stage of production conducted by each participant of the production chain. This means that the success of improving the results of agricultural activity will depend mainly on the ability of entities to manage risk [29, 34, 36, 45] Roder et al. [35] and Neuenfeldt et al. [31, 32], while they analyzed the impact of various socio-economic factors on changes in the specialization of farms on the basis of data at the farm level only. Recent studies also combine micro and macro data to make better use of available information when identifying and predicting structural changes in farms [37, 38]. The analysis of the obtained results also showed that regression modelling can be a useful tool for forecasting and explaining structural changes in agriculture. It should be noted here that on the territory of Poland the number of entities collecting milk has decreased while the amount of milk collected by these entities has increased. Therefore, it is noted that milk production is undergoing specialization by its concentration. Therefore, it can be clearly shown that the historical structure of farms explains the need to develop specialization of agricultural holdings. Dracha [16] in his research analyzed wheat, corn and soybean. Forecasts one month in advance were constructed using such techniques as dynamic model averaging (DMA), probability model median and Bayesian model averaging. Common features of these methods are the time-varying parameters of the approach to estimating regression coefficients and dealing with model uncertainty. The author started with many potentially important explanatory variables and constructed various linear regression models. Then, on the basis of these models he constructed an averaged forecast. Moreover, these techniques can be easily modified from model averaging to model selection approach. The interpretation of time-variable weights assigned to component models containing a given variable suggests that the economic development of emerging markets (Brazil, Russia, India and China) has recently been one of the most important drivers of agricultural goods prices. The analysis was conducted on monthly data between 1976 and 2016. The initial factors influencing the price were various fundamental, macroeconomic and financial factors [16]. Neunefeld et al. [31, 32] in their article analyzed the factors of structural change of farms in the EU-27, using a new analytical framework in the field of agricultural economics. They applied the model of multiplicative competitive interaction (MCI). The MCI offers a more economical specification for estimating models of shares of regional farm groups compared to the popular Markov approach. The MCI framework explains the shares of regional farm groups taken from the Farm Structure Survey (FSS) using socio-economic variables from the Farm Accountancy Data Network (FADN) and other databases from 1989 to 2013. The authors considered 8 production specializations and 2 classes of size at regional level NUTS 2. In addition, they conducted a simulation experiment in which they obtained the flexibility of structural changes in relation to time-dependent variables. The structural change seems to be the most flexible with respect to income and macroeconomic variables [31, 32]. Therefore, a deeper analysis of the results obtained also shows that some of the estimated coefficients suggest an unexplained response of farm specialization shares with respect to price. The reasons can partly be attributed to the peculiarities of the data set used. Agriculture is not a very dynamic segment of the economy. Therefore, the assumption of no changes or no business operation is confirmed by the observed time series [31, 32].

CONCLUSIONS

On the basis of regressive modelling conducted in order to obtain characteristics of the influence of changes in the number of wholesale milk suppliers on milk production, it can be stated that regressive modelling and the use of the least squares function allows to generate models describing the phenomenon of tendencies of changes in the volume of milk production depending on the number of suppliers in particular regions of Poland. The best fit was obtained for exponential model of the second order, which was characterized by the coefficient $R^2 = 0.987$; RMSE = 10.559; SEE = 445.942. Regressive modelling and the use of the least squares function allows also to generate models describing the volume of wholesale milk deliveries in Poland. The best fit was obtained for the power model of the second order, which had the following values for the quality factors under consideration: $R^2 = 0.793$; RMSE = 0.184 and SSE = 0.169. The analysis of the empirical data showed that the volume of milk delivered in the country increased within 8 years while the number of wholesale suppliers decreased. These results reflect the decreasing number of farms maintaining dairy cattle in Poland due to abandonment of commercial milk production in small farms in favor of farms specialized in this sector. It should be noted that changes in the concentration of production have

a significant impact on the quality of the raw material and products due to its professional specialization. This, in turn, increases the competitiveness of our production on the EU market.

WNIOSKI

Na podstawie modelowania regresywnego przeprowadzonego w celu uzyskania charakterystyk wpływu zmian liczby dostawców hurtowych mleka na produkcję mleka można stwierdzić, że modelowanie regresywne oraz wykorzystanie funkcji najmniejszych kwadratów pozwala na generowanie modeli opisujących zjawisko tendencji zmian wielkości produkcji mleka w zależności od liczby dostawców w poszczególnych regionach Polski. Najlepsze dopasowanie uzyskano dla modelu wykładniczego drugiego rzędu, który charakteryzował się współczynnikiem R2 = 0,987; RMSE = 10,559; ZOBACZ = 445.942. Modelowanie regresywne i wykorzystanie funkcji najmniejszych kwadratów pozwala również na generowanie modeli opisujących wielkość hurtowych dostaw mleka w Polsce. Najlepsze dopasowanie uzyskano dla modelu potęgowego drugiego rzędu, który dla rozważanych współczynników jakości miał następujące wartości: R2= 0,793; RMSE = 0,184 i SSE = 0,169. Analiza danych empirycznych wykazała, że ilość dostarczonego mleka w kraju wzrosła w ciągu 8 lat, natomiast zmniejszyła się liczba dostawców hurtowych. Wyniki te odzwierciedlają zmniejszającą się liczbę gospodarstw utrzymujących bydło mleczne w Polsce w związku z zaniechaniem towarowej produkcji mleka w gospodarstwach małych na rzecz gospodarstw wyspecjalizowanych w tym sektorze. Należy zauważyć, że zmiany w koncentracji produkcji mają istotny wpływ na jakość surowca i produktów ze względu na jego specjalizację zawodową. To z kolei zwiększa konkurencyjność naszej produkcji na rynku UE.

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Mgr inż. Patrycja CICHOŃSKA[1]
Prof. dr hab. Ewa DOMIAN[2]
Dr hab. Małgorzata ZIARNO, prof. SGGW[1]
[1]Department of Food Technology and Assessment, Institute of Food Science, University of Life Sciences – SGGW (WULS-SGGW), Warsaw, Poland
Katedra Technologii i Oceny Żywności, Instytut Nauk o Żywności, Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Polska
[2]Department of Food Engineering and Process Management, Institute of Food Science, University of Life Sciences – SGGW (WULS-SGGW), Warsaw, Poland
Katedra Inżynierii Żywności i Organizacji Produkcji, Instytut Nauk o Żywności, Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Polska

THE EFFECT OF HIGH-PRESSURE HOMOGENIZATION ON THE TEXTURE OF FERMENTED BEAN-BASED BEVERAGES®

Wpływ homogenizacji wysokociśnieniowej na teksturę fermentowanych napojów z fasoli®

Key words: plant-based beverages, bean-based beverages, milk substitutes, high-pressure homogenization, physical properties of food, texture.

Various types of technological treatments, including high-pressure homogenization (HPH), can be used to obtain plant-based yogurts. It is one of the technologies with a positive impact on food particles which leads to improvement of quality, shelf life, and popularity of the product. The aim of the study was to analyze the effect of HPH on the texture of fermented bean-based beverages. Selected texture discriminants (hardness, adhesiveness) for beverages prepared from germinated and non-germinated beans, subjected to and not subjected to HPH were analyzed. HPH bean-based beverages were lower pH values, before fermentation, after fermentation, and after 21 days of storage, which indicates that HPH results in a more efficient fermentation for bean-based beverages. In all the tested samples HPH significantly increased the hardness and adhesiveness of tested beverages. The values obtained for the tested texture determinants reached a similar level for the samples before fermentation, after fermentation, and after 21 days of storage, which indicates that the HPH was responsible for the texture shaping of the tested bean-based beverages. There is a need for further research into the physical properties of bean-based milk yogurt substitutes produced using HPH.

Słowa kluczowe: napoje roślinne, napój fasolowy, substytuty mleka, homogenizacja wysokociśnieniowa, właściwości fizyczne żywności, tekstura.

Różnego rodzaju zabiegi technologiczne, w tym homogenizacja wysokociśnieniowa (HPH), mogą być wykorzystane do produkcji jogurtów roślinnych. Jest to jedna z technologii pozytywnie wpływających na cząstki w żywności, która prowadzi do poprawy jakości, trwałości i popularności produktu. Celem pracy była analiza wpływu HPH na teksturę fermentowanych napojów na bazie fasoli. Analizie poddano wybrane wyróżniki tekstury (twardość, adhezyjność) napojów przygotowanych z fasoli skiełkowanej i nieskiełkowanej, poddanych i niepoddanych działaniu HPH. Napoje na bazie fasoli poddane HPH miały niższe wartości pH przed fermentacją, po fermentacji i po 21 dniach przechowywania, co wskazuje, że zastosowanie HPH skutkuje bardziej wydajnym procesem fermentacji napojów na bazie fasoli. We wszystkich badanych próbkach HPH istotnie zwiększyła twardość i adhezyjność napojów. Wartości uzyskane dla badanych wyznaczników tekstury osiągnęły podobny poziom dla próbek przed fermentacją, po fermentacji i po 21 dniach przechowywania, co wskazuje, że HPH odpowiadała za kształtowanie tekstury badanych napojów. Istnieje potrzeba dalszych badań nad właściwościami fizycznymi substytutów jogurtu mlecznego na bazie fasoli wytwarzanych z wykorzystaniem HPH.

INTRODUCTION

Sensory quality is one of the most important factors that consumers consider in their food choices. The sensory quality of food depends on many factors, including e.g. smell, taste, and texture [17]. Food texture is defined as all the rheological and structural attributes of the product perceptible using mechanical, tactile, and where appropriate, visual, and auditory receptors [7]. The texture of the product is of great importance in all food sectors, including the dairy industry. One of the most consumed dairy products worldwide is fermented milk and yogurts. Multiple researchers are concerned their texture and the possibility of its modification [8, 13].

Corresponding author - Adres do korespondencji: Patrycja Cichońska, Institute of Food Sciences, Warsaw University of Life Sciences (SGGW – WULS), 159c Nowoursynowska Street, 02-766 Warsaw, Poland, e-mail: patrycja_cichonska@sggw.edu.pl

The texture of yogurt-type products is mainly influenced by the technological processes used during their production. The texture of milk yoghurt is mainly shaped by the fermentation process. During fermentation, lactic acid bacteria convert the lactose present in the milk into lactic acid, which results in the formation of a curd [2, 27]. The most frequently studied texture parameters of yogurts are hardness and adhesiveness. Hardness was defined as the necessary force to attain a given deformation. This factor is a critical texture property for yogurt-like products. Adhesiveness is the required work for prevailing attraction force between foodstuff surface and various substances coming into contact with them. It is the force required to separate the material that sticks to the teeth during eating [21].

Due to the growing consumer awareness related to intensified animal production, the popularity of plant-based diets is increasing. As a result, there is a growing demand for various types of alternatives to animal products, including dairy products [11, 15]. The size of the global dairy alternatives market has been estimated at $ 20.50 billion in 2020 and the compound annual growth rate (CAGR) is expected to be 12.5% in 2021–2028 [5]. The most popular alternative products to dairy products are plant-based beverages, which are mainly treated as milk substitutes [1]. They are produced from various raw materials, including e.g. cereals, legumes, nuts, and seeds [22]. With the growing popularity of dairy alternatives, the demand for fermented plant products containing probiotics is increasing [24].

The most popular plant-based beverages are soybean-based beverages, but also other legumes (e.g. beans, peas, chickpeas) can be a suitable matrix for their production [22]. Beans come in many varieties (e.g. white, red, adzuki, and mung beans), but all of them are characterized by a high protein content, which is two to three times higher than in cereal grains. In addition, beans contain large amounts of dietary fiber, starch, vitamins, and minerals, as well as a wide range of phytochemicals [3]. Bean-based beverages are not produced on a large scale but have been successfully produced under laboratory conditions [30].

Plant-based beverages can be used to make plant-based yoghurt substitutes [9]. Plant-based products should be similar to conventional yogurt in terms of textural and sensory properties and the ability to host viable lactic acid bacteria for long-time storage. Fermentation applied to plant-based matrices has been identified as a natural and effective biotechnological option to increase their technological, sensory, nutritional, and functional properties [20]. Various types of technological treatments, including high-pressure homogenization (HPH), can also be used to obtain plant-based yogurts. [14]. Homogenization is the ability to produce a homogeneous size distribution of particles suspended in a liquid, by forcing the liquid under the effect of pressure through a specifically designed homogenization valve. Homogenizers process fluid matrices at a pressure ranging between 20–100 MPa, which allows to reduction particle size and consequently increase the stability of emulsions [23]. It is one of the technologies with a positive impact on food particles that leads to improvement of quality, shelf life, and popularity of the product, which is considered a suitable alternative to thermal processes due to the lack of thermal damage [16].

The available literature lacks research on the texture of yogurt-type bean-based beverages and the factors influencing it. Therefore, the aim of the study was to analyze the effect of HPH on the texture of fermented bean-based beverages. Selected texture discriminants (hardness, adhesiveness) for beverages prepared from germinated and non-germinated beans, subjected to and not subjected to HPH were analyzed. The tests were performed for beverages before fermentation, after fermentation, and after 21 days of refrigerated storage (6°C).

MATERIALS AND METHODS

Preparation of bean-based beverages

The bean-based beverages were prepared from white kidney beans "Piękny Jaś Karłowy" (Lestello Sp. z o.o., Poland). The beverages were made in two variants - from germinated and non-germinated beans. The germination was carried out in a sprouter at 25°C for 72 hours (with changing the water every 24 hours). Germinated and non-germinated beans were sterilized at 121°C for 15 minutes, mixed with drinking water in a ratio of 1:9 (m/m), and blended until a homogeneous mass was obtained. The resulting mass was filtered through a sieve with a mesh size of 0.1 mm. The obtained beverages were sterilized at 121° C for 15 minutes. Before final sterilization, half of the obtained beverages were subjected to high-pressure homogenization with NS 1001 L2 PANDA, GEA Niro Soavi (GEA, Italy) at a pressure of 50 MPa.

Fermentation of bean-based beverages

Three industrial freeze-dried starter cultures were used in the study, including:

– Beaugel Soja 1 (Ets Coquard, France), containing *Lactobacillus casei* (currently classified as *Lacticaseibacillus casei*), *Streptococcus thermophilus*, and *Lactobacillus delbrueckii* subsp. *bulgaricus*;
– YO-MIX 207 LYO 500 DCU (DuPont™ Danisco, Denmark), containing *Streptococcus thermophilus*, *Lactobacillus delbrueckii* subsp. *bulgaricus*, *Lactobacillus acidophilus*, and *Bifidobacterium lactis*;
– ABY-3 (Chr. Hansen, Denmark), containing *Lactobacillus acidophilus* La-5, *Bifidobacterium animalis* subsp. *lactis* BB-12, *Streptococcus thermophilus*, and *Lactobacillus delbrueckii* subsp. *bulgaricus*.

The inoculums were prepared by dissolving the freeze-dried starter cultures in distilled water. The beverages samples were inoculated at 1.0% (m/m) and incubated at 45°C for 6 hours. After the fermentation was completed, the beverages were refrigerated at 6°C and stored for 21 days.

Active acidity and microflora analysis

The analysis of active acidity and microflora was performed before the fermentation, after the fermentation, and after 21 days of storage under refrigeration conditions (6°C). The active acidity was determined by measuring the pH using a CPO-505 pH meter (Elmetron, Poland). Measurements were made in triplicate for each sample.

Texture analysis

The texture analysis of bean-based beverages included the determination of hardness and adhesiveness. The test was carried out for beverages before fermentation, after fermentation, and after 21 days of storage at 6°C, for 100 ml samples. The tests were carried out using a Brookfield CT3 10K texturometer (AMETEK Brookfield, USA) with a TA4 / 1000 cylindrical probe with a diameter of 38.1 mm and a height of 20 mm. A pressure force of 0.04 N was applied during the experiment. The probe used was moved at a speed of 2 mm/s towards the inside of the test and 4.5 mm/s in the opposite direction during withdrawal from the test. Hardness was expressed in N units and cohesiveness in mJ. The tests were carried out in 3 replications, with single penetration. The results were analyzed using the TexturePro CT V1.4 Build 17 software included with the measurement kit.

Data analysis

The results of the study were subjected to one-way analysis of variance (ANOVA), using the software Statistica 13.1 (StatSoft, Poland). It allowed determining the effect of HPH on the studied texture properties of bean-based beverages. The significance of the differences was analyzed by Tukey's test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Plant-based beverages are mainly treated as substitutes for dairy products. It is desirable to use technological processes that will allow to obtain plant-based products resembling their dairy analogs. Plant-based beverages usually differ in composition and sensory quality from milk; however, they can be fermented to produce dairy-free yogurt-type products while rendering the raw material into a more palatable form [15]. During the production of the tested bean-based beverages, fermentation and HPH were used to modify the quality of the final products.

The indicator of the progress of the fermentation is the pH of the product, which shows the level of active acidity. The acidity of fermented plant-based yogurts largely determines their taste, contributes to control microflora growth, and should be similar to the acidity of fermented commercial milk-based and plant-based yogurts [9, 28]. For most of the bean-based beverages samples tested, significant differences were observed in the pH value for homogenized and non-homogenized, germinated, and non-germinated beverages (Table 1). HPH bean-based beverages have lower pH values, both before and after the fermentation, and also after 21 days of storage. According to Mojka [19], the optimal pH for fermented milk beverages is in the range of 4.0 – 4.5. In the tested non-homogenized bean-based beverages, pH values close to 4.5 were achieved only in samples fermented with

Table 1. Changes in the active acidity in the high-pressure homogenized (HPH) and non-high-pressure homogenized (non-HPH) bean-based beverages. Values are presented as mean and standard deviation (± SD)

Tabela 1. Zmiany kwasowości czynnej w homogenizowanych (HPH) i niehomogenizowanych (non-HPH) wysokociśnieniowo napojach fasolowych. Wartości przedstawione są jako średnia i odchylenie standardowe (± SD)

Type of bean-based beverages	Time of the measurement	Starter cultures	pH	
			non-HPH beverages	HPH beverages
Non-germinated	before fermentation	-	6.25 ± 0.07 a	5.84 ± 0.14 b
	after fermentation	Beaugel Soja 1	4.95 ± 0.12 a	4.86 ± 0.12 a
		YO-MIX 207	4.84 ± 0.04 a	4.47 ± 0.11 b
		ABY-3	4.53 ± 0.11 a	4.15 ± 0.04 b
	after 21 days of storage	Beaugel Soja 1	4.94 ± 0.09 a	4.22 ± 0.05 b
		YO-MIX 207	4.77 ± 0.06 a	4.21 ± 0.12 b
		ABY-3	4.56 ± 0.05 a	4.14 ± 0.11 b
Germinated	before fermentation	-	6.37 ± 0.10 a	6.44 ± 0.12 a
	after fermentation	Beaugel Soja 1	4.56 ± 0.03 a	4.40 ± 0.10 a
		YO-MIX 207	4.86 ± 0.02 a	4.26 ± 0.06 b
		ABY-3	4.50 ± 0.09 a	4.12 ± 0.10 b
	after 21 days of storage	Beaugel Soja 1	4.76 ± 0.08 a	4.43 ± 0.11 b
		YO-MIX 207	4.73 ± 0.05 a	4.36 ± 0.04 b
		ABY-3	4.44 ± 0.04 a	4.24 ± 0.07 b

a, b – Within each row, the means values with the same letter do not differ significantly ($p \geq 0.05$).
a, b – W każdym wierszu średnie z taką samą literą nie różnią się istotnie ($p \geq 0,05$).

Source: The own study

Źródło: Badania własne

the ABY-3 starter culture, containing *L. acidophilus* La-5, *B. animalis* subsp. *lactis* BB-12, *S. thermophilus*, *L. delbrueckii* subsp. *bulgaricus*. In homogenized beverages, pH values in the range of 4.0 – 4.5 were observed for all samples of germinated beverages and the majority of non-germinated samples after the fermentation and after 21 days of storage. The higher value (4.86) was shown only for the sample of non-germinated beverage, fermented with the starter culture Beaugel Soja 1, containing *L. casei*, *S. thermophilus*, *L. delbrueckii* subsp. *bulgaricus.* This indicates that HPH results in a more efficient fermentation for bean-based beverages. The reason may be the increased availability of sugars constituting a substrate for the production of lactic acid during fermentation in beverages subjected to HPH.

When analyzing selected texture discriminants of the tested bean-based beverages, it was found that in all the tested samples, the HPH process significantly increased hardness and adhesiveness, both in germinated and non-germinated beverages (Figure 1, Figure 2). Non-homogenized bean-based beverages were characterized by a low level of hardness (in the range of 0.2 – 0.3 N) and adhesiveness (in the range of 0.1 – 1.0 mJ). In all tested non-homogenized samples, these values did not change significantly after the fermentation process, and after the 21-days of storage. Homogenized bean-based beverages were characterized by a significantly higher level of hardness (in the range of 1.2 – 1.8 N) and adhesiveness (in the range of 11.8 – 15.4 mJ). The texture discriminants tested remained high in the samples, after fermentation, and after 21 days of storage. This may indicate that the HPH was mainly responsible for the texture shaping of the tested beverages. Fermentation did not affect the shaping of the texture but caused only a significant decrease in the pH value. Different results are obtained by the authors for milk yogurts in which the fermentation is sufficient to shape the appropriate texture of the products [6, 12, 29]. This may be due to the different structure of plant proteins and milk proteins, which affects the rate and mechanisms of the gelling process.

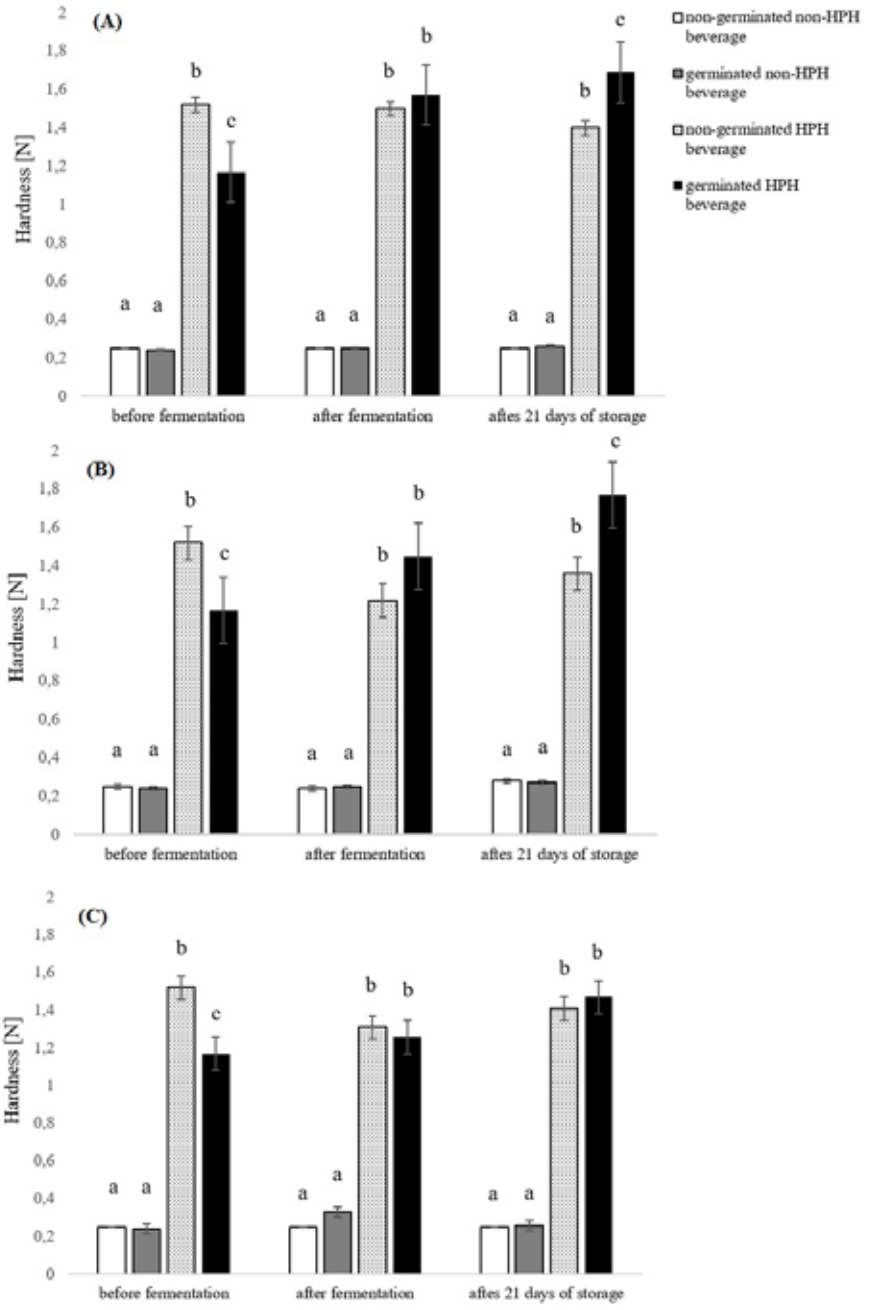

Fig. 1. The effect of HPH, germination and storage on hardness of bean-based beverages fermented using the Beaugel Soja 1 (A), YO-MIX 207 (B), ABY-3 (C) starter cultures.

Rys. 1. Wpływ HPH, kiełkowania i przechowywania na twardość napojów fasolowych fermentowanych z wykorzystaniem kultur starterowych Beaugel Soja 1 (A), YO-MIX 207 (B), ABY-3 (C).

a, b, c – Within each measuring period means with a common symbol are not significantly different ($p \geq 0.05$). Error bars represent standard error of the mean.

a, b, c – W ramach każdego okresu pomiarowego średnie z takim samym symbolem nie różnią się istotnie ($p \geq 0,05$). Słupki błędów reprezentują błąd standardowy średniej.

Source: The own study

Źródło: Badania własne

There was no unidirectional tendency for the influence of the germination process on the hardness and adhesiveness of the bean-based beverages tested. The changes in these parameters were mainly influenced by the HPH. Within the homogenized beverages, the changes in the values of the studied texture determinants were statistically insignificant or not greater than the decrease or increase in the range of 0.41 N for hardness and 3.4 mJ for adhesiveness.

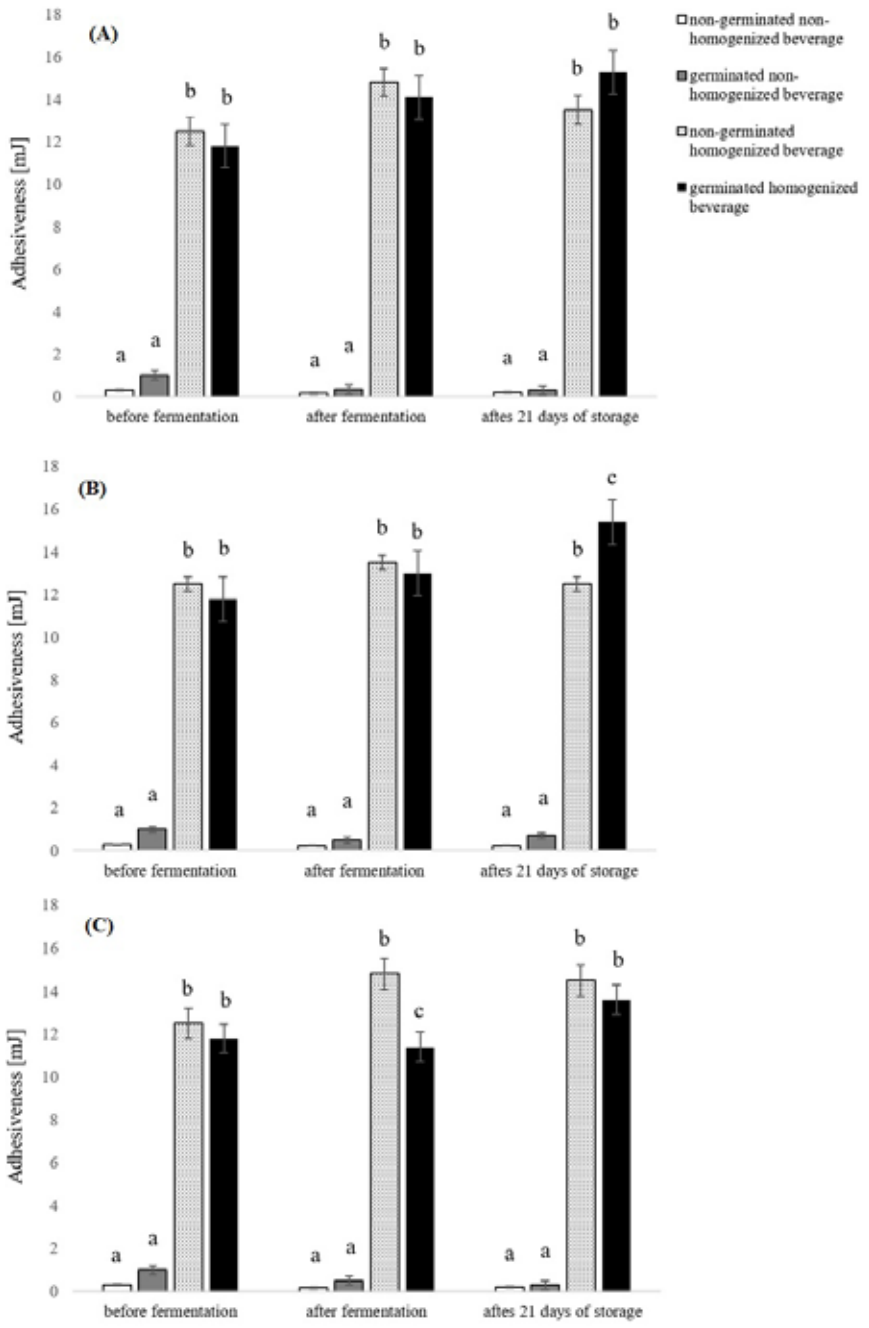

Fig. 2. The effect of HPH, germination and storage on adhesiveness of bean-based beverages fermented using the Beaugel Soja 1 (A), YO-MIX 207 (B), ABY-3 (C) starter cultures.

Rys. 2. Wpływ HPH, kiełkowania i przechowywania na adhezyjność napojów fasolowych fermentowanych z wykorzystaniem kultury starterowej Beaugel Soja 1 (A), YO-MIX 207 (B), ABY-3 (C).

a, b, c – Within each measuring period means with a common symbol are not significantly different ($p \geq 0.05$). Error bars represent standard error of the mean.

a, b, c – W ramach każdego okresu pomiarowego średnie z takim samym symbolem nie różnią się istotnie ($p \geq 0,05$). Słupki błędów reprezentują błąd standardowy średniej.

Source: The own study

Źródło: Badania własne

The available literature lacks research on the effect of HPH on the acidity and texture of fermented bean-based beverages. The use of this process in the production of other types of plant-based milk analogs has also not been extensively researched. Levy et al. [14] investigated the effect of HPH on the properties of a dairy-free yogurt-like fermented product made from potato protein isolate (PPI). PPI emulsions were homogenized at various pressures (0.1 MPa, 330–200 MPa), and inoculated (10 g/L) with LAB starter culture. In the HPH dairy-free yogurt samples tested, similar to the present test, a decrease in pH to about 4.5 was observed after 5-6 hours of fermentation at 37°C. The tested parameters of the texture (hardness, adhesiveness, and cohesiveness) showed that the 200 MPa yogurt alternative has the highest hardness (1.2 N). The mean adhesiveness in the samples tested was 2.5 N/mm and there was no difference between the samples treated with different pressure levels. In this study, a pressure of 50 MPa was used for the bean-based beverages samples and higher hardness values in the range of 1.2–1.8 N were achieved. The textural attributes may be related to the raw material used for the production of plant-based yogurts and gel microstructure differences.

Mei et al. [18] studied the effectiveness of different homogeneous methods on textural characteristics of soybean yogurt. One of the homogeneous methods used was HPH at a pressure of 100 MPa. Compared to the control samples, the yogurts subjected to HPH showed lower hardness and adhesiveness. Different results were obtained by Cruz et al. [4], who studied the effect of various parameters of ultra high-pressure homogenization (UHPH) (200–300 MPa, and 40–50°C) on the firmness (also defined as hardness) of a soy-yogurt product. There was a tendency to increase gel firmness as a combination of pressure and temperature increase, except in the more severe UHPH treatment (300 MPa, 50°C), in which this tendency was broken. In all samples subjected to homogenization, regardless of the parameters used, a significant increase in firmness was observed (values in the range of about 2.5 – 5.5 N were obtained) compared to the control sample. Differences between the results of other authors and the results obtained for bean-based beverages may result from differences in raw materials, the use of other technological processes, homogenization parameters, and the types of homogenizers.

The use of HPH in the production of milk yoghurts has been investigated to a much greater extent. It has been shown

that this process can improve the quality, increase shelf life, and maintain the nutritional and sensory properties of milk and dairy products [16]. Serra et al. [25] investigated the effect of UHPH of 200 and 300 MPa on the firmness of set yogurt. The use of UHPH allowed to obtain yoghurts with high firmness (1.83 N for a pressure of 200 MPa, and 1.99 N for a pressure of 300 MPa), and during the 28-day storage period, these values did not change significantly or increased. In the tested fermented bean-based beverages, similar hardness values were obtained despite the use of lower pressure values (50 MPa) during homogenization.

In studies on milk yoghurts, HPH influences the reduction of milk particle size which leads to the formation of finer dispersions than those obtained by conventional homogenization combined with heat treatment. In addition, the density of the gel, aggregation rate, and water retention can be improved [6, 10, 26]. There is a need to expand research on bean-based yogurt-type milk substitutes to determine the precise effects of HPH on the physical properties of the system, including, for example, particle size, gelling, and water retention.

SUMMARY AND CONSLUSIONS

The high-pressure homogenization (HPH) can be successfully used to produce bean-based yogurt-type milk substitutes. In this study, the use of this technological process positively influenced the acidity and texture properties of the obtained products. The use of HPH significantly influenced the obtaining of the optimal pH for yoghurts (in the range of 4.0 – 4.5), both in beverages made from germinated and non-germinated beans. These values did not change significantly during 21 days of storage. These results indicate that HPH allowed for more efficient fermentation of the tested plant matrix. This may be the result of the increased availability of sugars, which are used during fermentation by lactic acid bacteria as a substrate for the production of lactic acid.

HPH also influenced the tested bean-based beverage texture discriminants. In all the tested samples, this process significantly increased the hardness and adhesiveness, both in beverages made from germinated and non-germinated beans. Moreover, the values obtained for the tested texture determinants reached a similar level for the samples before fermentation, after fermentation, and after 21 days of storage. This indicates that the HPH was responsible for the texture shaping of the tested bean-based beverages. The fermentation did not significantly affect the tested texture determinants, but only caused a significant decrease in pH in all fermented samples.

The available studies on the influence of HPH on the fermentation and physical properties of fermented milk substitutes are limited. This process can largely influence the unique features of this type of product and lead to the production of plant-based yoghurt substitutes with properties that meet the growing demands of consumers. Accordingly, there is a need for further research into the physical properties of bean-based yogurt substitutes produced by HPH.

PODSUMOWANIE I WNIOSKI

Proces homogenizacji wysokociśnieniowej (HPH – ang. high-pressure homogenization) może zostać z powodzeniem wykorzystany do wytwarzania roślinnych substytutów jogurtów na bazie fasoli. W niniejszym badaniu zastosowanie tego procesu technologicznego pozytywnie wpłynęło na kwasowość otrzymanych produktów oraz badane wyróżniki tekstury. Zastosowanie HPH wpłynęło istotnie na uzyskanie optymalnego pH (w zakresie 4.0–4.5) dla jogurtów, zarówno w napojach wytworzonych z fasoli skiełkowanej, jak i nieskiełkowanej. Wartości te nie zmieniły się istotnie w trakcie 21-dniowego okresu przechowywania. Otrzymane wyniki wskazują, że HPH umożliwiła bardziej efektywną fermentację badanej matrycy roślinnej. Może to być wynikiem zwiększonej dostępności cukrów, które w trakcie fermentacji wykorzystywane są przez bakterie mlekowe jako substrat do produkcji kwasu mlekowego.

Proces HPH wpłynął również na badane wyróżniki tekstury napojów fasolowych. We wszystkich badanych próbkach proces ten wpłynął na istotne zwiększenie twardości i adhezyjności, zarówno w napojach wytworzonych z fasoli skiełkowanej, jak i nieskiełkowanej. Ponadto wartości badanych wyróżników tekstury osiągnęły podobny poziom dla próbek przed fermentacją, po fermentacji i po 21 dniach okresu przechowywania. Wskazuje to, że proces HPH miał wpływ na kształtowanie tekstury badanych napojów fasolowych. Proces fermentacji nie wpłynął istotnie na badane wyróżniki tekstury, a jedynie spowodował istotne obniżenie pH we wszystkich fermentowanych próbkach.

Dostępne badania dotyczące wpływu HPH na przebieg procesu fermentacji i właściwości fizyczne fermentowanych substytutów mleka są dość ograniczone. Proces ten może w szerokim zakresie wpływać na kształtowanie się unikatowych cech tego typu produktów i prowadzić do wytworzenia substytutów jogurtów o właściwościach, które sprostają rosnącym wymaganiom konsumentów. W związku z tym istnieje potrzeba prowadzenia dalszych badań dotyczących właściwości fizycznych substytutów jogurtów na bazie fasoli, wytwarzanych z zastosowaniem HPH.

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Dr hab. Krzysztof DASIEWICZ
Dr hab. Aneta CEGIEŁKA
Prof. dr hab. Mirosław SŁOWIŃSKI
Division of Meat Technology, Department of Food Technology and Evaluation, Institute of Food Sciences
Warsaw University of Life Sciences (SGGW – WULS), Poland
Zakład Technologii Mięsa, Katedra Technologii i Oceny Żywności, Instytut Nauk o Żywności
Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Polska

AN ATTEMPT TO USE VARIOUS FAT RAW MATERIALS IN THE PRODUCTION OF HOMOGENIZED SAUSAGES®

Próba wykorzystania zróżnicowanego surowca tłuszczowego w produkcji kiełbas homogenizowanych®

The research for this work, described in this publication, was carried out with using research equipment purchased as part of the „Food and Nutrition Centre - modernisation of the WULS campus to create a Food and Nutrition Research and Development Centre (CŻiŻ)" co-financed by the European Union from the European Regional Development Fund under the Regional Operational Programme of the Mazowieckie Voivodeship for 2014-2020 (Project No. RPMA.01.01.00-14-8276/17).

Key words: pork back fat, beef tallow, goose fat, homogenized sausage, quality features.

The aim of the research was an attempt to use various fat raw materials in the production of homogenized scalded sausages and to evaluate their effect on the quality features of sausages. The experimental material was homogenized scalded sausages produced with the addition of pork jowl, pork back fat, beef tallow and goose fat. The analytical part of the work included the analysis of the chemical composition, the measurement of color and texture parameters as well as the sensory evaluation of the sausages. On the basis of the obtained results, a significant influence of the type of fat raw material on the fat content in the analyzed meat product and its energy value was found. Significant differences were also noted between the treatments of sausages in the values of the color parameters: L, a* and b*, as well as in the texture parameters such as: shear force, cohesiveness, springiness, hardness and chewiness. Homogenized sausage containing goose fat was characterized by high sensory desirability, while the product with the addition of beef tallow was not approved by the sensory panel.*

Słowa kluczowe: tłuszcz wieprzowy grzbietowy, tłuszcz wołowy, tłuszcz gęsi, kiełbasa homogenizowana, cechy jakościowe.

Celem badań było podjęcie próby zastosowania zróżnicowanego surowca tłuszczowego w produkcji kiełbas homogenizowanych oraz ocena jego wpływu na wyróżniki jakości kiełbas. Materiał do badań stanowiły kiełbasy parzone homogenizowane wyprodukowane z udziałem podgardla wieprzowego, słoniny grzbietowej, łoju wołowego oraz tłuszczu gęsiego. W części analitycznej dokonano analizy składu chemicznego, pomiaru parametrów barwy i tekstury oraz przeprowadzono ocenę sensoryczną kiełbas. Na podstawie uzyskanych wyników stwierdzono istotny wpływ rodzaju surowca tłuszczowego na zawartość tłuszczu oraz wartość energetyczną kiełbas. Zauważono również istotne różnice w wartościach parametrów barwy L, a* i b*, a także w wyróżnikach tekstury takich jak: siła cięcia, spoistość, sprężystość, twardość i żujność. Wykazano, że produkt z tłuszczem gęsim odznaczał się wysoką pożądalnością sensoryczną, natomiast produkt z dodatkiem łoju wołowego nie uzyskał aprobaty oceniających.*

INTRODUCTION

Fat in food is, among others a carrier of flavor substances, participating in shaping the palatability of food products and is a protective factor for some food ingredients. It is also an important ingredient that influences the nutritional and health value of food products. It provides fat-soluble vitamins (A, D, E and K), participates in the synthesis of corticosteroids and vitamin D3, and is a valuable energy reserve for the human body [4, 26, 29]. Many consumers associate the term 'fat' primarily with the negatively perceived 'cholesterol', which, if consumed in excess, has a negative impact on human health [2, 3, 11, 18, 28, 30].

Fat raw materials also play a key role in meat processing. Fat – as a recipe ingredient of meat product – is involved in shaping its sensory characteristics, such as: palatability,

Adres do korespondencji - Corresponding author: Krzysztof Dasiewicz, Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Instytut Nauk o Żywności, Katedra Technologii i Oceny Żywności, Zakład Technologii Mięsa. ul. Nowoursynowska 159C, 02-776 Warszawa, e-mail: krzysztof_dasiewicz@sggw.edu.pl

juiciness, texture and color. These features often determine the choice and purchase of meat products by consumers. Therefore, in relation to many meat products, the presence of fat makes them better perceived from the point of view of consumer preference [5, 8, 21]. Among other things, the texture of meat products made of highly comminuted raw materials depends on the formation of a stable matrix. The formation of this matrix is associated with many factors, including the type, amount and functional properties of proteins (including the content of connective tissue proteins) present in the meat batter system, the type and amount of fat, water and salt content, pH value of the raw meat, etc. Not only the quantity but also the quality of the fat raw material has a significant impact on the quality of the fat-containing meat product. The fat tissue used as a raw material in processed meat products should be white in color and firm in consistency. From the point of view of the health quality and shelf life of the product, the stability of the fat raw material against oxidation processes is important [20]. It has been shown that with the increase in the share of the so-called 'hard fat' in the raw material composition of the meat batter, the values of rheological parameters that characterize the viscoelastic properties of the system are higher [9]. On the other hand, a significant reduction in the fat tissue content in the recipe composition of a meat product causes that the product becomes 'empty' in taste, its texture becomes more 'stiff, 'gummy' or 'mealy'. When selecting the fat raw material in the production of meat products, attention should be also paid to the degree of its freshness and consistency. Too 'soft' fat during the grinding process may 'melt' and also contribute to the formation of an increased loss during technological processes, e.g. thermal treatment and maturation. The selection of fatty raw materials for the recipes of specific groups of meat products is important for meeting the technological assumptions and obtaining the desired quality effects in relation to the product itself, as well as for economic reasons. Some meat products, e.g. dry sausages, require the use of a specific type of fat - pork back fat. The pork back fat is usually used for salami, and fine fat is suitable for the production of pâtés [7, 15, 16].

Literature data on the suitability of the fat raw material obtained from various species of animals for the production of homogenized scalded sausage are scarce. The lack of such information makes it difficult to rationally use fat in meat processing and to obtain the desired product quality in terms of technology, sensory and nutrition. **Therefore, the aim of this study was an attempt to use various fat raw materials (pork, beef and goose fat) in the production of homogenized scalded sausages, as well as to assess the usefulness of the fat raw materials for the production of this type of sausage based on the evaluation of the technological quality and sensory characteristics of sausages in comparison to a homogenized sausage containing pork jowl in recipe composition.**

MATERIALS AND METHODS

Research material

The pork, beef and goose fat raw material used in the production of homogenized scalded sausages was purchased once in an amount sufficient to perform the experiment. Each fat raw material was standardized by chopping into 2 cm x 2 cm pieces and thorough mixing. Then, the fat raw materials were divided into portions corresponding to subsequent production

Table 1. Recipe composition of homogenized scalded sausages

Tabela 1. Skład surowcowy kiełbas parzonych homogenizowanych

Ingredients [%] Składniki [%]	Treatments of homogenized scalded sausages Warianty kiełbas homogenizowanych			
	treatment I (Control) wariant I (kontrolny)	treatment II wariant II	treatment III wariant III	treatment IV wariant IV
Fat raw material / Surowiec tłuszczowy	pork jowl podgardle wieprzowe	pork back fat słonina	beef tallow łój wołowy	goos fat tłuszcz gęsi
Pork trimmings (class I) / Mięso wieprzowe kl. I	60,0	60,0	60,0	60,0
Fat / Tłuszcz	30,0	30,0	30,0	30,0
Pork skin emulsion / Emulsja ze skór wieprzowych	10,0	10,0	10,0	10,0
Ice / Lód	30,0*	30,0*	30,0*	30,0*
Curing salt / Peklosól	1,8*	1,8*	1,8*	1,8*
Soy protein preparation / Preparat białka sojowego	1,5*	1,5*	1,5*	1,5*
Phosphates / Fosforany	0,15*	0,15*	0,15*	0,15*
Sodium ascorbate / Askorbinian sodu	0,05*	0,05*	0,05*	0,05*
Spice mix / Mieszanka przypraw	1,0*	1,0*	1,0*	1,0*

* in relation to meat and fat raw materials / *w stosunku do surowca mięsnego i tłuszczowego

Source: The own study

Źródło: Badanie własne

series, vacuum-packed and stored in a freezer (temperature -18°C) for no longer than 4 weeks. The functional additives included in the recipe were purchased from a one of leading distributors of functional substances in the meat industry.

The material for the research was homogenized scalded sausages, which were produced according to the recipe composition showed in Table 1 and to the production scheme compliant with good production practice (Figure 1).

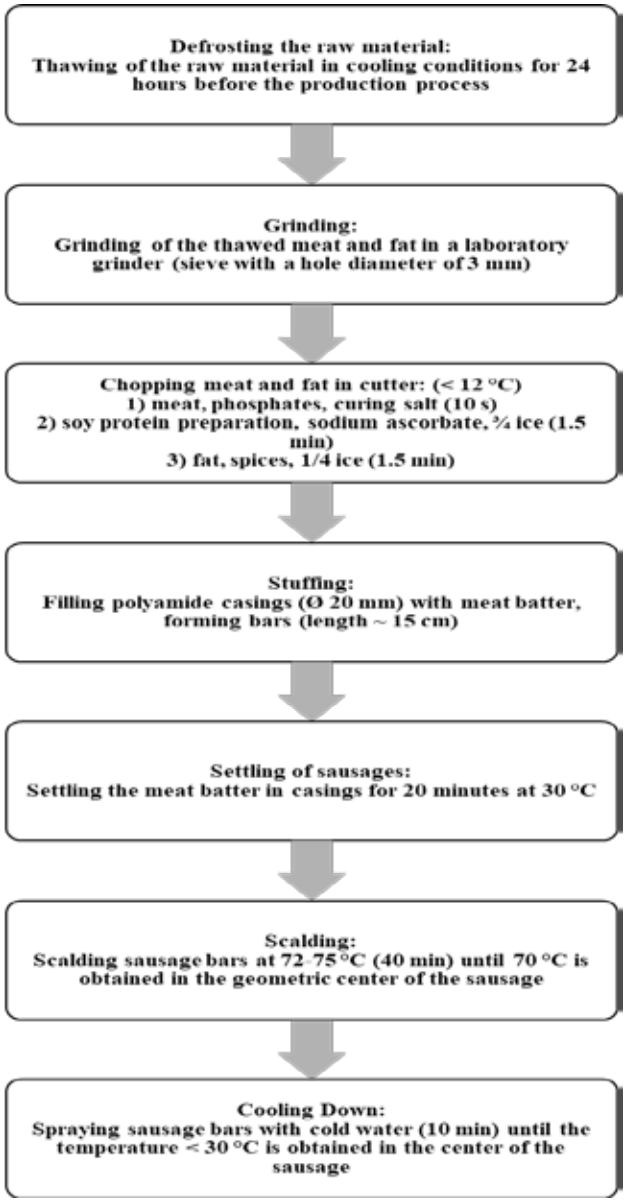

Fig. 1. Production scheme of homogenized scalded sausages.

Rys. 1. Schemat produkcji kiełbas parzonych homogenizowanych.

Source: The own study

Źródło: Badanie własne

Assessment of the chemical and physical quality characteristics of sausages

The production yield of each sausage treatment was calculated from the difference in weight of the sausage bars before and after the heat treatment. The content of basic chemical components in both fat raw materials and sausages was determined by use of a FoodScanÔ Lab apparatus (Foss Analytical A/S, Hillerød, Denmark) using the method of near-infrared reflectance (NIR) transmission spectrophotometry, working in the wavelength range 850-1050 nm. Measurements were made in accordance with the PN-A-82109: 2010 [26] standard and the operating manual of the apparatus. The color sausages was measured using the colorimetric method in accordance with PN-N-01252:1965 [25]. A Konica Minolta CR-200 colorimeter (light source: D65, observer angle: 2°, measuring head hole diameter: 8 mm) was used. Color parameters were measured in the CIEL*a*b* scale. The color of the products was measured on the surface and cross-section of sausage bars after 24 hours as well as after 14 days of storage of vacuum packed (vacuum: 50 mBa) sausages in cold room (4°C). Based on the value of the L*, a* and b* color parameters, ΔE was calculated, i.e. the absolute color difference between the control treatment of sausage (treatment I) and the experimental treatments of sausages (treatments II-IV) . The absolute color difference was calculated using the formula [23]:

$$\Delta E = \sqrt{(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2}$$

where: L*1, a*1, b*1 – are the color parameters of the control treatment of sausage,

L*2, a*2, b*2 – are the color parameters of the experimental treatment of sausage.

The texture of the sausages was measured using a Zwicki 1120 testing machine (Zwick GmbH & Co, Ulm, Germany) by performing a Texture Profile Analysis (TPA) test (double compression test). Texture measurements were carried out in sausages after 24 hours of storage (4°C), as well as after 14 days of storage (4°C) of vacuum-packaged (vacuum: 50 mBa). The measurements according to the instructions of the measuring apparatus [17]. Before the measurements, the sausage samples (20 mm 'tall' pieces of bar, without casing) were conditioned at the ambient temperature of about 20°C for 1 hour. To perform the TPA test, a cylindrical sausage sample was placed between two parallel plates and compressed to 50% of the original height in each test cycle. The working parameters of the testing machine were as follows: distance between the plates 40 mm, initial force 0.5 N, speed of the measuring head during the test 30 mm/min. The course and the measurement result were recorded using the testXpert computer program. Six measurements were made for each sausage treatment in each experimental series. The mean value of all measurements was taken as the final result [10, 17]. Ten panellists of both sexes participated in the sensory evaluation of sausages. All panellists were familiar with the principles of sensory evaluation of food products. The scaling method was used for the sensory evaluation of sausages. Sausages were evaluated warm, i.e. heated to 50 °C. Each sausage was cut into slices, which were randomly distributed in white plates, and identified with a random two-digit number. The sausage samples were evaluated for taste, smell, color, texture, feel of 'greasiness' and overall desirability. Each quality attribute of sausages was assessed using a scale from 1 to 5 points, corresponding to 'least acceptable' and 'most acceptable', respectively [1].

Statistical analysis of the results

Data were statistically analyzed using the Statistica™ v.12 software (StatSoft Inc., Tulsa, OK, USA). One-way analysis of variance (ANOVA) was performed to determine the significance of differences between the mean values. Tukey's HSD test was used to identify significant differences between the mean values at a level of $\alpha = 0.05$. Before applying ANOVA the Shapiro-Wilk test was used to evaluate the experimental data for normality and the Levene test was used to determine the homogeneity of variances for sets of analytical data [12, 14].

RESULTS AND DISCUSSION

The technological usefulness of animal fat raw materials is determined primarily by their physicochemical properties. The fat content in the tested raw materials, determined by the method of NIR spectrophotometry, showed a significant ($p < 0.05$) differentiation (Table 2). Goose fatty tissue was characterized by the highest fat content. Slightly lower fat content was found in pork back fat. On the other hand, beef tallow and pork jowl were characterized by the clearly lowest proportion of this chemical component, which could have been caused by the presence of small amounts of muscle tissue naturally occurring in this raw materials. The presence of muscle and connective tissue in the analyzed fat raw materials most likely influenced the percentage of protein in them (Table 2). The highest protein content was found in pork jowl and beef tallow, and the lowest in goose fat. The water content in the fat raw materials used in the production of sausages also varied (Table 2). Water content was significantly ($p < 0.05$) lower in goose fat and pork back fat, while it was higher in beef tallow. Higher water content in fatty tissue contributes to its greater susceptibility to the development of pathogenic microflora and an increased tendency to become rancid. Such fat is characterized by lower melting properties, and therefore its technological usefulness may be limited.

Different collagen content was also found in the analyzed fat raw materials – the highest in those characterized by the higher amount of muscle and connective tissue in the overall structure (pork jowl, beef tallow), and the lowest in the fat raw materials with the highest percentage of fat (pork back fat, goose fat) (Table 2).

The production yield of all treatments of homogenized sausages was determined by the weighing method after the completion of the technological process, which was typical for this type of product (Figure 1). It was not significantly ($p > 0.05$) differentiated by the fat raw material used and was at the level of about 85%. Only insignificantly lower thermal losses in the homogenized sausage with the addition of goose fat (88.6%) and higher in the product with the addition of pork jowl (81.9%) were found.

Physical and chemical quality characteristics of homogenized sausages differing in the type of fat raw material were determined by determining their basic chemical composition (Table 3), measuring color parameters according to the CIEL*a*b* scale (Table 4), instrumental texture measurement (Table 4) and evaluation of sensory quality (Table 6).

Consumers aware of the relationship between the quality of consumed food products and health, more often look for products with increased nutritional value and/or reduced energy value, and pay attention to its functional properties, i.e. a positive effect on human health. Meat and meat products are among the richest sources of protein and important sources of minerals, especially well-absorbed heme iron. With regard to meat products with improved health quality, consumer preferences are focused primarily on: modifying the fatty acid profile, lowering the salt content, increasing the share of fiber in the product [22].

The content of chemical components in meat products depends primarily on their raw material composition and the applied methods of technological processing. This relationship has been confirmed by the results obtained in this study. The differences in the protein and water content between the treatments of homogenized scalded sausages were not significant ($p > 0.05$). Only a slightly higher content of these chemical components in the product with the addition of pork jowl can be indicated (Table 3). However, the differences in the average fat content between treatments of meat products compared to the product with pork jowl (Control) were statistically significant ($p < 0.05$). The Control sausages had the lowest percentage of fat. Products with the addition of beef tallow and pork back fat had a similar fat content. On the other hand, the highest fat content was found in sausages with the

Table 2. The content of basic chemical components in fat raw materials used in the production of sausages

Tabela 2. Zawartość podstawowych składników chemicznych w surowcach tłuszczowych użytych do produkcji kiełbas

	Water [%] / Woda [%]	Fat [%] / Tłuszcz [%]	Protein [%] / Białko [%]	Collagen [%] / Kolagen [%]
Pork jowl **Podgardle wieprzowe**	30,79	58,28	9,91	1,75
Pork back fat **Słonina**	12,00	81,77	6,29	0,15
Beef tallow **Łój wołowy**	28,63	63,78	7,54	2,8
Goose fat **Tłuszcz gęsi**	9,53	90,39	2,41	0,67

Source: The own study

Źródło: Badanie własne

Table 3. The effect of the addition of a various fat raw material on the chemical composition of homogenized scalded sausages

Tabela 3. Wpływ dodatku zróżnicowanego surowca tłuszczowego na skład chemiczny badanych kiełbas homogenizowanych

Chemical component Składnik chemiczny	Sausage treatment/Wariant kiełbasy			
	homogenized sausage with pork jowl / kiełbasa homogenizowana z dodatkiem podgardla (Control)	homogenized sausage with pork back fat / kiełbasa homogenizowana z dodatkiem słoniny (treatment II)	homogenized sausage with beef tallow / kiełbasa homogenizowana z dodatkiem łoju wołowego (treatment III)	homogenized sausage with goose fat / kiełbasa homogenizowana z dodatkiem tłuszczu gęsiego (treatment IV)
Water/Woda [%]	59,10a±2,93	54,55a±3,24	56,00a±4,24	52,3a±3,90
Protein/Białko [%]	16,45a±1,29	15,49a±1,30	15,36a±1,24	14,22a±1,44
Fat/Tłuszcz [%]	21,71a±1,29	27,76bc±2,49	24,06ab±1,56	29,52c±1,44
Sodium chloride/Sól kuchenna [%]	1,80a±0,17	1,85a±0,20	1,76a±0,16	1,73a±0,26
Energy value/Wartość energetyczna [kJ/100 g]	262,79a±23,35	308,25b±26,00	289,23ab±16,43	310,62b±12,84

Means in the row marked with the same letter do not differ statistically significantly ($p > 0.05$).

Wartości średnie w wierszach oznaczone tą samą literą nie różnią się statystycznie istotnie ($p > 0.05$).

Source: The own study

Źródło: Badanie własne

addition of goose fat. The determined average fat content in the sausages constituting the research material in this study reflects its percentage share in the fat raw materials used in the production of individual treatments of the sausages. This means that the higher content of fat in the fat raw material resulted in a higher content of this chemical component in the homogenized scalded sausage. The diversified fat content in sausages differing in the type of fat raw material significantly ($p < 0.05$) influenced their energy value. Sausages made with the addition of pork back fat and goose fat had a significantly ($p < 0.05$) higher energy value. Therefore, they were treatments of sausages, the fat raw material of which contained the most fat in its composition.

The measurement of color parameters is one of the basic determinations used in the assessment of the quality of food products. Color is also one of the most important quality determinants of processed meat. Among other things, on the basis of it, the consumer makes a decision about the purchase and consumption of the product, an unusual or changed color is perceived negatively. The results of the instrumental color measurement showed significant ($p < 0.05$) differences in the lightness (L*) of the surface of the sausages. The highest value of lightness parameter measured on the surface was identified for sausages with the addition of goose fat. In the case of the remaining tested sausages, no significant differentiation of this color parameter was found. Significant ($p < 0.05$) differences in the mean value of the color parameter a * (redness) compared to the product with the addition of pork jowl (Control) were observed in sausages with beef tallow and goose fat. These products were characterized by a lower proportion of red color than the other tested sausages. Homogenized sausages with pork back fat had a slightly higher proportion of red color than the control product, but the difference was not significant ($p > 0.05$). The mean values of the b* color parameter (yellowness) measured on the surface of the homogenized sausages did not differ significantly ($p > 0.05$).

After 14 days of chilled storage, homogenized sausages with the addition of beef tallow (treatment III) and goose fat (treatment IV) were characterized by a significantly ($p < 0.05$) lighter color (higher value of the L * parameter) measured on the surface of the sausage bar compared to the product made with pork jowl (Control). In the case of the a* parameter, after 14 days of chilled storage compared to the Control treatment of the homogenized sausage, only the product with the addition of pork back fat (treatment II) was characterized by a significantly ($p < 0.05$) higher proportion of red color. Compared to the Control product (with pork jowl), both the sausage with beef tallow (treatment III) and goose fat (treatment IV) were characterized by a lower value of the a* parameter, but these differences were not statistically significant ($p > 0.05$). However, in the case of the b* parameter, it was shown that sausages with the addition of pork back fat (treatment II) and goose fat (treatment IV) were characterized by a higher yellowness than the product with the addition of pork jowl. The analysis of the color parameters of homogenized sausages, measured on the cross-section of sausage bars 24 hours after production (Table 4) showed that homogenized sausages with the addition of pork back fat and beef tallow (treatments II and III, respectively) were characterized by a significantly ($p < 0.05$) higher value of the color parameter L* compared to a sausage with pork jowl (Control). On the other hand, the use of goose fat in the recipe composition of homogenized sausage resulted in significantly ($p < 0.05$) the highest value of the lightness parameter measured on the sausage cross-section. The product with goose fat (treatment IV) had a significantly ($p < 0.05$) lower value of the a* parameter measured on the cross-section of sausage bars. The value of this parameter in the case of other treatments of sausages was at a similar level. The lowest value of the b * parameter measured on the cross-section of sausage bars was detected for product with beef tallow. After 14 days of refrigerated storage, the observed trends regarding

Table 4. The effect of the addition of a various fat raw material on the color parameters (L*, a*, b*) on the surface and on the cross-section, as well as on the texture parameters of the homogenized scalded sausages stored in cold room for 24 h and 14 days

Tabela 4. Wpływ dodatku zróżnicowanego surowca tłuszczowego na parametry barwy L*, a* i b* na powierzchni i na przekroju oraz parametry tekstury kiełbas homogenizowanych parzonych przechowywanych w warunkach chłodniczych przez 24 h i 14 dni

Characteristic Cecha	Sausage treatment/Wariant kiełbasy							
	homogenized sausage with pork jowl kiełbasa homogenizowana z dodatkiem podgardla (Control)		homogenized sausage with pork back fat kiełbasa homogenizowana z dodatkiem słoniny (treatment II)		homogenized sausage with beef tallow kiełbasa homogenizowana z dodatkiem łoju wołowego (treatment III)		homogenized sausage with goose fat kiełbasa homogenizowana z dodatkiem tłuszczu gęsiego (treatment IV)	
	24 h	**14 d**	**24 h**	**14 d**	**24 h**	**14 d**	**24 h**	**14 d**
Color parameters L*, a*, b* measured on the surface of the sausage bar Parametry barwy L*, a*, b* mierzone na powierzchni batonu kiełbasy								
L*	66,86a±2,67	67,04A±1,81	66,60a±2,85	66,38AB±3,19	67,70a±1,66	68,00B±1,27	70,74b±1,15	69,76C±0,99
a*	11,49c±0,97	11,19A±0,89	12,11c±0,10	12,57B±0,97	10,33b±1,42	9,76A±0,68	8,96a±1,08	8,96A±0,75
b*	11,53a±0,98	11,46A±1,05	12,57a±1,39	13,03C±1,55	11,53a±1,58	11,45A±1,22	12,10a±0,67	12,99B±1,06
Color parameters L*, a*, b* measured on the cross-section of the sausage bar Parametry barwy L*, a*, b* mierzone na przekroju batonu kiełbasy								
L*	67,50a±0,52	67,37A±0,75	68,65b±0,46	68,97B±0,34	68,37b±0,76	68,81B±0,74	74,13c±0,52	73,68C±0,44
a*	10,87b±0,59	11,12B±0,53	10,84b±0,57	11,41B±0,48	11,31b±0,59	11,28B±0,46	8,74a±0,69	9,02A±0,63
b*	9,36b±0,37	9,79B±0,36	10,32c±0,60	10,24B±0,45	8,69a±0,99	8,91A±0,88	9,90bc±0,27	10,02B±0,37
Texture parameters of the homogenized scalded sausages Parametry tekstury kiełbas homogenizowanych parzonych								
Shear force [N] Siła cięcia [N]	17,84b±2,28	21,80B±2,76	14,76a±1,94	17,92A±1,48	16,53ab±1,93	16,64A±1,38	15,17a±2,70	16,66A±1,42
Cohesiveness Spoistość	0,67a±0,05	0,72B±0,03	0,62a±0,05	0,66A±0,02	0,63a±0,07	0,66A±0,03	0,63a±0,04	0,69AB±0,06
Springiness Sprężystość	0,81bc±0,004	0,87B±0,02	0,78ab±0,03	0,84A±0,02	0,81c±0,04	0,86AB±0,01	0,77a±0,04	0,85AB±0,05
Hardness [N] Twardość [N]	12,27b±2,20	11,56B±1,48	11,17b±1,1	13,17C±1,46	11,26b±1,98	12,68CB±1,62	8,12a±2,33	9,17A±1,31
Chewiness [N] Żujność [N]	6,54b±0,99	7,29B±0,92	5,45b±0,96	7,34B±0,99	5,78b±1,41	7,71B±1,17	3,99a±1,46	5,41A±1,23

Means in the rows for sausages stored for 24 h and marked with the same lowercase letter do not differ statistically significant ($p > 0.05$).
Wartości średnie w wierszach odnoszące się do kiełbas przechowywanych przez 24 h i oznaczone tą samą małą literą nie różnią się statystycznie istotnie ($p > 0.05$).
Means in the columns for sausages stored for 14 d and marked with the same uppercase letter do not differ statistically significant ($p > 0.05$).
Wartości średnie w wierszach odnoszące się do kiełbas przechowywanych przez 14 d i oznaczone tą samą wielką literą nie różnią się statystycznie istotnie ($p > 0.05$).

Source: The own study

Źródło: Badanie własne

color differences on the cross-section of sausage bars (as after 24 hours from production) were maintained. The inclusion of goose fat in the recipe composition of sausages (treatment IV) had the greatest impact on the lightness of the color measured in the cross-section of the product.

The obtained data show (Table 5) that the absolute color difference ΔE concerning the color of the sausages on the cross-section and the surface of sausage bars between the homogenized scalded sausage manufactured with pork jowl (Control) compared to the sausage with pork back fat (treatment II) and with beef tallow (treatment III) was at a level noticeable only by an experienced observer. The highest absolute color difference on the cross-section and surface of sausages was observed in the case of homogenized sausage with the addition of goose fat (treatment IV). Compared to the Control treatment, the difference in color regarding the sausage surface of treatment IV was at the level noticeable by an inexperienced observer. In the case of the evaluation of the color difference on the cross-section of the sausage bar of treatment IV, the calculated ΔE value – regardless of the

Table 5. The absolute color difference ΔE of sausages in relation to the color evaluated on the cross-section of a homogenized sausage with pork jowl (Control)

Tabela 5. Wartość bezwzględnej różnicy barwy ΔE kiełbas w stosunku do barwy oznaczonej na przekroju kiełbasy homogenizowanej z dodatkiem podgardla (kiełbasa kontrolna)

The value of the absolute color difference ΔE Wartość bezwzględnej różnicy barwy ΔE			
Warunki pomiaru Measurement conditions	homogenized sausage with pork back fat / kiełbasa homogenizowana z dodatkiem słoniny (treatment II)	homogenized sausage with beef tallow / kiełbasa homogenizowana z dodatkiem łoju wołowego (treatment III)	homogenized sausage with goose fat / kiełbasa homogenizowana z dodatkiem tłuszczu gęsiego (treatment IV)
Surface of the sausage bar / Powierzchnia batonu			
24 h of cold storage 24 h przechowywania chłodniczego	1,21*	1,00*	4,07*
14 d of cold storage 14 dni przechowywania chłodniczego	1,74*	1,23*	4,48*
Cross-section of the sausage bar / Przekrój batonu			
24 h of cold storage 24 h przechowywania chłodniczego	1,83*	1,78*	6,75*
14 d of cold storage 14 dni przechowywania chłodniczego	1,67*	1,70*	6,65*

0 < ΔE < 1 – the observer cannot see the color differences

1 < ΔE < 2 – an experienced observer will notice a difference in color

2 < ΔE < 3,5 – an inexperienced observer will notice a difference in color

3,5 < ΔE <5 – there is a noticeable difference in color

5 < ΔE – the observer has the impression of two different colors

* statistically significant differences ($p < 0.05$) / * różnice statystycznie istotne ($p < 0.05$)

Source: The own study

Źródło: Badanie własne

storage time (24 h and 14 days) - indicated that the standard observer should have the impression of two different colors, which proves a significant influence of goose fat on the color of the meat product, which is a homogenized scalded sausage.

Texture is one of the most important features determining the quality and acceptance of products by consumers, as well as a quality factor related to satisfaction when consuming meat products. The International Organization for Standardization (ISO) defines texture as 'all the rheological and structural properties of a food product that can be perceived by humans through touch, mechanical and, if possible, visual and auditory receptors' [24]. There are main (independent) and secondary (dependent) texture parameters of food products. The main ones are: hardness, cohesiveness, elasticity (springiness), resilience, and adhesion. The secondary parameters of the texture include, among others chewiness, i.e. the energy needed to crush (chew) the product - this feature is related to hardness, elasticity and cohesiveness. The values of the texture parameters in meat products depend mainly on the characteristic features of the meat and fat raw materials used for their production and the technological processes carried out [13]. In this study, the highest values of shear force, regardless of the sausage storage time (24 hours and 14 days), were recorded for homogenized sausages prepared with the addition of pork jowl (Table 4). Based on the results of the TPA, it was found that the lowest values of the hardness, chewiness and springiness were obtained in homogenized sausage with the addition of goose fat (treatment IV). This tendency was found regardless of the storage time of the sausages (24 h and 14 days) in the cold room.

Among the many criteria that determine the selection and purchase of a food product, its sensory attributes are one of the most important [19]. Introducing new food products to the market is the result of changing market trends as well as the requirements and preferences of consumers. It is the consumer who decides whether the product will find its place on the market. Thus, the consumer plays a fundamental role in each of the stages of product design, both in the area of initiating the process of creating a new product, testing, and implementing it into production and sales on the market [6]. The results of the sensory evaluation of the sausages being the subject of this study are presented in Table 6.

Homogenized scalded sausages produced in this study were of good sensory quality, regardless of the type of fat used in production. The analysis of their sensory attributes showed that the best quality was achieved by homogenized sausage containing goose fat and pork jowl (variant IV and Control, respectively). For these sausage treatments the mean scores for color, aroma, taste and overall desirability were significantly ($p < 0.05$) higher than for those of sausages made with the addition of pork back fat and beef tallow (treatments II and III, respectively). Only the feeling of greasiness was significantly

Table 6. The effect of the addition of a various fat raw material on sensory quality attributes of the homogenized scalded sausages

Tabela 6. Wpływ dodatku zróżnicowanego surowca tłuszczowego na wyróżniki jakości sensorycznej kiełbas homogenizowanych parzonych

Sensory attribute Wyróżnik sensoryczny	Sausage treatment/Wariant kiełbasy			
	homogenized sausage with pork jowl / kiełbasa homogenizowana z dodatkiem podgardla (Control)	homogenized sausage with pork back fat / kiełbasa homogenizowana z dodatkiem słoniny (treatment II)	homogenized sausage with beef tallow / kiełbasa homogenizowana z dodatkiem łoju wołowego (treatment III)	homogenized sausage with goose fat / kiełbasa homogenizowana z dodatkiem tłuszczu gęsiego (treatment IV)
Color / Barwa	4,06b±0,76	3,91ab±0,78	3,63a±0,79	4,16b±0,77
Aroma / Zapach	4,03ab±0,78	4,16b±0,77	3,56a±0,72	4,31b±0,64
Taste / Smak	3,97b±1,18	3,03a±1,42	2,72a±0,85	3,91b±0,93
Texture / Konsystencja	4,16b±0,85	3,84ab±0,77	3,41b±0,61	4,25b±0,80
Feeling of greasiness / Odczucie tłustości	2,53a±0,91	2,87a±0,91	3,06b±0,88	3,09b±0,93
Overall desirability / Ogólna pożądalność	4,18b±0,64	3,34a±0,65	3,03a±0,90	4,03b±0,74

Means in the rows marked with the same letter do not differ statistically significant ($p > 0.05$).
Wartości średnie w wierszach oznaczone tą samą literą nie różnią się statystycznie istotnie ($p > 0.05$).

Source: The own study

Źródło: Badanie własne

($p < 0.05$) higher – which indicates a lower quality of the product – for homogenized sausages with the addition of beef tallow and goose fat (treatments III and IV, respectively).

SUMMARY AND CONCLUSIONS

The aim of the work was an attempt to use various fat raw materials: pork back fat, beef tallow and goose fat, in the production of sausages and to determine their influence on the technological quality and sensory characteristics of sausages in comparison to the control product containing the pork jowl. The experimental material was homogenized scalded sausages, manufactured according to a standard production process. In order to compare the quality of the sausages, the chemical composition analysis was carried out, the color and texture parameters were measured, and the sensory evaluation was performed. Based on the research, it was found that:

1. Although relatively high differences in the content of basic chemical components (water, protein, fat) of fat raw materials, the use of these raw materials for the production of homogenized sausages significantly differentiated only the content of fat and energy value of the products. The fat content and energy value of homogenized sausages produced with the use of fat raw material other than pork jowl was higher, ranging from slightly over 24% to around 30% and from around 290 kJ/100 g to slightly over 310 kJ/100 g, respectively. Regardless of the type of fat material, homogenized sausages were characterized by a relatively high protein content, i.e. not less than 14.22%, and a low salt content, i.e. not more than 1.85%. The obtained results confirm the possibility of modifying the nutritional value of this type of meat products through the selection of fat raw material for production. Taking into account the nutritional value of sausages, and mainly the fat content, it was found that especially products containing goose fat and pork back fat in the recipe composition should not be consumed by people limiting the amount of fat in their diet.
2. The significant differences found in the color parameters of homogenized sausages were also most likely caused by the type of fat used in production. The greatest differences in the color of sausages, both on the surface of the sausage bars and on the cross-section of the sausage bars, were caused by replacing pork jowl with goose fat. A significant increase in the L* color parameter and a significant decrease in a* color parameter – when measured on the cross-section – was found in the sausage with goose fat, both after 24 hours and 14 days of storage in cold room. The calculated values of the ΔE index showed that – regardless of the product storage time – the difference in the color of the surface between the sausage with goose fat and the Control sausage (with pork jowl) should be clearly noticeable by an inexperienced observer, and in the case of the color on the cross-section of both sausage treatments the observer may even get the impression that there are two different colors. The obtained results confirm that in creating the color of a meat product made of highly comminuted raw materials, not only the amount and type of meat, but also the fat raw material should be taken into account. The diversified structure of fat raw materials in terms of the content of muscle and connective tissue may result in a change in the lightness of the product as well as the share of redness and yellowness.
3. Based on the results of the sensory evaluation, it was shown that products with beef tallow in the recipe composition were the least desirable in terms of all attributes, which creates limited prospects for introducing this type of products to the market. The greatest potential

for replacing pork jowl in the production of homogenized scalded sausages would be goose fat. Average scores for the sensory attributes of sausage with goose fat did not differ significantly from those for sausage with pork jowl, except for the feeling of greasiness, which was more 'pronounced'.

* * *

Summarizing the results of this study, it can be concluded that research on the rational utilization of various fatty raw materials generated in meat production is still necessary, including the possibility of introducing them to the recipe composition of various types of meat products. Such projects should contribute to reducing the amount of waste in the food industry, reducing food waste, and thus improving living conditions.

PODSUMOWANIE I WNIOSKI

Celem przeprowadzonych badań była próba wykorzystania zróżnicowanego surowca tłuszczowego: wieprzowego, wołowego oraz gęsiego w produkcji kiełbas homogenizowanych oraz określenie jego wpływu na cechy jakości technologicznej i sensorycznej w porównaniu do produktu kontrolnego zawierającego w składzie surowcowym podgardle wieprzowe. Materiał doświadczalny stanowiły kiełbasy homogenizowane parzone, wytworzone zgodnie z typowym procesem produkcyjnym dla tej grupy wyrobów mięsnych. W celu porównania jakości kiełbas dokonano analizy ich składu chemicznego, pomiaru parametrów barwy i tekstury oraz przeprowadzono ocenę sensoryczną. Na podstawie badań stwierdzono, co następuje:

1. Pomimo znacznego zróżnicowania zawartości podstawowych składników chemicznych (woda, białko, tłuszcz) w surowcach tłuszczowych, zastosowanie tych surowców do produkcji kiełbas homogenizowanych różnicowało istotnie jedynie zawartość tłuszczu w produkcie oraz ich wartość energetyczną. Zawartość tłuszczu oraz wartość energetyczna kiełbas homogenizowanych wyprodukowanych z udziałem surowca innego niż podgardle wieprzowe była wyższa, kształtując się na poziomie odpowiednio od nieco ponad 24% do około 30% oraz od około 290 kJ/100 g do nieco ponad 310 kJ/100 g. Niezależnie od rodzaju surowca tłuszczowego, kiełbasy homogenizowane cechowały się relatywnie wysoką zawartością białka, tj. nie niższą niż 14,22% oraz niską zawartością soli kuchennej, tj. nie wyższą niż 1,85%. Uzyskane wyniki stanowią potwierdzenie możliwości modyfikacji wartości odżywczej tego typu produktów mięsnych przez dobór surowca tłuszczowego do produkcji. Biorąc pod uwagę wartość odżywczą kiełbas, a głównie zawartość tłuszczu, stwierdzono, że zwłaszcza produkty zawierające tłuszcz gęsi oraz słoninę w składzie recepturowym nie powinny być spożywane przez osoby ograniczające ilość tłuszczu w diecie.
2. Stwierdzone istotne różnice dotyczące parametrów barwy kiełbas homogenizowanych również były najprawdopodobniej spowodowane rodzajem surowca tłuszczowego użytego do produkcji oraz różnicami w barwie tych surowców. Największe różnice w barwie kiełbas, zarówno na powierzchni batonów, jak i na przekroju poprzecznym batonów spowodowane były zastąpieniem podgardla wieprzowego przez tłuszcz gęsi. W kiełbasie z tłuszczem gęsim stwierdzono istotny wzrost parametru barwy L* oraz istotne obniżenie wartości parametru barwy a*, mierzone na przekroju batonu, zarówno po 24 godzinach jak i po 14 dniach przechowywania chłodniczego. Obliczone wartości wskaźnika ΔE wskazywały, że - niezależnie od czasu przechowywania produktu w chłodni - różnica w barwie powierzchni między kiełbasą z tłuszczem gęsim a kiełbasą kontrolną (z podgardlem wieprzowym) była wyraźnie zauważalna przez niedoświadczonego obserwatora, zaś w przypadku barwy na przekroju poprzecznym obu wariantów kiełbas obserwator może nawet odnieść wrażenie występowania dwóch różnych barw. Uzyskane wyniki potwierdzają, że w kreowaniu barwy produktu mięsnego wytworzonego z surowców o dużym stopniu rozdrobnienia należy uwzględnić nie tylko ilość i rodzaj surowca mięsnego, ale także surowca tłuszczowego. Zróżnicowana struktura surowców tłuszczowych w zakresie zawartości tkanki mięśniowej i łącznej może skutkować zmianą jasności produktu oraz udziału w jego barwie czerwieni i barwy żółtej.
3. Na podstawie wyników oceny sensorycznej wykazano, że produkty z łojem wołowym w składzie recepturowym były najmniej pożądane pod względem wszystkich wyróżników, co stwarza ograniczone perspektywy dla wprowadzenia tego typu produktów na rynek. Największe możliwości zastąpienia podgardla wieprzowego w produkcji kiełbas homogenizowanych parzonych miałby tłuszcz gęsi. Noty średnie przyznane w ocenie sensorycznej kiełbasie z tłuszczem gęsim nie różniły się istotnie od tych przyznanych kiełbasie z podgardlem wieprzowym, za wyjątkiem odczucia tłustości, które było bardziej „wyraźne".

* * *

Podsumowując uzyskane wyniki można stwierdzić, że nadal niezbędne są badania nad racjonalizacją zagospodarowania różnych surowców tłuszczowych generowanych w produkcji mięsa, obejmujących m.in. możliwości wprowadzania ich do składu recepturowego różnorodnych przetworów mięsnych. Działania takie powinny przyczynić się do zmniejszenia ilości odpadów, ograniczenia marnotrawstwa żywności, a tym samym do poprawy warunków życia.

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Dr hab. inż. Sabina GALUS
Dr hab. inż. Agnieszka CIURZYŃSKA, prof. SGGW
Dr hab. inż. Monika JANOWICZ, prof. SGGW
Department of Food Engineering and Process Management, Institute of Food Sciences, Warsaw University of Life Science, Warsaw, Poland
Katedra Inżynierii Żywnosci i Organizacji Produkcji, Instytut Nauk o Żywności
Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Polska

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Key words: edible films, vegetable outgrades, apple pomace, apple pectin.

The article presents the results of research on the method of recycling the vegetable outgrades of cauliflower, broccoli, yellow and green beans in the form of edible packaging films. The prepared vegetable purees after drying in the form of thin layers did not show a continuous structure, therefore an attempt was made to use dried apple pomace, also a waste material, as a film-forming agent. Studies have shown that they do not fulfill their function due to the low gelling efficiency and a film-forming solution of apple pectin was used, which showed very good gelling capacity in combination with vegetable purées. The tests concerned the determination of appropriate concentrations of the film-forming substance, preparation and addition of vegetables, and drying parameters. It was found that vegetable films with acceptable functional properties were obtained with the use of a film-forming solution based on apple pectin at a concentration of 2.5% in combination with vegetable purees in the ratio of 50:50 and drying at a temperature of 60˚C for 4 hours.

Słowa kluczowe: folie jadalne; wysort warzywny, wytłoki jabłkowe; pektyna jabłkowa.

W artykule przedstawiono wyniki badań dotyczących sposobu zagospodarowania wysortu warzywnego z kalafiora, brokułu, żółtej i zielonej fasolki szparagowej w postaci opakowań jadalnych. Przygotowane purée warzywne po wysuszeniu w postaci cienkich warstw nie wykazywało struktury ciągłej, dlatego podjęto próbę zastosowania suszonych wytłoków jabłkowych, materiału odpadowego, jako substancji żelującej. Badania wykazały, że badane puree warzywne nie spełniło swojej funkcji z uwagi na niską efektywność żelowania i zastosowano foliotwórczy roztwór pektyny jabłkowej, która wykazała bardzo dobre właściwości żelujące w połączeniu z purée warzywnym. Próby dotyczyły określenia odpowiednich stężeń substancji powłokotwórczej, przygotowania i dodatku warzyw oraz parametrów suszenia. Na podstawie przeprowadzonych badań stwierdzono, że folie warzywne o akceptowalnych właściwościach użytkowych otrzymano z zastosowaniem roztworu powłokotwórczego na bazie pektyny jabłkowej o stężeniu 2% w połączeniu z warzywami w stosunku 50:50 oraz suszeniu w temperaturze 60˚C przez 4 godziny.

INTRODUCTION

The large amounts of waste from fruit or vegetable processing are the result of processing or production of juices. Among them skins, seeds, stalks, pomace, husks, leaves can be listed [6]. Improperly stored or utilized fruit and vegetable waste may pose a microbiological hazard and have a negative impact on the natural environment [2]. The main direction of recycling waste from fruit and vegetable industry is the recovery of valuable ingredients. After proper processing, potato skins become a source of fiber, necessary for the proper functioning of the human digestive system. Polyphenols being a bioactive ingredient, are recovered from the peels of citrus, apples and grapes, which often become waste after obtaining the juice. Lycopene and β-carotene can also be recovered

Adres do korespondencji – Corresponding author: Sabina Galus, Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Instytut Nauk o Żywności, Katedra Inżynierii Żywności i Organizacji Produkcji, ul. Nowoursynowska 159c, 02-776 Warszawa, e-mail: sabina_galus@sggw.edu.pl

from the waste obtained from tomatoes [1]. Pectin is produced from apple pomace and orange peels, which can be used to develop edible films and coatings [17]. Banana peels, which make up about 35% of the fruit's weight, are used, among others, in for the production of wine. Pineapple peel can produce ethanol, and properly processed tomato waste can be used as a substitute for wheat flour [1]. Waste from the fruit and vegetable industry can also be used to obtain enzymes. For example, banana peel can be used to produce α-amylase, while strawberry pulp has been used as a substrate for the production of polygalacturonase, which can be used in the clarification of wines and juices, as well as in the production of jams [23].

The discarded fragments and residues of fruit and vegetables are rich in components necessary for a balanced human diet, which can be recovered by different methods from waste and intended for consumption. Among them polyphenols, flavonoids, carotenoids, phytosterols and anthocyanins can be obtained. The main issue that must be taken into account when planning the recovery of valuable components from waste are the profitability and costs [1]. Vegetable outgrades are the parts of vegetables that did not meet certain quality standards allowing for sale, that mean parts rejected during production due to inadequate dimensions. During the production process, some parts, e.g. cauliflower or broccoli, are considered too small or too large and do not meet the classification requirements. However, those parts are still the same vegetable that can be consumed [20]. In this case, cauliflower, broccoli or other vegetables can be used in the production of edible packaging films in the form of sheets or wrappings, which together with the product are the source of vitamins and minerals. In addition, they provide carbohydrates, proteins, dietary fiber and organic acids [13]. Novel food called ''vegetable paper" or ''edible paper", kind of convinient food, seems to be more popular recently. This is a thin layer obtained by processing vegetables into a puree or past with the addition of various functional substances and then drying. This kind of food is characterised not only as green and nutrient rich components, but also show low sugar, sodium or fat content, which can be ready-to-eat crisp [12]. Vegetable or fruit waste can be used for the production of novel edible packaging films, which can also be a good carrier of nutrientional componds or other functional ingredients [9]. Previous studies showed that edible films such as fruit leather or pestil with a flexible structure can be obtained by hot air drying of fruit purees or juice concentrates with or without the addition of other ingredients. In addition, a lot of research has been carried out on the method of production, parameters and properties of this type of product made of various types of fruit [1, 2, 6, 9, 10, 11]. Edible films or coatings are thin layers of edible material that are formed directly onto the product, while edible coatings are obtained mostly by spraying or immersing the product in a film-forming solution formed by a structured matrix. Edible packaging films are in the form of separately formed sheets, which are then placed on the surface of the food or between the layers of the product [7, 8]. In addition, edible coating can be used as a pre-treatment in osmotic dehydration or drying for fruit or vegetables [15].

The aim of the study was an attempt to produce edible vegetable films from the vegetable outgrades of broccoli, cauliflower, green and yellow beans with the use of apple pomace and apple pectin as gelling substances. The tests concerned the determination of appropriate concentrations of the film-forming substance, preparation and addition of vegetables, and drying parameters. Dry matter and colour were tested and the surface structure was observed.

MATERIALS AND METHODS

Frozen vegetables outgrades were supplied by Unifreese Sp. z o.o. (Górzno, Poland). Apple pomace was obtained in laboratory conditions by drying at 60°C for 14 hours the waste left after squeezing. A low methylated apple pectin was pourchased from Agnex (Białystok, Poland). Glycerol (Avantor Performance Materials Poland S.A.Gliwice, Poland) was used as a plasticizer.

Technological methods

The frozen vegetables were boiled in water to getting soft (broccoli 7 min, cauliflower and green beans 10 min) and were ground to a smooth mass in a knife mill GM 200 (Retsch, Katowice). Each type of vegetable has been cooked and processed separately. The film-forming solutions were prepared in different variations by combining distilled water with powdered dried apple pomace at the concentration of 2, 4, 5 or 6% or apple pectin at the concentration 2 and 2,5%. The solutions were heated and stirred for 30 minutes using a RCT basic IKAMAG magnetic stirrer (IKA Poland, Warsaw) at the level of 200 rpm at a temperature of 60°C. After cooling, glycerol was added to the solutions in an amount representing 50% of the added apple pomace or apple pectin, and calcium lactate (Avantor Performance Materials Poland, Gliwice) in an amount representing 1% of the added film-forming substance. The vegetable purees and the film-forming solutions were combined in a mass ratio of 50:50 and poured on byko-charts test cards with a thickness of 0.35 mm (model A4 PA-2824, Eurotom Sp. z o.o., Warsaw) and spread using a slotted applicator using an automatic layering table (ZAA 2300, Zehntner Testing Instruments, Sissach, Switzerland) travel speeds 90 mm/s. The thickness of the applied layers was 2500 μm. The samples were dried from 35 to 60°C in a laboratory dryer SUP-65W (Wamed Wytwórnia Aparatury Medycznej SSP, Warsaw). The dryed vegetavble films were conditioned in a climate chamber model KBF 240 (Binder GmbH, Tuttlingen, Germany) at 25°C and relative humidity of 50% for 48 hours prior testing.

Colour

The colour test was performed using the CR-300 model colorimeter (Minolta, Japan) in the CIE $L^*a^*b^*$ system (L^* - lightness, a^* - green to red colour, b^* - blue to yellow colour). The measurement was performed in ten repetitions. For a better interpretation, the the total colour difference (ΔE) between the film and the white standard (L^*=97.12±0.10; a^*=0.05±0.01; b^*=1.84±0.04) was calculated according to the method described by Sobral, dos Santos & Garcia [22]:

$$\Delta E = \sqrt{(L^* - L)^2 + (a^* - a)^2 + (b^* - b)^2}$$

where: ΔE – total colour difference;
L*, a*, b* - parameters for white standard;
L, a, b – parameters for films.

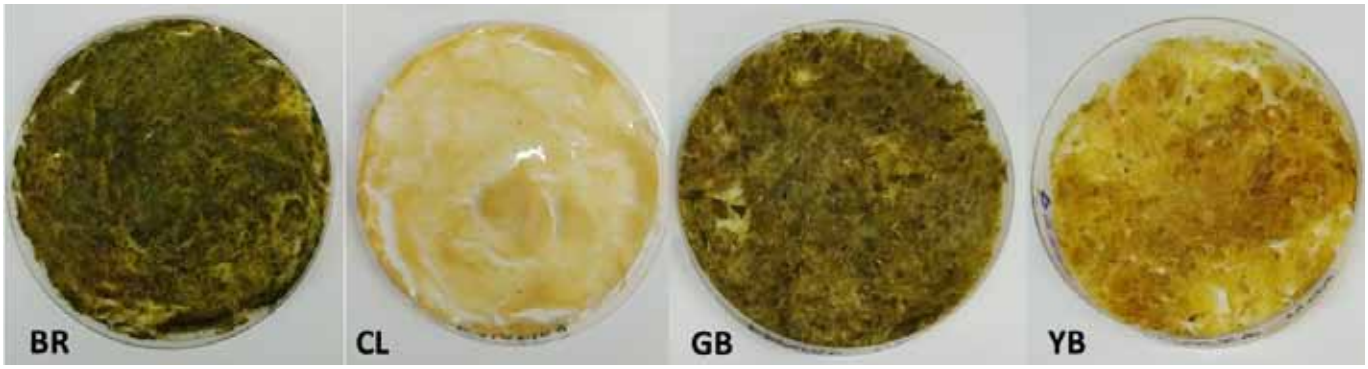

Fig. 1. Vegetable purees dryed at the temperature of 35˚C; BR – broccoli; CL - cauliflower, GB - green bean, YB - yellow beans.

Rys. 1. Wysuszone w temperaturze 35°C puree warzywne; BR – brokuł; CL – kalafior, GB – zielona fasolka szparagowa, YB – żółta fasolka szparagowa.

Source: The own study

Źródło: Badania własne

Dry matter

The film dry matter was determined at least in three repetitions through the weight loss undergone by the film after 24 h oven drying at 105±1°C.

Microstructure

The observations of the film microstructure were performed using the FEI Quanda 200 scanning electron microscope (Brno, Czech Republic) at low vacuum from 0.35 to 1 Torr and the magnification 100x.

Statistical analysis

Statistica 11 (StatSoft Inc., Tulsa, OK, USA) was used to analyze the obtained results. The analysis of variance (ANOVA) at a significance level of 0.05 was performed with Tukey's post hoc test to detect significant differences in film properties.

RESULTS AND DISCUSSION

Several studies have been carried out on the development of films or coatings based on fruits and vegetables [1, 2, 6, 9]. These investigations relied mostly upon combining different kind film-forming hydrocolloids with fruit and vegetable purees. Moreover, fruit and vegetable are sources of nutrients and antioxidants that may be ingested in form of edible films made from them [19]. The different types of vegetable films are determined from the different raw materials. Nowadays, the vegetable layers are developed mostly at home and have a single vegetable as the raw material. However, there is also a posibility to prepare a composite vegetable films based on the mixture of multiple vegetables. Nevertheless, most research is still at the laboratory stage [12]. Some fruits contain enough pectins that make them possible to produce films without the addition of gelling agents, such as apple, black currant or plum, which was presented in our previous study [11]. However, vegetables are characterized by different compositions and vegetable purees that were used in this study, from cauliflower, broccoli, yellow and green beans, did not contain a sufficient amount of gelling compounds to create thin layers with film-forming capacity (Fig 1). Therefore apple pomace, as waste material and apple pectin were used in different concentrations to form vegetable films. A summary of the tests carried out and the results achieved in this study are presented in Table 1. In general, in many studies, polysaccharides had been used as biopolymer materials, including alginate, carrageenan, starch and xanthan gum, which can form edible films or coatings to reduce petroleum-based packaging [18].

Films obtain from apple pomace and glycerol were brittle and did not show continuous structure, which was improved by the addition of calcium lactate. Fig. 2 shows the comparison of such films prepared at the concentration of 6% of apple pectin and dryed at 35°C. It can be clearly concluded that the addition of calcium lactate is necessary to maintain a homogeneous film structure. Then, different concentration and temperature as well as proportions of film-forming solutions and vegetable purees were used to obtain films with the desired film capacity. The main trials and results were presented in Table 1.

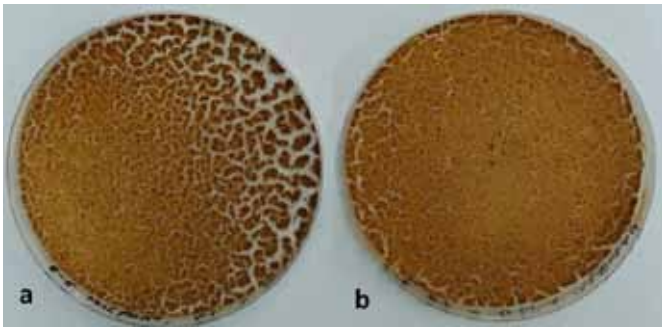

Fig. 2. Pure films prepared based on apple pomace without (a) and with calcium lactate (b).

Rys. 2. Folie wytworzone z wytłoków jabłkowych bez warzyw oraz bez dodatku (a) i z dodatkiem (b) mleczanu wapnia.

Source: The own study

Źródło: Badania własne

The first trial consisted in the production of films with a minimal addition of gelling substances in order to obtain so-called clean label with the most content of vegetable purees. The test was carried out to compare apple pomace and pectin-based films, since pectin is widely used biopolymer

Table 1. The most important technological trials of preparation films with vegetable purees with the obtained results
Tabela 1. Zestawienie najważniejszych prób technologicznych wytworzenia folii z purée warzywnego i osiągnięte wyniki

Type of film-forming agent	Concentration of film-forming agent [%]	Drying temperature [°C]	Drying time [h]	Observations
Apple pomace	2	60	24	lack of the desired gelling capacity and continuous structure; films too dry
	4	35	48	continuous structure, impossible to peel off the films
	5	60	24	lack of continuous structure, some parts burnt
	6	35	48	lack of desired gelling and continuous structure
Apple pectin	2	60	24	desired geling capacity, continuous structure, long time of drying, some parts burnt
	2,5	60	24	continuous and homogeneous structure, easy to peel off the films

Source: The own study
Źródło: Badania własne

in production of edible films or coatings and their properties meet the mechanical resistance requirements for packaging films [17]. Different temperatures were used from 35 to 60°C resulting in varied drying times. Relatively good results were observed when apple pectin was used at 2%, while films prepared with the addition of apple pomace showed rather noncontinuous structure due to the low content of pectin. The photograps of obtained vegetable films are presented in Fig. 3. Tarko et al. [24] observed that apple pomace contains pectins at the level of 0.6/100 g, however its content varies depending on the fruit type, method of processing and cultivator of fruit pomace [10, 14]. Therefore, increased concentations from 2 to 6% of apple pomace were used and different observations were noted indicating that there is no possibility to obtain smooth vegetable films with apple pomace as gelling agent due to the lack of film-forming capacity.

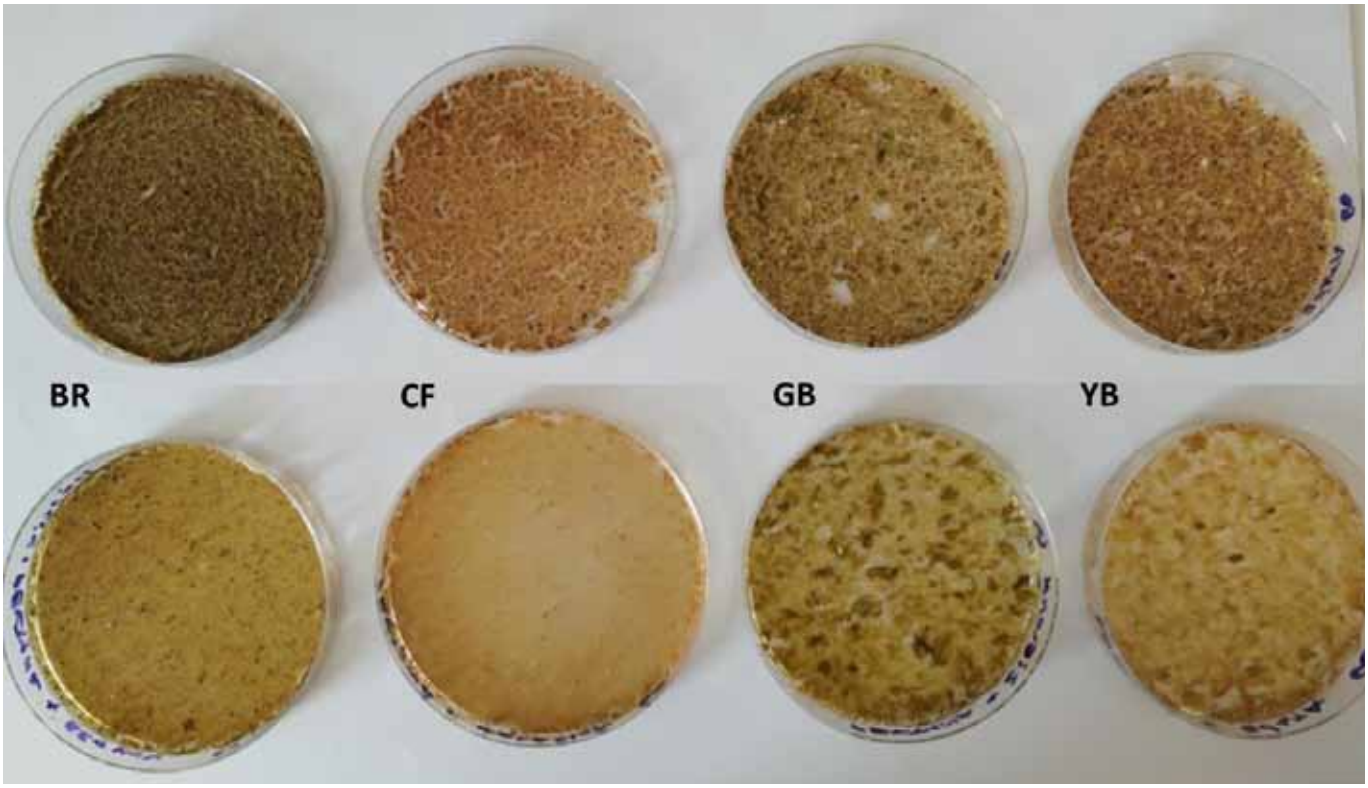

Fig. 3. Films prepared with the addition of apple pomace (top row) or apple pectin (lower row) based on vegetable puree from broccoli (BR), cauliflower (CF), green beans (GB), and yellow beans (YB).
Rys. 3. Folie wytworzone z dodatkiem wytłoków jabłkowych (powyżej) lub pektyny jabłkowej (poniżej) z puree warzywnego z brokułu (BR), kalafiora (CF), zielonej fasolki szparagowej (GB) i żółtej fasolki szparagowej (YB).

Source: The own study
Źródło: Badania własne

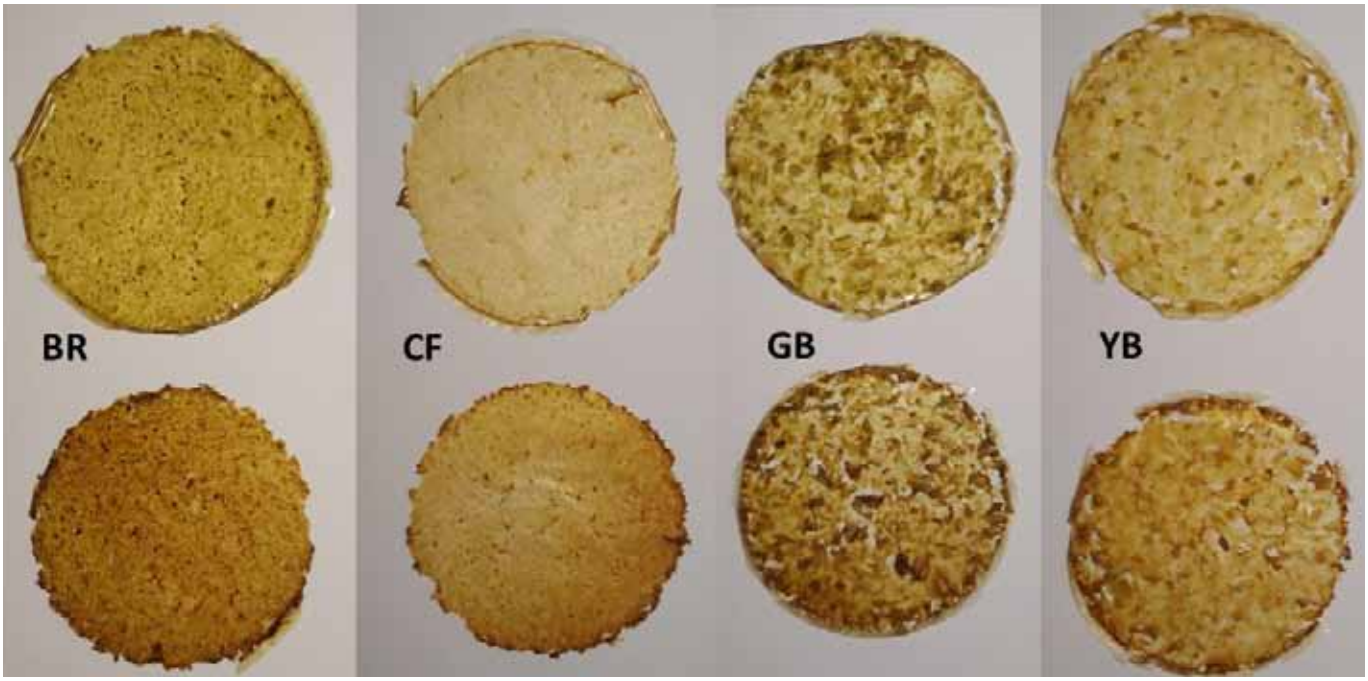

Fig. 4. Films prepared with apple pectin dryed at the temperature of 35°C (top row) and 60°C (lower row) (lower row) based on vegetable puree from broccoli (BR), cauliflower (CF), green beans (GB), and yellow beans (YB).

Rys. 4. Folie wytworzone z dodatkiem pektyny jabłkowej suszone w temperaturze 35°C (powyżej) i 60°C (poniżej) z puree warzywnego z brokułu (BR), kalafiora (CF), zielonej fasolki szparagowej (GB) i żółtej fasolki szparagowej (YB).

Source: The own study

Źródło: Badania własne

The addition of apple pectin was finally changed to lightly higher content (2.5%) to obtain films with better mechanical resistance. Different drying conditions were applied to determine the most relevant drying conditions to obtain films with desired functional properties. Fig. 4 shows the comparison of films dryed at 35°C for 72 h and 60°C for 24 h. It can be observed that higher temperature resulted in darker films with more compact structure, while films dryed at lower temperature were more humid with softened structure.

In the development process of edible films based on vegetables, it is necessary to protect the colour and retain its original colour [12]. The colour of the films is a crucial parameter, which need to be control and taken into account in order to minimize their change during the film preparation. The control films were transparent with lighty yellow colour connected to the pure pectin powder nature, while vegetable films showed colour similar to the vegetable that were used in the proces.

The results of colour parameters are presented in Table 2. Control films prepared without the addition of vegetables showed highest lightness (parametr L^*), 89.51, which is similar to the values obtained for pectin films by others [21]. Vegetable films were characterized by much lower L^* values, from 49.70 for films contaning green bean puree to 63.52 for films contianing yellow bean purees. Lighter vegetables, the lighter films were obtain, which can be observed for cauliflower and yellow bean purees contaning films (63.23–63.52). All vegetable films showed statistically significant lower lightness. All films had positive a^* (green-red) and b^* (blue-yellow) parameters. A statistically significant increase of the a^* parameter was observed, from 0.23 for control films to 11.54 for films containing cauliflower purees. Among vegetable films, the lowest values of parameter a^* were observed for films with the purees based on broccoli and green beans, 4.01 and 2.35, respectively. Films containing yellow beans showed a^* value of 8.84. The obtained data indicates that higher value of parameter a* means colour toward to red, however the values are relively low and it does not correspond with the natural colour of the raw vegetables. This is probably attributed to the changes of pigments that can occur durring the technological and drying proces, as well as the interactions between the biopolymer (apple pectin) and vegetables. Regarding the values of parameter b^*, it is noted that all films were positive values, from 13.06 for control films to 34.07 for films contaning puree from blocolli, indicating the colour toward yellow. Statistically significant increases in values were observed for films contanings purees from broccoli, cauliflower and yellow beans, which b^* values were similar, from 31.54 to 34.07, whereas films contaning green beans showed aproximate value to control films (16.69). The changes in colour parameters are due to the colour of pure apple pectin, which also affects the film appearance.

To better understand the colour changes, the total colour difference (ΔE) between the analyzed films and the white standard was calculated. The ΔE values ranged from 14.20 for control films to 51.12 for films contaning puree from broccoli. Statistically signifiact increase in ΔE values was observed for all films with vegetables, which indicates that the changes in colour are relatively high.

Table 2. L*, a*, b* colour parametres, total colour differece (ΔE) and dry matter of control films and films based on vegetable puree from broccoli (BR), cauliflower (CF), green beans (GB), and yellow beans (YB)

Tabela 2. Parametry barwy L*, a*, b*, całkowita różnica barwy (ΔE) i zawartość suchej substancji w foliach kontrolnych i z na bazie puree warzywnego z brokułu (BR), kalafiora (CF), zielonej fasolki szparagowej (GB) i żółtej fasolki szparagowej (YB)

Film	*L**	*a**	*b**	Δ*E*	Dry matter [%]
Control	89.51 ± 5.73^{c}	0.23 ± 0.03^{a}	13.06 ± 3.16^{a}	14.20 ± 3.66^{a}	3.05 ± 0.02^{a}
BR	58.23 ± 5.80^{b}	4.01 ± 1.66^{b}	34.07 ± 4.74^{b}	51.12 ± 1.44^{d}	6.63 ± 0.33^{bc}
CF	63.23 ± 2.53^{b}	11.54 ± 0.79^{d}	33.05 ± 1.05^{b}	47.54 ± 1.34^{bc}	5.12 ± 0.43^{b}
GB	49.70 ± 1.89^{a}	3.25 ± 0.64^{b}	16.69 ± 3.16^{a}	49.90 ± 1.49^{cd}	8.63 ±0.92^{d}
YB	63.52 ± 2.02^{b}	8.84 ± 0.48^{c}	31.54 ± 1.54^{b}	45.74 ± 1.45^{b}	7.67 ± 0.75^{cd}

Mean values ± standard deviations. Different superscripts letters ($^{a-d}$) within the same column indicate significant differences between the films ($p < 0.05$).

Source: The own study

Źródło: Badania własne

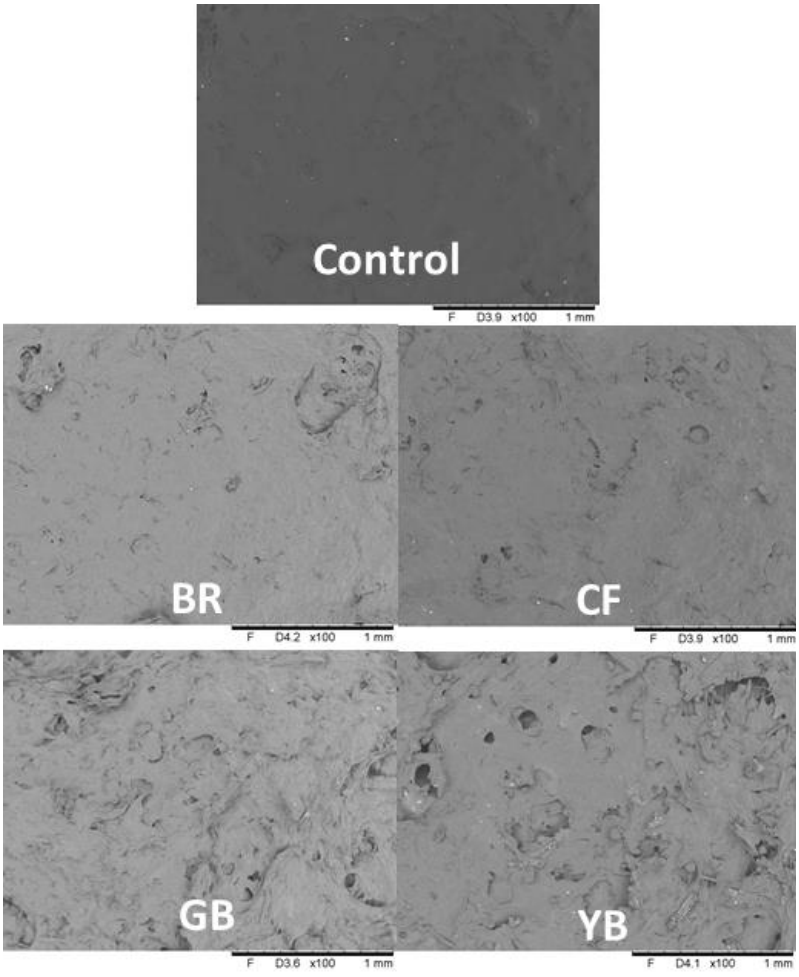

Fig. 5. Scanning electron micrographs of control films prepared only from apple pectin and films based on apple pectin and vegetable puree from broccoli (BR), cauliflower (CF), green beans (GB) and yellow beans (YB).

Rys. 5. Zdjęcia mikroskopowe folii wytworzonych z dodatkiem pektyny jabłkowej (control) i z dodatkiem puree warzywnego z brokułu (BR), kalafiora (CF), zielonej fasolki szparagowej (GB) i żółtej fasolki szparagowej (YB).

Source: The own study

Źródło: Badania własne

In general, those values are high and can be observed visually, based on the clasiffication presented by International Commission of Illumination (CIE), values of $\Delta E > 3.5$ are distinctly perceivable [21]. In addition, total colour difference is a good determinant of colour for films since it takes into account all three color parameters *L**, *a**, and *b** [8]. The study conducted by Chakravartula et al. [3] gave similar results, where the total colour difference of the 3% apple pectin films was 11.3. Similar results were obtained by Siracusa et al. [21].

The dry matter of analyzed films ranged from 3.05% for control films to 7.67% for films containing puree from yellow beans (Table 2.) Statistically significant increse in the values was observed for all vegetable films. A tendency of higher values (7.67–8.63%) can be noted for films based on green and yellow green beans, which can be connected with the higher content of solid parts and probably dietary fiber, which were observed in the films with heterogeneous structure. Therefore, more smooth films contaning cauliflower or broccoli purees were smoother and showed lower values of dry matter (5.12–6.63). Morover, taking into account that the film-forming solutions were mixed with vegetable purees at the proportion of 50:50 the values of dry matter of films are much lower that those noted for cauliflower [5] and broccoli [4], 9.3% and 11%, respectively.

The microstructure is the main characteristic of the film, which represents its surface morphology and internal structure [25]. Scanning electron micrographs of analyzed films are presented in Fig. 5. It can be observed that control films are characterized by homogeneous and continuous, both on a micro and macro scale. The surface is smooth, without pores or cracks, which is typical for most biopolymer films [8, 16]. All vegetable films showed rough, heterogeneous surface with pores, but continuous structure. There is

a lightly difference between films and it can be noted, that films contaning puree from cauliflower or broccoli are more homogeneous in comparison to the films prepared with the addition of green and yellow beans. This is attributed to the structure of the vegetables and their compositions, mostly dietary fiber content and other not soluble fractions. These observations are in line with the results of dry matter (Table 2), higher values corresponed with more heterogeneous structure.

PODSUMOWANIE

W artykule przedstawiono wybrane wyniki badań nad otrzymaniem folii jadalnych na bazie wytłoków jabłkowych oraz pektyny jabłkowej w połączeniu z puree z warzyw pochodzących z mrożonego wysortu warzywnego z kalafiora, brokułu, żółtej i zielonej fasolki szparagowej. Próby dotyczyły określenia odpowiednich stężeń substancji powłokotwórczej, przygotowania i dodatku warzyw oraz parametrów suszenia powłok. Zastosowane warzywa bez dodatku substancji żelujących nie miały właściwości powłokotwórczych. Wytłoki jabłkowe nie wykazały pożądanych właściwości żelujących. Zawartość pektyn o stężeniu 2 i 2,5% w roztworze powłokotwórczym była wystarczająca do otrzymania folii o akceptowalnych właściwościach użytkowych. Dodatek mleczanu wapnia był niezbędny do uzyskania jednolitej struktury. Najlepsze właściwości użytkowe wykazały folie warzywne otrzymane poprzez połączenie warzyw w stosunku masowym 50:50 z roztworem powłokotwórczym zawierającym 2.5% pektyny, w obecności glicerolu (50% względem pektyny) i mleczanu wapnia (1% w stosunku do pektyny). Optymalne warunki suszenia folii warzywnych to temperatura 60°C i czas 4 godziny. Wytworzone folie warzywne o zróżnicowanej barwie i strukturze mogą znaleźć zastosowanie w projektowaniu nowych produktów m.in.: jako bezglutenowe przekąski warzywne lub powłoki funkcjonalne do batonów owocowo-warzywnych.

SUMMARY

The article presents the selected results of the study on the preparation of edible films based on apple pomace and apple pectin in combination with vegetable puree obtained from a frozen vegetable outgrades of cauliflower, broccoli, yellow and green beans. The analyzes concerned the determination of appropriate concentrations of the film-forming solutions, preparation and addition of vegetables as well as parameters for film drying. The vegetables used without the addition of gelling substances showed no film-forming capacity. Apple pomace did not show the desired gelling properties. The pectin content of 2 and 2.5% in the film-forming solutions was sufficient to obtain a film with acceptable performance properties. The addition of calcium lactate was necessary to obtain a homogeneous structure. The best functional properties were demonstrated by vegetable films with acceptable functional properties, obtained by combining of vegetable puree and film-forming solutions based on apple pectin at 2.5% in a weight ratio of 50:50 and in the presence of and calcium lactate. The optimal conditions for drying the vegetable films were determined at the temperature of 60°C and the time of 4 hours. The analyzed vegetable films with different colours and structures can be used in the new product development e.g. as gluten-free vegetable snacks or functional coatings for fruit and vegetable bars.

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Dr inż. Barbara SIONEK
Institute of Human Nutrition Sciences, Warsaw University of Life Sciences (WULS, Poland)
Instytut Nauk o Żywieniu Człowieka, Szkoła Główna Gospodarstwa Wiejskiego w Warszawie (SGGW, Polska)

EVALUATION OF THE ADDITION OF PREBIOTICS ON THE QUALITY OF PROBIOTIC COCONUT DESSERTS®

Ocena wpływu dodatku prebiotyków na jakość probiotycznych deserów kokosowych®

Key words: prebiotics, probiotics, synbiotics, functional foods, *Lactobacillus, fermented foods.*

The aim of this study presented in the article was to develop a synbiotic coconut dessert with the satisfactory sensory quality without sugar, with the addition of probiotic bacteria and prebiotics. A selected strain of probiotic bacteria and the following prebiotics were added to the coconut desserts: inulin, maltodextrin, guar gum, β-glucan. Coconut drink was fermented at 37°C for 24 hours and stored at 4°C for 7 days. The dessert with Lactobacillus plantarum 299v had the best sensory quality and was selected for the study with using prebiotics. In the dessert with the addition of prebiotics, the survivability of the Lactobacillus plantarum 299v strain was high (>8 log CFU/mL) both after fermentation and during storage. The overall quality of the coconut dessert with Lactobacillus plantarum 299v and prebiotics was high after fermentation and during storage. At the end of the storage period, the highest overall quality has a coconut dessert with inulin and control sample. Coconut desserts have the required minimum number of cells of the Lactobacillus plantarum 299v strain and they can be considered as probiotic products.

Słowa kluczowe: prebiotyki, probiotyki, synbiotyki, żywność funkcjonalna, *Lactobacillus, żywność fermentowana.*

Celem pracy przedstawionej w artykule było opracowanie synbiotycznego deseru kokosowego bez dodatku cukru o zadowalającej jakości sensorycznej, z dodatkiem bakterii probiotycznych i prebiotyków. Do deseru kokosowego dodano wyselekcjonowany szczep bakterii probiotycznych oraz następujące związki prebiotyczne: inulinę, maltodekstrynę, gume guar, β-glukan. Napój kokosowy fermentowany był w temperaturze 37°C przez 24 godziny i przechowywany w 4°C przez 7 dni. Jako kulturę startową zastosowano szczepy bakterii probiotycznych i potencjalnie probiotycznych. Deser ze szczepem Lactobacillus plantarum 299v miał najlepszą jakość sensoryczną i został wybrany do badania z zastosowaniem prebiotyków. W deserze z dodatkiem prebiotyków przeżywalność szczepu Lactobacillus plantarum 299v była wysoka (>8 log jtk/mL) zarówno po fermentacji, jak i podczas przechowywania. Ogólna jakość deseru kokosowego z Lactobacillus plantarum 299v i prebiotykami była wysoka po fermentacji i podczas przechowywania. Pod koniec okresu przechowywania najwyższą ogólną jakość miał deser kokosowy z inuliną i próba kontrolna. Desery kokosowe zawierały wymaganą minimalną liczbę komórek Lactobacillus plantarum 299v, tym samym mogą być uznane za produkty probiotyczne.

INTRODUCTION

The interest in food that has a beneficial effect on health is a trend observed all over the world. Consumers increasingly make informed choices: they avoid food ingredients that contribute to diseases, such as animal fats, simple sugars, chemical preservatives and colorants, choose low-calorie foods, look for tasty and nutritious products. Functional foods becoming more popular. Positive opinions about the health-promoting effect of functional foods, in particular on functioning of the digestive and immune systems and the possible inhibition of the development of many diseases have been confirmed by many scientific studies and recommendations of authoritative institutions and agencies as FAO/WHO, EFSA, FDA, ESPHAGAN [6, 8, 18, 23]. It is believed that prebiotics may have health benefits. Prebiotics by increasing the number of commensal bacteria improve the balance in the human intestinal ecosystem [7, 25]. They have an impact on endocrine function of gastrointestinal tract, modulate gastrointestinal peptides, enhance immune system [1, 3, 4, 22]. More investigations are necessary to better understanding of mechanism involved and to prove the health effects associated with the consumption of prebiotics [14, 19]. Substances that are considered prebiotics are added to various food products, such as dairy products, plant-based drinks, health drinks, infant formulas and meat products [9]. Inulin and oligofructose are most common prebiotics on the market used in food production [13, 15].

Corresponding author – Adres do korespondencji: Barbara Sionek, Institute of Human Nutrition Sciences, Warsaw University of Life Sciences (WULS), Department of Food Gastronomy and Food Hygiene, Nowoursynowska Str. 159c, 02-776 Warsaw, Poland, e-mail: barbara_sionek@sggw.edu.pl

Probiotics are live microorganisms which when administered in adequate amounts confer a health benefit on the host [8]. The growing interest in probiotics is primarily related to their scientifically proven beneficial influence on the functioning of the digestive and immune systems and the possible inhibition of many diseases. Development of new functional foods containing probiotics and prebiotics is of great interest, because of the significant health benefits [2, 10]. The addition of probiotic and potentially probiotic microorganisms and/or prebiotics is positively perceived by consumers and is an incentive for food producers to search for new food products that meet the criteria of functional food. The combination of the addition of probiotic microorganisms and prebiotics in one food product results in a synbiotic product that seems to have an optimal effect on consumer health [17]. Gibson and Roberfroid (1995) first defined synbiotic as a mixture of probiotics and prebiotics that beneficially affects the host by improving the survival and implantation of live microbial dietary supplements in the gastrointestinal tract, by selectively stimulating the growth and/or by activating the metabolism of one or a limited number of health-promoting bacteria, and thus improving host welfare [11]. Choosing the right probiotic-prebiotic pair for a given food product is crucial and should maintain proper viability of the probiotic microorganisms during the storage period [24].

In addition to the health-promoting effect of synbiotics, a prerequisite for the development of such a product is to maintain or improve its sensory quality. In accordance with the above-mentioned preferences, the aim of the study was to develop a synbiotic coconut desserts without sugar and with the addition of probiotic bacteria and prebiotics with the satisfactory sensory quality.

MATERIAL AND METHODS

Material. The probiotic bacterial strains: *Lactobacillus plantarum* 299v*, Lactobacillus acidophilus* LA5*, Lactobacillus casei* 431 came from the collection of the Institute of Fermentation Technology and Microbiology of the Lodz University of Technology; potentially probiotic: *Lactobacillus casei* O12 *and Lactobacillus johnsonii* K4, came from the collection of Institute of Human Nutrition Sciences, Warsaw University of Life Sciences and were used as a starter culture. *Lb. casei* 012*, Lb. johnsonii* K4 were isolated from fermented cabbage and cucumber and their selected probiotic properties were confirmed in the previous studied [30].

Inulin, maltodextrin (China, distribution PPH Apimar, Poland), β-glukan (Medicaline Aliness, Poland) and guar gum (India, distribution PPH Apimar, Poland) were used as prebiotic components in the experiment. Desserts were made on the basis of a coconut drink without sugar (manufacturer Alpro, Wevelgem, Belgium) purchased at the local store.

Probiotic starter culture preparation. Pure LAB strains were stored in -80°C and revitalised before use. 5 mL of MRS broth (Biokar Diagnostics, France) was inoculated with the bacterial strain then the suspension was incubated at 37°C for 24h.Then 1 mL of culture was added to 9 mL of MRS broth and incubated again at 37°C for 24h.The 24-hour bacterial culture was added to the drink, after the broth was centrifuged (10 000g/5min) and replaced with the coconut drink. The number of examined bacteria cells in the starter culture used to inoculate a coconut drink was 9 log CFU/mL.

Fermented coconut desserts preparation. The study was divided into two stages. In the first stage of the research, the most suitable strain for the fermentation of the drink was selected, and sensory evaluation was used as a selection criterion. The second part of the study included the evaluation of the effect of addition of prebiotics on the growth of the bacteria strain selected in the first stage of experiment, after fermentation and during refrigerated storage. For that purpose, the coconut drink was supplemented with selected starter strain and independently with the addition of 1% (w/v) of the following prebiotics: inulin, maltodextrin, guar gum, β-glukan. The control sample without prebiotic added was also prepared. The drink was fermented at 37°C for 24 hours and stored in 4°C.

The microbiological analysis. The number of bacteria cells were determined using the deep plate method, from three subsequent dilutions and plates on a selective MRS agar (Biocar, Diagnostics, France). The plates were incubated at 37°C for 48 hours.

Measurement of pH. The pH values were measured using of pH meter Elmetron CP 501 (Elmetron sp. j., Poland) potentiometric method at room temperature, just after fermentation and after 3 and 7 days of storage. The pH-meter was equipped with automatic temperature compensation and combined electrode at two points (pH=4 i pH=7).

Sensory analysis. The sensory scaling and ranking method were applied for the selection of the strain [26]. To determine sensory quality changes of the desserts after fermentation and during storage the Quantitative Descriptive Analysis (QDA) was used [28]. As a result of the selection 14 quality descriptors were chosen including four descriptors of smell, seven descriptors of ftaste, consistency, colour and overall quality. The intensity of descriptors was marked on a unstructured linear scale [0 – 10 c.u.]. The panelists possessed the necessary skills to describe the sensory attributes of different samples. The trained panel were extensively and formally tested before being selected, according to the [27]. The assessment was carried out in a room free from foreign odors with natural light and minimized noise level at room temperature.

Statistical analysis were performed using statistica software (Statistica 13.3.,StatSoft, Poland). Analysis of variance (ANOVA) was used to assess the significance of the effects ($P < 0.05$). The difference between means was detected by the Tukey's test.

RESULT AND DISCUSSION

Selection of a Lactobacillus probiotic and potentially probiotic strain for the production of coconut dessert

In the study on the selection of the strain for fermentation the sensory evaluation was used as a way to assess the consumer preference of the product. Figure 1 shows the average results of sensory evaluation among individual samples of fermented coconut desserts with the use of selected strains of probiotic and potentially probiotic bacteria. The

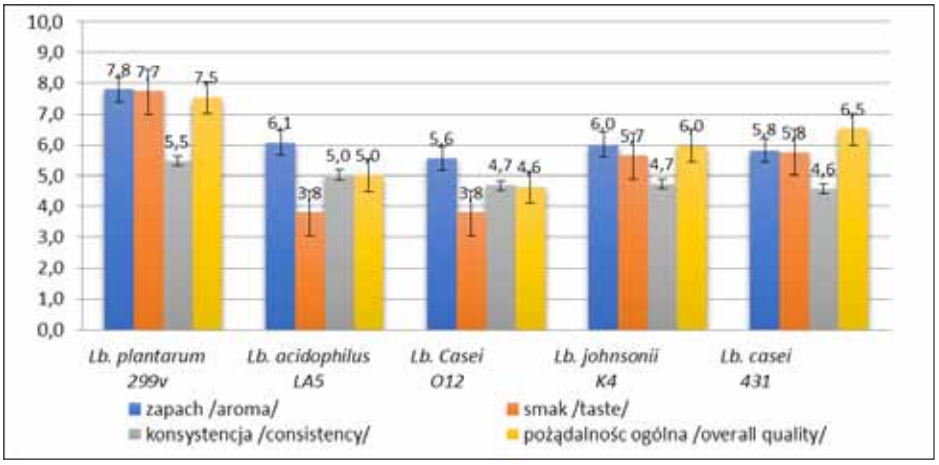


Fig. 1. Results of ratings of attributes of sensory quality of fermented coconut dessert depending on the strain of probiotic and potentially probiotic bacteria used - scaling method.

Rys. 1. Wyniki pożądalności wyróżników jakości sensorycznej fermentowanego deseru kokosowego w zależności od użytego szczepu bakterii probiotycznych i potencjalnie probiotycznych - metoda skalowania.

Source: The own study

Źródło: Badania własne

product inoculated with the strain *Lactobacillus plantarum* 299v achieved statistically significantly higher ($p>0.05$) desirability of taste, smell, overall quality compared to other samples. The taste was the descriptor that the most differentiated the samples. The results shown that the dessert with the addition of the strain *Lactobacillus plantarum* 299v characterised of the highest taste desirability (7.7 c.u.), while desserts with the *Lactobacillus casei* O12 and *Lactobacillus acidophilus* LA5 added, were the lowest taste desirability (3.8 c.u.) (fig.1.). There were no significant differences in the taste desirability for desserts with the addition of strains *Lactobacillus johnsonii* K4 and *Lactobacillus casei* 431 (5.7 c.u. and 5.8 c.u. respectively).

In the ranking method, which forces the order of the samples to be marked (fig. 2), the highest desire of the product with the *Lactobacillus plantarum* 299v strain was also found (the lowest value of the average rank, equal to 1.67). Differences in the sensory quality of desserts using the tested strains may be related to the ability of a given strain to metabolize nutrients and to produce compounds affecting smell and taste. Zielińska (2005) also found differences in the sensory quality of fermented (9 h/32°C) soy drinks using 10 strains of *Lactobacillus* [29].

The results obtained by scaling and ranking method indicated that the use of *Lb. plantarum* 299v strain allowed to obtain the best sensory quality of fermented drink. On this basis, it was decided to use this strain for further research.

Assessment of the change in the number of bacteria and pH of the coconut dessert after fermentation and during storage

Probiotic survival was evaluated in the coconut deserts after fermentation and at 3 and 7 days of storage. Survival of *Lactobacillus plantarum* 299v strain was high (cell counts was approximately 8 log CFU/mL) both after fermentation and during storage (fig. 3). As a result of the analysis, it was found that time had a significant ($p<0.05$) effect on the change in the number of cells of *Lb. plantarum* 299v in fermented samples. In coconut desserts with inulin and maltodextrin, a gradual increase in the number of cells of the probiotic strain was observed until the last day of storage studies.

Despite of increase in the number of bacteria, there were no significant changes in the pH in the dessert with inulin after fermentation and during storage (pH: 4.230, 4.350, 4.290 respectively) (fig. 4). In the dessert with β-glucan and a control sample, the number of probiotic bacteria cells on the 3rd day of storage significantly decreased, compared to the number of cells after fermentation. In desserts with maltodextrin, guar gum and inulin, the number of *Lb. plantarum* 299v that day was higher than after fermentation. In the study of Donkor et al. (2007) the addition of 2% inulin,1% of raffinose and 1% of glucose in fermented soya drink had a positive impact on the viability of *Lactobacillus acidophilus* L10, *Bifidobacterium animalis* B94 and *Lactobacillus casei* L26 [5].

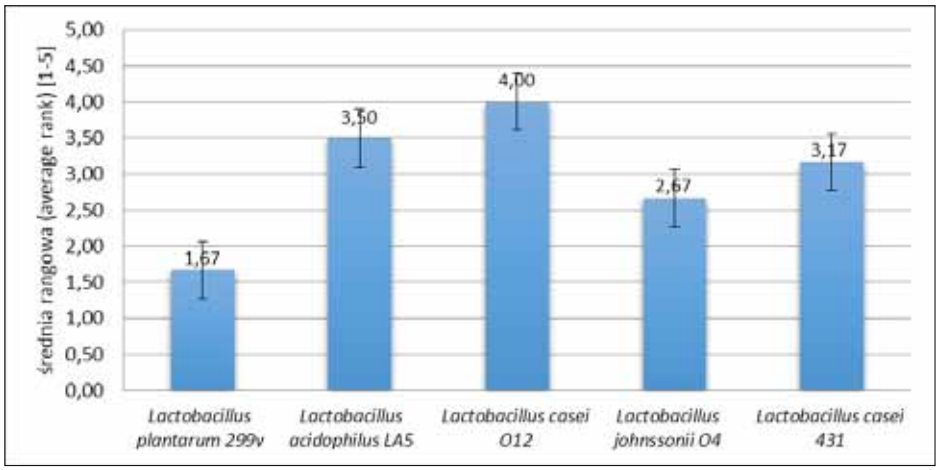
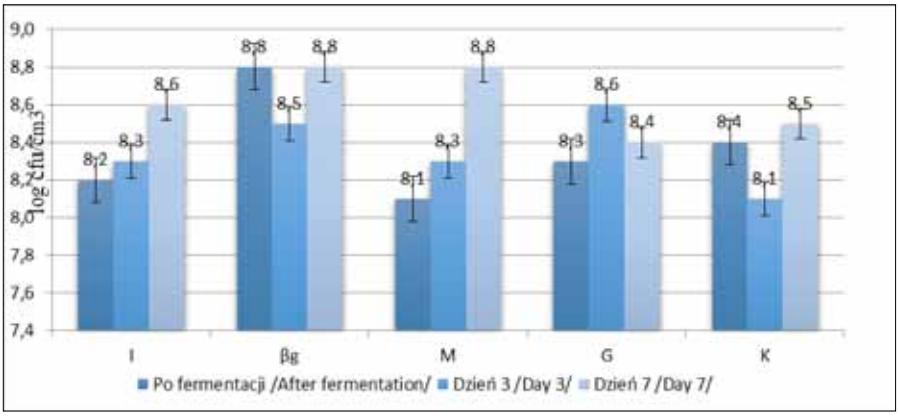


Fig. 2. Results of acceptability assessment of fermented coconut drink samples depending on the strain of probiotic and potentially probiotic bacteria used (ranking method, 1 – the best, 5 – the worse, $p < 0.05$).

Rys. 2. Wyniki oceny pożądalności fermentowanego napoju kokosowego w zależności od użytego szczepu bakterii probiotycznych i potencjalnie probiotycznych (metoda szeregowania, 1 – najlepszy, 5 – najgorszy, $p < 0,05$).

Source: The own study

Źródło: Badania własne



Explanatory notes: I – inulin, Bg - β-glukan, M – maltodextrin, G – guar gum, K – control sample

Objaśnienia: I - inulina, Bg – β-glukan, M – maltodekstryna, G – guma guar, K – próba kontrolna)

Fig. 3. The number of *Lactobacillus plantarum* 299v in the coconut desserts with 1% addition of prebiotic after fermentation (24 h/37°C) and after 3 and 7 days of storage in 4°C.

Rys. 3. Liczba komórek *Lactobacillus plantarum* 299v w deserach kokosowych z 1% dodatkiem prebiotyku po fermentacji (24 godz./37°C) oraz po 3 i 7 dniach przechowywania w 4°C.

Source: The own study

Źródło: Badania własne

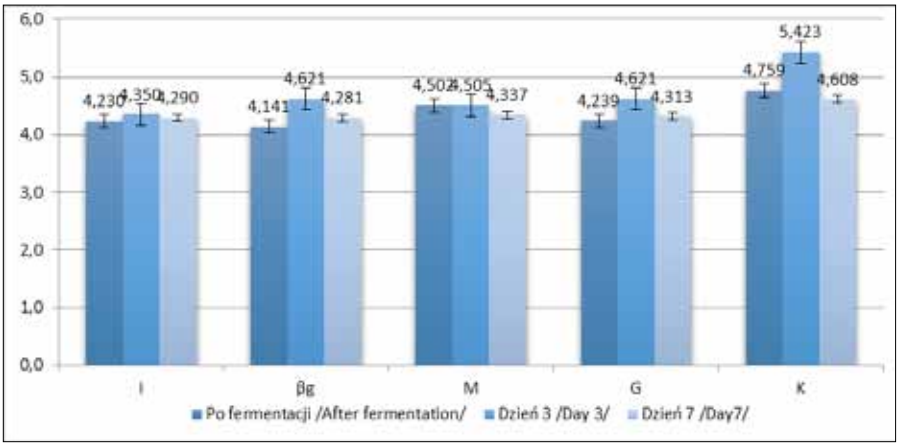


Fig. 4. pH values of coconut desserts made with the use of *Lactobacillus plantarum* 299v strain and with 1% addition of prebiotic after 24 h fermentation and after 3 and 7 days of storage in 4°C (explanatory notes as at fig. 3).

Rys. 4. Wartości pH w deserach kokosowych z użyciem szczepu *Lactobacillus plantarum* 299v i 1% dodatkiem prebiotyku po 24h fermentacji oraz po 3 i 7 dniach przechowywania w 4°C(objaśnienia jak na rys. 3).

Source: The own study

Źródło: Badania własne

The selected probiotic strains should maintain their viability during the entire shelf-life of the product. Many factors may affect the viability of bacteria selected strains, including added ingredients, pH, the presence of hydrogen peroxide and dissolved oxygen, the concentration of lactic acid, storage temperature [20, 21]. A factor that can directly affect the survival of bacterial strains is pH. According to Zielińska et al. (2019), lactic acid bacteria can survive in an environment with a pH of 4.5 to 7.0 and this is an individual feature of a specific genus, species or strain [30]. During storage, the pH of all coconut desserts with the addition of prebiotics was low, below 4.65 (fig. 6). The *Lb. plantarum* 299v was able to survive at low pH until the end of storage.

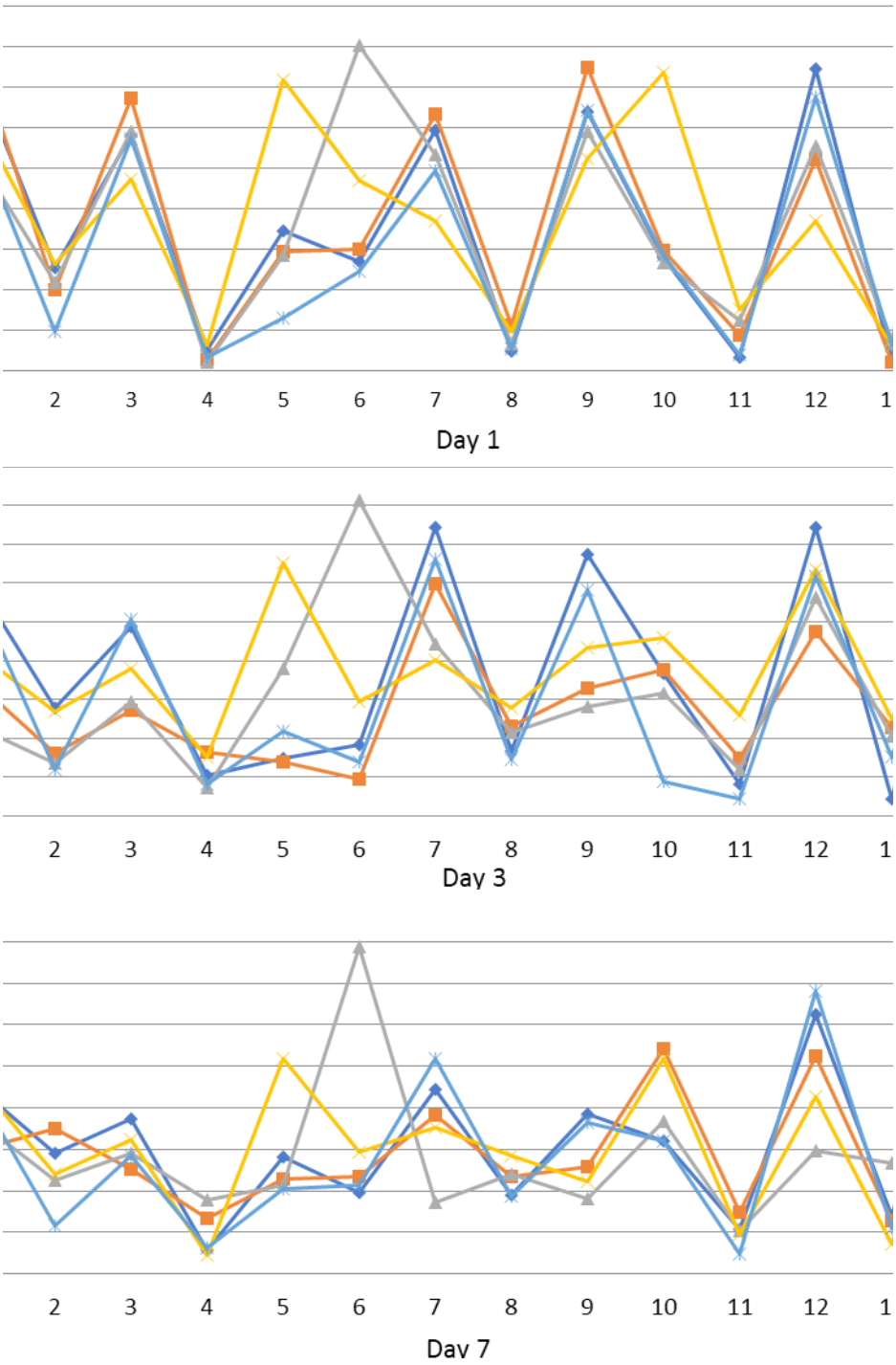
On the last day, the number of *Lb. plantarum* 299v in all tested variants of coconut desserts was high (from 8.4 log CFU/mL for dessert with guar gum to 8.8 for dessert with β-glucan), which indicates a good adaptation of the strains to environmental conditions (low pH) and the appropriate contents of nutrients in the coconut desserts. According to the FAO/WHO guidelines for both primary and secondary microflora (probiotic microflora), the number of live cells of lactic acid bacteria on the last day of shelf life of the product should not be lower than 10^6 CFU/mL [8]. The minimum number of probiotic bacteria requirement has been fullfilled.

The evaluation of the sensory quality of desserts with the addition of prebiotics

The average results of the profiling (QDA) analysis of the fermented desserts with prebiotics added are presented at fig.5.

The coconut dessert with the addition of inulin was characterized by high intensity of sweet taste both after fermentation and during storage, which in the case of a sugar-free product was positively perceived by assessors. Additionally, the high intensity of coconut taste, characteristic for coconut dessert and the milk taste and milk smell, possibly contributed to maintaining the high overall quality of this dessert throughout the study. The sensory characteristic of the product are influenced by the concentration of the prebiotic. In the study of Guven et al. (2005) it was found, that the addition of 1% inulin guaranteed an increase of the positive sensory characteristics of the product, and its greater amount already had a negative effect on the overall acceptability of yogurts and their consistency [12].

After fermentation, the most thick consistency had a dessert with guar gum, which is often used in food production as a stabilizer to give the products the desired texture [16]. β-glucan not only influenced the change of colour to a more yellow one, but also significantly increased intensity of the sour taste of a dessert, to a value of over 7 c.u. (fig. 5a). Other products, in the assessment of the intensity of sour taste reached values below 3 c.u., including dessert with maltodextrin,



Attributes/Wyróżniki: 1. sweet smell/zapach słodki, 2. sour s./zapach kwaśny, 3.milk s./zapach mleczny,4. irritating s/z. drażniący, 5. colour/barwa 6.konsystencja/consistency, 7. sweet taste/ smak słodki, 8. salty t./smak słony, 9. milk t./smak mleczny, 10. sour t./smak kwaśny,11. bitter t./smak gorzki,12. coconut t./smak kokosowy, 13. other t./smak obcy,14. overall quality/ jakość ogólna

Fig. 5a, b, c. Results of intensity of sensory attributes [c.u.] assessment of coconut prebiotic desserts - QDA method: a) after fermentation 24h/37°C b) after 3 days of storage at 4°C c) after 7 days of storage at 4°C (explanatory as at fig. 3).

Rys. 5a, b, c. Wyniki oceny intensywności wyróżników sensorycznych [j.u.] deserów kokosowych - metoda QDA: a) po fermentacji 24 godz./37°C b) po przechowywaniu 3 dni w 4°C c) po przechowywaniu 7 dni w 4°C (objaśnienia jak na rys. 3).

Source: The own study

Źródło: Badania własne

which at the same time achieved high intensity of milk taste (approximately 7.5 c.u.) and sweet taste (below 6 c.u.) (fig. 5a). Dessert with β-glucan was characterized by the intensity of the descriptors: coconut taste, sweet taste and milk smell below 5 c.u. In addition, the overall quality of this product was assessed as the lowest. Bitter and other taste, as negative quality descriptors were at low intensity in all studied products, while positive descriptors: coconut, milk and sweet taste as well as sweet and milky smell were at a high level (except for dessert with β-glucan), which could have a direct impact on the high overall quality of these products.

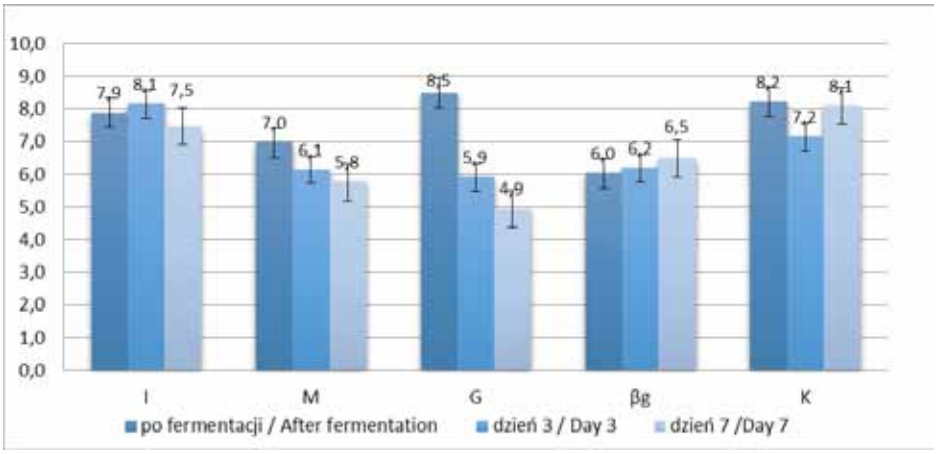
During storage, all desserts lost their sweet smell, which was less noticeable by assessors. For example, the intensity of the descriptor: sweet smell, for a dessert with inulin, decreased from over 7 c.u. (after fermentation) to approx. 6 c.u. and 5 c.u. on the 3rd and 7th day respectively (fig. 5b, c). During the storage, an increase in the perceptibility of smell and sour taste was noticed, which may be related to the increasing amount of lactic acid, formed as a result of lactic acid fermentation carried out by probiotic bacteria. On the seventh day, a product containing β-glucan obtained low intensity of positive descriptors ie.: sweet, milk and coconut taste, which could adversely affect the overall quality. This variant of the dessert was evaluated be the least desirable, characterised by a significant reduction in the intensity of milk smell and milk taste and an increase in the intensity of sour, other, salty and irritating taste. All the above-mentioned changes had an impact on the overall quality of the final product and caused a decrease in its attractiveness.

Sensory analysis showed that the addition of guar gum caused an increase in thick consistency of the coconut dessert, which was observed during the entire storage period. Dessert with the addition of guar gum on the 7th day of storage was characterised by the lowest descriptors for sweet, milk and coconut taste. These characteristics may have adversely affected the overall quality and, together with the decrease in the intensity of sweet taste, contributed

to the lowest overall quality of the studied dessert on the 7th day of storage (fig. 5c).

The addition of maltodextrin and β-glucan in the coconut desserts contributed to the highest intensity of sour taste both after fermentation and during storage, which may lower the overall quality (fig. 5a, b, c).

The overall sensory quality of desserts with *Lactobacillus plantarum* 299v and prebiotics was high after fermentation and during storage. After fermentation, the highest overall quality had the dessert with guar gum and the control sample (8.5 and 8.2 c.u. respectively) (fig. 6). The overall quality of the dessert with guar gum decreased from 8.5 c.u. after fermentation to 4.9 c.u. on the last day of storage, and the product was no longer sensory accepted. The overall quality of the dessert with β-glucan, inulin and maltodextrin was high during the entire storage time.



(Oznaczenia odpowiednio: I – inulina, M – maltodekstryna, G – guma guar, Bg – β-glukan, K – próba kontrolna)

Fig. 6. Comparison of the overall quality of coconut dessert samples with the addition of prebiotic (1%) and *Lactobacillus plantarum* 299v strain after 24 h of fermentation and 3 and 7 days of storage (QDA method).

Rys. 6. Porównanie ogólnej jakości próbek deseru kokosowego z dodatkiem prebiotyku (1%) i szczepem *Lactobacillus plantarum* 299v po 24 godz. fermentacji oraz 3 i 7 dniu przechowywania (metoda QDA).

Source: The own study

Źródło: Badania własne

CONCLUSIONS

1. The experiment allowed to selected from 5 probiotic and potentially probiotic strains – *Lactobacillus plantarum* 299v strain, which made it possible to obtain a coconut dessert with the highest sensory quality.
2. The number of viable cell counts of *Lactobacillus plantarum* 299v in the studied coconut desserts with the addition of various prebiotics: inulin, maltodextrin, β-glucan and guar gum remained at a high level during the storage period.
3. The obtained coconut desserts had a minimum number of cells of the *Lactobacillus plantarum* 299v and thus could be determined as probiotic products.
4. The sensory quality of the tested coconut desserts with the addition of *Lactobacillus plantarum* 299v strain was high both after fermentation and at the end of the storage period (7 days); only the overall quality of the product with 1% addition of guar gum on the last day of storage was 4.9 c.u. and the product was no longer sensory accepted.

WNIOSKI

1. Przeprowadzone doświadczenie pozwoliło na wybranie spośród 5 szczepów probiotycznych i potencjalnie probiotycznych – szczepu *Lactobacillus plantarum* 299v, który umożliwił uzyskanie deseru kokosowego o najwyższych notach w ocenie sensorycznej.
2. Liczba komórek szczepu *Lactobacillus plantarum* 299v w badanych deserach kokosowych z dodatkiem różnych prebiotyków: inuliny, maltodekstryny, β-glukanu oraz gumy guar utrzymywała się na wysokim poziomie przez cały okres przechowywania.
3. Uzyskane desery charakteryzowały się wymaganą, minimalną liczbą komórek szczepu *Lactobacillus plantarum* 299v i tym samym mogły zostać uznane za produkty probiotyczne.
4. Jakość sensoryczna badanych deserów kokosowych z dodatkiem szczepu *Lactobacillus plantarum* 299v była wysoka zarówno po fermentacji jak i do końca okresu przechowywania (7 dni); jedynie jakość ogólna produktu z 1% dodatkiem gumy guar ostatniego dnia przechowywania wynosiła 4,9 j.u. i produkt nie był już akceptowany pod względem jakości sensorycznej.

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Karolina SZULC, Ph.D. D.Sc.
Department of Food Engineering and Process Management, Institute of Food Sciences Warsaw University of Life Sciences (WULS), Warsaw, Poland
Katedra Inżynierii Żywności i Organizacji Produkcji, Instytut Nauk o Żywności
Szkoła Główna Gospodarstwa Wiejskiego (SGGW) w Warszawie, Polska

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Key words: emulsion stability, rheological properties, pea protein, soy protein, whey protein.

The article presents the results of research on the effect of the type and concentration of protein on the rheological properties and stability of O/W emulsions. The following proteins were used in the research: pea, soy and whey with a concentration of 0.5–10% in the water phase. The fat content of the emulsion was 20%. Studies have shown that among the tested proteins, pea protein provides the best emulsifying properties and emulsion stability even at low concentrations >0.5%. Moreover, it was found that the density, consistency coefficient and emulsion stability increased with increasing protein concentration.

Słowa kluczowe: stabilność emulsji, właściwości reologiczne, białko grochu, biało soi, białko serwatkowe.

W artykule przedstawiono wyniki badań dotyczące wpływu rodzaju i stężenia białka na właściwości reologiczne i stabilność emulsji typu O/W. Do badań użyto białka: grochu, soi i serwatki o stężeniu 0,5-10% w fazie wodnej. Zawartość tłuszczu w emulsji stanowiła 20%. Badania wykazały, że spośród badanych białek białko grochu zapewnia najkorzystniejsze właściwości emulgujące oraz stabilność emulsji już w niskich stężeniach >0,5%. Ponadto stwierdzono, że wraz ze wzrostem stężenia białka następował wzrost gęstości, wskaźnika konsystencji oraz stabilności emulsji.

INTRODUCTION

In a wide range of applications, emulsification is one of the most important functional properties of food proteins [5]. The proteins currently used by the food industry for their emulsifying abilities are mostly derived from milk (or caseins and whey), egg, soy, rice, and pea [12, 14, 16]. Applications for plant protein include vegan style yogurt, mayonnaise and dairy-free sports products, but it also used as partial dairy products protein substitutes for drinks.

Many proteins are surface-active molecules that can be used as emulsifiers due to their ability to facilitate formation, improve stability, and produce in oil-in-water emulsions with desired physicochemical properties [22]. The stabilization of emulsions by proteins results from their surfactant properties – they have the ability to adsorb at the interface, reduce the surface tension and retard the coalescence of the droplets by forming protective membranes around the droplets [19]. The stability of the food emulsion is the most important factor with respect to their industrial application rate and depends on the droplet size distribution of the dispersed phase, the rheology of the continuous phase, and the interaction between the particles of the dispersed phase [3].

The objective of this study was to evaluate the influence of protein type and concentration on the stability, flow characteristics, and oil droplet size of the stabilized emulsion by pea, soy and whey protein concentrates and to elucidate dependences between these variables.

Corresponding author – Adres do korespondencji: Karolina Szulc. Department of Food Engineering and Process Management, Institute of Food Sciences, Warsaw University of Life Sciences, Poland, 159c Nowoursynowska St., 02-776 Warsaw, e-mail: karolina_szulc1@sggw.edu.pl

MATERIALS AND METHODS

Whey protein concentrate (80% protein) was obtained from Mlekovita (Poland). Pea protein and soy protein were purchased from Agnex (Poland). The pea and soy protein, according to the label, were 80% protein. Rapeseed oil was obtained from a local supermarket.

Emulsion preparation

Pea, soy and whey proteins were dispersed in distilled water and stirred for 2 h. Rapeseed oil (20%) was added to an aqueous phase containing 0.5, 1, 1.5, 2, 2.5, 5, 7.5 or 10% protein (pea, soy, or whey protein). A coarse emulsion was prepared using a rotor-stator homogenizer (Ultra-Turrax IKA T25 digital, Germany) at 10,000 rpm for 4 min, then the pre-emulsification of the system was subjected to pressure homogenization (Panda 2K; Niro Soavi, Italy) at a pressure of 60 and 20 MPa in the first and second stage, respectively.

Oil droplet size

The oil droplet size of protein-based emulsions was measured using a Cilas 1190 laser diffraction particle analyser (Cilas, France). Drops of samples were added to the sample dispersion unit (containing distilled water) until the obscuration index reached approximately 8% and the average droplet size was reported in terms of the mean volume diameter d50.

Density and pH

The emulsion density was determined using a Densito 30PX densimeter (Mettler Toledo, USA). The pH of the emulsion was determined using pH-meter CPO-505 with ERH-111 electrode (Electron, Poland).

Rheological characteristics

Emulsion flow curves were determined at 20 °C using a Haake Mars 40 rheometer (Thermo Scientific, Germany) in steady shear mode with a linearly increasing shear rate from 0.1 to 300 s^{-1} in a coaxial cylinder measuring system. The course of the tests was controlled using the Haake RheoWin 4.7 software. Flow curves were fitted by the Ostwald de Waele model [1] using the HAAKE software RheoWinDataManager 4.75 (HAAKE Co., Germany):

$$\tau = K \cdot \gamma^{n}$$

where: τ – shear stress [Pa],
K – consistency coefficient [Pa· s^n],
γ – shear rate [s^{-1}],
n – flow behaviour index.

Emulsion stability

Protein-based emulsion stability measurements were performed during storage for 0, 1, 3 and 7 days at 4 °C, using Turbiscan Lab® Expert (Formulaction SA, France), which collected data from the entire height of the vial every 40 µm. Round flat-bottomed vials were filled with the test emulsion (20 ml) to of ¾ their height. The Turbiscan Stability Index (TSI) was determined based on the Turbiscan Soft Lab software.

Statistical analysis

All measurements presented are the means of data from triplicate analysis. The statistical analysis was performed by the statistical software, Statistica version 13.1 (StatSoft, Poland). Analysis of variance (ANOVA) and Tukey's post hoc statistical tests were used to evaluate significant differences. The level of significance was determined at $P < 0.05$.

RESULTS AND DISCUSSION

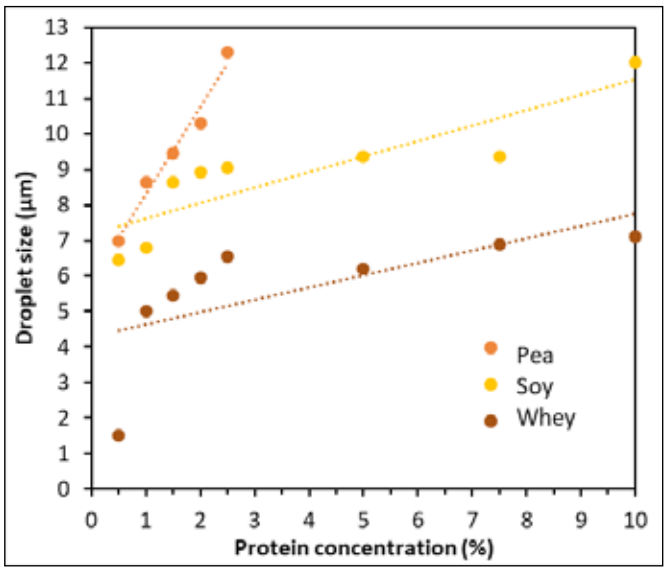

Fig. 1. Droplet size of emulsions with different protein type and concentration.
Rys. 1. Rozkład wielkości kropel w emulsjach o różnym rodzaju i stężeniu białka.
Source: Own study
Źródło: Opracowanie własne

The size of oil droplets in the emulsion ranged from 1.5 to 12.3 µm (Fig. 1). The whey protein emulsions were characterized by the smallest size of fat globules (<7.2 µm). Replacing animal-derived protein with plant resulted in an increase in the particle diameter of the dispersed phase. A higher oil droplet size was observed for the pea protein emulsion. Fernandez-Avila et al. [8] found that stabilized emulsions of soy protein isolate containing 20% oil phase showed a smaller size than emulsions of pea protein isolate emulsions, which was also confirmed in this study. Kopytowska and Domian [4] in research on spray drying of stabilized with pea protein also investigated the size of fat globules in emulsions obtained by pressure homogenization. The size of the dispersed phase of emulsions ranged from 6.4 to 9.8 µm. In the current study, the oil droplet size had values similar to those showed by Kopytowska and Domian [4]. Increasing protein concentration in the system from 0.5 to 2.5% increased the particle size of the dispersed phase which may indicate that oil droplet size is determined by the number of proteins and viscosity [6, 12]. As the viscosity of the system increases, the solubility of proteins (especially pea) is weaker, which may result in an increase in the droplet size of the emulsion. A further increase in protein concentration (5-10%) did not contribute to a considerable increase in the oil droplets. Mostly, higher protein levels favour higher surface loading, resulting in increased emulsifying potential and reduced oil droplet size [20]. However, the particle size in the emulsion system is determined not only by the size of the oil droplets covered by proteins, but also by the presence of protein aggregates [13, 18]. Furthermore,

a reduction of shear forces, inertial forces and cavitation during the pressure homogenization process as a result of the increasing viscosity may limit the rearrangement of proteins at the oil-water interface and subsequently inhibit their ability to stabilise oil droplets [21]. Higher pea protein concentrations (5-10%) were not tested, because the emulsions were too thick. Pressure homogenization of emulsions with increasing addition of pea protein caused transforming from viscous-like to gel-like systems.

An important factor that determines the density of a substance is its chemical composition, as well as the internal structure of the product. The emulsion density ranged from 0.971 to 0.986 g cm^{-3} and increased with increasing protein concentration (Table 1). The replacement of whey protein with soy protein contributed to an increase in the density of the emulsion, while the opposite trend was observed in the case of pea protein. On the other hand, the greatest increase in density along with the increasing contribution of protein was observed for the emulsion with the addition of pea protein.

The pH values for the emulsion variants ranged from 5.82 to 6.88, which proves the slightly acidic nature (Table 1). A decrease in pH was observed with increasing protein concentration in the emulsion. The lowest pH values were obtained for the soy protein emulsions. The poorest protein emulsifying properties usually exist around its isoelectric point (pH~4.5) [10]. Emulsification improves as the pH moves away from the isoelectric point of the protein [5].

The physical stability of the systems during storage was described by the TSI (Turbiscan Stability Index). The TSI varies from 0 to 100 and this is a parameter to monitor the destabilization kinetics of the emulsions. The higher the TSI value, the greater the change in the sample and therefore the greater the instability of the system [7]. The type and concentration of protein as well as the storage time determine the stability of the emulsion (Fig. 2). Whey and soy emulsions with a protein concentration <5% showed TSI values above 4.0 after 7 days of storage (Fig. 2a-b). For these emulsions, an accumulation of the dispersed phase particles was observed

Table 1. Density, pH and rheological parameters of the Ostwald de Waele model (K, n) of emulsions with different protein type and concentration

Tabela 1. Gęstość, pH oraz parametry reologiczne modelu Ostwalda de Waele (K, n) emulsji o różnym rodzaju i stężeniu białka

Type of protein	Protein concertation (%)	Density (kg·m^{-3})	pH	*K* (mPa·s^n)	*n* (-)
pea	0.5	0.971^{a}	6.86^{i}	398.4^{a}	0.429^{def}
	1	0.972^{a}	6.85^{i}	2456.0^{b}	0.301^{abc}
	1.5	0.972^{a}	6.83^{i}	4271.3^{c}	0.271^{ab}
	2	0.976^{b}	6.81^{hi}	6495.7^{d}	0.241^{ab}
	2.5	0.980^{bc}	6.73^{g}	10105.3^{e}	0.203^{a}
soy	0.5	0.979^{b}	6.19^{d}	20.0^{a}	0.717^{ijk}
	1	0.980^{bc}	6.15^{d}	24.8^{a}	0.770^{k}
	1.5	0.980^{bc}	6.10^{cd}	38.4^{a}	0.738^{jk}
	2	0.981^{bc}	6.00^{bc}	169.2^{a}	0.619^{hi}
	2.5	0.982^{cd}	5.92^{b}	231.0^{a}	0.569^{gh}
	5	0.983^{cd}	5.82^{a}	571.5^{a}	0.493^{efg}
	7.5	0.985^{de}	5.81^{a}	2858.3^{b}	0.333^{bcd}
	10	0.986^{e}	5.80^{a}	3285.7^{b}	0.330^{bcd}
whey	0.5	0.976^{b}	6.81^{hi}	1.5^{a}	1.154^{lm}
	1	0.978^{b}	6.79^{h}	1.9^{a}	1.099^{m}
	1.5	0.978^{b}	6.78^{h}	3.4^{a}	1.066^{lm}
	2	0.979^{b}	6.72^{g}	3.5^{a}	1.060^{lm}
	2.5	0.980^{bc}	6.70^{g}	9.4^{a}	0.968^{l}
	5	0.981^{bc}	6.63^{f}	68.6^{a}	0.763^{k}
	7.5	0.981^{bc}	6.56^{e}	137.8^{a}	0.700^{ijk}
	10	0.983^{cd}	6.52^{e}	296.1^{a}	0.636^{hij}

Source: Own study

Źródło: Opracowanie własne

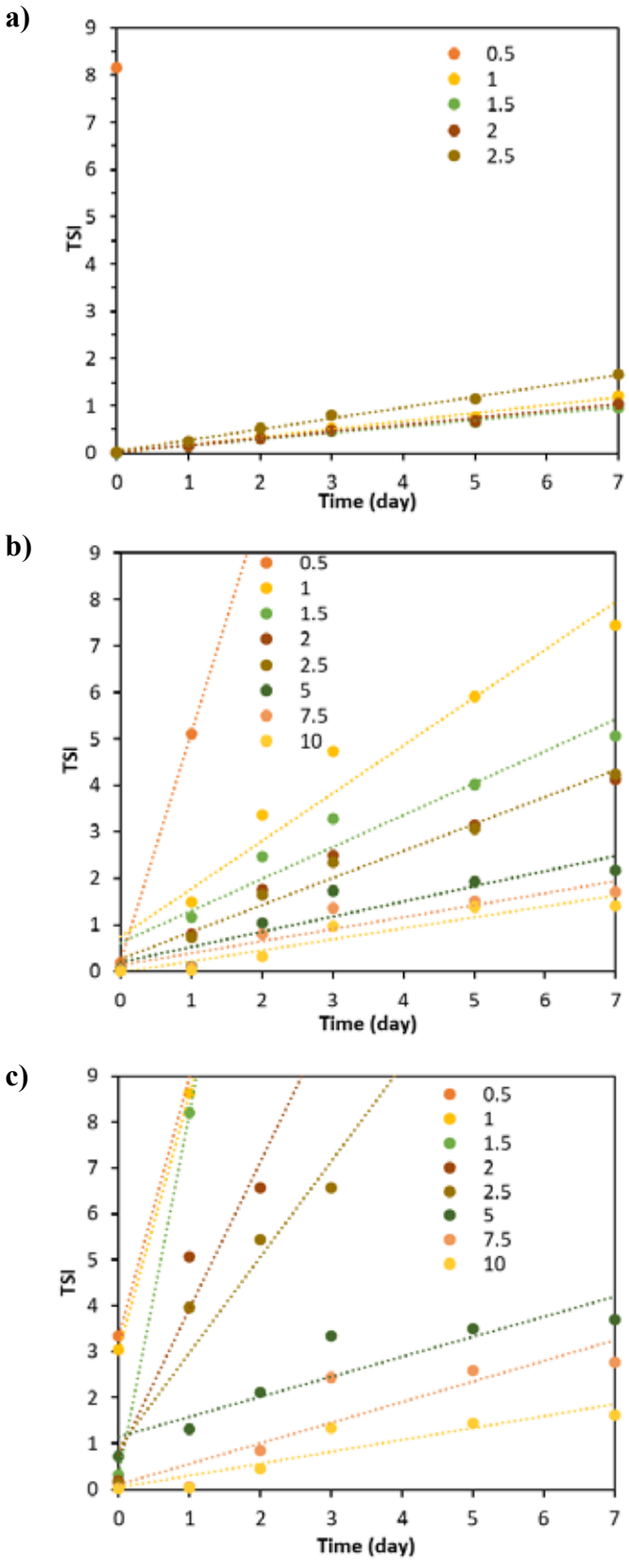

Fig. 2. Turbiscan Stability Index TSI of emulsions stabilized by pea (a), soy (b), and whey (c) protein at different protein concentration (0.5–10%).

Rys. 2. Wskaźnik stabilności TSI emulsji stabilizowanych białkiem grochu, soi oraz serwatki o różnym stężeniu białka (0,5–10%).

Source: Own study

Źródło: Opracowanie własne

in the upper part of the vial, and thus creaming was observed, indicating instability of the emulsion. It has previously been shown that, as the protein to fat ratio decreases in oil-in-water systems, the amount of protein available for emulsification decreases, leading to droplet coalescence [9]. The increase in protein concentration in the system contributed to the reduction of the TSI value, and thus to the improvement of the emulsion stability, which was also confirmed by Aziz el al. [2]. Protein concentration is an important parameter of emulsion stabilization due to a threshold level of protein required to create a protective barrier around the oil droplets [15]. The pea protein emulsions showed the greatest storage stability (Fig. 2c). Exceeding the protein content > 0.5% guarantees the achievement of stable emulsions for which the TSI value did not exceed 1.66. The smaller oil droplets diameters of whey protein - stabilized emulsions, compared to the emulsions with pea protein, did not respond to the higher whey protein emulsion stability. Pea protein may be a better stabilizer and WPC a better emulsifier. For emulsion with a pea protein content of 2.5%, a slight increase in the TSI value was observed, which may be the result of obtaining a larger size of oil droplets (Fig. 1). Larger droplet sizes lead to a lower interfacial layer, which consequently reduces stability of emulsion [17]. Results of TSI confirmed that pea protein in low concentrations may be a very good stabilizer and emulsifier of oil-in-water emulsions, as indicated in studies conducted by Sridharan et al. [16].

The flow behaviours of the emulsion were described by fitting the experimentally measured shear stress-shear rate data to the model. The shear-thinning behaviour of protein emulsions could be described by the Ostwald de Waele model [13]. Protein types and protein concentration significantly affected the consistency index (K) and flow behaviour index (n). Increased protein concentration in emulsions intensifies the shear-thinning effect, as evidenced by a decrease in the value of n and an increase in the value of the K which was also confirmed by Anema et al. [1], Lupi et al. [11]. Consistency index indicates the fluid viscosity. The K values in the emulsions were diversified, it is especially visible when the range of values for animal proteins (1.5–296.1 mPa·s^n) is compared to the values obtained for plant proteins, where this coefficient reached the value of 10105.3 mPa·s^n (2.5% pea protein) (Table 1). The pea protein variant showed significantly higher K values than soy and whey protein. The higher its value, the more viscous the emulsion is.

The flow behaviour index was close to 1 at 0.5–2.5% for the whey protein emulsion, further increasing the protein concentration led to a decrease of n values to 0.64 at 10% protein concentration, indicating that the samples at 0.5–2.5% whey protein concentration are Newtonian but as the protein concentration increased, the emulsions developed progressive more shear thinning ($n < 1$). The plant protein-based emulsions showed lower n values than the whey protein; lower n correspond to the more pronounced shear thinning. This indicates that the structure in emulsions at higher protein concentrations is rearranged to a less viscous state under the shear conditions [1].

SUMMARY

The mean droplet size in the emulsion ranged from 1.5 to 12.3 μm, which indicates the appropriate distribution of the fat globules and thus the possibility of obtaining more stable colloidal systems. An increase in the shear thinning effect was observed with increasing protein concentration in the emulsions; as evidenced by a decrease in the flow behaviour index and an increase the consistency index.

Pea protein emulsions showed the best storage stability. TSI stability index below 1.7 after 7 days of storage showed emulsions with pea protein concentration above 0.5%. Replacing animal-derived protein (whey) with pea protein allows for a stable emulsion during storage, despite the larger particle size of the dispersed phase.

The pea protein provides good emulsifying properties that allow it to meet the current consumer demands for alternative sources of plant protein. It is possible to further enhance the functionality of the pea protein and promote a wider use in the food industry.

PODSUMOWANIE

Średnia wielkość kropel w emulsji wahała się od 1,5 do 12,3 μm, co wskazuje na odpowiednie rozproszenie kuleczek tłuszczu, a tym samym na możliwość uzyskania bardziej stabilnych układów koloidalnych. Zaobserwowano wzrost efektu rozrzedzania ścinaniem wraz ze wzrostem stężenia białka w emulsjach; o czym świadczy obniżenie wskaźnika płynięcia i wzrost wskaźnika konsystencji.

Najlepszą stabilność podczas przechowywania wykazały emulsje na bazie białka grochu. Wskaźnik stabilności TSI poniżej 1,7 po 7 dniach przechowywania wykazały emulsje o stężeniu białka grochu powyżej 0,5%. Zastąpienie białka pochodzenia zwierzęcego (serwatki) białkiem grochu pozwala na uzyskanie stabilnej emulsji podczas przechowywania, pomimo większej wielkości cząstek fazy rozproszonej.

Białko grochu zapewnia dobre właściwości emulgujące, które pozwalają spełnić obecne zapotrzebowanie konsumentów na alternatywne źródła białka roślinnego. Możliwe jest dalsze zwiększenie funkcjonalności białka grochu oraz promowanie jego szerszego zastosowania w przemyśle spożywczym.

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[1]PhD, DSc Jolanta KOWALSKA, prof. of WULS
[1]PhD, DSc Hanna KOWALSKA, prof. of WULS
[2]PhD, DSc Grażyna CACAK-PIETRZAK
[1]MSc. Eng. Sylwia ZAWADZKA
[1]Department of Food Engineering and Process Management, [2]Department of Food Technology and Assessment, Institute of Food Sciences
Warsaw University of Life Sciences (WULS)
Katedra Inżynierii Żywności i Organizacji Produkcji, Katedra Technologii i Oceny Żywności, Instytut Nauk o Żywności
Szkoła Główna Gospodarstwa Wiejskiego w Warszawie (SGGW)

THE USE OF DRIED APPLES IN THE PRODUCTION OF YEAST ROLLS®

Zastosowanie suszu jabłkowego w produkcji bułek drożdżowych®

Keywords: dried apples, yeast rolls, baking industry.

Bread can be considered the most frequently consumed food product that is present in the daily diet of almost every consumer. In this study, yeast rolls were prepared, in the composition of which sugar was partially or completely replaced by dried apples. Along with the increase in the addition of dried apples, an increase in the antioxidant potential was shown, which was confirmed by a higher total polyphenol content and a higher activity against DPPH radicals. The highest scores in the sensory assessment were given to rolls of standard composition. The best, among the samples with modified composition, were rolls with 75% sugar replaced with apple dry.

Słowa kluczowe: susz jabłkowy, bułki drożdżowe, przemysł piekarski.

Pieczywo można uznać za najczęściej spożywany produkt spożywczy, który jest obecny w codziennej diecie niemal każdego konsumenta. W niniejszym badaniu przygotowano bułki drożdżowe, w składzie których cukier częściowo lub całkowicie zastąpiono suszem jabłkowym. Wraz ze zwiększeniem dodatku suszu jabłkowego wykazano wzrost potencjału przeciwutleniającego, potwierdzonego wyższą zawartością polifenoli ogółem oraz wyższą aktywnością wobec rodników DPPH. Najwyższe noty w ocenie sensorycznej przyznano bułkom o standardowym składzie. Najlepiej, spośród próbek o modyfikowanym składzie, oceniono bułki, w składzie których 75% cukru zastąpiono suszem jabłkowym.

INTRODUCTION

Bread is one of the basic and indispensable groups of products that is most often found in the everyday diet of humans [1]. Bread play a vital role in ensuring your daily energy intake. It is also a source of carbohydrates, protein, vitamins, mainly from group B, and minerals, including potassium, iron, calcium, and phosphorus. The quality of bread is shaped in the technological process and depends to a large extent on the raw materials used to obtain them [4]. The importance of eating bread may be demonstrated by placing cereal products in the food pyramid. Prof. dr hab. n. med. Mirosław Jarosz, interpreting the pyramid as the third principle of proper nutrition and lifestyle, indicated the consumption of cereal products, especially whole grains [5]. In the average Polish food ration, cereal products, which are dominated by bread, provide the most carbohydrates from all food groups (about 60% of the supply in the diet). The nutritional value of bread is determined by the content of protein, fats, carbohydrates, minerals, vitamins and depends, among others, on on the used flour and flavor additives [17, 3]. The average monthly consumption of bread is about 3 kilograms per person - data from 2019 and 2.75 kg – data from 2020 [6].

The contemporary customer is very aware of his choices, which are based on the analysis of the raw material composition, pro-health values, as well as the search for producers who produce in the spirit of modernity and care for the environment [12]. These factors contribute to significant changes in the bakery market. Bakeries introduce new products to meet the needs of customers, but also to stand out from the competition not only with quality and freshness, but also with a variety of assortment and health benefits.

The high potential of ingredients contained in dried fruit is used to increase the nutritional value of products, as well as to make the offer more attractive on the foodstuff market [8]. Moreover, producers strive to reduce or eliminate sugar from the composition of food products, for which the properties of dried fruit can be used. Especially products constituting the basis of the daily diet, such as bread, should contain ingredients that have a beneficial effect on the health of consumers [13].

Corresponding author: Jolanta Kowalska, Department of Food Engineering and Process Management, Institute of Food Sciences, Warsaw University of Life Sciences (WULS), Nowoursynowska Str. 159c, 02-776 Warsaw, e-mail: jolanta_kowalska@sggw.edu.pl

The aim of this study was to develop a technology for obtaining confectionery bread with the addition of dried fruit and to analyze the antioxidant properties expressed in the total polyphenol content and antiradical activity against stable DPPH and sensory evaluation on the example of yeast rolls.

METHODOLOGY

The first stage of this research was the development of the technology for obtaining yeast rolls. The raw material composition, parameters of the dough production process and baking parameters were determined. The raw materials for the production of yeast rolls were: type 550 wheat flour, white crystal sugar, water, fresh baker's yeast, margarine, iodized food salt, dried apples, fresh hen eggs. Six modifications to the recipe composition were prepared. The basic composition was flour, water, sugar, margarine, yeast and salt. Sugar was partially or completely replaced with dried apples (3 variants). An attempt was also made to partially replace the flour with dried apples (2 variants). The recipe composition of the prepared yeast rolls is shown in Table 1.

Technological methods

Dried apples were obtained from apples of the Golden delicious variety, which were successively pre-processed: washing, removing the seed nests and cutting into slices 0.5 cm thick in the Coupe CL 50 Robot. The drying process was carried out at the temperature of 65° C for 7 hoursin a convection dryer. After cooling down, the dried fruit was ground in a Vorwerk Terrmomix TM6 device. Grinding parameters - turbo program in 5 times 2 seconds mode.

The dough was prepared by kneading all the ingredients in a MANKIEWICZ model SP-800A planetary mixer. The yeast was liquefied in water in a ratio of 1: 2. The margarine was dissolved by heating it on an electric heating plate. The weighed and prepared ingredients were dispensed into the bowl and mixed for 2 minutes at low speed (132 rpm) followed by 7 minutes at medium speed (234 rpm). The kneaded dough was left to rise at 30° C ± 1° C for 60 minutes. After this time, the dough was kneaded (pierced) for 1 minute at slow speed (132 rpm). Then, billets weighing 50 g were weighed in a Divider Rounder DR Robot Automatic DAUB Bakery Machinery divider-rounder at a height of 3.5; revolutions 5.0 and pressure 4.5. The billets were placed on the sheets and subjected to subsequent proofing for 40 minutes at the temperature of 30°C ± 1°C. After about 20 minutes, the billets were smeared with the beaten egg. The rolls were baked at 180° C for 18 minutes.

Analytical methods

Total polyphenol content determination

The content of polyphenols was determined by the Folin Ciocialteu method for acetone extracts. The extracts were prepared by pouring 20 g of roll crumb into 200 ml of an aqueous acetone solution (70%) and then shaking for 60 minutes. The extracts were then filtered through a fluted filter. In order to convert the content of total polyphenols, a standard curve for gallic acid was prepared. An aliquot of 50 mg of gallic acid was dissolved in 70% acetone solution (extraction solution) in a 50 cm 3 volumetric flask, making up to the mark with the extraction solution. Then 0, 25, 50, 75 and 100 µl of gallic acid solution (in duplicate) were collected in the test tubes successively and each tube was supplemented with the extraction solution to the volume of 300 µl. To each test tube was added: 4.15 ml of deionized water, 500 µl of 20% sodium carbonate solution, 50 µl of Folina-Ciocialteu reagent. A blank sample was prepared. After 20 minutes, the absorbance at 700 nm was measured in a Shimadzu UVmini-1240 spectrophotometer. On the basis of the obtained results, dependencies of the absorption of the solution on the amount of gallic acid contained in it were graphically plotted.

Total polyphenol content was determined on proper samples containing 300 µl of extract, 4.15 ml of deionized water, 500 µl of 20% sodium carbonate solution, 50 µl of Folin-Ciocialteu reagent. A blank test was prepared in parallel. After 20 minutes, the absorbance was measured on a Shimadzu UVmini-1240 spectrophotometer at a wavelength of 700 nm. Based on the standard curve, the total polyphenol content was calculated and expressed as gallic acid equivalents per 100 g of product. The determination was performed in four parallel replications.

Table 1. Raw material composition of yeast rolls

Tabela 1. Skład surowcowy bułek drożdżowych

raw materials	variant 0 basic composition	variant I sugar:dry 50%:50%	variant II sugar:dry 25%:75%	variant III sugar:dry 0%:100%	variant IV flour: dry 75%:25% sugar:dry 100%:0%	variant V flour: dry 75%:25% sugar:dry 0%:100%
mass of raw materials [g]						
flour	1000,0	1000,0	1000,0	1000,0	750,0	750,0
water	450,0	450,0	450,0	450,0	450,0	450,0
sugar	150,0	75,0	37,5	0,0	150,0	0,0
margarine	100,0	100,0	100,0	100,0	100,0	100,0
yeast	60,0	60,0	60,0	60,0	60,0	60,0
salt	10,0	10,0	10,0	10,0	10,0	10,0
apple drought	0,0	75,0	112,5	150,0	250,0	400,0

Source: The own study

Źródło: Badania własne

Determination of antioxidant activity

Extracts prepared for the determination of total polyphenols were used to determine the ability of extracts to deactivate stable DPPH radicals. The DPPH solution was prepared by weighing out 19.7 mg of radicals, which were transferred to a 100 cm^3 volumetric flask and made up to the mark with methanol. The control sample contained 4 cm3 of 70% acetone and 1 cm^3 of the DPPH radical solution. The proper sample contained 100 µl of extract, 3.9 cm^3 of 70% acetone and 1 cm^3 of DPPH radical solution. Blank test: 100 µl of extract, 3.9 cm^3 of 70% acetone, 1 cm^3 of methanol. The samples were mixed and, 30 minutes after the addition of DPPH radicals, the absorbance was measured in a Shimadzu UVmini-1240 spectrophotometer at a wavelength of 517 nm. The antiradical activity of the extracts against DPPH radicals was calculated according to the following formula:

$$A = \frac{A_K - (A_{wł} - A_{śl})}{A_K \cdot 100} \quad (1)$$

where: A – antiradical activity against DPPH radicals (%)
A_K – control sample absorbance
$A_{wł}$ – absorbance of the sample proper
$A_{śl}$ – absorbance of the blank

Sensory analysis

The subject of the sensory evaluation were six types of yeast rolls with different amounts of dried apple in their raw material composition. The sensory evaluation by a group of twenty people was carried out according to specific quality parameters such as: the color of the crust, the thickness of the crust, the color of the crumb, the porosity of the crumb, the smell and the taste. The discriminants were characterized and assigned appropriate weighting factors (Table 2).The results of sensory tests were determined on a five-point scale:

5 – quality extremely desirable
4 – desirable quality
3 – quality somewhat desirable (tolerated)
2 – undesirable quality
1 – defective product

RESULTS AND DISCUSSION

Total polyphenol content

The antioxidant potential expressed in the total content of polyphenols was determined in the prepared yeast rolls. The content of the determined parameter was also analyzed in dried apples, determining the total content of polyphenols at the level of 163.55 mg of gallic acid in 100 grams of the product. In the analyzed samples of rolls, the content of polyphenols was determined at the level of 54.23–749.19 mg gallic acid in 100 g of product (Fig. 1). The increase in the addition of dried apples, as expected, increased the content of total polyphenols. The lowest content of polyphenols was determined in rolls with a standard composition of 54.23 mg of gallic acid / 100 g of product, and the highest – 749.19 mg of gallic acid in 100 g of the product - in rolls with the highest addition of dried apples - variant V (Table 1). With a low content of dried apples, in variants I and II the total poly-phenols content was below 100 mg. Variant III contained 150 g of dried apples, and the determined content of total polyphenols was almost six

Table 2. Characteristics of quality markers

Tabela 2. Charakterystyka wyrożników jakościowych

attribute	weighting factor	points				
		5	4	3	2	1
the color of the rind	0,2	golden to brown, even	slightly darker or lighter, even	darker or lighter, slightly uneven	too dark or too light, uneven	brown to black, very light, gray
the thickness of the rind	0,1	even, medium thick	medium thick	a bit too thick or a bit too thin	too thick or too thin, uneven	very thick
the color of the crumb	0,15	perfectly even, natural	aligned	a bit too dark or too light, different in terms of zones	clearly different from the natural, very light or very dark	brown, gray, lack of alignment
the porosity of the crumb	0,1	evenly distributed and very well developed pores of the same size	evenly distributed and well-developed pores of similar size	pores unevenly spaced, quite different in size	pores unevenly spaced, very varied or absent	no pores or large empty holes
flavor	0,2	very pleasant	pleasant	not very expressive	weak with a slight foreign smell	unpleasant, foreign (e.g. mold, yeast)
taste	0,25	very pleasant, aromatic	pleasant, aromatic	not clear, too sweet or not sweet enough, slightly sour	strongly acidic, excessively sweet or not sweet enough	stranger

Source: The own study

Źródło: Badania własne

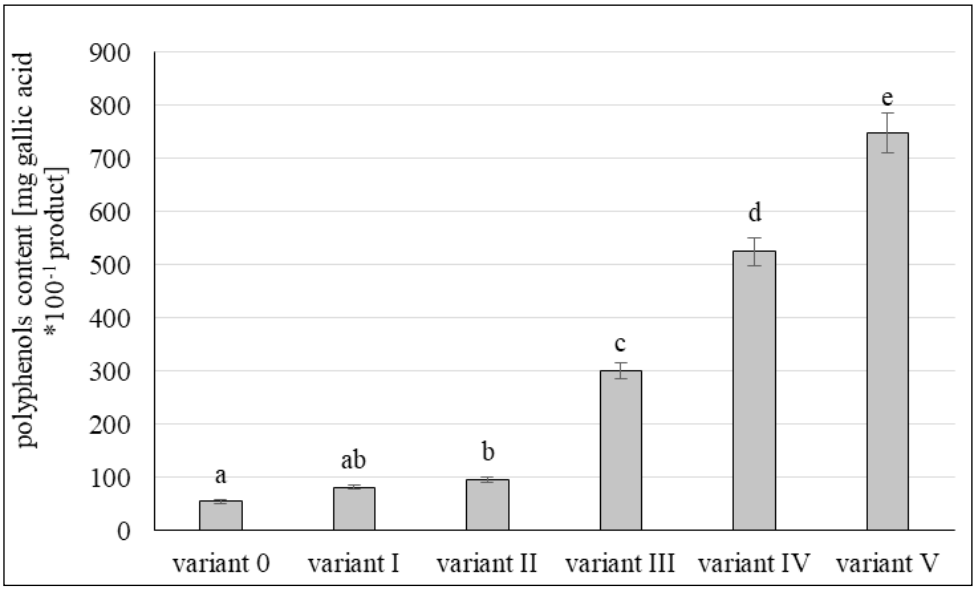

Fig. 1. Total polyphenols content in the analyzed yeast rolls (sample markings used – Table 1).

Rys. 1. Zawartość polifenoli ogółem w analizowanych bułkach drożdżowych (zastosowane oznaczenia próbek – Tabela 1).

Source: The own study

Źródło: Badania własne

times higher than in the samples with the basic composition and over three times higher than in the rolls of variants I and II. The determined content of polyphenols resulted both from the amount of the determined parameter in basic raw materials (variant 0) and from the potential of a given dried apple.

Reis et al. [11] confirmed the beneficial effect of the addition of dried apple pomace to extruded and baked rolls. Dried apple pomace was also used in the studies by Sudha et al. [14]. They showed a beneficial effect and an increase in the content of phenolic compounds with an increased addition of pomace. They determined the optimal addition of pistons in rolls at 15%, in muffins – 30%, and in cookies – 20%. The highest levels of total polyphenols were found in extruded products with 30% added pomace.

Antiradical activity against stable DPPH radicals

The antioxidant activity expressed against stable DPPH radicals was determined in the range from 25.81% to 46.7%. The lowest antioxidant activity was shown by rolls with the basic composition and with 50% addition of dried apples instead of sugar (Fig. 2). Statistical analysis confirmed that there were no significant differences between these samples. Similarly, the antiradical activity of rolls with the composition defined as variants II and III was at a similar level, which was confirmed by statistical inference (Fig. 2). The correlation analysis showed a strong correlation between the total polyphenol content and the anti-radical activity at the level of 0.9693.

The highest activity was determined for samples composed of the V variant, which were also characterized by the highest total polyphenol content. Nakov et al. [9] obtained similar results to those obtained in this study. Increasing the addition of dried apple peel increased the content of total polyphenols, as well as increased antiradical activity. The correlation between the content of polyphenols and their ability to scavenge free radicals was confirmed. The relationship was similar to that shown in the current study. The differences in the defined anti-radical activity were significantly lower compared to the determined total polyphenol content in the same samples. Thermal treatment may affect the composition of the polyphenols and the antioxidant capacity of the products. Low humidity and high temperature (about 200°C) favor the conversion of quercetin into other compounds), while thermal treatment facilitates the release of phenolic acids from cell walls and improves their bioavailability [18].

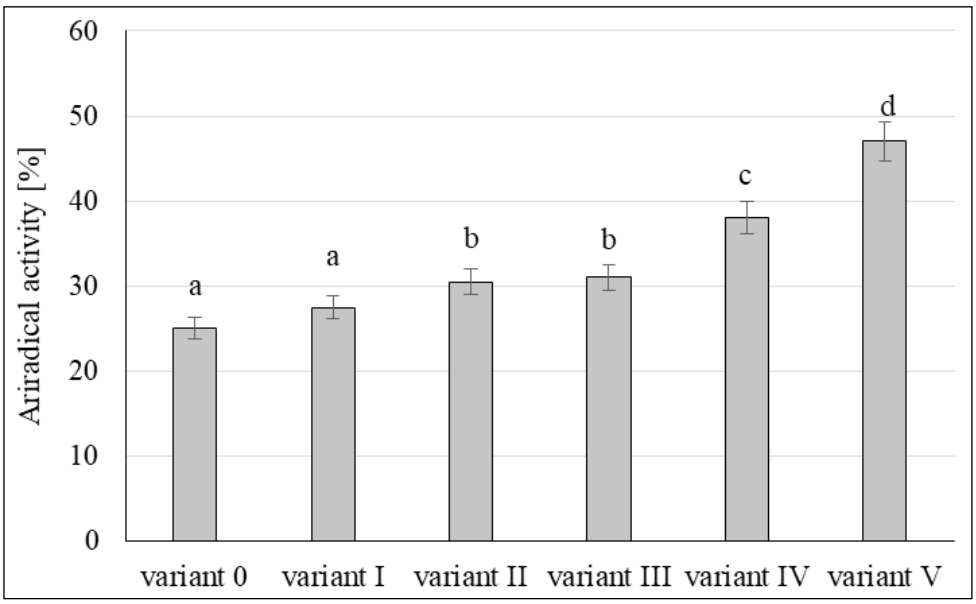

Fig. 2. Antiradical activity against stable DPPH radicals (sample markings used – Table 1).

Rys. 2. Aktywność przeciwutleniająca wobec stabilnych rodników DPPH (zastosowane oznaczenia próbek – Tabela 1).

Source: The own study

Źródło: Badania własne

Sensory analysis

Sensory analysis is one of the tools used to evaluate new products [10]. The yeast rolls were assessed for six discriminants (Table 2). The awarded scores were averaged and multiplied by the weighting factor. The color of rolls with a standard composition was assessed the highest (0.9). On the other hand, the lowest scores were given to variant III, which did not contain sucrose (Fig. 3). The team members indicated that the lower scores resulted from the too light color of the crust of the analyzed rolls. the color of the skins of yeast rolls resulted In their research, Jannati et al. [7] also obtained a lower evaluation of the skin color for bread to which apple pomace was added. In contrast, Tańska and Rotkiewicz [16] recorded higher scores for samples with the addition of pomace. The peel thickness was assessed in the range of 0.36–0.45 points (Fig. 3). The highest score was given to the rolls with the basic composition (variant 0), while the lowest score was given to the skin of rolls from variant IV. The remaining variants of rolls obtained a similar score (0.41–0.42), and the thickness of the crust was assessed as moderately thick and even. For this discriminant, Tańska and Rotkiewicz [16] again obtained opposite relationships than in the current research – higher scores compared to the control sample were obtained by bread with the addition of apple pomace.

The color of the crumb was significantly dependent on the amount of dried apples added. The apples were dried with the skin, which was visible as darker particles in the crumb. The crumb of basic rolls was rated the highest (0.68). On the other hand, the lowest score was given to rolls, in the composition of which 25% of flour was replaced with apple dry (variant IV). The team members indicated that the rolls in which part of the sucrose and / or flour had been replaced with dried material had a distinctly different color than the natural ones. Similar dependencies were shown in their studies by Sudha et al. [15]. Bread with the addition of expeller scored lower than the samples without their addition. On the other hand, Tańska and Rotkiewicz [16] obtained scores opposite to that of Sudha et al. [15] and the current analyzes. Low scores were awarded to crumb porosity (0.3–0.42) (Fig. 3). The lowest scores were given to rolls in which part of the flour was replaced with dried apples. The porosity of the remaining rolls was similarly rated, with a score of 0.4–0.42. The evaluators described the pores in the crumb as well-developed and even, while for the low-rated samples as unevenly distributed and diversified in terms of size. Tańska and Rotkiewicz [16] for the samples with a 10% addition of bagasse showed no differences in the assessment of porosity, which was confirmed by the results obtained for the samples with the modification of sugar itself, in which the dry content was 8–15% in relation to the amount of flour. On the other hand, Sudha et al. [15] noticed that a 30% addition of bagasse in bread resulted in lower porosity scores, which is confirmed by the results obtained in this study. The most aromatic for the evaluators turned out to be rolls, in which 75% of sugar was replaced with dried apples (0.94) (option II). On the other hand, the least pleasant to smell was bread with the highest dry content (0.66) (variant III). All other samples were assessed within the limits of 0.69–0.77. Tańska and Rotkiewicz [16] and Jannati et al. [7] noted a significant increase in the scores for the smell of bread with apple pomace compared to the control sample. The last distinguishing feature was flavor. The panelists liked the rolls with the basic composition and variant III - the composition of which sucrose was completely replaced with dried apples (Fig. 3). The lower taste ratings were explained by the panelists with too low sweetness, which may also be the result of habit. Tańska and Rotkiewicz [16], as well as Jannati et al. [7], who obtained higher scores in their research for bread with apple pomace, were again different. In order to summarize the sensory evaluation, the results of the mean

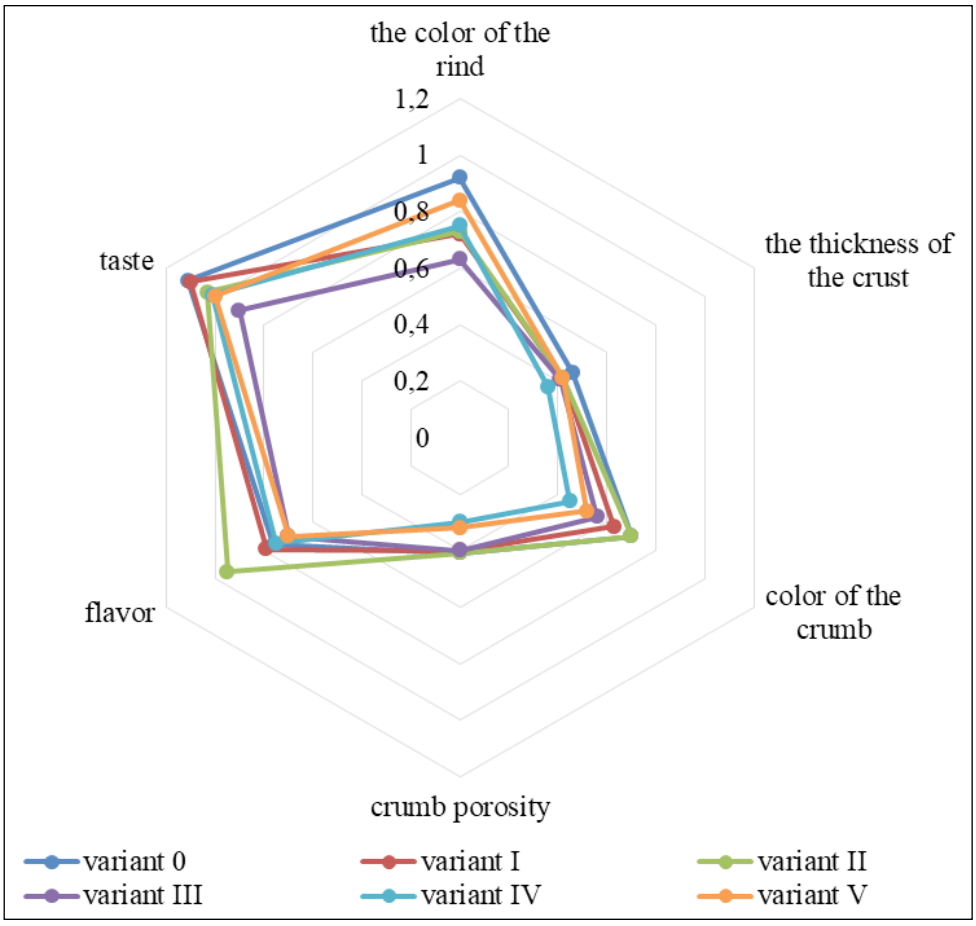

Fig. 3. Sensory evaluation of the analyzed yeast rolls (sample markings used – Table 1).

Rys. 3. Ocena sensoryczna analizowanych bułek drożdżowych (zastosowane oznaczenia próbek – Tabela 1).

Source: The own study

Źródło: Badania własne

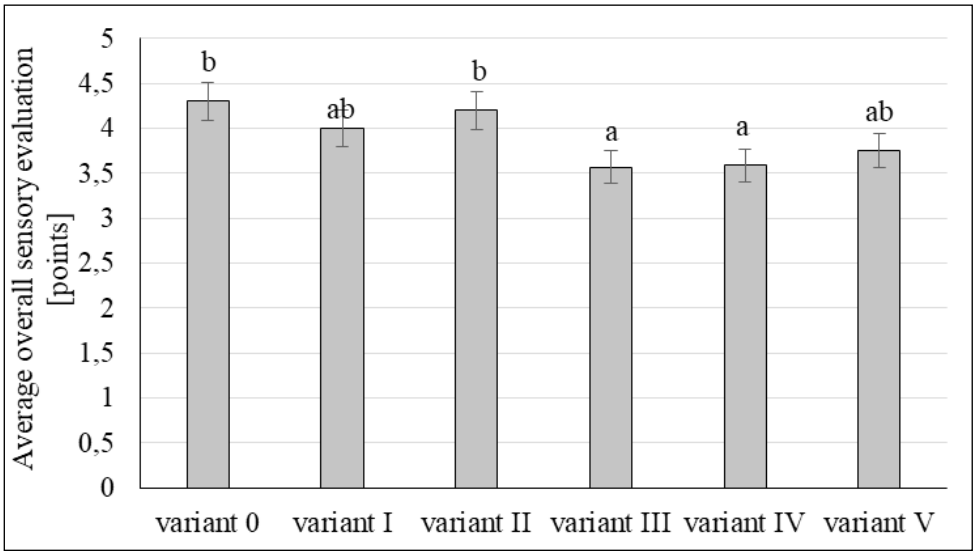

Fig. 4. Average overall sensory evaluation of the analyzed yeast rolls (sample markings used – Table 1).

Rys. 4. Średnia ogólna ocena sensoryczna analizowanych bułeczek drożdżowych (zastosowane oznaczenia próbek – Tabela 1).

Source: The own study

Źródło: Badania własne

overall evaluation of the analyzed yeast rolls were summarized (Fig. 4). The lowest overall score was awarded to rolls in the composition of which sucrose was completely replaced with dried apples (variant III) and in samples where 25% of flour was replaced with dried apples (variant IV). The highest grades were rolls with basic composition (variant 0) and rolls with 75% of sucrose replaced with dried apples (variant III). Baca et al. [2] and Jannati et al. [7] also found that a high level of added fiber or apple pomace significantly reduced the acceptability of the bread, which was mainly manifested in a darker color and bitter taste. The first of the mentioned authors considered the addition of fiber to be acceptable, while Jannati et al. [7] – only up to 3% of apple pomace.

CONCLUSIONS

Bread is one of the basic products in the daily diet. Its quality is influenced by: the raw materials used for production, the method of keeping the dough and the duration of fermentation. The use of dried apple as a raw material, which is a natural source of bioactive compounds, allows to increase the bioactive potential of yeast rolls. It is confirmed by the results of the determined content of total polyphenols and the anti-radical activity of the analyzed samples. From a nutritional point of view, it is preferable to use dried apples as a sucrose replacement ingredient. It is also important that the potential consumer accepts the new product. In the sensory evaluation, the panelists rated the rolls with a high content of dried apples lower in terms of color, crumb porosity and smell. The best grades were rolls with the basic composition and those with 75% sugar replaced with dried fruit. This indicates the sensory acceptability of rolls with the addition of dried apples, but at the same time containing sugar. This may result from consumer habits and indicates the need for research to optimize the composition of yeast rolls.

WNIOSKI

Pieczywo jest jednym z podstawowych produktów występującym w codziennej diecie. Na jego jakość mają wpływ: surowce użyte do produkcji, metoda prowadzenia ciasta oraz czas trwania fermentacji. Zastosowanie jako surowca suszu jabłkowego, będącego naturalnym źródłem związków bioaktywnych, pozwala na zwiększenie potencjału bioaktywnego bułek drożdżowych. Potwierdzeniem są wyniki oznaczonej zawartości polifenoli ogółem oraz aktywności przeciwrodnikowej analizowanych próbek. Korzystne, z żywieniowego punktu widzenia, jest zastosowanie suszu jabłkowego jako składnika zastępującego sacharozę. Istotne jest także zaakceptowanie nowego produktu przez potencjalnego konsumenta. W ocenie sensorycznej, paneliści niżej ocenili bułki z wysoką zawartością suszu jabłkowego pod względem barwy i porowatości miękiszu oraz zapachu. Najlepiej zostały ocenione bułki o składzie podstawowym oraz te, w składzie których 75% cukru zastąpiono suszem owocowym. Wskazuje to na akceptowalność sensoryczną bułek z dodatkiem suszu jabłkowego, ale zawierających jednocześnie w składzie cukier. Może to wynikać z przyzwyczajeń konsumenckich i wskazuje na konieczność badań w kierunku optymalizacji składu bułek drożdżowych.

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Dr hab. Agnieszka CIURZYŃSKA, prof. SGGW
Mgr Katarzyna RYBAK
Mgr inż. Magdalena KARWACKA
Dr hab. Sabina GALUS
Dr hab. Monika JANOWICZ, prof. SGGW
Department of Food Engineering and Process Management, Institute of Food Sciences, Warsaw University of Life Science (SGGW–WULS), Warsaw, Poland
Katedra Inżynierii Żywności i Organizacji Produkcji, Instytut Nauk o Żywności
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We would like to thank mgr Monika Szczęsna, whose research carried out in the master thesis was used to prepare this publication.
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Key words: vegetable, freeze-drying, anthocyanin, polyphenol, sorption properties, colour, sugars, thermal properties.

The article of the study was to investigate selected physical and chemical properties of freeze-dried vegetables which were rejected as a waste of freezing process due to non-compliance with the size criterion. Cauliflower, carrot, yellow bean, potato and onion were freeze-dried with registration of drying kinetics and next sugars, anthocyanin and polyphenols content were determined, rehydration and sorption properties as well as colour, water activity and content and thermal properties. It was shown that obtained samples were characterized typical properties for freeze-dried vegetables and may be used as an e.g. component of freeze-dried vegetable mix or innovative food product.

Słowa kluczowe: warzywa, liofilizacja, antocyjany, polifenole, właściwości sorpcyjne, barwa, cukry, właściwości termiczne.

Celem artykułu było przedstawienie zbadanych wybranych właściwości fizykochemicznych warzyw liofilizowanych, które zostały odrzucone jako odpad z procesu mrożenia z powodu niespełnienia kryterium wielkości. Liofilizowano kalafior, marchew, żółtą fasolę, ziemniak i cebulę z rejestracją kinetyki suszenia, a następnie oznaczono zawartość cukrów, antocyjanów i polifenoli, właściwości rehydratacyjne i sorpcyjne, a także barwę, aktywność wody oraz zawartość i właściwości termiczne. Wykazano, że otrzymane próbki charakteryzowały się właściwościami typowymi dla warzyw liofilizowanych i mogą być wykorzystywane m.in. jako składnik liofilizowanej mieszanki warzywnej lub innowacyjnego produktu spożywczego.

INTRODUCTION

Diet rich in vegetables, which contain significant amounts of bioactive phytochemicals, may provides desirable health benefits such as reduce the risk of chronic diseases, what was confirmed in investigations. More and more countries encourage the consumption of vegetables to prevent various diseases, e.g. cancer, cardiovascular disorders [38, 47]. This protective effect may be connected with its against diseases initiated by free radicals, which results from the presence of compounds with antioxidant properties, e.g. polyphenols, anthocyanins [60]. More than 8,000 phenolic compounds

Adres do korespondencji – Corresponding author: Agnieszka Ciurzyńska, Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Instytut Nauk o Żywności, Katedra Inżynierii Żywności i Organizacji Produkcji, ul. Nowoursynowska 159c, 02-776 Warszawa, e-mail: agnieszka_ciurzynska@sggw.edu.pl

have been isolated from various natural products, including flavonoids and phenolic acids. Polyphenolic compounds can be divided in terms of the structure of the basic carbon skeleton into: phenolic acids, flavonoids. The content of phenolic compounds in products foods varies greatly and depends on a number factors. Depending on the technological processing the phenolic content of processed foods is different from fresh foods [21]. The greatest amounts of polyphenols are found in [50]: cruciferous vegetables (red cabbage, broccoli); onion vegetables (onion, garlic); root vegetables (red beet); nightshade vegetables (red pepper). Vegetables provide adequate amount of many vitamins and minerals for humans. They are rich source of carotene, ascorbic acid, riboflavin, folic acid and different minerals [19], but they have short shelf live because of they contain a large proportion of water. The widely used technique for vegetable preservation is drying [52]. Appropriate drying technique should maintain food qualities such as flavour, texture, functionality and high nutritional content, but also chemical compounds including the content of phenolics [40], protection of vitamins or carotenoids [51].

During the process of freezing vegetables, some of the raw materials are largely rejected because they do not meet the shape or size criteria. Then they become waste, which in terms of quality are wholesome vegetables and can be successfully used, for example, in the production of multi-vegetable freeze-dried snacks [14] or as a component of freeze-dried vegetable mix.

The aim of the research was to assess the selected chemical and physical properties of freeze-dried vegetables. The same vegetables were used to obtain innovative vegetable bars with hydrocolloids [14]. The scope of this work include investigations of total polyphenol, flavonoids and sugars content, sorption isotherms and hygroscopic properties, colour, water content and activity, as well as thermal properties for freeze-dried onion, carrot, yellow bean, potato and cauliflower. During the freeze-drying process, the kinetics of freeze-drying was registered.

MATERIALS AND METHODS

The research material were rejected frozen vegetables: cauliflower, onion, potato, yellow beans and carrots, stored in a chest freezer (Electrolux EC4200A0W1, Sweden) at the temperature of -18°C in ziplock bags. They were rejected in the course of the production of frozen vegetables due to their improper shape or uneven colour. Vegetables were varied in terms of shape. The freeze-drying was carried out in a Christ ALPHA 1-16 freeze dryer (Germany) at the temperature of the heating shalves of the freeze dryer 30°C for 24 h, under the presure of 63 Pa, safety pressure of 137 Pa. During the freeze-drying process, the kinetics of freeze-drying was determined. Until the tests, the freeze-dried vegetables were stored in barrier packages, limiting the access of oxygen, moisture and light, and stored in controlled conditions (temperature 25°C, humidity RH 50%) in a climatic chamber.

Water activity of freeze-dried vegetables was measured by HygroLab Rotronic Company apparatus with accurancy of ±0,001, at a temperature 25±0.5°C, according to the manufacturer's instruction. Water content was determined in a WAMED SUP 65 W/G convective dryer (Poland) for 24 hours at the temperature of 60°C [16]. Colour measurement was done for the thawed and freeze-dried vegetables with the use of Chroma – Meter CM-5 Minolta Company (Austria) [12].

The colour indicators were calculated with the use of the following formula:

ΔE – relative colour difference index

$$\Delta E = \sqrt{(L^{*0} - L^{*})^2 + (a^{*0} - a^{*})^2 + (b^{*0} - b^{*})^2}$$

where: L* – lightness coefficient [dimensionless value]
a* – red colour coefficient [dimensionless value]
b* – yellow colour coefficient [dimensionless value]
L^{*0}, a^{*0}, b^{*0} – colour coefficients for thawed vegetables (relate to) [dimensionless value].

Total polyphenols content was determined by the Folin-Ciocalteu method, using gallic acid standard [42]. To determine the content of total flavonoids, the spectrophotometric method was used, based on the measurement of the absorbance of colored complexes formed between flavonoid compounds with aluminum chloride [43]. The liquid chromatography method with refractive index detection was used to determine sugars [56]. In order to determine the hygroscopic properties of the dried material, the method proposed by Nowacka & Witrowa-Rajchert [44] was used. Determination of sorption isotherms was performed using an automatic gravimetric water sorption analyzer (AQUADYNE DVS-2HT QUANTAHROME INSTRUMENTS) according to the manufacturer's instruction. To describe the water sorption isotherms of freeze-dried vegetables four mathematical models (Oswin [31], Lewicki [32], Peleg [32], GAB [31]) were considered based on R2 correlation coefficient; MRE mean relative error; RSS residual sum of squares and SEE error of water content estimation [10, 13]. The structure of vegetables after freeze-drying was determined with the use of a scanning electron microscope TM-3000 HITACHI [11]. From freeze-dried vegetables a piece about 1-2 mm were cut out across the sample. Structural changes were determined at 100x magnification. TGA and DTG curves were registered with the use of Thermogravimeter TGA/DSC 3+LF (Mettler Toledo Company, Poland). 5-6 mg of every sample were put in aluminium Pan 40 µl and were heated at a rate of 5°C/min with gas flow N2 50 ml/ min, in the temperature range of 30-600 ℃. Statgrafics Plus, version 4.1. MS Excel 2010 (Microsoft) was used in the following statistical analysis. For the obtained results pooled standard deviations were calculated. Homogeneous groups were determined using the Tukey's test, with a significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

Figure 1 presents kintetics of the freeze-drying process for yellow bean, cauliflower, potato, carrot and onion. The u/u0 is the ratio of water content during drying to initial water content before drying [61]. All samples were freeze-dried in the same conditions. On the basic of obtained drying curves it was shown that most of samples obtain similar drying kinetics. Only cauliflower freeze-drying curve indicates that this vegetable characterize lower drying rate. It may

be also connected with the higher initial water content for cauliflower than for other investigated vegetables. On freeze-drying process different factors influence, such as drying temperature, chamber pressure, and sample thickness [3]. In the case of analysed samples, different structure and shape of the vegetable: cubes for potato, onion and carrot, florets for cauliflower, pieces for yellow bean may have influence on drying kinetics (Figure 1). Similar drying rate obtained Lin et al. [35] for sweet potato with the use of far-infrared freeze-drying and Wang et al. [59] for freeze-dried potato. Reyes et al. [54] obtained lower freeze-drying rate for carrot than results presented on Figure 1, but authors indicated that samples which were quick frozen obtained higher drying rate than samples slow-frozen, which might be due to a more open structure obtained by quick freezing.

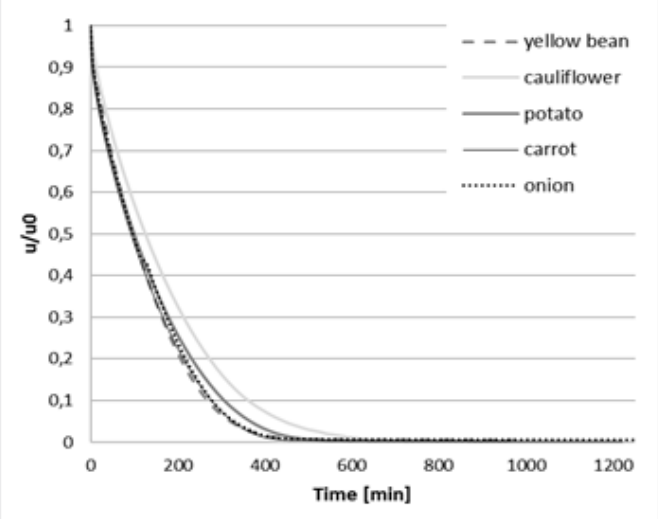

Fig. 1. Kinetic curves of freeze-dried vegetable waste.
Rys. 1. Krzywe kinetyki liofilizacji odpadów warzywnych.

Source: Own study

Źródło: Opracowanie własne

Freeze-dried vegetables obtained low water content in the range of 0.005–0.023 g H_2O/kg (Table 1). The lowest value was shown for freeze-dried potato. Between onion and carrot, as well as yellow bean and cauliflower differences were statistically insignificant. Guine & Barroca [24] obtained similar water content value for freeze-dried onion. Baloch, Xia & Sheikh [4] measured moisture content of raw and cabined dried cauliflower and indicate that this vegetable should be preserved as soon as possible. Cui et al. [15] obtained higher value of moisture content for freeze-dried carrot, but differences may be connected with e.g. different drying conditions, or samples size. Water activity of freeze-dried vegetables was also on low level, in the range of 0.088–0.126 (Table 1). In most cases differences were statistically significant. The value lower than 0.60, ensures complete inhibition of microbial growth in food products [25]. Choi et al. [9] showed that for sweet potato the drying process reduced the water activity (a_w) by accumulation of sugars during processing, what increased the final product shelf-life due to the prevention of microbial growth. Rajkumar et al. [52] obtained significant higher value of a_w for carrot (0.422), but they conducted freeze-drying process in temperature 45°C.

Table 1. Water content and water activity for freeze-dried vegetable waste

Tabela 1. Zawartość i aktywność wody w liofilizowanych odpadach warzywnych

Sample	Water content [g H_2O/kg]	Water activity
yellow bean	$^{(b)}$0.018±0.000	$^{(a)}$0.088±0.001
cauliflower	$^{(b)}$0.019±0.001	$^{(b)}$0.117±0.005
potato	$^{(a)}$0.005±0.000	$^{(d)}$0.100±0.003
onion	$^{(c)}$0.023±0.001	$^{(c)}$0.126±0.004
carrot	$^{(c)}$0.023±0.000	$^{(cd)}$0.099±0.006

Abbreviations: Value are mean (n=2) ± standard deviation ($P < 0.05$). The means with the same letter (^{abcd}) in the lines are not significantly different according to ANOVA and Tukey's multiple comparison tests.

Oznaczenia: Wartości to średnia (n=2) ± odchylenie standardowe ($P < 0,05$). Średnie z takimi samymi literami (^{abcd}) w wierszach, nie różnią się znacząco według testów wielokrotnych porównań ANOVA i Tukeya.

Source: Own study

Źródło: Opracowanie własne

Colour retention of dried vegetables can indicate retention of the pigments and nutrients such as carotenoids, flavonoids, phenols [17]. Natural colour compounds determine the colour of vegetables and they may be oxidized during the preservation processes especially when high temperature and oxygen is used [36]. In particular carotenoids become rapid decomposition in the presence of oxygen [23]. Carrot is reach in caretonoids, which are organic pigments naturally occure in chloroplasts and chronoplasts [28]. The α- and β-carotene constitute over 90% of all carotenoids and have to be protect before thermal destruction, because degradation of carotenoids affects not only the colour of food products, but also their nutritive value and flavour [34]. Even that freeze-drying is recognized as a method, which protect sensitive compounds the absolute colour difference parameter (ΔE) calculated for freeze-dried vegetables indicates drying influence on colour changes (Figure 2). Freeze-dried vegetables obtained ΔE in the range of 16.5–27.1 units. The highest colour changes were observed for potato, and only for this sample differences were statistically significant in comparison to the other vegetables. The colour of potatoes is a very important criterion strictly related to consumer perception and acceptance [48]. Pedreschi et al. [49] argue that for potato colour change is mainly due to the Maillard reaction, which depends on the amino acids, proteins and content of reducing sugars at the sample surface, which can be sensitive for the temperature and time of drying. Cooking step before freeze-drying leads to a Maillard reaction, and characteristic golden brown zones may be achieved [8]. Such pre-treatment before freeze-drying was used for potato and yellow bean. Pedreschi et al. [49] for freeze-dried potato chips obtained ΔE parameter at the level about 13, but as reference sample raw potato was used.

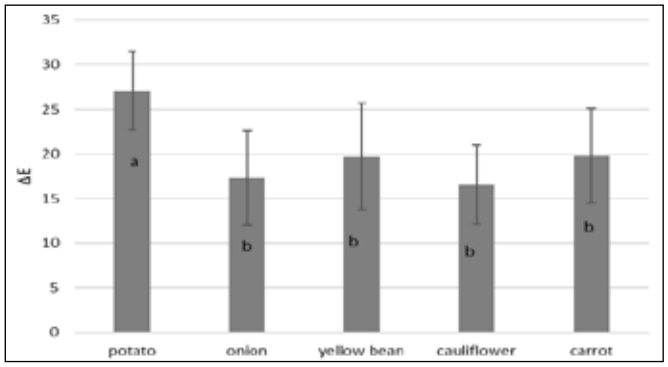

Fig. 2. The absolute colour difference of freeze-dried vegetable waste. Value are mean (n=2). The means followed with the same letter (abcd) are not significantly different according to ANOVA and Tukey's multiple comparison tests.

Rys. 2. Bezwzględna różnica barwy liofilizowanych odpadów warzywnych. Średnie (n=2) opisane takimi samymi literami (abcd) nie różnią się znacząco, według testów wielokrotnych porównań ANOVA i Tukeya.

Source: Own study

Źródło: Opracowanie własne

Mokrzycki & Tatol [39] indicated that when the value of ΔE is below 2.0, trained observers would notice the difference, while when this values is over 3.5, a clear difference in colour is noticed even by average observers. For all freeze-dried vegetables this parameter was above 3.5, so differences in comparison to thawed samples are visible for average observers. It may be connected with the highest increase of potato lightness coefficient after freeze-drying (Table 2). It was also observed on photos made for thawed and freeze-dried samples. Statistically significant increase of lightness coefficient (L*) was observed for all vegetables as an effect of porosity increase (not presented in this publication) in freeze-dried samples. Structure changes during drying process may influence on perception of colour of dried products which may be different from that of raw vegetables [33]. Colour coefficients value obtained for freeze-dried carrot are lower than presented by Reyes et al. [54]. Ren et al. [53] showed that fresh onions were characterized by L* coefficient at 74.24 units and after freeze-drying this parameter increased to the range of 80.8–93.74 units, but investigations were conducted for samples after pre-treatment as blanching and ultrasounds, which could influence on this index. Also freezing and next thawing could caused that onion obtained lower lightness coefficient value than in Ren et al. [53] research. Negi & Roy [41] confirmed such a statement for dehydrated carrots,

Table 2. Photos and colour coefficients of thaved and freeze-dried vegetable waste

Tabela 2. Zdjęcia i współczynniki barwy rozmrożonych i liofilizowanych odpadów warzywnych

Colour coefficient	Vegetable									
	Potato		onion		yellow bean		cauliflower		carrot	
	thaved	freeze-dried	thaved	freeze-dried	thaved	freeze-dried	thaved	freeze-dried	thaved	freeze-dried
Lightness coefficient **(L*)**	^{a}52.26 ±2.04	^{b}77.72 ±4.49	^{a}46.39 ±1.54	^{b}60.77 ±6.50	^{a}50.08 ±4.38	^{b}67.72 ±6.76	^{a}55.47 ±2.59	^{b}71.15 ±4.47	^{a}34.28 ±2.72	^{b}53.65 ±5.76
Red colour coefficient **(a*)**	^{a}-1.75 ±0.54	^{a}-2.14 ±0.48	^{a}-3.92 ±0.21	^{b}0.33 ±1.18	^{a}-5.40 ±0.46	^{b}-2.27 ±1.17	^{a}-3.27 ±0.20	^{b}-1.80 ±0.24	^{a}25.43 ±2.75	^{a}23.75 ±1.29
Yellow colour coefficient **(b*)**	^{a}23.86 ±2.31	^{b}14.70 ±0.83	^{a}15.61 ±1.52	^{b}23.10 ±2.07	^{a}19.74 ±1.92	^{b}27.00 ±2.59	^{a}9.00 ±1.78	^{b}13.88 ±0.82	^{a}33.57 ±3.33	^{a}32.64 ±2.84
Photos of thawed and freeze-dried samples										

Abbreviations: Value are mean (n=10) ± standard deviation (sd) ($P < 0.05$). The means with the same letter (^{abcd}) in the lines are not significantly different according to ANOVA and Tukey's multiple comparison tests conducted to comparison between thaved and freeze-dried samples.

Oznaczenia: Wartości to średnia (n=10) ± odchylenie standardowe (sd) ($P < 0,05$). Średnie z takimi samymi literami (^{ab}) w wierszach, nie różnią się znacząco, zgodnie z testami wielokrotnych porównań ANOVA i Tukeya, przeprowadzonymi w celu porównania między próbkami rozmrożonymi i liofilizowanymi.

Source: Own study

Źródło: Opracowanie własne

which quality does not only depend on the drying method and conditions, but also on the other operations before and after drying. Increase of red (a*) and yellow (b*) colour coefficients for most of investigated vegetables may be connected with formation of colour compounds occured as an effect of nonenzymatic browning during drying [53, 58].

The thermal pre-treatment as blanching, boiling or freezing may reduce antioxidant activity and total phenolic content of vegetables [57]. Maskan [36] indicated that colourless polyphenols as an effect of enzymatic browning may change colour of vegetable during eg. drying process. The lack of oxygen access and a lower freeze-drying temperature may contribute to a better preservation of the quality indicators of the dried material. Less damage to the permeability of cell membranes is also important, since water is removed from the material by the gradual movement of the ice front from the surface to the interior [18].

In most cases of freeze-dried vegetables significant decrease of total polyphenol content (TPC) was observed from 15 to 59% (Figure 3). Only for carrot increase of investigated parameter after freeze-drying was observed (83%), while Witrowa-Rajchert et al. [61] showed for carrot with purple roots after the freeze-drying of material frozen at temperature of -20°C an almost 10% reduction of polyphenol content. Ren et al. [53] indicated that the yellow colour coefficient [b*] was correlated to total polyphenol content of hot-air dried samples, but such correlation of the colour coordinates with the bioactive compounds was not shown in freeze-drying. For freeze-dried onion Ren et al. [53] obtained TPC on the level of 9.21±0.82 of gallic acid equivalents per dry weight. Fabisiak et al. [18] indicated that losses of polyphenols can be contributed with the presence of polyphenol oxidase, which participates in oxidation substances containing polyphenolic compounds. The optimal thermal operation for this enzyme is temperature 40°C. Freeze-drying process was conducted in the temperature of heating shelves 30°C, what could influence on polyphenol content reduction.

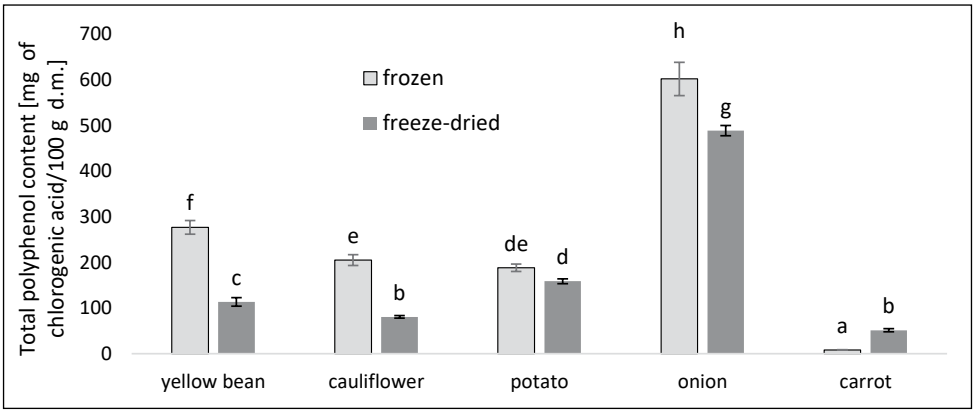

Fig. 3. Total polyphenol content of freeze-dried vegetable waste Value are mean (n=2). The means followed by same letter (abcd) are not significantly different according to ANOVA and Tukey's multiple comparison tests.

Rys. 3. Całkowita zawartość polifenoli w liofilizowanych odpadach warzywnych. Średnie (n=2) opisane takimi samymi literami (abcd), nie różnią się znacząco według testów wielokrotnych porównań ANOVA i Tukeya.

Source: Own study

Źródło: Opracowanie własne

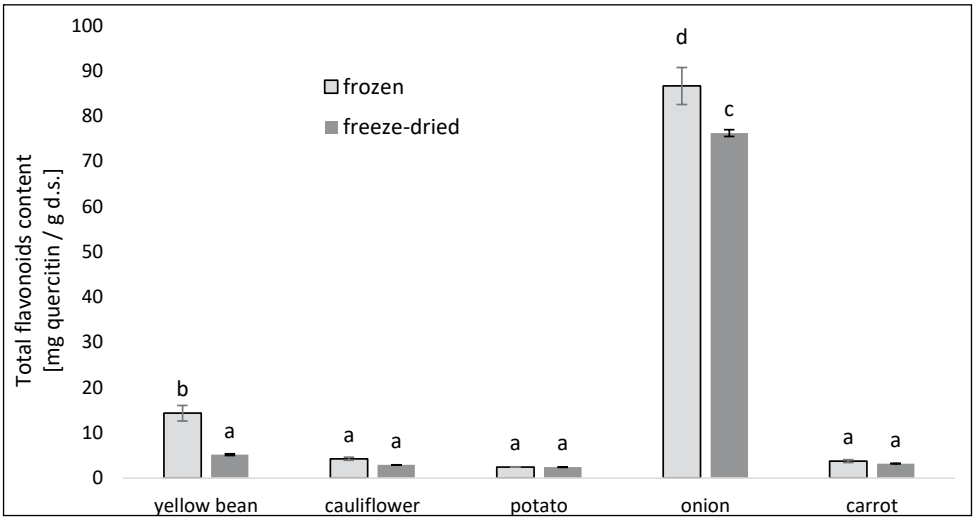

Fig. 4. Total flavonoids content of freeze-dried vegetable waste. Value are mean (n=2). The means followed by same letter (abcd) are not significantly different according to ANOVA and Tukey's multiple comparison tests.

Rys. 4. Całkowita zawartość flawonoidów w liofilizowanych odpadach warzywnych. Średnie (n=2) opisane takimi samymi literami (abcd), nie różnią się znacząco według testów wielokrotnych porównań ANOVA i Tukeya.

Source: Own study

Źródło: Opracowanie własne

It was shown that freeze-drying proces decreased total flavonoid content (TFC) of freeze-dried vegetables, but only for yellow bean and onion differences were statistically significant (Figure 4). It was also indicated that for cauliflower, potato and carrot investigated parameter was on the level below 5 mg quercetin/g d.s., for yellow bean thawed and freeze-dried, respectively, 14 and 5 mg quercetin/g d.s., whereas for onion 87 and 76 mg quercetin/g d.s. Ren et al. [53] indicated that TFC of freeze-dried onion was on the level 4,10±0,08 mg of quercetin equivalents/g d.s.

It was shown that freeze-dried vegetables were differ in sugars content (Figure 5). In freeze-dried onion and carrot total sugar content was the highest ~60±1%. Freeze-drying process decreased

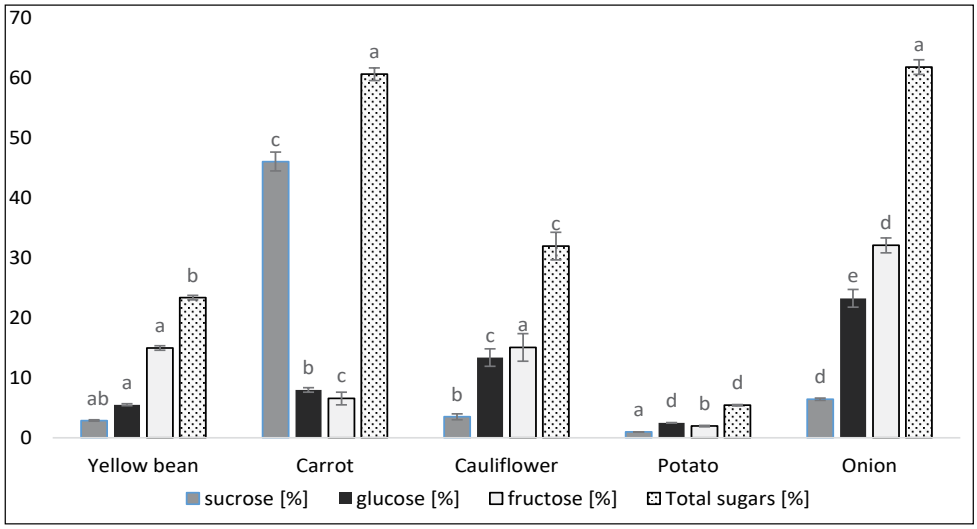

Fig. 5. Sugars content in freeze-dried vegetable waste. Value are mean (n=2). The means followed by same letter (abcde) are not significantly different according to ANOVA and Tukey's multiple comparison tests.

Rys. 5. Zawartość cukrów w liofilizowanych odpadach warzywnych. Średnie (n=2) opisane takimi samymi literami (abcde), nie różnią się znacząco według testów wielokrotnych porównań ANOVA i Tukeya.

Source: Own study

Źródło: Opracowanie własne

reducing sugars content. For carrot, glucose and fructose content was equal 8.25±0.37% and 6.68±0.16% respectively, while Leong & Oey [30] shown that for fresh carrot, reducing sugars were on 15±0.43%. For freeze-dried potato reducing sugars content were on the level 2.48±0.04% and 1.96±0.15% respectively (glucose and fructose), while Lati et al. [29] shown that fresh potato obtained reducing sugars 1.6%. Differences may be connected with different variety of vegetables.

It was shown that freeze-dried vegetables were differ in internal structure (Figure 6). Freeze-dried onion and yellow bean were characterised in porous structure, but for onion structure was more uniform, while for yellow bean closer to the center of the sample bigger open pores were shown. For potato and carrot structure was more closed and uniform. Similar structure for carrot obtained Reyes et al. [54]. The structure of cauliflower was delicate, porous, with small pores and present bigger open spaces. Similar structure obtained Cui et al. [15] for freeze-dried carrot. Bhatta et al. [5] argue that if the freezing step is properly done at adequate low temperatures (without ice crystals destroying/weakening the cell walls), cellular materials are better prepared to save structure during the freeze-drying. Mechanical properties and structural strength may be more important in keeping product integrity than glass transition temperature.

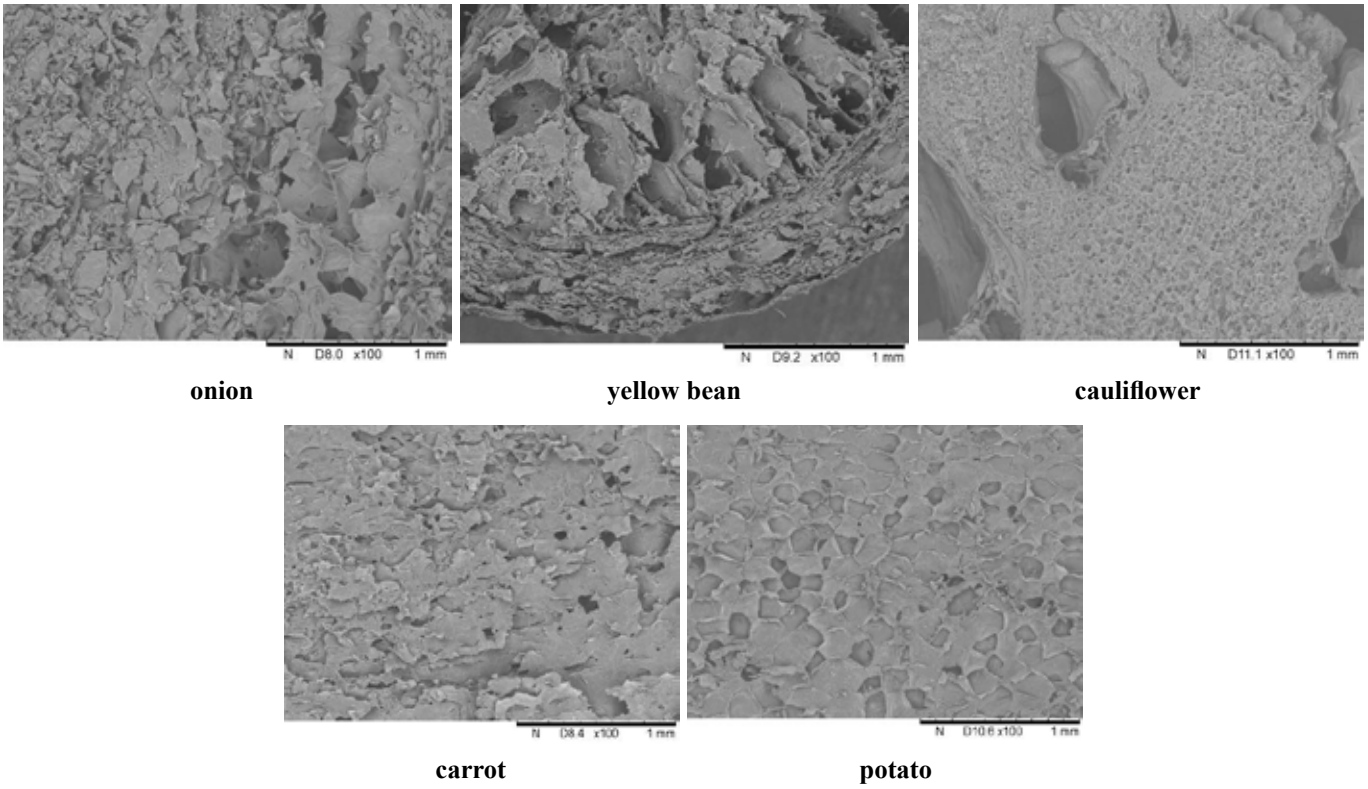

Fig. 6. The structure of freeze-dried vegetable waste. Magnification 100x.

Rys. 6. Struktura liofilizowanych odpadów warzywnych. Powiększenie 100x.

Source: Own study

Źródło: Opracowanie własne

The dried food peaces should have a short preparation time ~5–15 min [6]. The degree of damage caused by dehydration determines the extent of water binding and holding. Rehydydration should be fast and may be respected as the method to measure the degree of changes in the material in the drying process [62], but even if the rehydration was run for a very long time dehydrated material does not completely return to its form before drying, because irreversible changes in the structure of a plant tissue occure [61].

For most of freeze-dried vegetables rehydration process characterized a gradual water content increase, and after 24 hours stabilization was observed while the intracellular spaces of vegetables became saturated (Figure 7). All samples were rehydrated in high degree, almost threefold increase in water content was observed. Freeze drying removes water through sublimation, keeping the shape of the raw material very well, creating a porous structure, which increases the rehydration degree and rate of rehydration [26]. The exception was the sample of freeze-dried potato, which was characterized by an almost 4 times higher increase in water content. For potato, water was rapidly absorbed from the beginning of the process. Futhermore, Ghosh & Gangopadhyay [22] obtained high rehydration capacity for freeze-dried potato. It may be connected with presence of gelatinised starch in dried potato, which strongly absorbed water. Witrowa-Rajchert & Lewicki [62] argue that during rehydration water was absorbed by gelatinised starch and swelling of the material was observed from the beginning of rehydration process. The dried starch with numerous amorphous domains became well hydrated. Lower rehydration ratio for potatos obtained Wang et al. [59], but they conducted rehydration for freeze-dried potato chips, not cubes.

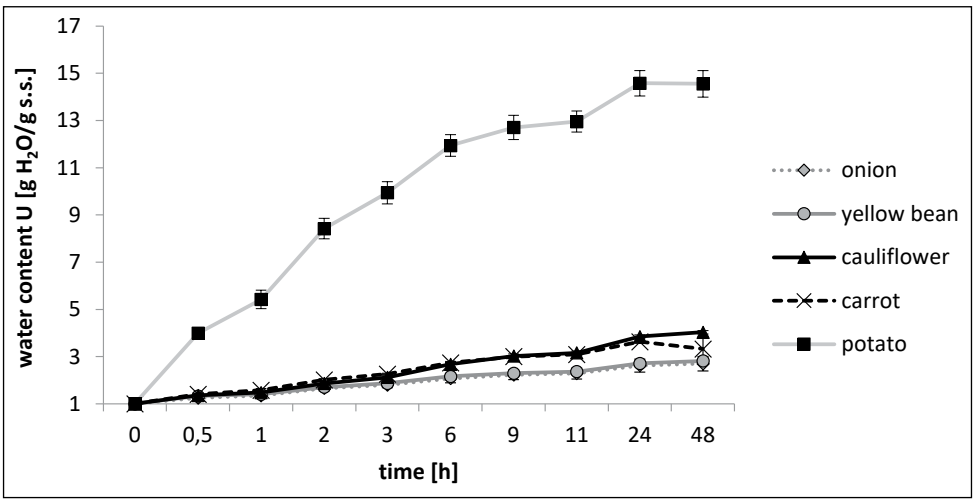

Fig. 7. Rehydration properties of freeze-dried vegetable waste.
Rys. 7. Właściwości rehydracyjne liofilizowanych odpadów warzywnych.
Source: Own study
Źródło: Opracowanie własne

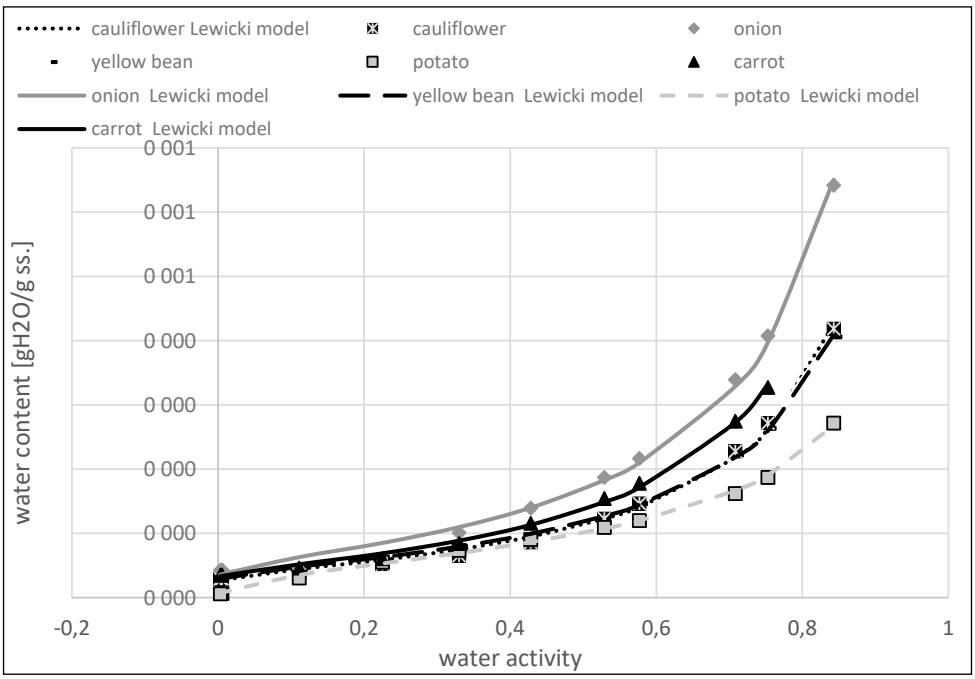

Fig. 8. Water vapour adsorption isotherms for freeze-dried vegetable waste.
Rys. 8. Izotermy sorpcji pary wodnej liofilizowanych odpadów warzywnych.
Source: Own study
Źródło: Opracowanie własne

The quality characteristics for dried foods may be predicted by moisture sorption isotherm determination [63]. Very often the BET (Brunauer-Emmett-Teller) equation is used to describe multilayer sorption isotherms, but the range of water activity is limited to 0.05–0.35 [1], so more often others modified kinetic and empirical models are used (Table 3). On the sorption isotherm models the type and composition of foods have influence [2]. Regardless of the vegetable type, freeze-dried samples exhibited a sigmoidal sorption curve as a function of water activity (Figure 8) and were classified as type II based on the classification of Brunauer, Emmett Teller [7].

Oh, Lee & Hong [45] obtained the same type of sorption isotherms for sweet potato. This is also in agreement with results for potato investigated by McMinn & Magee [37]. Four models were tested to describe the sorption equilibrium isotherms of freeze-dried vegetables and Lewicki's model was chosen as the best on the basis of fitting parameters (Table 3).

Table 3. Parameters of fitting water vapor sorption models for freeze-dried vegetable waste

Tabela 3. Parametry dopasowania modeli sorpcji pary wodnej dla liofilizowanych odpadów warzywnych

Cauliflower				
Model Coefficient	GAB	Lewicki	Peleg	Oswin
RSS	0.002	0.0005	0.0005	0.002
MRE	23.26	8.22	7.50	23.16
SEE	0.044	0.023	0.023	0.043
R^2	0.987	0.997	0.996	0.988
Onion				
Model Coefficient	GAB	Lewicki	Peleg	Oswin
RSS	0.004	0.002	0.003	0.003
MRE	21.029	12.618	15.55	20.76
SEE	0.060	0.038	0.053	0.059
R^2	0.990	0.996	0.992	0.991
Yellow bean				
Model Coefficient	GAB	Lewicki	Peleg	Oswin
RSS	0.002	0.0001	0.001	0.002
MRE	20.223	4.334	9.603	22.032
SEE	0.042	0.012	0.027	0.045
R^2	0.995	0.999	0.995	0.986
Potato				
Model Coefficient	GAB	Lewicki	Peleg	Oswin
RSS	0.0001	0.0001	2.8708E-05	0.0002
MRE	14.704	6.168	11.283	7.602
SEE	0.012	0.011	0.005	0.014
R^2	0.998	0.998	0.994	0.997
Carrot				
Model Coefficient	GAB	Lewicki	Peleg	Oswin
RSS	0.002	0.0002	0.0001	0.002
MRE	22.635	5.568	3.302	22.579
SEE	0.048	0.015	0.012	0.048
R^2	0.976	0.998	0.999	0.976

Abbreviations: Designations in methodology of determination of water vapour adsorption isotherms.

Oznaczenia: Oznaczenia w metodyce wyznaczania izoterm adsorpcji pary wodnej.

Source: Own study

Źródło: Opracowanie własne

The lowest sorption properties obtained from freeze-dried potato, while the highest cauliflower and onion (Figure 8). The obtained water sorption isotherms of the freeze-dried vegetables are typical of products with e.g. high sugar content which absorbs a relatively small volume of water at low water activity and a larger volume of it when the water activity is higher [46]. As expected, the obtained equilibrium moisture content values show an increase with increasing water activity. The freeze-dried vegetables analysed in this work show a sharp increase in sorption capacity above 0.529 water activities, which is typical for high-sugar fruit materials [27]. Freeze-dried vegetable also contain sugars what may influence on such course of sorption curves. The chemical composition, the type of components and the structure of the investigated samples may influence differences in the moisture content [11].

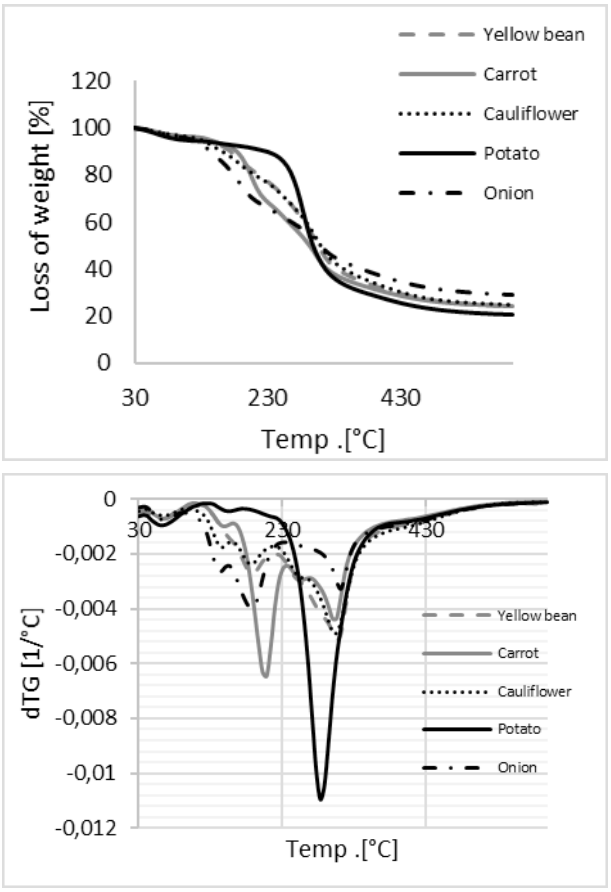

Fig. 9. TGA (a) and DTG (b) curves for freeze-dried vegetable waste.

Rys. 9. Krzywe TGA (a) i DTG (b) liofilizowanych odpadów warzywnych.

Source: Own study

Źródło: Opracowanie własne

Using thermogravimetry (TGA), the loss of weight (Δm) during sample heating can be recorded and the changes presented on the TGA curve ($\Delta m = \int (T)$). The rate of weight change (dm / dt) is also recorded, yielding a differential thermogravimetric curve (DTG): as a function of temperature ($dm / dt = \int (T)$) [20]. In the course of the TGA (Figure 9a) and DTG (Figure 9b) curves, three characteristic stages can be determined. In most cases for freeze-dried vegetables the most intensive loss of weight (about 60%) was observed in the temperature range of 130-440°C (Figure 9a). The TGA

curves of freeze-dried yellow-bean show three general regions of weight loss (30–139.25°C, 139.25–334.75°C, and 334.75–599.25°C). For freeze-dried carrot regions, those regions were in the temperature range of (30–122°C, 122–334.75°C, 334.75–599.25°C), for freeze-dried cauliflower (30–122°C, 122–346.25°C, 346.25–599.25°C), freeze-dried potato (30–173.75°C, 173.75–352°C, 352–599.25°C) and freeze-dried onion (30–122°C, 122–426°C, 426–599.25°C). For potato at a temperature of 283°C the elongatd peak was observed on DTG curve (Figure 9b), which may indicate a strong gas adsorption of decomposition products on the surface of the newly formed phase [55].

SUMMARY

The article assessed whether the vegetable waste from freezing process may be used as a full quality product for freeze-drying. Most of investigated vegetables obtained similar drying curves, exept cauliflower which drying rate was the lowest, but for all samples water activity and content was low, what indicates that samples are microbiologically safe. After freeze-drying colour of vegetables significantly changed in comparison to thawed samples. In most cases a significant decrease in total polyphenol content was observed and only for carrot an increase in the investigated parameter was shown after freeze-drying. Freeze-drying process decreased total flavonoid content, but in most cases insignificantly.

Freeze-dried vegetables differed in internal structure. For onion, yellow bean and cauliflower structure was porous, more delicate, whereas for potato and carrot, it was more closed and uniform. Freeze-dried samples obtained a sigmoidal sorption curves, classified as type II and described by Lewicki's model. The lowest sorption properties obtained freeze-dried potato, while the highest cauliflower and onion probably as an effect of structure. Rehydration process of freeze-dried vegetables indicated gradual water content increase, and after 24 h stabilization was observed. Freeze-dried potatoes was characterized by an increase in water content almost four times higher as an effect of high starch content.

PODSUMOWANIE

W artykule oceniono, czy odpady warzywne z procesu zamrażania mogą być wykorzystane jako pełnowartościowy produkt do liofilizacji. Większość badanych warzyw uzyskała podobne krzywe suszenia, z wyjątkiem kalafiora, którego szybkość suszenia była najniższa, ale dla wszystkich próbek zarówno aktywność jak i zawartość wody była niska, co wskazuje, że próbki są bezpieczne mikrobiologicznie. Po liofilizacji barwa warzyw istotnie zmieniła się w porównaniu z próbkami rozmrożonymi. W większości przypadków zaobserwowano znaczne obniżenie zawartości polifenoli ogółem i tylko w przypadku marchwi wykazano wzrost badanego parametru po liofilizacji. Proces liofilizacji obniżył całkowitą zawartość flawonoidów, ale w większości przypadków tylko nieznacznie.

Warzywa liofilizowane różniły się budową wewnętrzną. W przypadku cebuli, fasoli żółtej i kalafiora struktura była porowata, delikatniejsza, natomiast w przypadku ziemniaka i marchwi bardziej zwarta i jednolita. Próbki liofilizowane uzyskały sigmoidalne krzywe sorpcji, sklasyfikowane jako typ II i opisane modelem Lewickiego. Najniższe właściwości sorpcyjne uzyskał ziemniak liofilizowany, natomiast najwyższe kalafior i cebula – prawdopodobnie był to efekt wpływu struktury. Proces uwadniania warzyw liofilizowanych wykazał stopniowy wzrost zawartości wody, a po 24 godzinach nastąpiła stabilizacja. Liofilizowane ziemniaki charakteryzowały się prawie 4-krotnie większym wzrostem zawartości wody w wyniku wysokiej zawartości skrobi.

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Msc Eng. Anna IGNACZAK[1]
PhD, DrSc. Łukasz WOŹNIAK[2]
PhD, DrSc. Jolanta KOWALSKA[1], prof. of WULS
PhD, DrSc. Hanna KOWALSKA[1], prof. of WULS
[1]Department of Food Engineering and Process Management, Institute of Food Sciences, Warsaw University of Life Sciences, WULS, Warsaw, Poland
Katedra Inżynierii Żywności i Organizacji Produkcji, Instytut Nauk o Żywności, Szkoła Główna Gospodarstwa Wiejskiego, SGGW, Warszawa, Polska
[2]Department of Food Safety and Chemical Analysis, Institute of Agriculture and Food Biotechnology-State Research Institute, 36 Rakowiecka St. 02-532 Warsaw, Poland
Zakład Bezpieczeństwa i Analizy Chemicznej Żywności, Instytut Biotechnologii Przemysłu Rolno-Spożywczego-Państwowy Instytut Badawczy, Rakowiecka 36, 02-532 Warszawa, Polska

EVALUATION OF THE AVAILABILITY OF THESE PRODUCTS ON THE POLISH MARKET AND THE KNOWLEDGE OF CONSUMERS ABOUT DRIED FRUIT SNACKS®

Ocena stanu wiedzy konsumentów na temat przekąsek z suszonych owoców i dostępności tych produktów na polskim rynku®

Key words: dried fruit, fruit snacks, dried fruits/vegetables snack market.

The changing lifestyle and the growing awareness of consumers regarding the impact of the daily diet on the health and functioning of the organism lead to some kind of control in the selection of products containing natural bioactive ingredients with pro-health properties. Attention is also paid to the products without the addition of simple sugars and fats with an unfavorable profile. The answer to this type of challenge may be dried fruit or vegetables, which, obtained using various drying techniques, can be eaten as a separate valuable snack. The article presents the results of the evaluation of the availability of dried fruit on the example of selected stores of various sizes and a survey conducted among consumers regarding their knowledge and preferences regarding dried fruit snacks.

Słowa kluczowe: suszone owoce, przekąski z owoców, rynek suszonych przekąsek z owoców /warzyw.

Zmieniający się tryb życia i wzrastająca świadomość konsumentów odnośnie wpływu codziennej diety na zdrowie i funkcjonowanie organizmu, skłaniają do pewnego rodzaju kontroli w wyborze produktów zawierających naturalne składniki bioaktywne o właściwościach prozdrowotnych. Zwraca się też uwagę na produkty bez dodatku cukrów prostych i tłuszczów o niekorzystnym profilu. Odpowiedzią na tego typu wyzwanie mogą okazać się suszone owoce lub warzywa, które otrzymywane z wykorzystaniem różnych technik suszenia mogą być spożywane jako oddzielna wartościowa przekąska. W artykule przedstawiono wyniki oceny dostępności suszy z owoców na przykładzie 5 sklepów o różnej wielkości i ankiety przeprowadzonej wśród konsumentów, odnośnie ich stanu wiedzy i preferencji na temat przekąsek z suszonych owoców.

INTRODUCTION

Fruits and vegetables are an essential component of people's diets. Their chemical composition is very diverse. These raw materials are largely made of water (75–96%), so they are not high in calories. Carbohydrates dominate in the dry matter of fruit and vegetables, but the protein and fat content is quite low. Some fruits and vegetables have the ability to store starch, which is hydrolyzed into simple sugars during maturation. Fruits and vegetables are a very good source of vitamins, fiber, minerals, and compounds with bioactive potential. For this reason, they affect the proper functioning of the body and maintain health, which is why their consumption is so important [4]. Berries are especially valuable, including strawberries, raspberries, black currants, chokeberry, and cranberry. These fruits are a very good source of many health-promoting compounds, such as vitamins (especially vitamin C), polyphenols, carotenoids, and tocopherols. Many of these compounds show an antioxidant effect, eliminating free radicals that can cause cancer, cardiovascular diseases, and others [8, 19].

Corresponding author – Adres do korespondencji: Hanna Kowalska, Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Instytut Nauk o Żywności, Katedra Inżynierii Żywności i Organizacji Produkcji, ul. Nowoursynowska 159c, 02-776 Warszawa, e-mail: hanna_kowalska@sggw.edu.pl

In food technology, drying fruit and vegetables is a very good solution, especially in the case of an overproduction of raw materials or seasonal ones, the consumption of which is very limited throughout the year [14]. Drying fruits and vegetables is a good way to extend their shelf life. This process effectively lowers water activity, which minimizes chemical reactions occurring in the raw material and inhibits the growth of microorganisms, thanks to which even seasonal fruit in an attractive form can be available all year round.

In recent years, there has been an increasing interest in a healthy lifestyle and the quality of consumed food. Poles read labels more often and consciously choose less processed, more natural products, without the so-called artificial additives. For this reason, incl. instead of highly processed snacks, they eat dried fruit or vegetables, as well as whole grain products [3]. Dried fruit and vegetables are very important in food processing. For example, dried fruits are used in the production of confectionery and bakery products, but are also used in various types of desserts and dairy products, and in breakfast cereals. On the Polish market, there are various snacks of dried fruit and vegetables in the form of crispy chips, often with no added sugar. Some companies produce these chips by pre-fortifying them with fruit or vegetable juices. Such treatment, in addition to enriching with natural ingredients, allows for the development of attractive sensory values (color, taste, smell). Packages of about 30 g of these chips are very convenient and can be eaten at work, on travel, or when there is a need for a snack. The share of fruit and vegetables in the production of the so-called "healthy food" is increasing [10, 18].

Dried fruit and vegetables are a source of concentrated nutrients and minerals and, to a large extent, many other health-promoting ingredients. They contain vitamins (A, C, group B) responsible for the proper functioning of the immune system. The content of vitamin C in dried apples is 5-30 mg/100g [20]. They contain magnesium, potassium, calcium, and phosphorus, they are also a source of fiber, which is responsible for the proper functioning of the intestines. The fiber content of prunes is 9.4–14.3%. In addition, dried plums are characterized by a high content of boron, which is responsible for better absorption of calcium, and has a very good effect on the skeletal system [15, 17]. Dried fruit is also a source of polyphenolic compounds showing antioxidant activity, reducing the risk of, among others. cardiovascular and heart diseases. The highest levels of polyphenols can be found in dried dates [16], apricots [5] and dried apples, the content of which is 662–2120 mg/kg, depending on the variety and cultivation method [20]. However, the proportion of carbohydrates in dried fruit is significantly increased compared to that of fresh fruit. For example, their content in fresh plums was about 11.7 g/100 g, and in dried plums about 68.9 g/100 g [17].

About 8,000 tons of dried fruit are produced in Poland annually, mainly apples and plums. This is a small number compared to world production, which is around 2.5 million tonnes. The largest amounts of dried fruit are produced in Turkey, Iran, the USA, Saudi Arabia, and China [6].

The aim of the article is to present the obtained results regarding the availability of dried fruit in selected small and large-format and online stores in Poland and research the knowledge and preferences of consumers about dried fruit snacks.

MATERIALS AND METHODOLOGY

The availability of dried fruit snacks was carried out on the example of 3 physical stores and 2 online stores:

- a local store operating on a franchise basis.
- hypermarket 1,
- hypermarket 2,
- bio food online store,
- online store 2.

The forms and types of selected dried fruit snacks available on the Polish market were presented and the leader in the production of dried fruit was indicated.

A survey on the level of knowledge and preferences of consumers regarding dried fruit snacks was conducted in 2021. A questionnaire consisting of single-choice closed-type questions was prepared, aimed at determining the frequency of consumption and consumer knowledge about the impact of dried fruit snacks on the health and condition of the body, a semi-open question that allowed to distinguish the dried fruit that consumers choose most often, and questions concerning the determination of sociodemographic characteristics (gender, age, place of residence and education). The survey was made available via the website www.docs.google.com on the social networking site Facebook. The study was conducted on a sample of 367 respondents, 78.1% of which were women and 21.9% men. Among the respondents, the largest group were people aged 19–30 (79.7%), living in cities with more than 100,000. inhabitants (50.1%) with secondary (43.5%) or higher (41.8%) education. Thus, it can be concluded that the research group consisted mainly of women aged 19–30, living in large cities, during their studies or shortly after their graduation. The results were analyzed using the descriptive method.

RESULTS AND DISCUSSION

Availability of dried fruit snacks on the Polish market

The dried fruit market in Poland is developing dynamically [12]. Currently, in Poland and in the world, the behavior of "being fit" is observed. More and more consumers pay attention to the quality of the food they eat and understand the need to be physically active. According to Gruszczyńska et al. [7] a pro-health lifestyle is associated with a conscious decision about systematic physical exertion included in the routine of everyday life.

Many consumers choose natural, ecological, and low-processed products from among those available on the market. Increasingly, they buy fresh fruit, including those prepared for immediate consumption, washed, peeled, sliced, and packed in small convenient packages. A very attractive form of the recommended snacks is dried fruit or vegetables. And because of life "on the run", they are eagerly eaten as a quick snack that gives you a feeling of satiety [3].

Currently, dried fruit is sold on the market in the form of:

- in bulk, by weight – the price is given for 1 kg, individually for each species,

- in packages of several or several dozen pieces – dried fruit is packed in 15 g – 1kg grammages, and in 15–100 g grammages are mainly freeze-dried fruit,
- on trays – dried fruit placed on trays,
- in a tube – usually mixes of freeze-dried fruit in the grammage of 70–150 g are sold.

Table 1. List of dried fruit offered by selected stores in Poland

Tabela 1. Zestawienie suszonych owoców oferowanych przez wybrane sklepy w Polsce

Store type / Dried fruit	Local store	Hiper-market 1	Hiper-market 2	Bio food online store	Online store 2
Plums	1	6	5	3	
Apricots	1	4	5	2	
Raisins	1	5	5	2	9
Cranberries	1	4	5	2	7
Bananas	1		3	2	
Strawberries	1				
Blueberries		1			
Goji berries		1	4	1	
Figs			2	2	
Quince			1		
Cherries			1	1	
Apples			1	2	
„Miechunka”			2		
Dates		3	2	3	6
Pineapple		2	3	2	
„Hawajka” mix		2			
Christmas Eve mix				1	
Pears				1	
Raspberries				2	
Mango		1	1	1	
Total dried fruit	**6**	**21**	**40**	**27**	**22**

Source: The own study

Źródło: Opracowanie własne

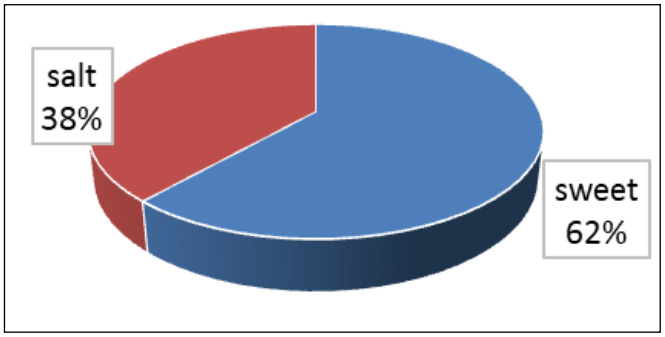
Analyzing the availability of dried fruit on the Polish market, the store with the highest supply of dried fruit was hypermarket 1 (large-format store), where the number of products discussed in this study was 40 (Tab. 1). The hypermarket 2 store had 21 products, although, like hypermarket 1, it was a large-format store. The first online store, offering organic products with bio certification, had 27 dried fruits, and the second had 22. The lowest, only 6 dried fruits, was offered by a local, chain store. Raisins and dried cranberries were found to be the most available snacks on the market, as these fruits were in every store, and as the store size decreased, its assortment also decreased. It can be concluded that some types of dried snacks are still not available in smaller stores and may be difficult for consumers to find.

The Polish market for dried fruit snacks is quite significant, smaller in the case of vegetables. There are many companies that produce dried fruit, incl. Bakalland brand, offering 21 dried fruit snacks in the stores analyzed, as well as Makar, Denver Food, Bakal, Helio, Kresto, and hypermarket brands.

Results of the survey on the assessment of consumer knowledge and preferences

The results of the study clearly show that consumers are more likely to eat sweet snacks (62%), and less often salty (38%) (Fig. 1a). Moreover, the vast majority of respondents (85%) declared that they prefer fruit snacks, and the remaining respondents (15%) had vegetable snacks (Fig. 1b).

a)



b)

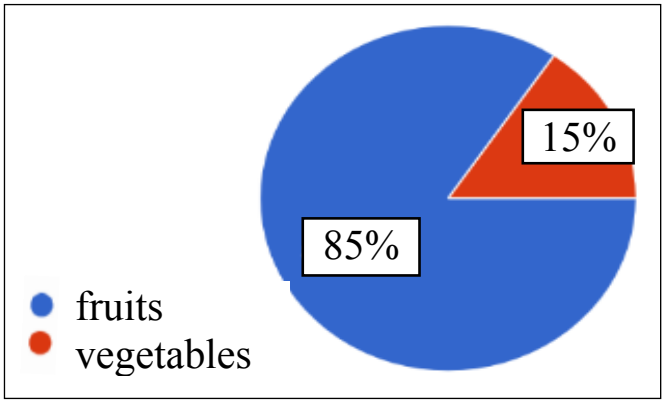


Fig. 1. List of respondents' answers to the question: a) "Do you choose salty or sweet snacks more often?"; b) regarding the declaration of selection of salty or sweet snacks.

Rys. 1. Zestawienie wyników odpowiedzi respondentów na pytanie: a) „Czy częściej wybiera Pan/Pani przekąski słone, czy słodkie?"; b) odnośnie deklaracji wyboru przekąsek słonych lub słodkich.

Source: The own study

Źródło: Opracowanie własne

The vast majority, as many as 85%, stated that they prefer fruit snacks, and only 15% prefer vegetable snacks (Fig. 1). When asked whether the respondents consume dried fruit snacks, more than half of the respondents (62%) answered in the affirmative.

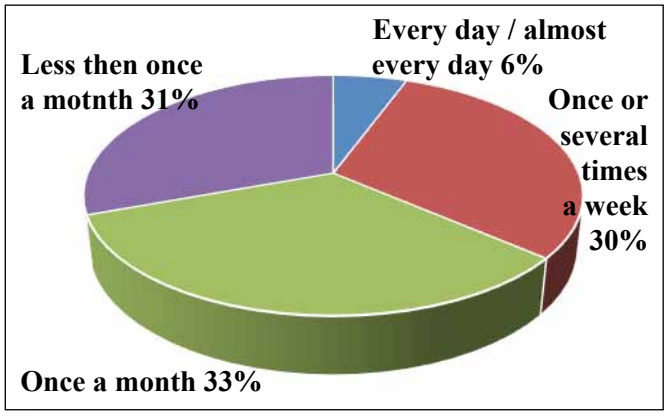


Fig. 2. List of respondents' answers regarding the frequency of consumption of dried fruit snacks.

Rys. 2. Zestawienie wyników odpowiedzi respondentów dotyczące częstotliwości spożycia przekąsek z suszonych owoców.

Source: The own study

Źródło: Opracowanie własne

The next question was to determine the frequency of consumption of dried fruit snacks among people who eat them (Fig. 2). Research has shown that about 33% of respondents eat snacks in the form of dried fruit once a month, and 30% of respondents eat them once or several times a week. A large number of respondents (31%) declared that they choose them less frequently than once a month. By contrast, only 6% buy dried fruit snacks every day or almost every day.

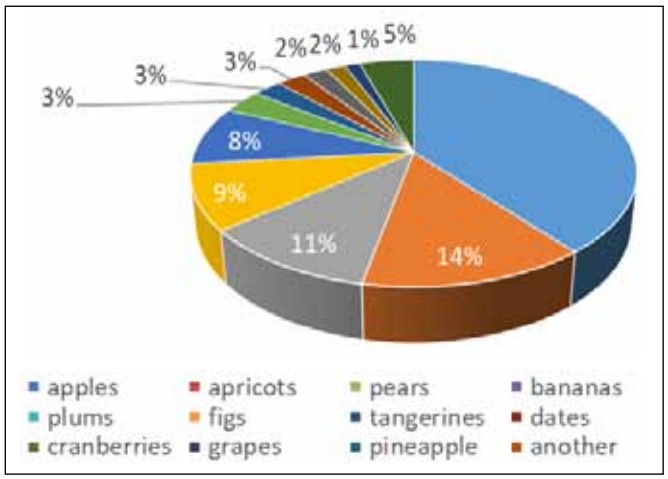


Fig. 3. List of respondents' answers regarding the preferences of the respondents regarding the type of dried fruit most often consumed.

Rys. 3. Zestawienie wyników odpowiedzi dotyczących preferencji ankietowanych odnośnie rodzaju najchętniej spożywanych suszonych owoców.

Source: The own study

Źródło: Opracowanie własne

The respondents were also asked about their preferences regarding the type of the most chosen dried fruit snacks. Most respondents (39%) indicated that they eat dried apples, a smaller number of respondents (14%) declared that they are eager to eat dried apricots, 11% of respondents chose pears, 9% bananas, and 8% plums. The remaining responses concerned such dried fruits as figs (3%), mandarins (2%), dates (2%), cranberries (2%), grapes (2%), pineapple (1%). The respondents also indicated other answers, including raspberries, strawberries, blueberries, mangoes, and cherries.

Another question was to indicate how often consumers read the information on the package when purchasing dried fruit snacks (Fig. 4). Most respondents, 33%, usually do it, 22% with each purchase, and 22% from time to time. Almost every fourth person (23%) declared that they did not check the information on the packaging before purchasing this type of product. It can be concluded that every third person makes an informed decision about dried fruit snacks with every purchase.

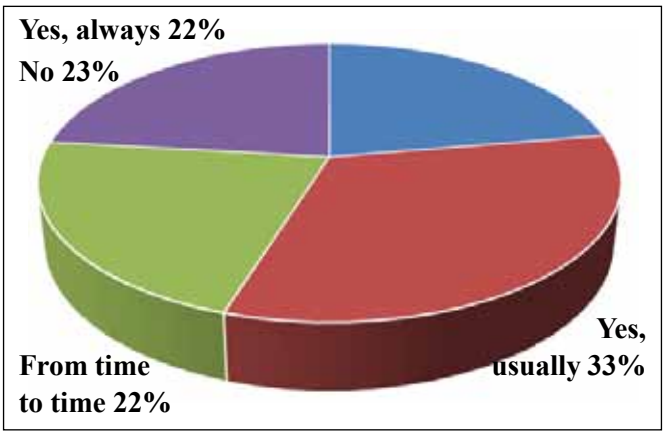


Fig. 4. List of respondents' answers to the question: "When buying dried fruit snacks, do you pay attention to the information on the packaging?".

Rys. 4. Zestawienie wyników odpowiedzi dotyczących pytania: „Czy kupując przekąski z suszonych owoców zwraca Pan/Pani uwagę na informacje zawarte na opakowaniu?".

Source: The own study

Źródło: Opracowanie własne

A large number of people, 21%, strongly agree with the statement that dried fruit snacks are appropriate for maintaining health (Fig. 5), 44% of respondents rather agree, and 21% of respondents are not sure what the health and safety of dried fruit snacks, while quite a few people (around 6%) disagree or strongly disagree (around 6%) with this view.

Assessing consumers' knowledge of the impact of fruit drying on calorific value and sugar content (Fig. 6a), a significant number, 52%, showed that dried fruit contained more calories and sugar compared to fresh fruit, 27% found that drying fruit does not significantly affect the content of nutrients and vitamins and therefore their composition is similar to that of fresh fruit. A significant number of people indicated that dried fruit has less calories and sugar compared to fresh fruit. To test the understanding of the meaning of drying and to compare the calorific value of fresh and dried fruit, a short task was included in the questionnaire (Fig. 6b). The idea was to indicate in which case the same portion (1 cup) of pitted apricot fruit, fresh or dried, contains more calories. The vast majority of respondents indicated dried fruit as the more calorific and richer in sugar. Unfortunately, among the respondents who selected fresh apricots, about 50% believe that the drying process reduces the nutritional and caloric value of these fruits. Fresh fruit contains 85-95% water, which makes it relatively low in

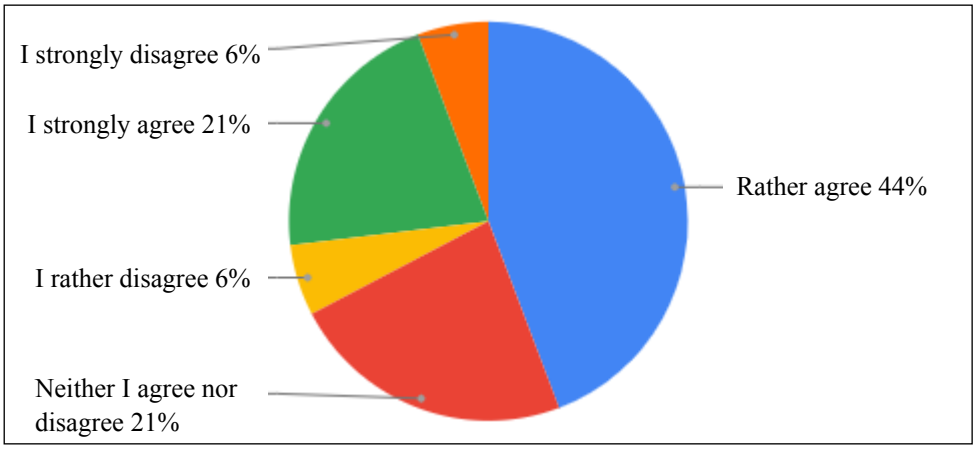


Fig. 5. List of respondents' answers to the question: "To what extent do you think that such dried fruit snacks are "healthy" and safe for the human body?".
Rys. 5. Zestawienie wyników odpowiedzi dotyczących pytania: „W jakim stopniu uważa Pan/Pani, że takie przekąski z suszonych owoców są „zdrowe" i bezpieczne dla organizmu człowieka?".
Source: The own study
Źródło: Opracowanie własne

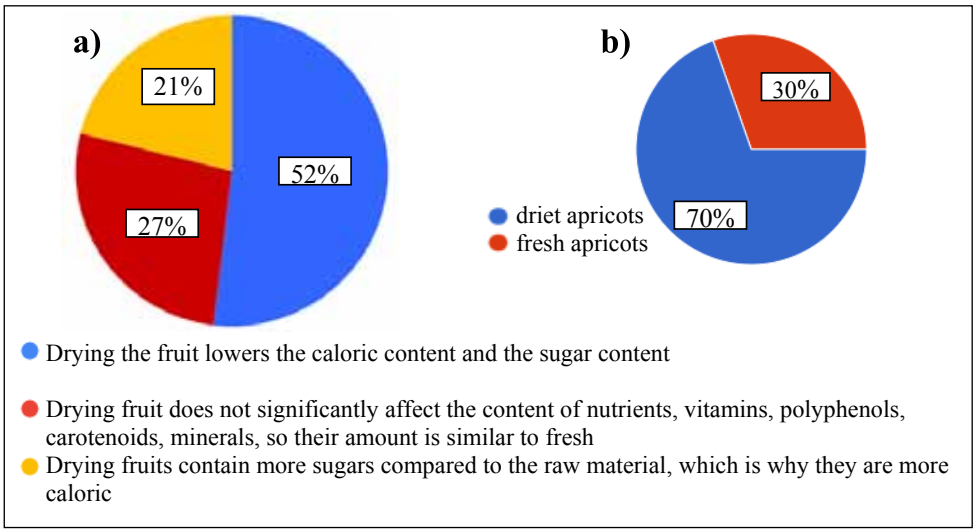


Fig. 6. List of respondents' answers regarding: a) the impact of fruit drying on its calorific value and sugar content, and b) indications which fruit from fresh and dried apricots (the same portions, 1 cup) are more caloric.
Rys. 6. Zestawienie odpowiedzi ankietowanych odnośnie a) wpływu suszenia owoców na ich kaloryczność i zawartość cukru oraz b) wskazania, które owoce spośród moreli świeżych i suszonych (taka sama porcja, 1 szklanka), są bardziej kaloryczne.
Source: The own study
Źródło: Opracowanie własne

calories. According to the tabular data [11], the caloric value of 100 g of fresh apricots is about 48 kcal, while there is much less water in dried apricots, and the caloric value increases to about 240 kcal. Fruit drying significantly increases the content of many ingredients, especially sugars [17]. Currently, various methods of drying fruits and vegetables are used in the food industry, but convection drying is probably still the dominant one. Each of the methods has a more or less destructive effect on the sensory characteristics and quality of the dried material. As has been stated many times, obtaining high-quality dried material requires the selection of an appropriate method and conditions of drying [9]. Drying methods using reduced pressure are particularly noteworthy, as they allow for effective drying at a temperature lower than at atmospheric pressure. Freeze drying, due to the long process time, is considered a method generating high costs, but the products obtained by this method are especially valued, mainly due to the significant preservation of natural food ingredients [14]. It is possible under appropriate process conditions. By using the elevated temperature, the process time can be reduced, but the quality of such droughts can be degraded. Many producers use hybrid drying, assisted by microwaves. This method, due to the much shorter drying time, compared to other methods, affects energy savings and high product quality, comparable to freeze-drying. The combination of reduced pressure and the effect of microwaves increases the drying efficiency and the possibility of producing attractive droughts and requires a lower energy demand [1, 2, 14].

When assessing whether the respondents are able to accept fruit and vegetable snacks of a different color (Fig. 7a) or taste than the raw material (Fig. 7b), the majority of respondents (55–60%) answered yes, approximately 19% of the respondents did not she was sure, while 21–26% expressed the opinion that they did not like it. Snacks, e.g. pre-enriched in juice (juice concentrate), have appeared on the Polish market. In this way, it is possible to advantageously modify the taste and aroma of red beet or carrot chips or to impart new characteristics, e.g. red apple chips, which have been obtained by pre-concentrating chokeberry or red beet juice.

Initial osmotic dehydration in fruit juices or concentrates in combination with innovative drying methods allows for to elimination of color changes and even enrichment with biocomponents (natural antioxidants, organic acids, vitamins, minerals, and others) and thus increasing the attractiveness of the obtained dried products [13].

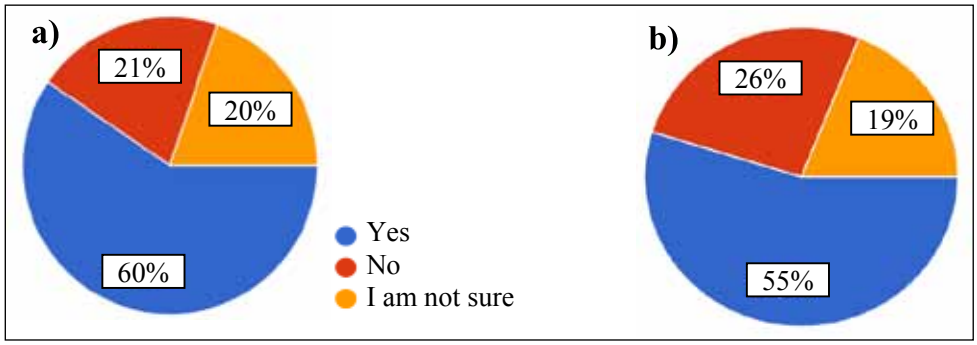


Fig. 7. List of respondents' answers to the question regarding: a) the acceptance of fruit or vegetable snacks with a color other than the raw material, b) with a taste other than the raw material.

Rys. 7. Zestawienie odpowiedzi ankietowanych na pytanie dotyczące: a) akceptacji przekąsek owocowych lub warzywnych o innej barwie, niż surowiec, b) o innym smaku, niż surowiec.

Source: The own study

Źródło: Opracowanie własne

CONCLUSIONS

When assessing the availability of dried fruit on the Polish market, it can be concluded that this market is gradually developing. Large-format stores (hypermarkets) offer a much wider range of such products, compared to smaller stores, the so-called housing estates. Online stores have a wide range of dried fruit, but stores are strictly focused on selling the so-called "Healthy" or "bio" products. Dried fruits are often sold in small packages (a portion to be eaten), in trays, or in tubes.

There are many producers of fruit and vegetable snacks on the market, some companies offer a large variety of this type of assortment. It can be said that these are brands with traditions, observing the needs and preferences of consumers, which is why they introduce more and more attractive snacks.

People taking part in the survey, mainly women and people aged 19-30, are consumers who are aware of the quality of the products they buy. About 55% of respondents showed that they read the product label before buying. Over 65% (some of whom chose the answer "I rather agree") know about the health-promoting properties of dried fruit and vegetables. They are also knowledgeable (about 52%) about the increased caloric content and sugar content of dried snacks, especially fruit, compared to fresh snacks. They prefer sweet snacks (about 62%), and more often eat dried fruit than vegetables, usually once a month or several times a week. Their favorite foods are apples, apricots, and pears. When asked if they would be interested in fruit snacks with a different taste and color than the raw material, more than half of the respondents answered in the affirmative. Fewer people (19%) admitted that they would not be interested in such a product.

WNIOSKI

Oceniając dostępność suszonych owoców na polskim rynku można stwierdzić, że rynek ten sukcesywnie się rozwija. Sklepy wielkopowierzchniowe (hipermarkety) oferują znacznie większy zakres takich produktów, w porównaniu z mniejszymi sklepami tzw. osiedlowymi. Sklepy internetowe mają bogaty asortyment suszonych owoców, ale dominują sklepy stricte ukierunkowane na sprzedaż tzw. „zdrowych" lub „bio" produktów. Suszone owoce często sprzedawane są w małych opakowaniach (porcja do zjedzenia), na tackach lub w tubach.

Na rynku występuje wielu producentów przekąsek z owoców i warzyw, niektóre firmy oferują dużą różnoroność tego typu asortymentu. Można stwierdzić, że są to marki z tradycjami, obserwujące potrzeby i preferencje konsumentów, dlatego wprowadzają coraz bardziej atrakcyjne przekąski.

Osoby biorące udział w ankiecie, głównie kobiety i osoby w wieku 19-30 lat, to konsumenci świadomi jakości kupowanych produktów. Około 55% respondentów wykazało, że przed zakupem czyta etykietę produktu. Powyżej 65% (w tym niektórzy wybrali odpowiedź „raczej się zgadzam"), wie o prozdrowotnych właściwości suszonych owoców i warzyw. Posiadają także wiedzę (około 52%) na temat zwiększonej kaloryczności i zawartości cukru suszonych przekąsek, zwłaszcza z owoców, w porównaniu do świeżych. Preferują przekąski słodkie (około 62%), częściej sięgają po suszone owoce, niż warzywa, przeważnie raz w miesiącu lub kilka razy w tygodniu. Najchętniej lubią spożywać jabłka, morele i gruszki. Na pytanie, czy byliby zainteresowani przekąskami owocowymi o innym smaku i barwie, niż surowiec, ponad połowa ankietowanych odpowiedziała twierdząco. Mniej osób (19%) przyznała, że nie byłaby zainteresowana takim produktem.

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Dr inż. Elżbieta WIERZBICKA
Inż. Julia MOMOT
Department of Human Nutrition, Institute of Human Nutrition Sciences
Warsaw University of Life Sciences (SGGW-WULS), Poland
Katedra Żywienia Człowieka, Instytut Nauk o Żywieniu Człowieka
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Ocena spożycia kofeiny z żywności i napojów w grupie młodych kobiet®

Key words: caffeine; caffeine intake, assessment, coffee, caffeine-containing products, women.

Caffeine is a purine-like alkaloid, a widely consumed psychostimulant, found in many plant species of which coffee beans, tea leaves, guarana, and cocoa beans are the most well-known. Furthermore, caffeine is an additive used in the food and beverage industry, it occurs in cola-type beverages and formulated caffeinated beverages or energy drinks, and in some dietary supplements. Due to the increasingly available offering of caffeine-containing products on the market, it is necessary to monitor the amount of caffeine consumed in the context of safety concerns for young women. The aim of this study were 1) to assess caffeine intake in relation to the dose considered by the EFSA as safe for adults in the general healthy population, and 2) to identify the main sources to caffeine intake among young women in Poland. The study was conducted from March to April 2021 in a group of 152 Polish young women aged 18 to 30 years (23.3±5.6). The study was carried out using the CAWI technique with the use of a 20-item food-frequency questionnaire to assess the frequency of consuming caffeine-containing products. The mean daily caffeine intake from all sources was 232 mg (95th percentile: 549 mg), which based on body weight (bw) was 2.88 mg/kg bw/day (P95: 7.62 mg/kg bw). The assessment of caffeine intake showed that in the studied group of women there is a risk of consuming excessive amounts of caffeine. In approx. 19% of women the dose of 5.7 mg/kg bw per day was exceeded, significantly more often in women aged 18-24 than in women aged 25–30 (23% vs 15%; p=0.036). In about 19% of women the daily intake was high (≥400 mg), in half of women (about 51%) it was moderate (200-400 mg), and in about 30% - it was low (<200 mg). Major contributors to caffeine intake were coffee (39%) and tea (34%), a smaller share included energy drinks and cola-type beverages and (12% and 9%, respectively). Approx. 20% of young women, whose caffeine consumption exceeded the safe level of caffeine intake, should limit the consumption of products which are the main sources of caffeine in their diet. In order to improve and shape the correct eating habits of young women, it is necessary to undertake educational activities aimed at the appropriate food choices of the assortment and the control over the amount of consumed caffeine-containing beverages.

Słowa kluczowe: kofeina, spożycie kofeiny, ocena, kawa, produkty zawierające kofeinę, kobiety.

Kofeina jest purynowym alkaloidem wywołującym określone efekty fizjologiczne, występującym w wielu gatunkach roślin, w tym w ziarnie kawy, liściach herbaty, guaranie i ziarnach kakaowca, także jest dodawana do napojów energetyzujących, napojów typu cola i jest składnikiem niektórych suplementów diety i środków farmaceutycznych. Ze względu na wzrastający trend rynkowej oferty produktów spożywczych zawierających kofeinę konieczne jest monitorowanie wielkości jej spożycia. Celem badania była ocena spożycia kofeiny w odniesieniu do dawki uznanej przez EFSA za bezpieczną dla ogólnej populacji oraz określenie produktów i napojów będących głównymi źródłami kofeiny w diecie młodych kobiet w Polsce. Badanie przeprowadzono od marca do kwietnia 2021 r. w grupie 152 młodych kobiet w wieku od 18 do 30 lat (23,3±5,6). Zastosowano technikę CAWI z wykorzystaniem 20-punktowego kwestionariusza częstotliwości spożycia produktów zawierających kofeinę. Wykazano, że średnie dzienne spożycie kofeiny wyniosło 232 mg (95-percentyl: 549 mg), co w przeliczeniu na masę ciała stanowiło 2,88 mg/kg mc. (P95: 7,62 mg/kg mc.). Stwierdzono, iż w badanej grupie młodych kobiet istnieje realne zagrożenie spożycia nadmiernej ilości kofeiny. U ok. 19 osób odnotowano przekroczenie dawki 5,7 mg/kg mc, istotnie częściej u kobiet w wieku 18-25 lat niż w wieku 25–30 lat (23% vs 15%; p=0,036). W przypadku ok. 19% osób spożycie kofeiny było duże (≥400 mg), u połowy osób (ok. 51%) na poziomie umiarkowanym (200-400 mg), a w przypadku ok. 30% - małe (<200 mg/dzień). Głównymi źródłami kofeiny w diecie młodych kobiet były kawa (39%) i herbata (34%), mniejszy udział stanowiły napoje energetyzujące (12%) oraz napoje typu cola (9%). Podsumowując, w przypadku ok. 20% badanych kobiet, u których stwierdzono przekroczenie bezpiecznej dawki, zalecane jest ograniczenie spożycia produktów będących głównymi źródłami kofeiny. Dla poprawy i kształtowania prawidłowych zwyczajów żywieniowych młodych kobiet konieczne są działania edukacyjne mające na celu zwrócenie uwagi na odpowiedni dobór asortymentu i ilości spożywanych napojów.

Corresponding author – Adres do korespondencji: Elżbieta Wierzbicka, Department of Human Nutrition, Institute of Human Nutrition Sciences, Warsaw University of Life Sciences (SGGW-WULS), 159c Nowoursynowska Street, 02-776 Warsaw, Poland, e-mail: elzbieta_wierzbicka@sggw.edu.pl

INTRODUCTION

Caffeine (1, 3, 7-trimethylxanthine) is a purine alkaloid found naturally in coffee infusions (filter coffee, espresso, instant coffee, and vending machines) and tea (loose leaves, bags, instant tea, and vending machines), which are widely consumed and constitute a part of everyday diet, as well as are consumed with products containing cocoa beans, extracts of guarana seeds. It is also consumed as a flavoring ingredient in a variety of beverages (e.g. energy drinks and cola-type drinks) [1, 7, 8, 31, 33]. Due to the broad market offer and availability, it is estimated that these processed products are consumed by population of all ages, including the majority of women [1, 5, 7, 10, 20, 27, 31]. As a result of the increased market offer, caffeine intake has increased in young women in many countries over the last decades [2, 8, 9, 10, 11, 16, 17, 18, 19, 20, 22, 27, 29, 32].

Caffeine induces many different physiological effects in health with a potentially positive impact on health when consumed in moderation and a negative impact at high dose, and the impact depends, among others, on the consumed dose, age, physiological condition and individual caffeine sensitivity and tolerance [1, 3, 4, 6, 7, 12, 21, 25, 33]. Short-term effects of caffeine on health are well known, including stimulation of the central nervous system with the effects on psychomotor and cognitive performance [1, 4, 13, 21, 31, 34, 35]. By stimulating the central nervous system, among others, it impacts the processes of sleep and wakefulness, it improves concentration and reduces the feeling of sleepiness. In case of higher doses, it can have a negative impact on sleep in a dose-dependent manner if consumed late in the day [3, 7, 21, 28]. Moreover, it stimulates the motor zone of the cerebral cortex, may cause psychomotor agitation, irritability, anxiety and fear, insomnia, as well as increased diuresis and intensified dyspeptic symptoms [4, 7, 13, 21, 24, 31, 34, 35]. Longer-term effects of caffeine consumption on health are more debated [6, 13]. A meta-analysis of randomized controlled study and umbrella review indicated that caffeine may increase systolic blood pressure after several weeks of moderate to high caffeine intake [6, 12, 25].

Some research results indicate that caffeine increases the concentration of cholesterol and homocysteine in the blood [15], and by increasing arterial wall stiffness, consequently causing hypertension, contributes to an increased risk of ischemic heart disease. In some individuals, it causes, among others, dilatation of coronary vessels and endothelial dysfunction, and it may lead to arrhythmias [4, 6, 12, 13, 15, 21, 33]. Recent studies have found associations between coffee consumption and the risk of developing cardiovascular diseases, and many have found that there **is no association** between coffee consumption and an increased risk of cardiovascular disease [6, 12, 15, 25]. Moreover, while some studies indicate that energy drinks have proaggregatory affects, which may be associated with an elevated risk of thrombosis, others indicate that coffee in fact reduces platelet activation, which may be beneficial for prophylaxis of thrombosis, and modify the progression of cardiovascular diseases [23]. On the other hand regular moderate caffeine consumption has beneficial effects for health such as a reduced risk of several types of cancer, as well as cardiovascular, metabolic conditions, and possibly decreases the risk of cognitive disorders [1, 12].

In this context, the European Food Safety Authority (EFSA) [8] and other authors [3, 4, 13, 21, 34] have set population recommendations for caffeine intake. For the general healthy population of adults, except children, adolescents and pregnant women, the dose of caffeine without adverse health effects is less than 400 mg per day (about 5.7 mg/kg bw per day). Caffeine-containing products are easily available on the market [1, 5, 7, 8, 10, 20, 27, 32.], their excessive consumption may lead to exceeding the safe level, therefore it is reasonable to assess the consumption of caffeine from all sources.

The purpose of this study was to assess of caffeine intake in a group of Polish young women in relation to the dose considered by the EFSA as safe for adults in the general healthy population, and to identify the main sources to caffeine intake.

MATERIAL AND METHODS

Participants and data collection

The study group consisted of 152 Polish women aged 18–30 years old who correctly completed the consumption questionnaire using the Computer Assisted Web Interview (CAWI) method. A descriptive cross-sectional study was performed in March-April 2021.

Participants completed, online and in a voluntary and completely anonymous way, a survey designed using the Google Forms tool. For this study, pregnant or breastfeeding women were excluded. All women were informed of the purpose of the study. Consent to participate in the study was given by agreeing to complete the survey. The protocol was in accordance with the Declaration of Helsinki for research of involving human participants and was approved by the local Ethics Committee.

Quantitative data on the consumption of caffeine-containing products, as well as products that may be a source of caffeine, was collected using a self-reported 20-item food-frequency questionnaire, with the verification of consumption data by describing the size of the consumed portion of products and drinks. The frequency intake of common products containing caffeine was ascertained using questions with daily, weekly or monthly frequency options provided.

Calculation of daily caffeine intake

For each person, the average consumption of beverages prepared from ground roasted coffee beans, instant coffee extracts and other coffee-based beverages, tea (black, white and green), mate, as well as the consumption of coffee-flavored beverages (cola-based soft drinks, iced teas, formulated caffeinated beverages or energy drinks) and cocoa products (chocolate and chocolate-based confectionary and other cocoa products) was calculated. The use of caffeine-containing food supplements was also taken into account.

The source of data on the caffeine content in common caffeinated foods and beverages was the average caffeine concentrations determined in the Scientific Opinion published by EFSA on the safety of caffeine [8], and the caffeine level reported on the packaging labels, when present. The caffeine content in food supplements was adopted in accordance with the manufacturer's declaration.

Based on such data, for each person individually, the daily caffeine consumption (mg) was calculated and expressed as per kg body weight (mg/kg bw). The values of daily caffeine intake from food and beverages were compared with the dose considered by the EFSA [8] which does not give rise to safety concerns for the general healthy population, amounting up to 400 mg per day, which is approx. 5.7 mg/kg bw per day. Moreover, based on criteria used in other studies, daily caffeine intake was rated as low (<200 mg), moderate (200-400 mg) or high (> 400 mg) [3, 21].

Statistical Analysis

Statistical analysis of the obtained data was carried out using IBM SPSS Statistics 26.0 software. Descriptive analysis was used to report the frequencies and percentages of categorical variables, and the mean, standard deviation (±SD) and median (25, 75 and 95 percentiles) were reported for quantitative variables. The significance of differences for qualitative variables was assessed by the Pearson's chi-square test, and for quantitative variables by the Mann-Whitney U-test. All statistical tests stratified by age group. Statistical significance were accepted at a p-value below 0.05.

RESULTS

Characteristics of the study group

The age of women ranged between ages of 18 and 30 years, and the following age groups: 18–24 (n = 79); 25–30 (n = 73) amounted to 52% and 48% of the studied group, respectively. At the time of the research, the respondents were on average 23.3 ± 5.6 years old. Approximately 45% of people came from a large-city environment, approx. 1/3 from small-town and approx. 1/4 from rural areas. A significant proportion of the women (65%) had higher education. In the older group (aged 25–30) there was a significantly higher percentage of people with higher education compared to the younger age group (aged 18–24), where those who completed secondary education or undergoing studies constituted the highest percentage.

Daily caffeine intake

Table 1 presents the daily intake of caffeine in the entire studied group of women and in individual age groups. Overall, the caffeine consumption for all women was 232 (±108) mg/day with a P95 estimated at 549 mg/day. Mean caffeine intake was significantly higher in the group aged 25-30 years than in under 25 years, with 257 (±113) and 230 (±108) mg/day and 95th percentile of 475 and 426 mg/day, respectively. However, when converted to mg/kg of body weight, women aged 18-24 years reported statistically significantly higher caffeine consumption than women aged 25-30 (3.57 vs. 2.34 mg/kg bw/day; p=0.028). The intake at the 95th percentile level was 426 mg/day and 7,62 mg/kg bw/day. On average, it was about 2.88 (±1.84) mg/kg bw/day with fluctuations in the range from 0.3 to almost 9 mg/kg bw/day.

Assessment of daily caffeine intake

Figure 1 describes the daily caffeine intake per kg of body weight, relative to the safe dose determined by the EFSA [5]. In this regard, the Figure also highlights that 15% and 23% of the Polish women consumed more than 400 mg/day or 5.7 mg/kg per day of caffeine, respectively. In both age groups, there were people whose caffeine intake was greater than 400 mg/day, which was higher than the dose considered safe for adults. This situation concerned 15% and 23% of the studied age groups, respectively. Overall, the percentage of participants with caffeine consumption >400 mg/day was significantly higher among women aged 20–30 (approx. 23%) than among women in the older age group (approx. 14%). In the case of approx. half of the women (49%) caffeine consumption was moderate (200–400 mg/day), and in the case of approx. 28% of the respondents it was low (<200 mg/day).

Table 1. Caffeine intake (mg/ day or mg/kg/day) in young women

Tabela 1. Spożycia kofeiny (mg/dzień lub mg/kg mc/dzień) w grupie młodych kobiet

□	Total N=152		18–24 years n=79		25–30 years n=73	
	mg/d	mg/kg mc/d	mg/d	mg/kg mc/d	mg/d	mg/kg mc/d
Mean±SD	232±108	2.88±1.84	230±108	2.34±1.79*	257±113	3.57±1,85*
Min-max	17.8 – 642	0.31 – 8,81	17.8 – 496	0.30 – 8.32	26.5 – 652	0.42 – 8.81
Percentiles 25	112	2.01	104	1,82	118	2.31
50	234	2.49	226	2,35	143	2.87
75	278	4.41	232	4,01	291	4,87
95	551	7.62	426	7,56	475	7,94

* Means differed significantly at p≤0.05; Mann–Whitney U test

* Średnie różnią się istotnie statystycznie przy p≤0,05; test U Manna-Whitneya

Source: Own study

Źródło: Opracowanie własne

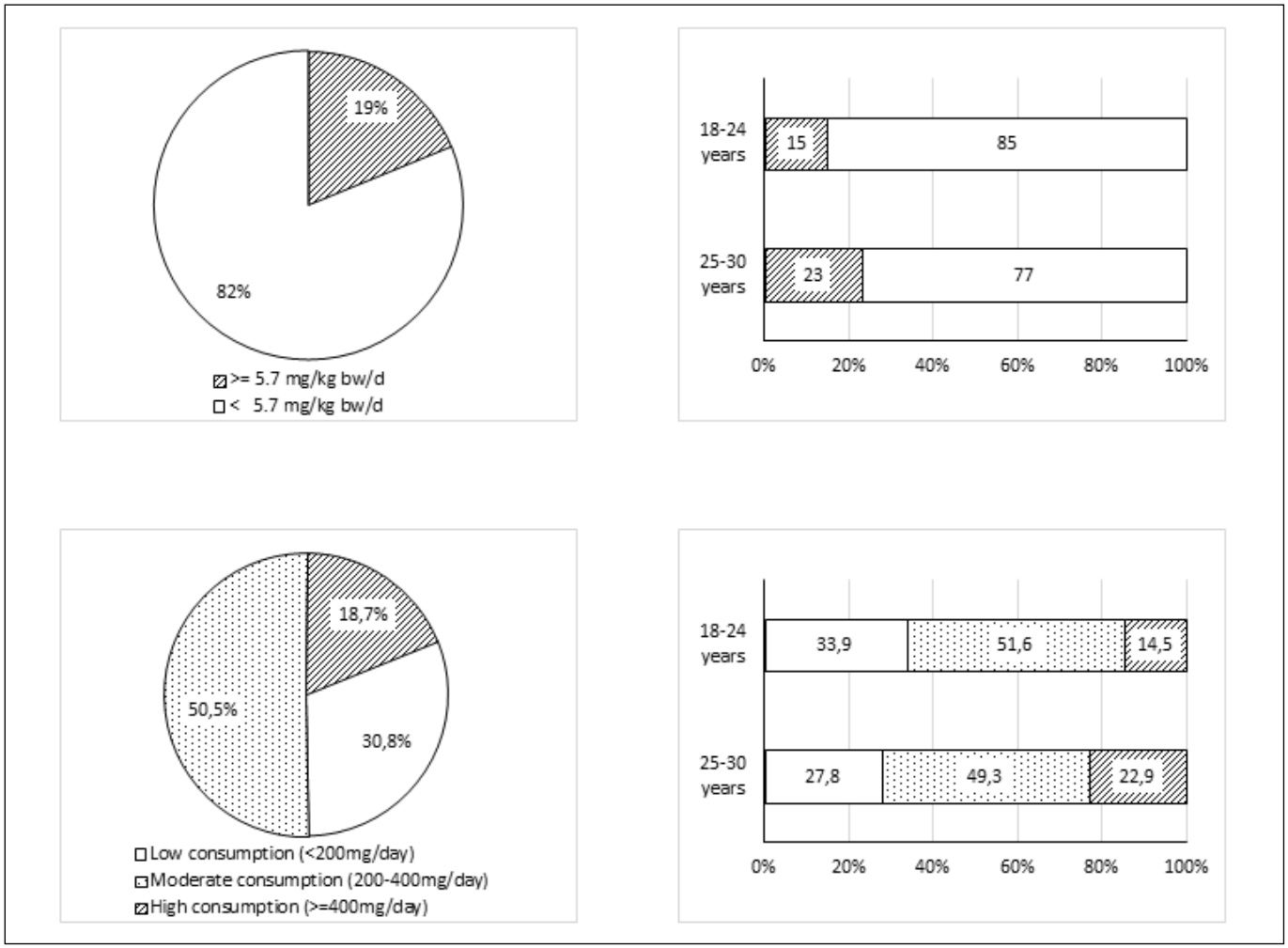

Fig. 1. Assessment of daily caffeine intake in young women.
Rys. 1. Ocena spożycia kofeiny w grupie młodych kobiet.
Values are expressed as means and represent the percentage (%) of the studied group of women exceeding the recommendation of 400 mg (or 5.7 mg/kg bw per day).

Wartości przedstawiono jako średni odsetek (%) badanej grupy kobiet przekraczających zalecenie 400 mg (lub 5,7 mg/kg mc na dobę).

Source: Own study

Źródło: Opracowanie własne

Main sources of daily caffeine intake

Figure 2 shows the main food group sources of caffeine and the contribution of each caffeine source to the total caffeine intake. Two significant main sources of caffeine in the diet of the women participating in the study in both age groups are coffee – 39% of the total intake, with a greater share of coffee beans (in the group aged 25–30) and tea – 34% of overall intake, with a significant predominance of black tea in both age groups.

The youngest age group differed from the rest with a higher share of consumption of other beverages (Fig. 2). The share of energy drinks and cola type drinks was significantly higher among women aged 18–25 than among women aged 25–30, 23% and 19%, respectively. Other products were of little significance in this respect. With regard to dietary intake of caffeine products, approx. 95% of the respondents consumed black tea and approx. 55% consumed green tea. Similarly, many people drank coffee, i.e. 75% – infusion of roasted (ground) coffee, and 58% of respondents - instant coffee. There were 63% and 52% of women drinking cola-type soft drinks and energy drinks, respectively. Cola-type beverages, energy drinks and instant coffee were more common among younger women, and ground coffee infusions among the older age group of women.

DISCUSSION

The quantitative consumption of coffee, tea and other products was the basis for estimating caffeine intake with the daily food ration of the women participating in the study in various age groups. Coffee is one of the most consumed beverages worldwide. [1, 7, 8, 20, 27, 32], also in Poland [5, 33]. The assessed diet was characterized by different levels of caffeine, i.e. in the range from 17.8 to 642 mg/day, which was 0.31 to 8.81 mg/bw (the median was 234 mg/day and 2.49 mg/kg bw/day, respectively). The obtained results were within the range of data obtained by other authors [9, 10, 16, 18, 19, 28, 29, 30].

When analysing caffeine consumption in particular age groups, the highest intake was recorded among women aged

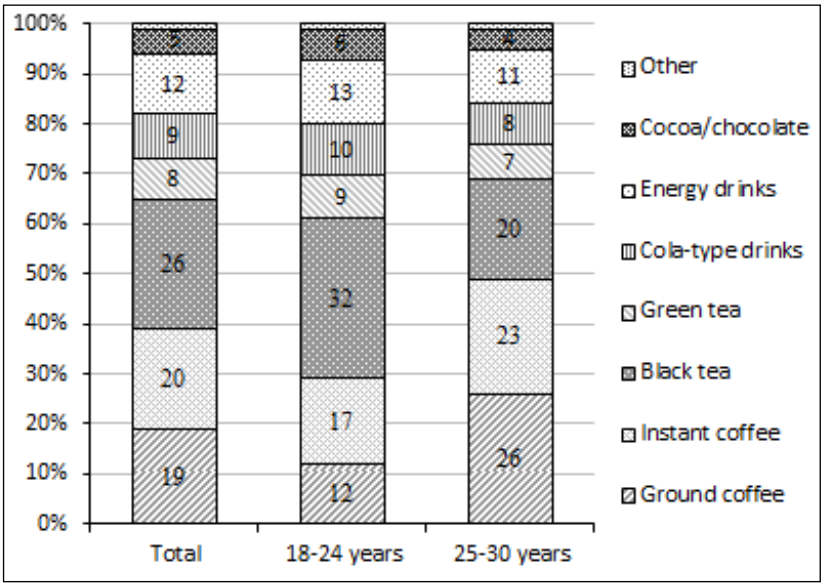

Fig. 2. Main food sources of daily caffeine intake in young women.
Rys. 2. Główne źródła kofeiny w diecie młodych kobiet.
Values are expressed as means and represent the percentage (%) of caffeine contribution in of each food group with respect to total daily caffeine intake.

Wartości przedstawiono jako średni odsetek (%) poszczególnych grup produktów w odniesieniu do całkowitego dziennego spożycia kofeiny w grupie młodych kobiet.

Source: Own study

Źródło: Opracowanie własne

25–30 (257 mg/day), and lower among the respondents aged 18–24 (230 mg/day). The evaluation of caffeine consumption showed that for 19% of women there is a real risk of consuming excessive amounts of caffeine above the dose of 5.7 mg/kg of body weight considered safe [5]. In addition, the consumption of caffeine was assessed at the level of the 95th percentile, which was 549 mg/day (7.41 mg/kg bw), which also indicates that the daily dose of caffeine safe for adults was exceeded, i.e. 400 mg/day and 5.7 mg/kg bw/day [8, 34, 21]. In such circumstances, one should strive to significantly reduce the consumption of products that contain significant amounts of caffeine. The presented situation seems to be concerning, as high caffeine consumption may cause side effects [4, 7, 13, 31, 34. 35], incl. psychomotor agitation, irritability, restlessness and anxiety, an increase in blood pressure and arrhythmias. Sleep disturbances or insomnia may also occur. The potential harmful effects may depend not only on the consumed dose, but also on individual sensitivity as well as the limited and lower ability to metabolize caffeine in the liver due to the insufficient amount and activity of the cytochrome P450 isoenzyme, i.e. CYP1A2. The risk of adverse health effects increases in particularly sensitive individuals, i.e. those with slow caffeine metabolism [1, 7, 8]. The EFSA considers up to 400 mg/day of habitual caffeine consumption to be safe for adults, and recommends that pregnant or breastfeeding women restrict their caffeine intake to less than 200 mg/day [8].

The assessment of caffeine consumption, paying attention to young women as a group at risk of higher intake, has been the subject of many national [2, 11, 19, 22] and foreign [3, 9, 10, 17, 27, 28, 32] studies. The estimated caffeine consumption in women in this study was similar to the results of other national studies [19] and the observed trends in caffeine consumption in other European countries [9, 16, 18, 24, 28, 29, 30]. Caffeine consumption reported in U.S. studies [10, 17, 20] was at a slightly lower level and was dependent on the nutritional habits of women, associated with a significant share of soft drinks. Particularly in terms of women's nutrition, it should be emphasized that the excessive use of stimulants is also indicated among many risk factors for osteoporosis. The adverse effect of caffeine may result from the higher consumption of soft drinks containing caffeine at the expense of consumption of dairy drinks, which constitute a good source of calcium. When calcium intake is sufficient, caffeine does not reduce bone mass [13, 21]. Given the popularity and prevalence of energy drinks, caffeine intake could reasonably be expected to increase quickly among young women. In studies of pregnant women, the substantial majority finding from observational studies and meta-analyses is that maternal caffeine consumption is associated with negative pregnancy outcomes, and pregnant women and women contemplating pregnancy are advised to avoid caffeine [14].

Determining the share of particular groups of products played an important role in the estimation of caffeine intake in the studied group of women. The main sources of caffeine in the daily food rations of the women participating in the study included tea, then coffee and flavoured carbonated drinks, including cola type drinks and energy drinks. Observations on the frequent consumption of carbonated drinks containing caffeine by younger age groups are also confirmed by other national studies [2, 11, 19, 22]. It should be emphasized that both European [16, 18, 27, 29, 30] and U.S. [10, 17, 20, 26] studies indicate that coffee, tea and flavoured soft drinks are the most significant sources of caffeine, and the greatest potential for reducing the amount of caffeine intake can be achieved by limiting coffee consumption (in adults) and consumption of energy drinks and cola type drinks (in younger population groups). In addition, the dietary sources of caffeine shift over the lifespan: adult women primarily consume coffee and tea, whereas adolescents and young women consume caffeinated beverages and chocolate (cacao), which contain much lower amounts of caffeine [7, 16, 27, 32].

Taking into account the dynamically developing market of energy drinks and sugar-rich beverages, many studies have found that their consumption is widespread [7, 11, 15, 16, 18, 19, 22, 26] and has been recognized as a significant factor of adverse health effects [3, 8, 21, 24, 26, 28, 31, 34, 35]. The amounts of caffeine consumed by women in these studies may facilitate the formulation of proposals for changes in diet, leading to a reduction in its consumption from the main sources and greater control of the level of caffeine consumption within a daily diet, considering the increasing consumption trend of healthy beverages.

CONCLUSIONS

Caffeine-containing products are easily available on the market, and the selection is large and constantly growing. Approx. 20% of the young women participating in the study, who were found to exceed the maximum intake of 400 mg/day recommended by EFSA, should limit the consumption of caffeine-containing products (coffee and tea), as well as flavoured caffeine-containing beverages (cola-type drinks, energy drinks) preferred especially by the younger age group.

In order to improve and shape the correct eating habits of young women, it is necessary to undertake educational activities aimed at the appropriate food choices of the assortment and the control over the amount of consumed caffeine-containing beverages.

PODSUMOWANIE

Produkty zawierające kofeinę są łatwo dostępne na rynku, a ich oferta jest duża i stale rosnąca. W przypadku ok. 20% badanych młodych kobiet, u których stwierdzono przekroczenie zalecanego przez EFSA maksymalnego spożycia do 400 mg/dzień (5,7 mg/kg mc/dzień) należy ograniczyć spożywanie produktów będących źródłami kofeiny (kawy i herbaty), a także preferowanych szczególnie przez młodszą grupę wiekową aromatyzowanych napojów bezalkoholowych (napoje typu cola, napoje energetyzujące).

W celu poprawy i kształtowania prawidłowych nawyków żywieniowych w badanej grupie młodych kobiet konieczne jest podejmowanie działań edukacyjnych mających na celu odpowiedni dobór asortymentu produktów i napojów oraz kontrolę ilości spożywanych napojów zawierających kofeinę.

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Dr hab. inż. Katarzyna SZWEDZIAK, Prof. PO[1]
Department of Biosystems Engineering and Chemical Processes
Opole University of Technology, Poland
Prof. Dr hab. Inż. Petr DOLEŻAL[2]
Department of Animal Nutrition and Forage Production (FA), Mendel University in Brno
Czech Republic
Mgr inż. Dominika KOTYSZ
mgr inż. Anna GUMENIUK

THE USE OF GLUTEN-FREE FLOURS FOR THE PRODUCTION OF GLUTEN FREE FOOD®

Zastosowanie mąk bezglutenowych do produkcji żywności bezglutenowej®

Key words: gluten-free flours, millet flour, buckwheat flour, quinoa flour, quality, food, food production, gluten-free diet.

The article analyzes selected quality parameters of millet, buckwheat and quinoa flour. In order to determine the quality indicators, the water content and titratable acidity were determined for each type of flour. The study showed that buckwheat flour has the characteristics most similar to that of wheat flour. Based on the organoleptic evaluation carried out among the respondents, it can be concluded that buckwheat flour products are pleasant to the taste and smell. Manufactured products made of gluten-free flours have a specific consistency, which is due to the inability to produce a gluten mesh.

Słowa kluczowe: mąki bezglutenowe, mąka jaglana, mąka gryczana, mąka z komosy ryżowej, jakość, żywność, produkcja żywności, dieta bezglutenowa.

W artykule dokonano analizy wybranych parametrów jakościowych mąki jaglanej, gryczanej i mąki z komosy ryżowej. W celu określenia wskaźników jakości przeprowadzono oznaczenie zawartości wody oraz kwasowości miareczkowej dla każdego rodzaju mąki. Badania wykazały, że mąka gryczana ma najbardziej zbliżoną charakterystykę do mąki pszennej. Na podstawie przeprowadzonej oceny organoleptycznej wśród ankietowanych, można stwierdzić że wyroby z mąki gryczanej są przyjemne w smaku oraz w zapachu. Wyprodukowane wyroby z mąk bezglutenowych charakteryzują się specyficzną konsystencją, co jest spowodowane niemożnością wytworzenia siatki glutenowej.

INTRODUCTION

A gluten-free diet consists in replacing traditional products made of cereals containing gluten proteins with their gluten-free counterparts, naturally gluten-free or where gluten has been eliminated in a technological manner. Today there are tons of gluten-free products available to replace confectionery, flour and wheat bread. The high availability of these products and their diversity still generate the problem of balancing such a gluten-free diet and the costs incurred [9, 11]. A gluten-free diet has become very popular because it contributes to weight loss. However, the unjustified exclusion of gluten from one's diet causes negative changes in the human body, including a deficiency of iron, minerals and B vitamins [7, 9]. The exclusion of gluten from the diet has become very popular, but it is seen more as a trend than the diet supporting the treatment of disease. The elimination of gluten proteins from the diet without a reason leads to a deficiency of B vitamins, iron and valuable minerals [9].

Nevertheless, the best method for treating celiac disease is to maintain a gluten-free diet for life [3, 4, 6, 11]. According to legal regulations, gluten-free products must have special labels, such as crossed ear, the content of gluten proteins cannot exceed 20 mg per 1 kg of the product. Wheat grains can be subjected to complex technological processes to remove gluten proteins, but it is impossible to get rid of it 100%, therefore some foodstuffs obtained by this method may contain minimal gluten protein residues [7, 8, 9, 11].

One of the gluten-free cereals is buckwheat, distinguished by a high content of resistant starch, which allows for combining dietary fibers and probiotics. It improves the condition and efficiency of the large intestine, and lowers the level of glucose in the blood. Thanks to the insoluble substances, the gallbladder is cleansed. The risk of the formation of kidney stones is then reduced. The intestine is released and its walls are strengthened. Despite the improvement in appetite, a gradual reduction in excess weight begins, which is why buckwheat flour is also used in diarrhea. Buckwheat is considered as a very healthy and beneficial component of the diet [3, 4, 5, 6]. The starch contained in buckwheat flour has a white color and does not change color during thermal treatment [1, 2].

Adres do korespondencji:- Corresponding author: Katarzyna Szwedziak, Opole University of Technology, Faculty of Production Engineering and Logistics, Departament of Biosystem Engineering and Chemical Processes, ul. Mikołajczyka 5, 45-271 Opole, e-mail:k.szwedziak@po.edu.pl

Millet is also classified as a gluten-free cereal and is the starting material for the production of millet flour. It is enriched with minerals that are essential for our body, such as potassium, magnesium, iron or silica, which are rarely found in cereal preparations [10]. Millet grains contain vitamins B1, B6, B2, biotin and pantothenic acid. The parameter that distinguishes millet from among others is the ability to alkalize the human body. It also has a diuretic effect, strengthens the kidneys, and supports the functions of the stomach and pancreas. It prevents the growth of bacteria in the mouth. Products made from millet flour can be used in the diet of people suffering from thrush, also helps with diarrhea, diabetes and indigestion.

Quinoa is classified as the most nutritious grain used in food, with a rich chemical composition [12]. The protein found in Quinoa is often compared to that of cow‘s milk because it has similar nutritional values. The amount of lysine, methionine and cysteine is much greater than in other grains and legumes. It is also worth noting that it contains valuable oils containing beneficial fatty acids and vitamin E [12]. Its grains contain abundant amounts of minerals such as: magnesium, copper, phosphorus and manganese [13].

PURPOSE AND SCOPE OF WORK

The aim of this study was to evaluate the properties of selected quality parameters of millet flour, buckwheat flour and Quinoa flour used for the production of gluten-free food. The scope of the work included the determination of acidity and water content in individual flours. Additionally, pancakes recipes using gluten-free flours were developed, pancakes were produced, a research questionnaire was formulated and an organoleptic evaluation was performed. Based on the research, the results were analyzed and conclusions were drawn.

RESEARCH METHODOLOGY

Chemical and organoleptic tests were performed to determine the quality and suitability for consumers. The research material consisted of three types of flour: millet flour, buckwheat flour; quinoa flour. Water content and potential acidity were determined. Total humidity was determined using a balance dryer. 3 g of material was measured for individual flours and the drying process was carried out at 105° C, during 15 minutes.

In order to determine the acidity of individual flours, 5 g of flour were weighed out and transferred to a conical flask. 100 cm^3 of distilled water at 20° C were measured in a measuring cylinder. 10 cm^3 from a measuring cylinder were added to the sample and mixed thoroughly with a glass rod to break up any flour lumps. While stirring, the mixture was made up with the remainder of the distilled water. The samples were allowed to stand for 5 minutes, 3 drops of an alcoholic phenolphthalein solution was added and titrated with 0.1 M NaOH solution until a pink color appeared for about 1 minute.

Fig. 1. A sample millet flour before determination the water content.
Rys. 1. Próbka mąki jaglanej przed oznaczeniem zawartości wody.
Source: Own study
Źródło Opracowanie własne

Fig. 2. A sample of buckwheat flour before determining the water content.
Rys. 2. Próbka mąki gryczanej przed oznaczeniem zawartości wody.
Source: Own study
Źródło: Opracowanie własne

Fig. 3. A sample of quinoa flour before determining the water content.
Rys. 3. Próbka mąki quinoa przed oznaczeniem zawartości wody.
Source: Own study
Źródło: Opracowanie własne

Fig. 4. Determination of acidity of millet flour.
Rys. 4. Oznaczenie kwasowości mąki jaglanej.
Source: Own study
Źródło: Opracowanie własne

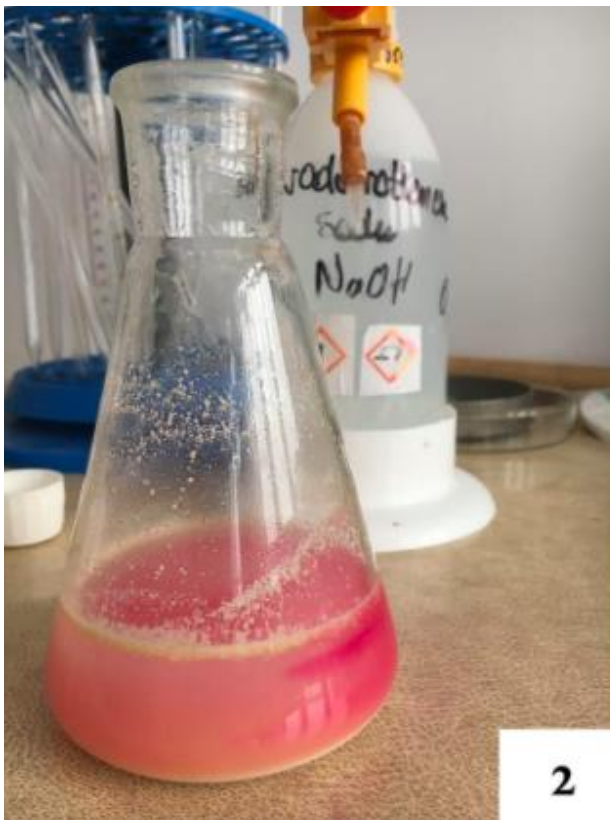

Fig. 5. Determination of the acidity of buckwheat flour.
Rys. 5. Oznaczenie kwasowości mąki gryczanej.
Source: Own study
Źródło: Opracowanie własne

Fig. 6. Determination of acidity of quinoa flour.
Rys. 6. Oznaczenie kwasowości w mące quinoa.
Source: Own study
Źródło: Opracowanie własne

The results of water content determination for individual flours were interpreted in accordance with the formula:

$$X = \frac{m1 - m2}{m1} \times 100\% \quad (1)$$

where: x – total humidity [%]
m1 – mass of the sample before drying [g]
m2 – mass of the sample after drying [g]

The interpretation of the acidity determination results for individual flours was performed in accordance with the formula:

$$X = 20 * a * n \quad (2)$$

where: a – volume of standard 0.1 M sodium hydroxide solution [cm³],
n – NaOH molarity,
X – flour acidity in degrees,
20 – acidity conversion factor in degrees

The degrees of acidity correspond to the number of cm³ of 0.1 M NaOH solution used to titrate the acids contained in 100 g of flour.

The organoleptic evaluation of millet, buckwheat and Quinoa flour was carried out in processed form. According to the recipe, pancakes were produced. Each batch of pancakes was made of the same amount of flour. The additional ingredients were: eggs, milk, baking powder, salt, honey, brown sugar, rapeseed oil. The following quality characteristics were assessed: texture, smell, color, external appearance and taste. The test was carried out in two stages: immediately after

Fig. 7. Dough consistency: 1 – millet flour dough; 2 – buckwheat dough; 3 – Quinoa flour dough.
Rys.7. Konsystencja ciasta: 1 – ciasto z mąki jaglanej; 2 – ciasto z mąki gryczanej; 3 – ciasto z mąki quinoa.
Source: Own study
Źródło: Opracowanie własne

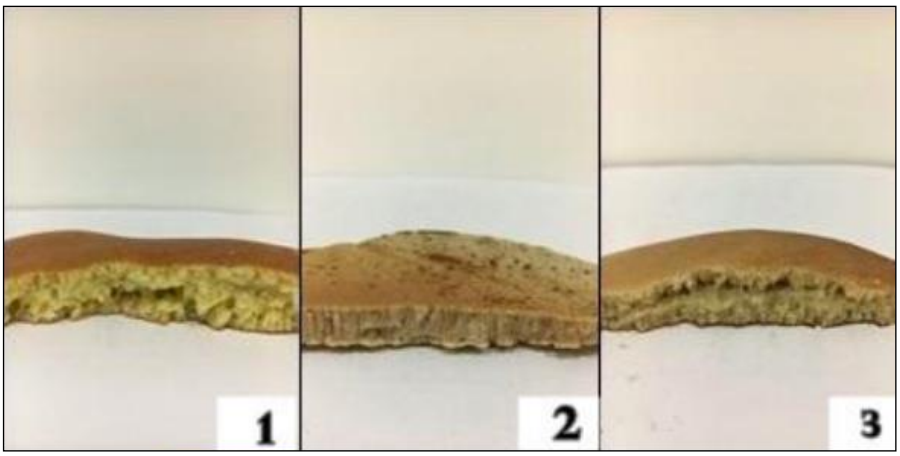

Fig. 8. Pancake texture in cross-section: 1 – made of millet flour; 2 – from buckwheat flour; 3 – with Quinoa flour.
Rys.8. Faktura naleśnikowa w przekroju: 1 – z mąki jaglanej; 2 – z mąki gryczanej; 3 – z mąki quinoa.
Source: Own study
Źródło: Opracowanie własne

preparation and after cooling. Selected features were assessed using the five-point method. The evaluation was made by 15 people, including 8 women and 7 men aged 20–30.

ANALYSIS AND DISCUSSION OF THE RESULTS

Based on the research, the obtained results were summarized and analyzed.

Water contents for millet, buckwheat and quinoa flour

Millet flour had the greatest ability to evaporate water, the moisture index of which was at the highest level. Buckwheat flour had similar parameters to millet flour. Quinoa flour was characterized by the lowest water evaporation capacity.

Titratable acidity of millet, buckwheat and quinoa flour

The titratable acidity is equal to the total concentration of acidic hydrogen atoms that are present in the test sample also in the form of hydronium ions H_3O^+, and both in undissociated form, where they are neutralized by reaction with bases. It is conditioned by the presence of organic acids, acidic salts, acid anhydrides and other chemical compounds. After the acidity determination of millet, buckwheat and Quinoa flour, you can notice a significant difference in the obtained results. Millet flour has the lowest acidity among the three tested samples because it meets the characteristics of basic substances. Its acidity was 0.4, while buckwheat flour showed the highest acidity between the three tested samples, which was 3.8, but compared to wholemeal flour, which contains more bran with higher acidity, and is 8, it has a much lower value. Sample 3 from Quinoa, as well as millet flour, is characterized by a weak acidity equal to 1, which proves the alkaline characteristics of the tested sample.

Organoleptic evaluation of millet, buckwheat and quinoa flour products

Features such as color, taste, smell, texture and external appearance were assessed organoleptically. The mean for each quality index was determined, and the results were summarized in the form of a graph.

Millet flour pancakes were characterized by a specific color. They were slightly sweet in taste, but their aroma was faint. Texture evaluation indicated dry, but external appearance was positive.

Pancakes prepared from buckwheat flour, according to the respondents, were distinguished by a very good taste, while the color was dark, uncharacteristic. The smell was intense but pleasant, peculiar to buckwheat. The texture was judged to be rubbery, but the external appearance was positively assessed by the testers.

Pancakes made of quinoa flour stood out among others because of their bitter taste and porous texture. They have an intense grain scent, a characteristic color and are positively assessed in terms of external appearance.

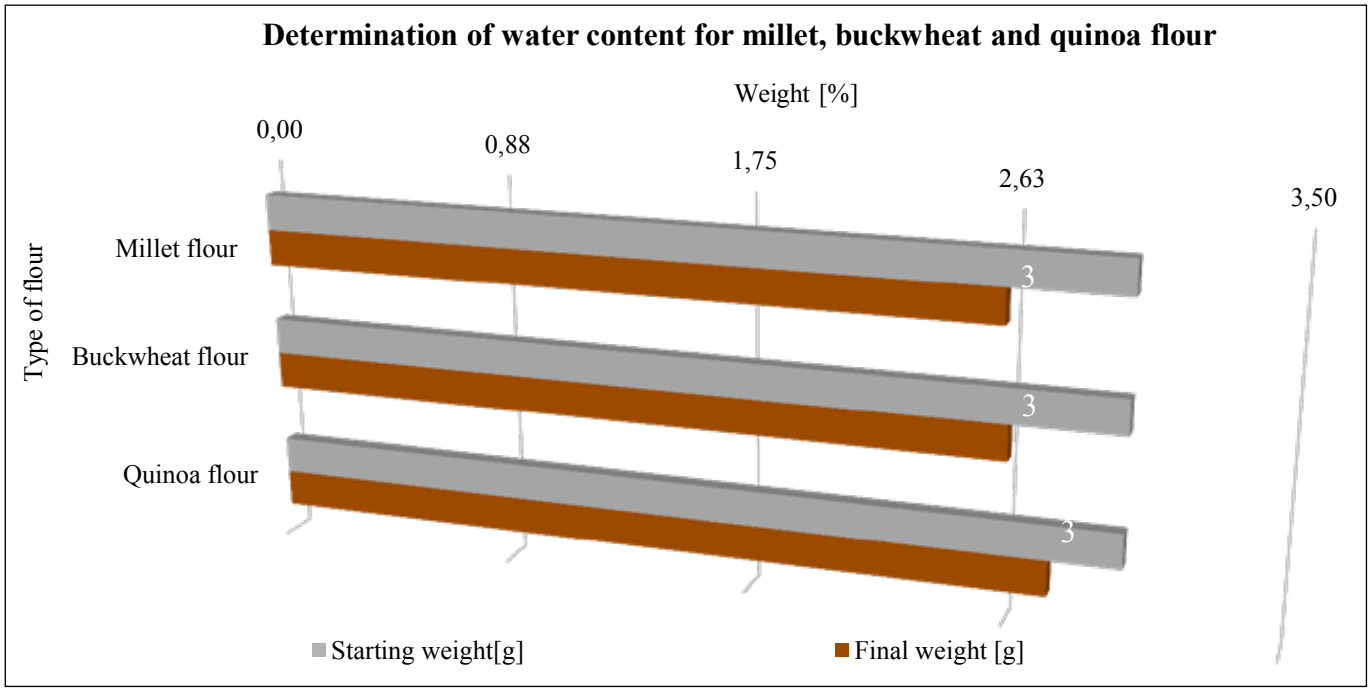

Fig. 9. Determination of water content for millet, buckwheat and quinoa flour.
Rys.9. Oznaczenie zawartości wody w mące z prosa, gryki i quinoi.
Source: Own study
Źródło: Opracowanie własne

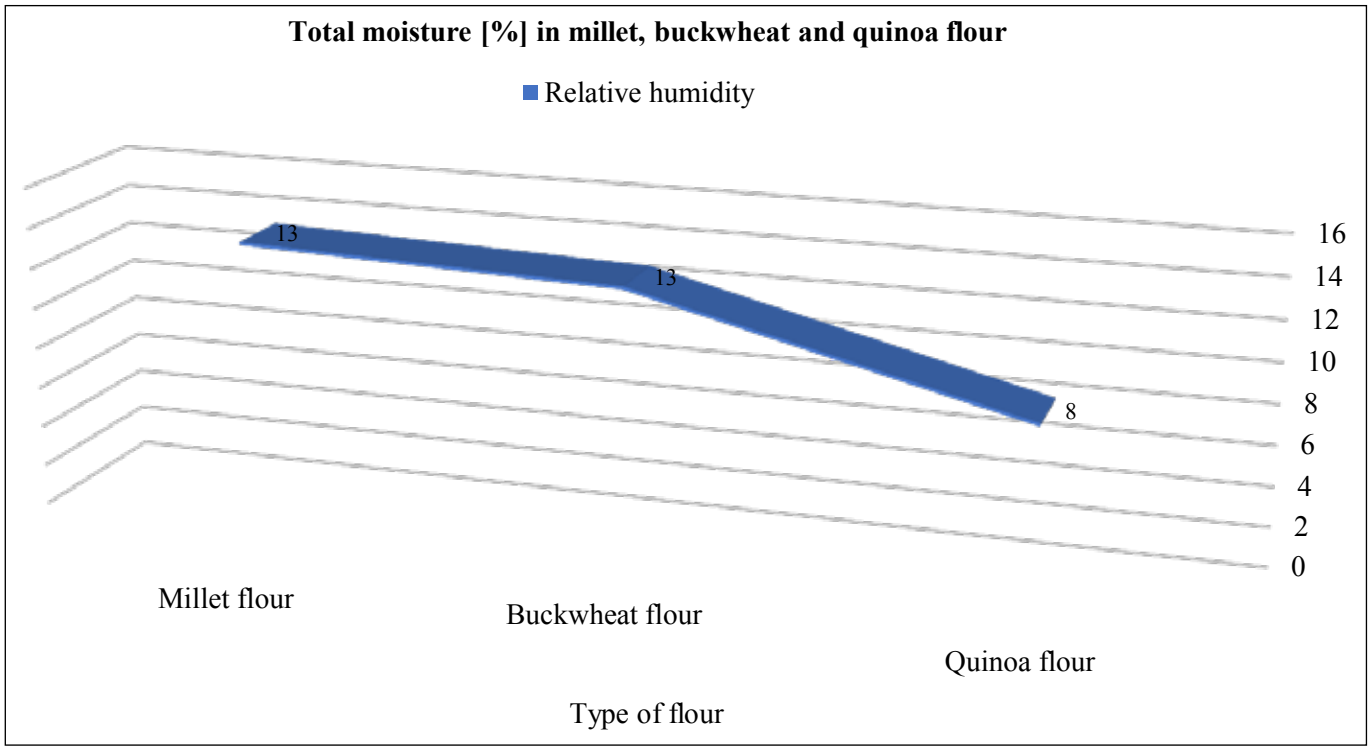

Fig. 10. Total moisture for millet, buckwheat and quinoa flour.
Rys. 10. Wilgotność całkowita w mące jaglanej, gryczanej i quinoa.
Source: Own study
Źródło: Opracowanie własne

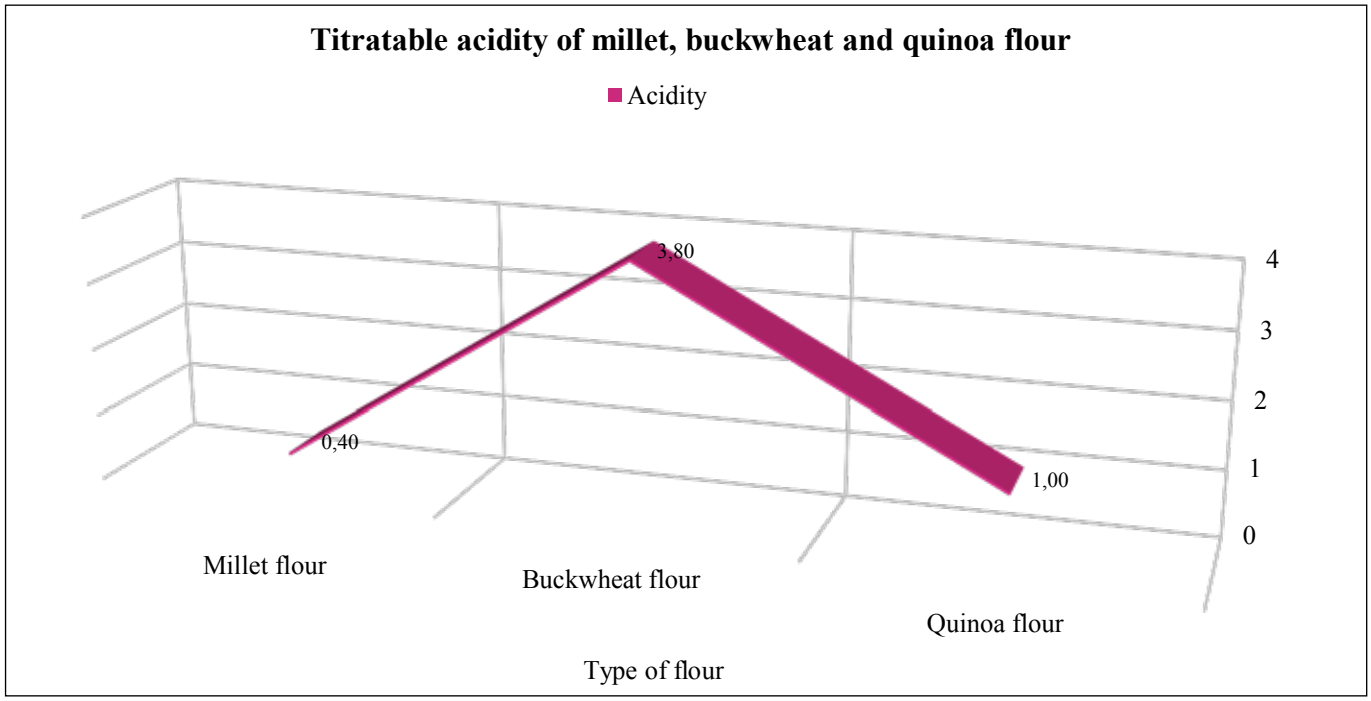

Fig. 11. Titratable acidity of millet, buckwheat and quinoa flour.
Rys. 11. Kwasowość mąki jaglanej, gryczanej i quinoa.
Source: Own study
Źródło: Opracowanie własne

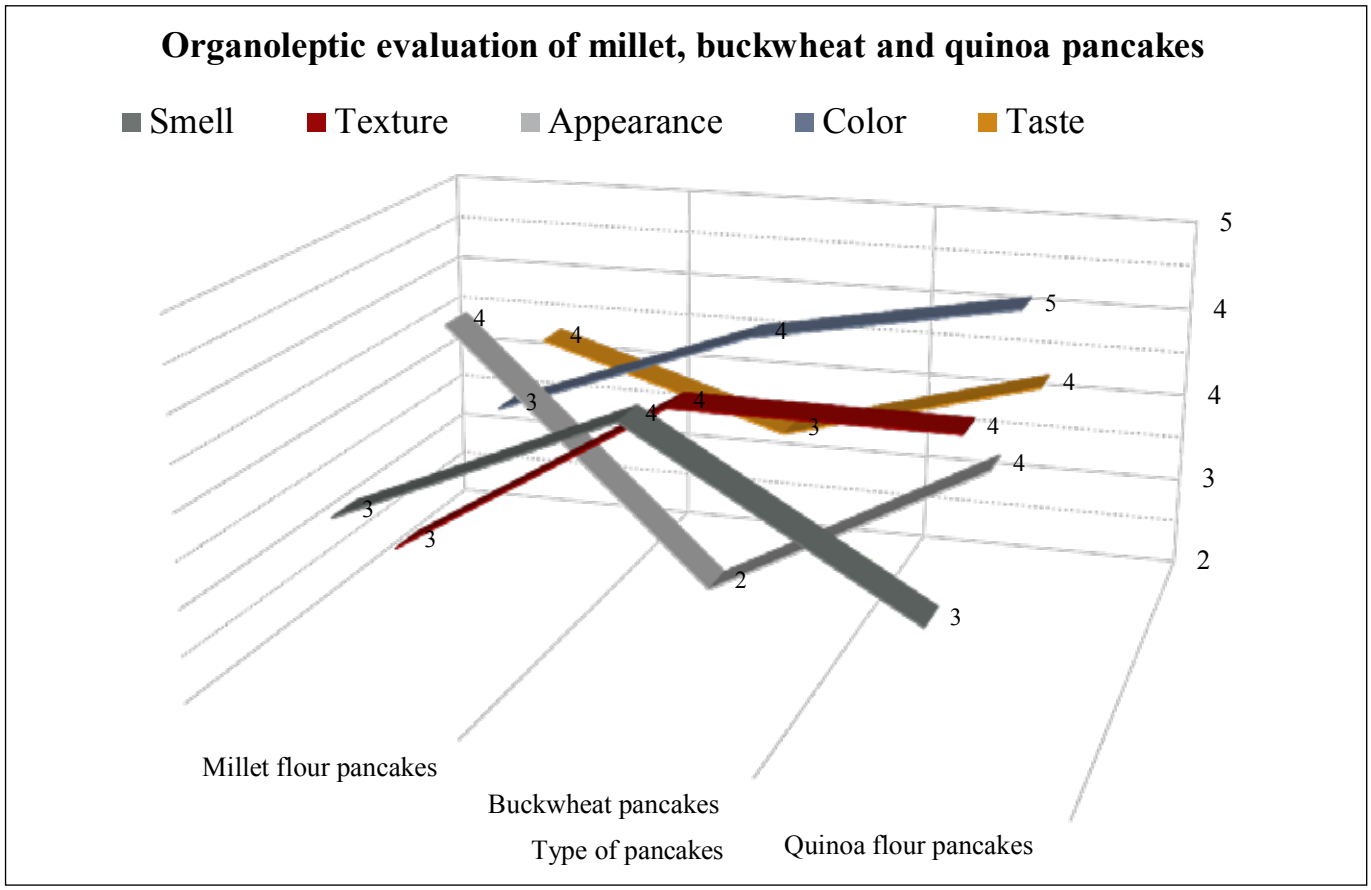

Fig. 12. Organoleptic evaluation of pancakes made of millet, buckwheat and quinoa flour.
Rys.12. Ocena organoleptyczna naleśników z mąki jaglanej, gryczanej i quinoa.
Source: Own study
Źródło: Opracowanie własne

CONCLUSIONS

Based on the conducted research, it can be concluded that:

1. Millet flour had the highest water content index.
2. All tested flours were alkaline.
3. In the organoleptic assessment, the products in the form of pancakes were best assessed when used in the production of millet flour.
4. The moisture of the flour has a significant influence on the texture of the dough.

WNIOSKI

Na podstawie przeprowadzonych badań można stwierdzić, że:

1. Najwyższym wskaźnikiem zawartości wody charakteryzowała się mąka jaglana.
2. Wszystkie testowane mąki miały odczyn zasadowy.
3. W ocenie organoleptycznej najlepiej oceniano produkty w postaci naleśników z mąki jaglanej.
4. Wilgotność mąki ma istotny wpływ na konsystencję ciasta.

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Mgr inż. Magdalena KARWACKA
Dr hab. inż. Sabina GALUS
Dr hab. inż. Monika JANOWICZ, prof. SGGW
Department of Food Engineering and Process Management, Institute of Food Sciences, Warsaw University of Life Science (SGGW-WULS), Warsaw, Poland
Katedra Inżynierii Żywności i Organizacji Produkcji, Instytut Nauk o Żywności
Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Polska

EFFECT OF STRUCTURE AND TEXTURE FORMING ADDITIVES ON PROPERTIES OF FREEZE-DRIED SNACKS – REVIEW®

Wpływ dodatku substancji kształtujących strukturę i teksturę na właściwości liofilizowanych przekąsek – przegląd®

Key words: freeze-dried snacks, hydrocolloids, fruit pomace, carrier agent, food properties.

The purpose of this paper was to review recent findings focused on the development of freeze-dried snacks with addition of hydrocolloids as carrier agents and evaluate the possibility of replacement of such additives with fruits pomace on the base of reports conducted on their application as additives modifying properties of various food products. The use of hydrocolloids allows to obtain freeze-dried gels characterised by porous and crispy structure that attracts consumers. These carrier agents increase glass transition temperature and reduce water adsorption ability of products, improving their stability and easing storage. On the other hand, fruit pomace managed as new foods ingredients affect functional properties of products too. There are findings proving that dried pomace powders affect quality of bread, confectionaries, yoghurt and meat products, principally enhancing their nutritional value and texture. Moreover, products fortified with fruit pomace are attractive and interesting for consumers, what improve their value even more. Dried fruit pomace powders has great potential for application in food industry, especially considering environmental point of view, therefore replacement of hydrocolloids in freeze-dried products seems to be promising subject for further research.

Słowa kluczowe: liofilizowane przekąski, hydrokoloidy, wytłoki owocowe, nośniki, modyfikacja właściwości żywności.

Celem pracy był przegląd najnowszych doniesień naukowych dotyczących opracowywania liofilizowanych przekąsek z dodatkiem hydrokoloidów jako nośników oraz dokonanie oceny możliwości zastąpienia tych składników wytłokami owocowymi na podstawie wyników otrzymanych w czasie badań prowadzonych na różnych produktach spożywczych wzbogaconych dodatkiem wytłoków. Dzięki zastosowaniu hydrokoloidów możliwe jest otrzymanie liofilizowanych żeli charakteryzujących się porowatą i chrupką strukturą, która jest atrakcyjna dla konsumentów. Te nośniki podwyższają także temperaturę przejścia szklistego produktów oraz obniżają zdolność pochłaniania wody z otoczenia, co poprawia stabilność i ułatwia przechowywanie. Zastosowanie wytłoków owocowych wpływa także na właściwości funkcjonalne żywności. Wykazano, że dodatek proszku z wytłoków kształtuje jakość produktów piekarsko-ciastkarskich, mlecznych oraz mięsnych, ze szczególnym uwzględnieniem wartości odżywczej i tekstury. Ponadto, produkty z dodatkiem wytłoków są atrakcyjne dla konsumentów i wzbudzają ich zainteresowanie. Proszki z suszonych wytłoków owocowych mają duży potencjał aplikacyjny w przemyśle spożywczym, szczególnie uwzględniając aspekt środowiskowy, dlatego też zastosowanie ich jako zamienników nośników hydrokoloidowych w produktach liofilizowanych jest obiecującym kierunkiem do dalszych badań.

INTRODUCTION

Fruits and vegetables are a natural source of nutrients and bioactive compounds a lot of which may be lost during processing. Because of high water content, extension of shelf life of fruits and vegetables is provided e.g. due to drying, which aims to reduce water content and activity, but also causes changes in products quality. Therefore, among many drying methods, freeze-drying was found to be the one ensuring the best quality of obtained products in terms of raw material characteristics preservation [4]. Recent research, focused on the development of healthy and attractive for consumers snacks, shows that producing of fruit and vegetable snacks due to freeze-drying requires the use of carrier agents that support structure, texture and functional properties creation [22]. That

Adres do korespondencji – Corresponding author: Magdalena Karwacka, Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Instytut Nauk o Żywności, Katedra Inżynierii Żywności i Organizacji Produkcji, ul. Nowoursynowska 159c, 02-776 Warszawa, e-mail: magdalena_karwacka@sggw.edu.pl

need results from low glass transition temperature of simple carbohydrates contained in aforementioned plant materials. Therefore, high molecular weight compounds (biopolymers), like hydrocolloids, maltodextrins, proteins and fibres, are applied to increase glass transition temperature that improves processing efficiency and, what is more important, products quality and stability [27,35]. Low glass transition temperature causes unwanted changes, such as stickiness, caking, structure collapse and phase transition, as a consequence of which products lose crispiness and became gummy, occurring even already at the time of freeze-drying or during storage [35]. The addition of carrier agents results in obtaining better quality and stability of products, but particular compounds used in this role affect characteristics of freeze-dried materials in the matter of mechanical, chemical and functional properties in their own way [13].

There were several research on the possibilities of using various biopolymers as additives modifying properties of freeze-dried snacks based on fruits, vegetables, pulps, juices and concentrates [8,9,14,35], but knowing freeze-drying is very time and energy consuming process, those products may not fit in the policy of food and agriculture industry sustainable development [20,39]. It is a fact that manufacturing of hydrocolloids, being compounds typically used as carrier agents, also is energy and resource demanding and such components usually are acquired using by-products as raw materials [17]. Combining that with recent findings about ability of such by-products, e.g. fruits pomace that are used as source for pectin extraction, to have positive influence on properties of food products they are applied in [24], it seems to be promising direction for further research to substitute traditional additives with new, more sustainable ones.

Therefore, the purpose of this review was to summarize recent findings focused on the development of freeze-dried snacks with addition of hydrocolloids as carrier agents. The second part was to evaluate the possibility of replacement of such additives with fruits pomace on the base of reports conducted on juice production by-products used as additives modifying various food products properties.

HYDROCOLLOIDS AS CARRIER AGENTS IN FREEZE-DRIED PRODUCTS BRIEF CHARACTERISTIC OF HYDROCOLLOIDS

Hydrocolloids are long chain carbohydrates and proteins the properties of which, including water absorption capability, strongly depend on their molecular structure and configuration [5,10,26] in association with external condition, e.g. pH, sugar content and ionic strength of the solution [8,10,14]. The use of hydrocolloids allows to recreate porous matrixes comparable to cellular tissue, but characterised by a set of designed and controlled properties [8]. Optimisation of gels with specific attributes may also be provided by blending various hydrocolloids, mutually influencing their behaviour. Due to synergism, quality of products obtained with biopolymers mixtures -are improved in comparison to features following the stand-alone application of particular

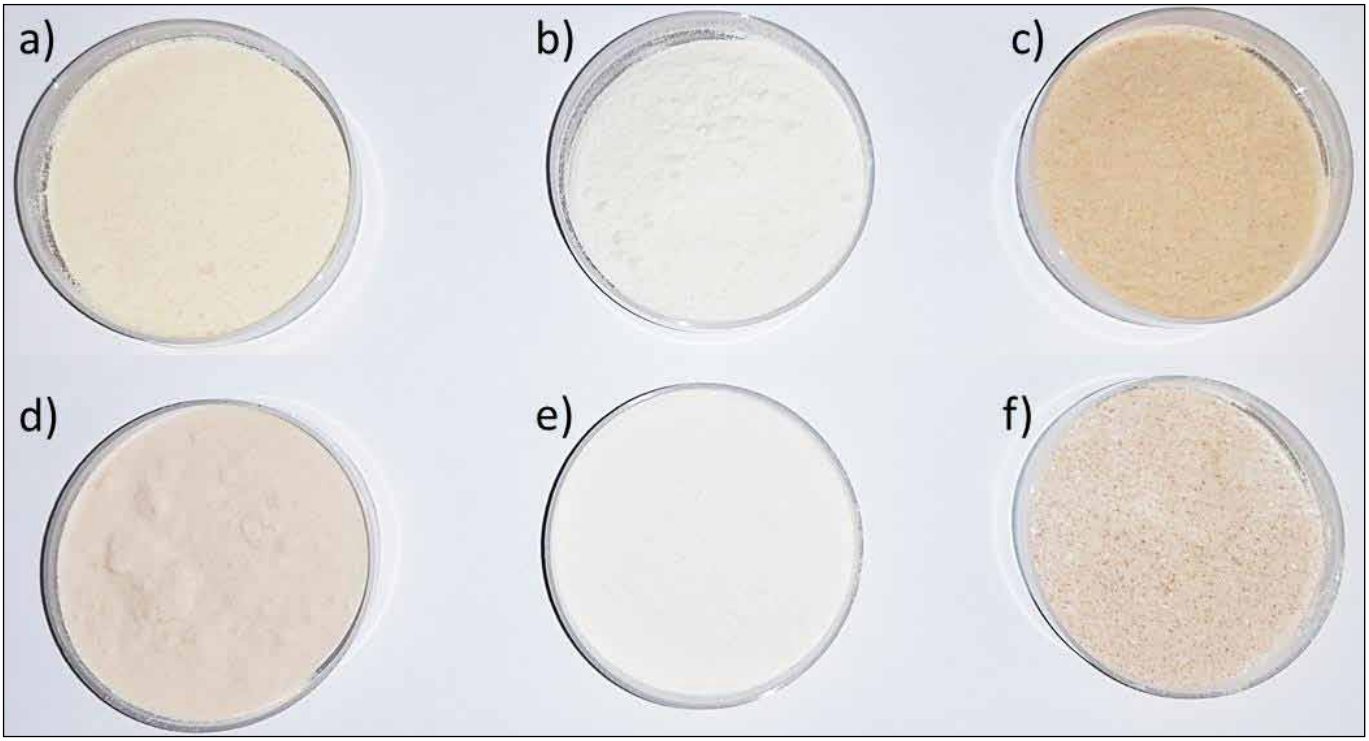

Fig. 1. Exemplary photos of hydrocolloids: guar gum (a), locust bean gum (b), low-methoxyl pectin (c), Arabic gum (d), sodium alginate (e) and high-methoxyl pectin (f).

Rys. 1. Fotografie przykładowych hydrokoloidów: guma guar (a), mączka chleba świętojańskiego (b), pektyna niskometylowana (c), guma arabska (d), alginian sodu (e) oraz pektyna wysokometylowana (f).

Source: Own study

Źródło: Opracowanie własne

compound [10]. Hydrocolloids dissolve or swell, when mixed with water, creating three-dimensional network that can exist at the presence of moisture, causing material to be plastic and viscous, or can be solidified due dehydration at specific conditions [14,18]. The best way to procure solidified gel products, maintaining the internal structure formed by hydrocolloids within processing, is freeze-drying that enables water removal without destroying sensitive bonds [10]. Because of their characteristics, hydrocolloids are used in food industry for various purposes, containing gelling, emulsifying, thickening, coating, structure- and texture-formation [26]. Various hydrocolloids, typically used in scientific research and food technology, are presented in Figure 1.

EFFECT ON WATER-RELATED PROPERTIES

Water acts as plasticiser in freeze-dried products, therefore, apart from microbiological safety, it is the factor determining textural and functional properties. When exposed to water, the freeze-dried material loses its crunchiness and becomes ductile and sticky. Consequently, optimisation of specifically low water content and activity in freeze-dried products is very important in terms of products quality and attractiveness [11,35]. Ciurzyńska et al. [9] investigated the effect of freeze-dried strawberry powder (7, 10%), calcium lactate (0.01, 0.05%), glucose (0, 5.2%) and chokeberry concentrate (0, 5.2%) concentration on the properties of freeze-dried gels obtained with 1.5% sodium alginate addition. Reduced amount of strawberry powder affected water content and activity, causing decrease (from 3.8 to 1.8%) and double increase to 0.39 of such properties, respectively. The investigation of the effect of the contribution of glucose and chokeberry concentrate in the composition of freeze-dried alginate gels revealed that supplementation of sugar source in the form of glucose, concentrate and both reduced water activity (0.39) by more than 50%, but only the addition of simple sugar caused significant increase of water content in the products to 4.9%. It also was found that freeze-dried sodium alginate gels rehydrated better when contained more sugar from fruit concentrates than pure glucose addition. Recently, Jakubczyk et al. [18] found that increasing amount of apple concentrate from 0 to 20% in agar gels had limited water activity reduction due freeze-drying, but maltodextrin used as supportive carrier agent contributed to significant decrease of such property. It was also investigated that freeze-dried gels obtained with strawberry pulp were characterised by lower water activity in comparison to model samples prepared by mixing hydrocolloids, water, sugars and citric acid. However, the use of fruit pulp significantly reduced water absorption capacity of the material, but regardless of composition rehydrated samples contained over 90% of water, which was more than initial water content in fresh mixtures before freeze-drying [12].

Martínez-Navarrete et al. [25] examined the influence of gellan gum and whey protein isolate blends applied in freeze-dried snacks obtained from mandarin juice. It was found that the addition of biopolymers multiplied water content in the products compared to simple freeze-dried juice, what was related to increased amount of non-freezable water that do not sublimate within freeze-drying. However, temperature of processing also affects water removal from the material and, when its increased, dehydration is intensified and final water content lessens, despite shorter drying time. In comparison, Ciurzyńska et al. [14] investigated multilayer freeze-dried snacks based on frozen vegetables, sodium alginate (1.5%) and mixture of locust bean and xantan gum, 1% each, were used to manufacture. Unlike aforementioned products based on fruits or hydrocolloids only, the snacks were characterised by much lower water activity (<0.045) and water content in range of 1.5–3.3%. It was presumed that such results were a consequence of strong water bonding capacity of hydrocolloidal systems used, since preparation of the material for freeze-drying required addition of about 58% of water, but it may be related to lower sugar content in vegetables compared to fruits what indicate more effective water removal as well.

Other research was carried out to examine the effect of hydrocolloid concentration, low-methoxyl pectin at 2, 2.5 and 3.5% specifically, on properties of freeze-dried gels obtained with freeze-dried strawberry powder. It was found that changes in properties are not linear with increasing concentration of hydrocolloid. Material with 2.5% of low-methoxyl pectin featured significantly lower water content and water activity. Even water gain due rehydration did not increase with the rise of carrier agent concentration and samples with 2.5% of pectin absorbed more water than others, but final water content after 30 mint of rehydration at 20°C decreased with the growth of hydrocolloid content [8]. Cassanelli et al. [5] examined impact of amount of hydrocolloid on properties of freeze-dried gels too. They used low and high acyl gellan gums at 1.5, 2, 2.5 and 3% proving that not only concentration but molecular structure of hydrocolloids determine processing and properties of final products. Gels obtained with high acyl gellan gum were characterised by significantly higher water activity and reached its values low enough to ensure microbiological safety after at least 30 h of dehydration, while samples with low acyl gum achieved that level at a time shorter than 24 h, attaining final water activity in range of 0.1–0.2 compared to 0.2–0.4 achieved by material with high acyl gellan gum after 48 h of freeze-drying. That experiment also confirmed that water activity values are not linearly connected with hydrocolloid concentration. A type of gellan gum turned out to be factor settling rehydration properties. Products with high acyl gum gained significantly low water compared to materials structured with low acyl hydrocolloid water content of which were found to depend on gellan gum concentration, thus the addition of 2.5 and 3% notably decreased water absorption capability. Blending of both types of gellan gum (1:1) allowed obtaining of material characterised by water activity reduction and rehydration properties closer to low acyl and high acyl gellan gum, respectively, and not at the halfway.

The use of various biopolymers, such as gums, maltodextrin, starches and fibres, as carrier agents reduces hygroscopicity that is high and crucial for porous freeze-dried materials. An increase of glass transition temperature by 5–15°C resulting from the addition of such compounds blends to orange snacks was estimated too, especially at low water activity [35]. Accordingly, an infusion of carrier agents is followed by an improvement of stability and, as a further consequence, perseverance of products quality during storage.

EFFECT ON COLOUR

Colour of the freeze-dried products is determined by natural colour of compounds used, principally the ones featured the greatest concentration of colourants. The addition of biopolymers induces lightness increase and colour intensity fading, what is related to their natural creamy or close to white colour, which can be observed in Figure 1. On the other hand, freeze-dried materials colour also depends on moisture content and the higher it is, the more intense the colour become, but water could activate biochemical reactions causing colourants degradation and dilution as well [35]. Colour of freeze-dried sodium alginate gels with freeze-dried strawberry powder depended on the addition of the powder and greater quantity intensified colour parameters, such as redness and hue angle, making products more attractive. Glucose and chokeberry concentrate addition to sodium alginate gels with strawberry powder also changed colour of such products in comparison to material without any of those, causing lightness and hue angle decrease and redness growth [9].

Concentration of low-methoxyl pectin in freeze-dried gels with strawberry powder also affected colour parameters, causing lightness and redness of them vary. But among other samples (2 and 3.5%), colour of the material with 2.5% of hydrocolloid was found closer to strawberry powder that was used as reference material, however, the differences of L^* and a^* were still about 10 and 7 units, respectively [8]. Carrier agents affect colour parameters of the material they are in, but they also act like protectors saving colourants from degradation caused by oxidation or thermal treatment [25].

EFFECT ON STRUCTURE AND TEXTURE PROPERTIES

Carrier agents support strengthening of the internal structure of freeze-dried products tending to collapse and lose crispiness to gumminess. Materials featuring high sugar content, such as fruit juices, are difficult to freeze-dry because of its low phase transition temperature that makes them less stable during storage. However, despite the addition of carrier agents, freeze-dried snacks exposed to relatively humid environment lose crunchiness and their mechanical properties change within time [25]. According to Silva-Espinoza et al. [35], biopolymers infusion into the formulation of freeze-dried fruit snacks extends the range of water activity in which the samples retain their properties, making them easier to store.

Structure and texture of the freeze-dried products may be modified not only by containing of certain additives, but also by using specific processes and parameters supporting formation of desired features. Both temperature and pressure, the freeze-drying is conducted at, are parameters influencing specific texture and sensory perception of freeze-dried snacks obtained with biopolymers as carrier agents [32, 33]. Optimisation of freeze-drying conditions also determines energy consumption of the processing, which is high for this dehydration method, so selection of processing parameters that work best lead to improvement of both quality and environmental impact of products [34]. Ciurzyńska and Lenart [7] analysed the effect of a type of hydrocolloid and aeration time, used as a process supporting porous structure formation, on the selected properties of freeze-dried gels. Examination of low-methoxyl pectin (3%) and mixtures of xantan gum with locust bean (1:0.5%) or guar (0.5:1.5%) gums aerated for 3 or 7 minutes implicated that both, type of carrier and time of aeration, determined properties of materials prepared under the same conditions. It was estimated that porosity of every sample was over 98%. Moreover, mean pores size was specific for each structure-forming additive used and increased with the prolongation of aerating. Structure of the freeze-dried gels obtained with low-methoxyl pectin was more organised and characterised by significantly greater pores, that grew with aeration, what induced higher water gain during rehydration. Combination of hydrocolloids may have an synergistic effect on the gelling properties, but considering presented findings, structure of materials obtained using mixes was more delicate and fragile comparing to samples with low-methoxyl pectin only. However, the authors observed that products structure softness after freeze-drying may be a consequence of gels stability before freezing and dehydration that indicates differences in gelling strength of particular hydrocolloids. The freeze-dried gels obtained with low-methoxyl pectin and the mixtures of gums performing aeration at various time showed that a type of hydrocolloid has strong impact on mechanical and acoustic properties. Samples with pectin were even double harder than gels with xantan and locust bean gums and more cracking of the internal structure were observed within compression of such sample, while curves determined for material formed with other carriers were smoother. Harder texture indicated also stronger acoustic emission that also can attract consumers [11]. In other work, significant impact of a type of hydrocolloid and aeration time on structure and texture of the freeze-dried gels was also proven [10]. The authors found that such factors affect porosity and pores size, internal structure and hardness of products, but it may be modified by addition of sugars, citric acid and calcium lactate mixture that interacts with hydrocolloids and works as strengthening factor, causing material to be compact and less porous at the same time. A comparison of low-methoxyl pectin and various hydrocolloids (xantan, locust bean and guar gums) working in synergistic mixtures structuring model system of strawberry containing 6.8% glucose, 1% sucrose and 0.64% citric acid and gel obtained with strawberry pulp induced that freeze-dried products obtained with pectin featured better and more regular structure, whether it was model or regular sample. It was assumed that using pectin is more beneficial for systems characterised by increased sugar content, therefore that is an additive recommended for optimisation freeze-dried products based on fruits and fruits derivatives [12]. Porosity and pore size distribution can be determined by molecular structure of hydrocolloids. In case of gellan gum at 2%, application of low acyl gellan gum leads structure of the freeze-dried gel to be designated by more numerous smaller pores that are evenly distributed in all volume of the material, while samples with high acyl gum were characterised by disarranged structure with smaller number of large pores in irregular shape. Moreover, combination of both types of gellan gum effected creation of structure with bigger pores in comparison to the material with low acyl gum, but not as large and definitely more organised as those observed in samples with high acyl gellan gum [5]. Carrier agent concentration in freeze-dried products has the greatest impact on structure and texture. An increase of low-methoxyl pectin amount had a great impact on texture of the

freeze-dried gels, causing them to become harder and less fragile. In terms of functional properties and similarity to conventional products (freeze-dried strawberries and freeze-dried strawberry powder) the results were compared to, the best quality was identified in freeze-dried gels with low-methoxyl pectin addition at 2.5%. Since all samples (2 and 3.5%) were prepared using the same processing conditions, the authors explained variation of results to be dependent on different water binding and gelation ability of pectin at various concentration. As a consequence of that, highly porous and fragile structure was developed [8]. Compression test performed on freeze-dried sodium alginate gels shows that both amount of strawberry powder and calcium lactate significantly influenced textural properties of the freeze-dried gels strengthening their structure by increasing quantity of the compounds. Increasing sugar content also induced strengthening of the freeze-dried gels texture [9]. But it should be concerned that enhancement of sugar content by addition of fruit concentrate may cause structure collapse followed by crispiness loss. So in order to obtain possibly the best freeze-dried gels quality, optimal level of sugar should not be over heightened [18]. Moreover, hardness of freeze-dried vegetable gels structured with sodium alginate (13.2–13.3 N) was two times higher than products with the mixture of locust bean and xantan gums. Such results were found much lower in comparison to similar products obtained on the base of fruits, but closer to plain vegetable tissue subjected to freeze-drying. Considering, porosity of the examined materials also was lower and that usually indicates harder texture, referred results confirm the importance of sugar content and its strengthening effect on dehydrated structure [14]. And, according to Martínez-Navarrete et al. [25], consumers prefer snacks that are not particularly harder, but crispier, what is portrayed as turbulent compression curve characterised by a great number of force peaks and drops.

EFFECT ON NUTRITIONAL VALUE AND SENSORY PROPERTIES

Freeze-drying is the process carried out at low temperature and with very oxygen-reduced atmosphere, so bioactive compounds contained in materials processed with this method are safe from degradation in general. There were some mentions that an increase of shelf temperature during freeze-drying may even improve vitamin C extraction from the products, but the addition of high molecular weight biopolymers, like hydrocolloids, as carrier agents may limit accessibility of bioactive compounds as well [25]. On the other hand, Silva-Espinoza et al. [33] found that bioaccessibility of vitamin C and phenolic compounds had grown after freeze-drying of orange snacks, what lead to conclusion on protective effect of infusing biopolymers into the formulation on bioactive compounds retention due dehydration.

A huge part of hydrocolloids is accounted to dietary fibre, which improves natural functioning of human body and shows preventive effect on some of serious diseases, e.g. cardiovascular disease or diabetes [26]. According to Ciurzyńska et al. [8], highly porous structure of freeze-dried products obtained by addition of hydrocolloids seems promising as factor influencing satiety and energy intake through slowing down digestion. Therefore, consumption of such products seems promising in terms of body weight control. However, consumers should be cautious, because hydrocolloids decrease sensory perception, therefore to improve attractiveness of freeze-dried gels by intensifying their flavour compounds such as sugar and citric acid may be applied [11]. Those enhance textural properties, but increase sugar content and energy intake of products, causing them to be inappropriate for specific groups of consumers, such as diabetics and people working on weight loss. Freeze-dried gels obtained with hydrocolloids, flavour and aroma shaping additives and water only do not represent high nutritional value, but using fruit pulp instead allows to create similar characteristics and obtaining products of quality improved [12].

FRUIT POMACE AS ADDITIVES IN FOOD PRODUCTS BRIEF CHARACTERISTIC OF FRUIT POMACE

Pomace is a by-product, containing solid matter, peels and seeds, remained after fruits processing, e.g. juice or wine production [1]. Due to its relatively high moisture content, one of the most common method of pomace preservation is drying that eases storing and allow to obtain high quality product for further processing [15]. Figure 2 shows powders obtained by grinding dried fruits pomace. As reported by Diez-Sánchez et al. [15], dried pomace obtained from various berry fruits usually contain over 90% of dry matter that consists compounds as protein (2–17%), fat (0.6–22%), carbohydrates (up to 90%), ash (0.7–7%) and total dietary fiber in the range of 16 to even 96%. Berry pomace also contains great amounts of polyphenols that are responsible for high antioxidant capacity. In comparison, approximate composition of dried apple pomace includes protein (1.2–6.9%), fat (0.3–8.5%), simple sugars (14–72.5%), ash (0.5–4.3%) and total dietary fiber up to 82%. Additionally, it supplies polyphenols and micro- and macro- nutrients as well [3]. Pomace usually is disposed for animal feed, but because of low economical value and high bioactive compounds content, pomace infusion into a formulation of new food products became a significant subject of scientific research [1]. It was often exposed that addition of fruit pomace affects stability, nutritional and functional values of food products, including increase of antioxidant capacity and fiber content and prevention of microbiological spoilage and lipid oxidation, but it induces significant sensory and texture changes, which are not always recognise as attractive or even positive [3,15]. Fruit pomace is a rich source of pectin, therefore after subjection to hydrothermal treatment at certain conditions [16], it has a huge potential to create texture and structure of food products.

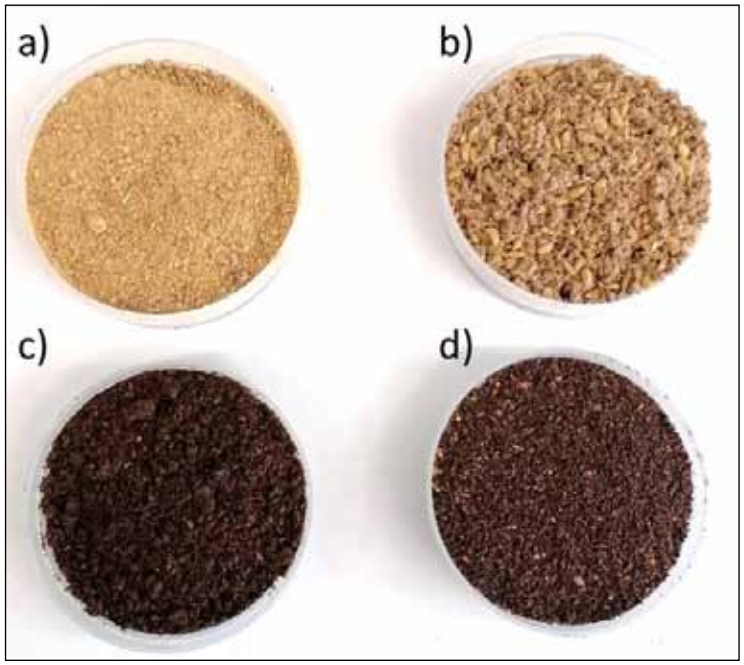

Fig. 2. Exemplary photos of dried apple (a), raspberry (b), blackcurrant (c) and chokeberry (d) pomace powders.
Rys. 2. Fotografie proszków z suszonych wytłoków jabłkowych (a), malinowych (b), z czarnej porzeczki (c) oraz aronii (d).

Source: Own study
Źródło: Opracowanie własne

FRUITS POMACE AS ADDITIVES CREATING FOOD PRODUCTS PROPERTIES

The effect of the addition of strawberry, raspberry, chokeberry, apple and blackcurrant pomace at 10, 20 and 30% on the characteristics of shortcrust pastries was studied in the bakery and pastry industry. Sensory analysis showed that the addition of fruit pomace increased the attractiveness of the products, improving their taste and aroma. Fruit pomace also significantly enriched the composition of the biscuits, so that they were defined as pro-health products [29]. Similar studies conducted by Siemianowska et al. [31] have also shown that fruit pomace increases the antioxidant activity of shortcakes, and its addition does not negatively affect mechanical, storage and sensory properties. Tańska et al. [37] showed that shortbread cookies with the addition of 20% berry fruit pomace (elderberry, rosehip, rowan, blackcurrant) had similar size and shape compared to the control sample, but had higher hardness, fibre content and antioxidant activity. The additives used also caused a significant change in the colour of the products. During the sensory evaluation, all cookies were evaluated by the panellists to be acceptable in terms of taste, sweetness, aroma, hardness, crispness, shape and colour. Due to their high fibre content, fruit pomace significantly lowers the glycaemic index of biscuit products, making this type of product, in which part of the wheat flour is replaced by pomace, suitable for consumption by diabetics [2].

In the case of bread, the addition of grape pomace also affected the product properties, but in contrast to the previously discussed cakes, Šporin et al. [36] described the observed changes as unfavourable. Changes in physical properties, such as colour, volume after baking, firmness and elasticity, as well as the sour aftertaste remaining after consumption of bread with added pomace were the reason for the lower product quality assessment. However, the addition of grape pomace significantly increased the polyphenol content and antioxidant activity of the baked goods, thus having a positive effect on their nutritional value and health-promoting properties. The results of studies in which apple pomace [38] and citrus pomace [6,28] were added to bread dough also indicate that the products obtained in this way are characterised by a higher content of fibre, polyphenols and antioxidants, as well as a higher hardness and a markedly different sensory profile compared to baked goods without the addition of pomace.

Jannati et al. [19] tested the influence of apple pomace infusion to traditional Iranian bread at the level of 1, 3, 5, 7%. There was found that extensibility of the dough was significantly reduced regardless the amount of pomace, but adhesive force was increasing with an increase of pomace addition. After baking, the breads with apple pomace were less hard comparing to control sample, which was bread without any addition of pomace, and hardness was growing slower due storage for 72 hours. The amount of pomace decreased also bread cohesiveness factor measured 24 h after baking, but within elongation of the storage time cohesiveness lowered, but the contribution of pomace was no longer significant. The changes in the texture of dough and bread was explained by interaction between gluten and fiber from apple pomace, what led to weakening the gluten network. Apple juice production waste also caused reduction of lightness (L^*) and an increase of a^* (redness) and b^* (yellowness) colour parameters. Moreover, the results of sensory analysis indicate that the addition of apple pomace to the level not higher than 3% improves bread quality and attracts consumers. In this research, the addition of apple pomace was not to extended, but other researchers investigated 25, 50 and 75% replacement of wheat flour to apple pomace flour in cookies in order to obtain reduced gluten confectionery [45]. They reported dietary fiber content enhanced to over 10, 20 and 30 g/100 g while control sample contained only 1.7 g/100 g. Apple pomace addition significantly multiplied total polyphenols and flavonoid contents, what was followed by boost in antioxidant activity. Sensory analysis showed the use of apple pomace flour may enhance structure, chewiness, odour, taste and overall perception, but only if it is coarse, not fine, ground and the amount do not exceed 50%. However, the best notes were received by attributes of cookies with 25% flour substitution, yet considering nutritional value and the lowest changes in bioactive compound content and sensory properties observed after 12 months storage, it was concluded that replacement of wheat flour with coarse apple pomace powder up to 50% may be successfully apply in pastry products. On the other hand, basing on their own research, Liang et al. [23] stated that dough properties and the quality of biscuits were acceptable only with addition of apple pomace powder at the level of 10%, and exceeding such amount, dough and product value dropped rapidly.

Fruit pomace has also found applications as ingredients infused to meat products. Yadav et al. [42] studied the effect of the addition of dried apple pomace on the quality of poultry sausages. The addition resulted in reduced protein and water content, which was reflected during sensory evaluation as reduced juiciness, and increased fibre content. Changes in colour and textural properties were observed, increasing hardness, gumminess and springiness, but despite this, the pomace-enriched products were also rated very well by the sensory evaluation panellists, although they received lower scores than the control sample. Studies carried out on beef sausages showed that apple pomace performs well as an emulsifying agent, has the ability to retain water and oil, has antimicrobial properties and lowers the glycaemic index of products enriched with it. In the case of beef sausage, it was unequivocally found that the addition of pomace improved both the sensory profile, the physicochemical properties and nutritional value of the products [43]. Younis and Ahmad [44] came to similar conclusions when analysing the properties of beef patties enriched with apple pomace powder, which also shaped both the physicochemical, sensory and structural characteristics of the products. In the meat industry, pomace can be used not only as a source of fibre, but also as a fat substitute in calorie-reduced products [30].

In the dairy sector, the possibility of using fruit pomace was studied on the example of yoghurt. In the case of apple pomace, an increase in the total acidity of yoghurts, changes in the rheological properties, including a particularly significant reduction in the hardness of yoghurts, and a reduction in the process of syneresis were observed. In addition, the products were characterised by a significantly darker colour, but despite this they were very well evaluated in terms of taste, which was dominated by distinct fruit notes [46]. Wang et al. [40] found that the addition of freeze-dried apple pomace powder shortens time of yoghurt fermentation and increases gelation pH. Storage stability of yogurts with pomace powder at the level of 0.5% was improved in comparison to control sample and products with the addition of 0.1 and 1% of dried pomace. When investigating stirred yoghurt fortified with apple pomace, water holding capacity of pomace powder also reduced syneresis, influencing textural properties and storage stability as well. Supplementation was followed by significant increase of polyphenols and dietary fiber in the products, what enhanced their nutritional value [41].

The addition of dried red grape pomace powder as sugar and milk powder substitute in chocolate spreads affected firmness and spreadability, which are crucial parameters for texture of this type of products. It heightened total phenols content, but limited digestibility. Moreover, increasing amount of grape pomace (up to 15%) induced unfavourable changes in sensory perception, so optimal content was recommended to not exceed 10%. It was also emphasized that factors as particle size of pomace powder and processing parameters (conching time, ball-mill rotation) should be modified to adjust product quality [1].

Lately, there were also a few attempts of applying fruit pomace in the form of dried powder as carrier agents in freeze-dried vegetable products [21,22]. The authors pointed out an increasing importance of environmental problems facing food industry and the future of human population in general, which, from food producing point of view, may be reduced by reusing of food waste and by-products as material for new products development. And considering current global changes, such as climate warming and population growth, even the slightest action aimed to sustainability is worth considering. Moreover, a type of carrier agent used in the formulation of freeze-dried snacks determines products appearance and attractiveness for consumers, what is presented in Figure 3. Freeze-dried snacks obtained by Karwacka et al. [21] were characterised by properties similar to aforementioned products obtained with hydrocolloids as carrier agents. Water activity of the products was very low and did not exceed 0.02 and such level was not achieved by any of freeze-dried snacks reported before. Structure of the materials also was highly porous (86-90%), but defined as more fragile and brittle but their hardness was significantly greater than those obtained for other freeze-dried products. Interestingly, such snacks were manufactured only with vegetables (string beans, carrot, potato) and 2% addition

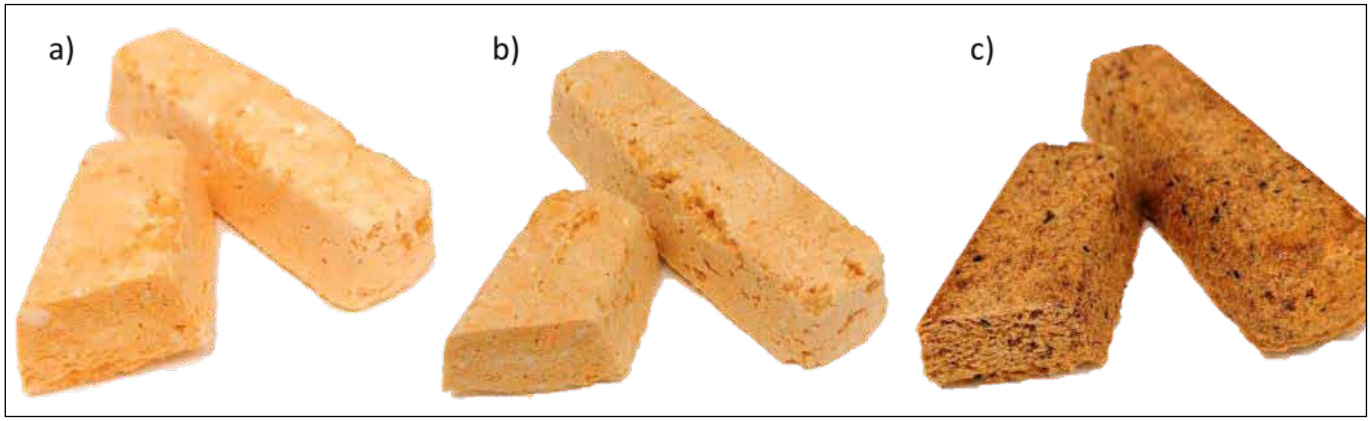

Fig. 3. Freeze-dried carrot snacks obtained with 1.5% of low-methoxyl pectin (a), 2% of dried apple pomace powder (b) and 2% of dried blackcurrant pomace powder (c).

Rys. 3. Liofilizowane przekąski marchewkowe z dodatkiem 1.5% pektyny niskometylowanej (a), 2% proszku z suszonych wytłoków jabłkowych (b) oraz 2% proszku z suszonych wytłoków z czarnej porzeczki (c).

Source: Own study

Źródło: Opracowanie własne

of dried apple pomace powder, without any liquid or additives that could had support formation of proper structure and texture of products. The addition of traditional hydrocolloid carrier, which was sodium alginate at level of 1.5% combined with 0.01% of calcium lactate, required halving the amount of vegetable compound and water substitution [22]. As an effect, despite lower initial water content, freeze-drying process had been lasting as long as it was recorded for samples with sodium alginate, meaning close to 48 h. The use of apple pomace powder as carrier agent resulted in more fragile texture that did not crack under pressure, but slowly compressed, what indicates lower crunchiness and could be related to smaller pores appearance in the structure of the snacks. Regardless weaker structure- and texture-forming ability of apple pomace, attempts to apply them as additives in food products is still promising and worth further research because of health benefits following those compounds. Compared to sodium alginate, dried apple pomace powder multiplied total phenols content and antioxidant capacity of the vegetable snacks, enhancing their pro-health value.

SUMMARY

Recently, development of new freeze-dried products that would do both attract consumers and reduce environmental impact of this type of products is intensively investigated. One of the key role in such process is optimisation of proper formulation that will result in the products characterised by desired quality, which can be modified by infusion of functional additives. A conscious choice of carrier agent applied in the formulation of foods is very important, principally considering its impact on crucial parameters of products, such as physicochemical, textural and structural properties along with sensory perception and nutritional value. Hydrocolloids are typically used as such compounds, however, in the light of recent reports and trends in scientific research motivated by the problem of food waste management, a new branch has emerged regarding the use of fruit pomace as a functional food ingredient. Numerous investigations provided on various food products fortified with fruit pomace show that they significantly affect food properties, especially enhancing nutritional value by increasing dietary fiber and bioactive compounds content that also results in higher antioxidant capacity. On the base of all of the referred findings and discovered properties, fruit pomace has a potential to be apply as substitutes for hydrocolloid carrier agents in freeze-dried snacks.

PODSUMOWANIE

W ostatnim czasie bardzo intensywnie prowadzone są badania nad opracowaniem liofilizowanych produktów, które będą jednocześnie atrakcyjne dla konsumentów i przyjazne dla środowiska. Jednym z kluczowych rozwiązań jest optymalizacja składu w taki sposób, aby otrzymać produkty charakteryzujące się pożądaną jakością, którą można modyfikować poprzez stosowanie dodatków funkcyjnych. Świadomy wybór nośników dodawanych do żywności jest bardzo ważny, szczególnie po uwzględnieniu ich wpływu na fundamentalne cechy produktów, takie jak właściwości fizyko-chemiczne, tekstura i struktura, a także atrybuty sensoryczne i wartość odżywcza. Zwykle w tym celu stosuje się hydrokoloidy, natomiast w świetle najnowszych doniesień i trendów obserwowanych w nauce, napędzanych problemem zagospodarowania odpadów, pojawiła się nowa gałąź, badająca możliwości wykorzystania wytłoków owocowych jako funkcjonalnych składników żywności. Przeprowadzono liczne badania, wzbogacając różnorodne produkty spożywcze dodatkiem wytłoków owocowych, które istotnie wpłynęły na ich właściwości, szczególnie wartość odżywczą i prozdrowotną, co nastąpiło w konsekwencji zwiększenia zawartości błonnika i związków bioaktywnych, a co za tym idzie większej aktywności przeciwutleniającej. Na bazie wszystkich przytoczonych prac oraz wykazanych właściwości wytłoków owocowych, można stwierdzić, że wykazują one duży potencjał jako zamienniki nośników hydrokoloidowych w liofilizowanych przekąskach.

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Joanna FRĄCKIEWICZ, Ph.D, assistant professor
Department of Human Nutrition, Institute of Human Nutrition Sciences
Warsaw University of Life Sciences (SGGW-WULS), Poland
Katedra Żywienia Człowieka, Instytut Nauk o Żywieniu Człowieka
Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Polska

THE NUTRITIONAL AND HEALTH VALUE OF MILK AND FERMENTED MILK DRINKS®

Wartość odżywcza i zdrowotna mleka i mlecznych napojów fermentowanych®

Key words: milk, fermented milk drinks, nutrients, health-promoting effect.

Milk and fermented milk drinks are foods rich in a range of essential nutrients. They include, among others highly digestible proteins, B vitamins, vitamins A and D, calcium, potassium and phosphorus. It is also worth noting that the use of bacterial starter cultures in the production of fermented milk drinks increases the bioavailability of some of these nutrients. The fermentation leading to the formation of such beverages therefore results in the end-products gaining not only a texture, aroma and taste different from milk, but also other properties. Increases, among others digestibility of their proteins, and as a result of the partial breakdown of lactose, they become more affordable for people with intolerance to this disaccharide. The nutritional value of milk and fermented milk drinks has a positive impact on human health. Among other things, the beneficial effect of the ingredients of these products on bone health and the ability to lower blood pressure have been proven, and the preventive role of milk in the risk of developing metabolic syndrome diseases has been confirmed.

Słowa kluczowe: mleko, mleczne napoje fermentowane, składniki, działanie prozdrowotne.

Mleko i mleczne napoje fermentowane to produkty bogate w szereg niezbędnych składników odżywczych. Należą do nich m.in. wysoce przyswajalne białka, witaminy z grupy B, witaminy A i D, wapń, potas i fosfor. Warto także zauważyć, że użycie kultur starterowych bakterii podczas produkcji mlecznych napojów fermentowanych przyczynia się do zwiększenia biodostępności niektórych z tych składników odżywczych. Fermentacja prowadząca do powstania takich napojów sprawia zatem, że końcowe produkty zyskują nie tylko odmienną od mleka teksturę, zapach i smak, ale także inne właściwości. Zwiększa się m.in. strawność ich białek, a w wyniku częściowego rozpadu laktozy, stają się one bardziej przystępne dla osób z nietolerancją tego dwucukru. Wartość odżywcza mleka i mlecznych napojów fermentowanych ma swoje przełożenie na ich pozytywny wpływ na zdrowie człowieka. Udowodniono, między innymi korzystne oddziaływanie składników zawartych w tych produktach spożywczych na zdrowie kości, zdolność obniżenia ciśnienia krwi, a także potwierdzono prewencyjną rolę mleka w przypadku ryzyka rozwoju chorób zespołu metabolicznego.

INTRODUCTION

Milk and fermented milk drinks are foods rich in a range of essential nutrients. They include, among others highly digestible proteins, B vitamins, vitamins A and D, calcium, potassium and phosphorus [36]. It is also worth noting that the use of bacterial starter cultures in the production of fermented milk drinks increases the bioavailability of some of these nutrients. The fermentation leading to the formation of such beverages therefore results in the end-products gaining not only a texture, aroma and taste different from milk, but also other properties. Increases, among others digestibility of their proteins, and as a result of the partial breakdown of lactose, they become more affordable for people with intolerance to this disaccharide [32].Therefore, the aim of this study was to analyze the articles in terms of the nutritional and health value of coffee, tea and herbal infusions.

The nutritional value of milk and fermented milk drinks has a positive impact on human health. The beneficial effect of milk components on bone health, the ability to lower blood pressure has been proven, and the preventive role of milk in the risk of developing metabolic syndrome has been confirmed [1, 43, 45]. Fermented milk drinks have an effect on the skeletal system, even more beneficial than milk, and their role in the prevention of certain malignant neoplasms has also been proven.

Due to its many health-promoting properties, fermented milk and milk drinks should be consumed every day. The latest nutritional recommendations for the consumption of milk and milk products in Poland were presented on October 17, 2020 by the National Institute of Public Health. Recommendations for healthy eating are presented graphically in the form of a healthy eating plate and in the form of 3-step instructions for

Corresponding author – Adres do korespondencji: Joanna Frąckiewicz, Department of Human Nutrition, Institute of Human Nutrition Sciences, Warsaw University of Life Sciences (SGGW-WULS), 159c Nowoursynowska Street, 02-776 Warsaw, Poland, e-mail: joanna_frackiewicz@sggw.edu.pl

changing eating habits. In the „eat more" category, there were low-fat dairy products with special emphasis on fermented ones, while in the „swap" category, it was proposed to change full-fat dairy products to low-fat dairy products. The same recommendation is listed as the first step in the „three steps to health". The next steps are: daily consumption of two glasses of milk, which can be replaced, for example, with kefir or yogurt, and choosing unsweetened dairy products [33]. Unfortunately, the consumption of milk by Polish consumers is much lower than recommended. The data of the Central Statistical Office also indicate persistence the downward trend in its consumption, despite the steadily increasing milk production in Poland for ten years [6].

Therefore, the aim of this study was to analyze the articles in terms of the nutritional and health value of milk and fermented milk drinks.

CHARACTERISTICS AND NUTRITIONAL VALUE OF MILK

In the PWN dictionary of the Polish language, milk is defined as an opaque, white liquid that is produced in the mammary glands of female animals and women, serving as food for newborn offspring [10]. However, when considering milk as a product intended for human consumption, of animal origin, you can define milk as udder discharge that has not been extracted or has any additives and is obtained from at least one milking [40]. Similarly, milk is defined by the Food and Drug Administration as a milk secretion that is almost completely colostrum-free, obtained by milking one or more healthy cows [13]. Milk is used to meet the earliest nutritional needs of the offspring, but humans are the only mammals to continue drinking the milk of other animal species after weaning [16].

The history of human consumption of milk dates back to the beginning of the Neolithic, when milk became available for consumption by adults, after the domestication of cattle, goats and sheep in southeastern Anatolia (present-day Turkey) and in the Middle East, around 10,500 years. ago. Some early Neolithic populations produced milk but probably could not digest it due to the lack of the enzyme lactase. They most likely processed the milk into cheese, yoghurt, and other lactose-reduced products that were easier for them to digest [27]. The earliest direct evidence of human consumption of milk, despite being lactose intolerant, dates back to six thousand years ago. Consumption of dairy products was confirmed by detecting milk protein (beta-lactoglobulin) in tartar in seven out of ten people living in what is then the United Kingdom [7]. Thus, the milk of farm animals, such as cows, has accompanied man for many millennia. Being the first food for newborn animals, it is an excellent source of many nutrients. Among other things, milk is a very good source of protein rich in exogenous amino acids and many other macronutrients, as well as micronutrients and vitamins necessary for humans.

Milk is a complex, colloidal mixture of fat, proteins, carbohydrates, minerals, vitamins, and other diverse ingredients dispersed in water. The composition of milk varies between species of mammals, but even within one species, the composition may vary depending on factors such as the stage of lactation, milking method, environment, the animal's feeding system and its age [37, 47]. The energy value of milk varies greatly and depends mainly on the fat content of milk, but also on the addition of non-fat milk mass or sugars. For example, whole milk (3.2% milk fat) provides about 150 kcal per cup, reduced-fat milk (2%) provides an average of 121 kcal per cup, and low-fat milk provides about 104 kcal per cup [26].

This drink provides a high concentration of nutrients in relation to the energy value. Cow's milk is considered, among other things, as an excellent source of the highest-quality protein, because it contains all the essential amino acids that the human body is unable to synthesize. Moreover, the amino acids present in milk are present in proportions relatively well suited to the needs of an adult [31]. Cow's milk proteins contain, among other things, a large amount of the essential amino acid, which is lysine, which makes milk a perfect complement to plant products, including cereals, whose proteins are poor in this amino acid [3].

Fat present in cow's milk was once considered its most valuable component, and years ago the nutritional value of milk was assessed mainly through the prism of the content of this macronutrient. Milk lipids are chemically similar to those present in other raw materials, but are distinguished by a very wide range of fatty acids. Up to 400 fatty acids have been found in them, although most of them in trace amounts [14]. Only about fifteen of them occur in the amount exceeding 1%. Among the fatty acids present in milk are lauric and myristic acids, which have an adverse effect on the cardiovascular system, as well as palmitic fatty acid, which increases the level of total cholesterol in the blood, and its LDL fraction [4]. However, the fatty acid profile of milk cannot be completely considered unfavorable, because it also comprises fatty acids valuable for human health. Some of them have an antiatherosclerotic effect or limit the development of cancer, they can also have anti-inflammatory properties and support the functioning of the intestinal epithelium. Fatty acids with such health-promoting effects are, among others, butyric acid, vaccenic acid, odd and branched fatty acids and polyunsaturated fatty acids, such as linoleic and α-linolenic acids, which are substrates for CLA [41].

Carbohydrate makes up about 5% of the nutrients in milk and consists mainly of lactose, to a lesser extent glucose and galactose, and oligosaccharides. Lactose concentration in milk ranges from 4.2% to 5%, and its low level may be caused, among others, by inflammation of the cow's udder. Lactose is a disaccharide consisting of α-D-glucose and β-D-galactose molecules [20]. Its presence makes milk a highly fermentable medium. Many species of bacteria can hydrolyze lactose to lactic acid, which lowers the pH of the milk and can cause coagulation. Unintentional fermentation spoils the milk, but controlled fermentation is the basis for the production of many dairy products, such as yoghurt and cheese [22].

Apart from calcium, the mineral fraction of milk also contains significant amounts of potassium and phosphorus. The average concentration of calcium is about 1200 mg in one liter of milk, and this amount is broken down into the micellar and water phases where it is bound to casein phosphoseryl residues or to whey proteins. Milk is also characterized by a relatively high content of B vitamins, such as vitamin B_1, B_2, B_6, B_{12} and folic acid. These vitamins are important enzyme

cofactors and are involved in many metabolic pathways such as neurotransmitter production and hormone synthesis. Although almost 90% water is present, fat-soluble vitamins are also present in milk, in particular vitamin A. Whole milk is considered a very good source of this vitamin, providing approximately 172μg/100g of it. However, in the case of non-fat milk, the vitamin A content is only about 5 μg/100 g [26, 36].

Currently, there are milk available on the market that differ in the percentage of fat, distinguished by the presence or absence of lactose, or divided according to taste.

HEALTH EFFECTS OF MILK CONSUMPTION

Currently, there are very divergent opinions on the role of milk in human nutrition and its impact on health, both in popular science and in scientific publications. It should be taken into account that the daily consumption of milk is included in the dietary recommendations of many European countries and the world. Therefore, it may be inclined to believe that the benefits of consuming milk outweigh the potential risks associated with consuming it.

Milk is one of the most important foods in the human diet to meet calcium requirements. In the average Polish diet, milk and dairy products account for more than half of the total calcium supply. The share of milk in the supply of calcium is around 21.5% [17]. The mean calcium requirement (EAR) of both women and men aged 19–50 is 800 mg/day [19]. This amount of calcium contains just over 2.5 cups of cow's milk with 2% fat. Few other foods naturally contain as much calcium as milk. Moreover, the calcium in milk also has a relatively high bioavailability. It is higher than, for example, the bioavailability of calcium found in leafy green vegetables, which also contain oxalates that limit the absorption of this element. However, milk provides not only calcium, but also other nutrients necessary for growth and development. Minerals and vitamins present in milk with particular importance for bone health are zinc, potassium, vitamin A, K, and in fortified milk also vitamin D. Many studies have confirmed the important role calcium plays in bone health [8, 48, 51]. It has been shown that diets with low dairy consumption are associated with an increased risk of osteoporosis, and that milk consumption may have a positive effect on bone mass in premenopausal women and reduce bone mineral loss [50]. A Korean study, which found data from more than 10,000 people aged 19-64, found that increased consumption of milk and dairy products is associated with a reduced risk of bone disease, and daily consumption of these foods may play an important role in maintaining optimal health bone [1]. For Caucasians, the positive effect of daily milk consumption on bone health was also confirmed. It has been proven that each additional dose of milk per day reduces the risk of hip fracture by as much as 8%, in both men and women over 50 years of age [12]. Milk is also very important for young people who use the valuable macro and micronutrients contained in it. Protein and calcium in particular are essential nutrients for bone development and maintenance at an early age, and milk is a rich source of them. In a study conducted among over 500 people aged. It has been proven that the consumption of milk promotes the development of adolescents aged 14–17, positively influencing their growth. At the same time, the influence of milk on the increase of BMI or the development of obesity was not demonstrated [35]. The lack of influence of milk consumption on the development of obesity among children and adolescents is also confirmed by previous studies. It has been proven that milk consumption can even protect against the risk of obesity. The consumption of milk and dairy products by the adults participating in the study improved body composition and aided in weight loss when they were on reduction diets. In contrast, when using normocaloric diets, milk consumption had a neutral effect on body weight [11]. Consuming milk can therefore be recommended to obese people, but also to those who, apart from abdominal obesity, also exhibit other features of the metabolic syndrome. A study involving over 130,000 people showed that the incidence of metabolic syndrome was significantly lower in people with higher milk consumption. Its higher consumption was inversely related to components of the metabolic syndrome such as elevated blood triglycerides, excessively large waistlines, and decreased levels of high-density lipoprotein (HDL cholesterol) in the blood [43]. In addition to having a lower chance of having elevated blood triglycerides and increased waistlines, they also had less frequent elevated blood pressure [18].

Consumption of milk is certainly associated with health benefits and a reduced risk of many diseases, but it is not an ideal drink and appropriate for all population groups. The health effects of milk can also be negative. For example, a paradox has been observed that hip fracture rates are higher in developed countries where calcium intake is high than in developing countries where calcium intake is low. Such a phenomenon has been proven, among others in a Swedish cohort study in which high milk consumption was associated with a higher incidence of fractures in women and higher mortality in both men and women [30]. FAO (Food and Agriculture Organization of the United Nations) and WHO (World Health Organization) experts concluded that the "calcium paradox" may be a more complex problem and may concern different amounts of protein, sodium and vitamin D intake in different countries [50].

Research describing the influence of milk consumption on the incidence of cancer is also controversial. A cancer that is often associated with the consumption of cow's milk by the public is breast cancer. This is because milk may contain relatively high levels of estrogen and progesterone metabolites and insulin-like growth factor (IGF-I), substances that may increase the risk of breast cancer. A study in over 30,000 women found that long-term high-volume unfermented milk consumption (two or more than two servings a day) was associated with an increased risk of breast cancer with positive estrogen and progesterone receptors (ER+/PR+). Such a relationship was observed especially in women with a BMI below 25 kg/m^2 [21]. Although the authors of the cohort study conducted on over 90,000 women also point to IGF-I and hormone metabolites as potentially carcinogenic substances, their test results are different. The study found that milk consumption by women 50 years of age and younger was associated with a reduced risk of breast cancer compared with those who consumed milk very infrequently (less than

a serving per week) [44]. The question of the influence of milk consumption on the development of cancer, especially breast cancer, remains unclear. However, many researchers and nutritionists argue about the superiority of the health-promoting properties of milk, and the recommendation for its consumption is still valid. Despite this, however, milk consumption in Poland is decreasing, and diets excluding milk and dairy products are becoming more and more popular. Nowadays, an exaggerated concentration on the food consumed is often noticeable, and people, especially in rich societies, are more and more often characterized by orthorectic inclinations. Such people often give up dairy products because they consider cow's milk to be a product that is difficult to digest, causes allergies and has a negative impact on the immune system [5]. Meanwhile, the currently available scientific literature suggests that the consumption of milk and its derivatives in accordance with the current recommendations may be beneficial for all age groups. The only exceptions are people suffering from specific diseases, such as allergy to milk proteins or lactose intolerance [29, 49].

CHARACTERISTICS AND NUTRITIONAL VALUE OF FERMENTED MILK DRINKS

Most fermented foods contain naturally occurring organic acids, ethanol, or other antibacterial compounds that inhibit the growth of spoilage organisms. Therefore, thanks to the possibility of preservation, fermented foods have been present in the human diet for many millennia. The microorganisms used to produce fermented milk products are lactic acid bacteria of the genera *Lactobacillus, Streptococcus and Leuconostoc* [24]. In the case of fermented milk drinks, the microorganisms used in their production must be viable, active and abundant in the product until the end of its shelf-life [25]. Lactic fermentation in milk begins with the hydrolysis of lactose into a glucose molecule and a galactose molecule, and then, thanks to lactic bacteria, lactic acid and energy are formed from the glucose molecule. The lactic acid produced in this process causes the coagulation of milk proteins, thanks to which it changes its taste and structure. Fermented milk drinks not only gain a different texture, smell and taste, but also other properties. For example, they are easier to digest due to a change in the structure of proteins and a greater amount of free amino acids. However, as a result of the partial breakdown of lactose and the formation of β-galactosidase, which facilitates the breakdown of lactose in the small intestine, these products become more affordable for people intolerant to this disaccharide. As a result of fermentation, the bioavailability of calcium, phosphorus and iron also increases, and the content of folic acid and cobalamin increases [32, 46].Fermented milk drinks are a very diverse group. Milk is used to make yogurt, kefir and other drinks, such as koumiss, buttermilk, curdled milk, acidophilic or bifidus milk. A particularly popular fermented milk drink is yoghurt, both natural and flavored. The etymology of the word yogurt is derived from the Turkish verb "yoğurmak", meaning thickening and kneading. This concentration in the Turkish name occurs precisely at the moment of coagulation during fermentation, as a result of lowering the pH level. A symbiotic mixture of *Lactobacillus delbrueckii subsp*. Strains is most often used as a starter culture. bulgaricus and *Streptococcus thermophilus*. These microorganisms are responsible for creating yoghurt's typical flavor and texture [52]. A special fermented milk drink is kefir, the production process of which involves not only lactic fermentation, but also alcoholic fermentation. It is made from kefir grains, or so-called kefir mushrooms, which consist of bacteria that produce lactic acid and acetic acid, as well as lactose-fermenting yeast and non-fermenting yeast that live in symbiosis. At the end of kefir production, in the cooling stage, alcoholic fermentation leads to the accumulation of CO_2, ethanol, as well as B vitamins [39].

Although it may seem that the composition of fermented milk drinks should remain almost identical to that of milk, some differences are noticeable. It has been shown that fermentation with lactobacilli improves the nutritional value of food products by increasing the digestibility, bioavailability, but also the amount of certain nutrients. Fermentation has been found to increase the folic acid content of yogurt and bifidus milk, and also to increase the niacin and riboflavin content of yogurt [23]. Based on the data contained in the tables of the composition and nutritional value of food [26], it can also be noticed that the highest increase in the content of B vitamins compared to natural milk occurs in the case of both flavored and natural yoghurt. However, in the case of kefir and buttermilk, the content of most minerals and vitamins is lower than in milk or yoghurt.

HEALTH EFFECTS OF FERMENTED MILK DRINKS CONSUMPTION

Milk consumption is positively related to bone mineral density. However, scientific evidence is emerging that fermented milk products have a particularly beneficial effect on skeletal health. Fermented milk drinks, such as milk, contain valuable nutrients such as protein and calcium to help increase bone mass. However, in dairy products that are fermented, the pH changes to a lower one because of the lactic acid produced. From the initial value of 6.7, characteristic of milk, the pH of the yogurt drops to 4.7 [28]. Such an acidified environment promotes better bioavailability of many nutrients. For example, to be able to absorb calcium, it must be dissolved in the stomach into its ionic form. In the case of weaker secretion of HCl acid and an increase in the pH level in the stomach, calcium may have a much lower bioavailability, and its absorption in the intestines may be difficult [2]. Therefore, the low pH of fermented milk-based beverages may contribute to a greater absorption of calcium and therefore a very beneficial effect of these products on bone health. Among other things, it has been shown that high yogurt consumption is associated with a reduction in the risk of hip fractures in postmenopausal women compared to little or no consumption of this drink [34]. Consumption of fermented milk products also positively affects bone growth and homeostasis. The presence of nutrients such as calcium, phosphorus and protein is crucial. In addition to influencing age-related bone loss, fermented milk drinks also affect calcium balance by preventing secondary hyperparathyroidism [38].

Many of the health-promoting properties of fermented milk beverages are not only related to the health of the skeletal system. They also show a beneficial effect in the case of malignant neoplasms, incl. colon and breast. Consumption

of fermented milk drinks has been shown to affect the gut microbiota, may stimulate gut-related immune cells, and have beneficial effects in inflammatory bowel disease and colon cancer. A diet rich in fermented milk products may also inhibit the growth of breast cancer [15]. Kefir has been shown to induce cell apoptosis, arrest the cell cycle, and reduce tumor growth in breast cancer. Kefir has an anti-cancer effect and induces cell apoptosis not only in breast cancer, but also in colorectal cancer and lung cancer. In addition, it is used in the prevention and treatment of various other diseases, such as allergies, hypertension and diseases of the digestive system [42].

It is the health-promoting properties of fermented milk drinks that are particularly important in the case of the digestive system. Lactic acid formed during fermentation has an acidifying effect in the environment and thus prevents the development of putrefying bacteria in the intestines. It also has the ability to accelerate intestinal peristalsis, while preventing diarrhea [32]. Many yoghurts and kefirs may also contain probiotic bacteria, which have a beneficial effect on changes in the intestinal microflora. The gut microbiota is a population of microbes that live in the gut, especially in the colon. The bacteria found in the intestines include, among others *Bifidobacterium*, *Lactobacillus* and *Streptococcus*. These bacteria are important for the production of short-chain fatty acids, the maintenance of immune activity, the extraction of energy from food, and even brain activity [9]. The fermented milk drink, which additionally contains probiotic bacteria, which have the ability to modulate the intestinal microflora, therefore gains many health-promoting properties. These bacteria help to regulate the work of the intestines and colonize them, preventing the multiplication of pathogenic bacteria and their penetration through the mucous membranes in the intestines.

CONLUSIONS

The properties of milk are a frequently discussed topic, both in the media space and in scientific communities around the world. Although this drink has a group of opponents and it is certainly not favored by people with lactose intolerance, it cannot be denied that it has many health-promoting properties. Milk is appreciated by people from many social groups. Children consume them for proper growth and development, young people are recommended them as a prophylaxis in order to reduce the risk of bone diseases. It is also recommended for obese people on reduction diets, as well as for people with symptoms characteristic of the metabolic syndrome. Milk in its composition contains B vitamins, vitamins A and D, calcium, phosphorus, potassium, but also the highest quality protein, providing all the necessary amino acids. Products that are made from it by fermentation also gain, among others, preventive properties in the case of some malignant neoplasms, and are able to positively affect the intestinal microflora and counteract digestive system ailments. However, despite the numerous benefits of consuming milk and fermented milk drinks, the trend of their consumption in Poland has been declining for many years. Therefore, it seems justified to conduct research on the impact of drinking milk and fermented milk drinks on human health depending on the frequency of consumption, but also on the type of selected product in different age groups.

PODSUMOWANIE

Właściwości mleka to często poruszany temat, zarówno w przestrzeni medialnej, jak i w środowiskach naukowych na całym świecie. Choć napój ten ma pewne grono przeciwników i z pewnością nie są mu przychylne osoby z nietolerancją laktozy, to nie sposób odmówić mu wielu prozdrowotnych właściwości. Mleko doceniane jest przez ludzi z wielu grup społecznych. Dzieci spożywają je w celu prawidłowego wzrostu i rozwoju, osobom młodym zaleca się je w ramach profilaktyki, w celu zmniejszenia ryzyka chorób kości. Polecane jest także osobom otyłym stosującym diety redukcyjne, jak i osobom z objawami charakterystycznymi dla zespołu metabolicznego. Mleko w swoim składzie zawiera witaminy z grupy B, A, D, wapń, fosfor, potas, ale i najwyższej jakości białko, dostarczające wszystkich niezbędnych aminokwasów. Produkty, które powstają z niego na drodze fermentacji zyskują ponadto m.in. właściwości prewencyjne w przypadku niektórych nowotworów złośliwych, a także są w stanie wpływać pozytywnie na mikroflorę jelit i przeciwdziałać dolegliwościom ze strony układu pokarmowego. Pomimo licznych korzyści płynących ze spożywania mleka i mlecznych napojów fermentowanych, tendencja ich spożycia w Polsce jest od wielu lat spadkowa. Dlatego zasadne wydaje się prowadzenie badań nad wpływem spożycia mleka i mlecznych napojów fermentowanych na zdrowie człowieka w zależności od częstotliwości ich spożycia, ale także od rodzaju wybieranego produktu w różnych grupach wiekowych.

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Dr inż. Marlena PIELAK[1]
Prof. dr hab. Ewa CZARNIECKA-SKUBINA[1]
Dr Assoc. Prof. Ingrida KRAUJUTIENĖ[2]
[1]Chair of Food Gastronomy and Food Chemistry
Department of Food Gastronomy and Food Hygiene
Institute of Human Nutrition Sciences
Warsaw University of Life Sciences – SGGW, Poland
Zakład Technologii Gastronomicznej i Chemii Żywności
Katedra Technologii Gastronomicznej i Higieny Żywności
Instytut Nauk o Żywieniu Człowieka
Szkoła Główna Gospodarstwa Wiejskiego w Warszawie – SGGW, Polska
[2] Faculty of Technologies, Kauno Kolegija/ University of Applied Sciences, Kaunas, Lithuania

MICROWAVE HEATING PROCESS – CHARACTERISTICS, BENEFITS, HAZARDS AND USE IN FOOD INDUSTRY AND HOUSEHOLDS – A REVIEW®

Ogrzewanie mikrofalowe – charakterystyka, korzyści i zagrożenia oraz zastosowanie w przemyśle spożywczym i gospodarstwach domowych – przegląd®

Key words: microwave heating, food industry, household, nutritional value, food safety, hazards.

The article presents the advantages and disadvantages of using microwave heating in the food industry and in households. A review of the literature in this field revealed many positive aspects of microwave heating. The microwave oven enables fast heat transfer, which translates into a short heating time and high energy efficiency compared to a conventional heating process. The efficiency of the process depends on many factors, including the shape and size of the product, the properties and position of the food during heating, and the process parameters used. However, the challenge for producers is still uneven temperature distribution, and hence uneven heating of the product. In summary, the quality of food prepared in a microwave oven differs from that of food prepared with conventional heating. The authors report both the highest and average sensory quality of vegetables prepared in a microwave oven and good nutrients retention. However, microwave heating also raises concerns among consumers due to the penetration of waves into the product and among other the possibility of acrylamide formation, as well as the safety of people operating the devices. Based on the research, it is known that the combination of microwave heating and conventional methods significantly improves the efficiency of the process, affecting the higher product quality, including the microbiological quality of the products obtained in this way.

Słowa kluczowe: ogrzewanie mikrofalowe, przemysł spożywczy, gospodarstwa domowe, wartość odżywcza, zagrożenia.

W artykule przedstawiono zalety i wady stosowania ogrzewania mikrofalowego w przemyśle spożywczym oraz w gospodarstwach domowych. Przegląd literatury z tego zakresu wykazał wiele pozytywnych aspektów ogrzewania mikrofalowego. Kuchnia mikrofalowa umożliwia szybki transfer ciepła, co przekłada się na krótki czas nagrzewania, wysoką efektywność energetyczną w porównaniu z konwencjonalnym procesem ogrzewania. Wydajność procesu zależy od wiele czynników, m.in. kształtu i wielkości produktu, właściwości i położenia żywności podczas ogrzewania a także zastosowanych parametrów procesu. Wyzwanie dla producentów wciąż jednak stanowi nierównomierny rozkład temperatury, a co za tym idzie nierównomierne nagrzewanie się produktu. Podsumowując, jakość żywności przygotowanej w kuchence mikrofalowej różni się w porównaniu z żywnością przygotowywaną za pomocą ogrzewania konwencjonalnego. Autorzy donoszą zarówno o najwyższej, jak i przeciętnej jakości sensorycznej warzyw przygotowanych w kuchni mikrofalowej oraz o dobrym zachowaniu składników odżywczych. Jednakże ogrzewanie mikrofalowe budzi też obawy wśród konsumentów ze względu na wnikanie fal w głąb produktu i m.in. możliwość tworzenia się akryloamidu, a także bezpieczeństwo osób obsługujących urządzenia. Na podstawie badań wiadomo, że połączenie ogrzewania mikrofalowego i metod konwencjonalnych znacznie poprawia wydajność procesu, wpływając na wyższą jakość produktu, w tym jakość mikrobiologiczną tak uzyskanych produktów.

Corresponding author – Adres do korespondencji: Ewa Czarniecka-Skubina, Warsaw University of Life Sciences – SGGW, Poland, Institute of Human Nutrition Sciences, Department of Food Gastronomy and Food Hygiene, Nowoursynowska Str. 159c, 02-776 Warsaw, Poland, e-mail: ewa_czarniecka_skubina@sggw.edu.pl, http://orcid.org/0000-0001-6557-5436, phone +48 22 593 70 63

INTRODUCTION

Microwaves (MWs) are electromagnetic (EM) waves, which are synchronized perpendicularly oscillations of electric and magnetic fields that propagate at the speed of light in a free space. MWs are characterized by the frequency (between 300 MHz and 300 GHz) and the wavelength (ranging from 1m to 1mm). According to the countries and regions, five frequencies (433, 896, 915, 2375, and 2450m MHz) are authorized for MW heating operations. The 2450 MHz is the exclusive frequency for home appliances [42].

The process of heating food in microwave ovens differs from conventional methods in which heat is transferring from the outer surface of the product to its interior. Microwave heating causes vibrations of molecules with polar properties, mainly water, and causes direct heating of the interior, without any additional heat transfer medium. As the microwave propagate to the surface of the dielectric material, the energy will be divided into three parts i.e., the transmitted part, the reflected part, and the absorbed part. The absorbed microwave energy is converted into heat by polarizing the solid dipoles in dielectric materials and then used to improve the internal energy of the charge. The frequency of microwave wave radiation is in the range from 300 MHz to 300 GHz. Microwave heating also depends on the electrical properties of the food, which in turn affects the degree of energy conversion [13].

The aim of this study is to characterize microwave heating and present the benefits of its use in terms of the protection of nutrient and maintaining food safety, but also the concerns related to its use in food preparation and processing.

DATA COLLECTION

All data presented in this review were summarized from the references, including scientific journals and book chapters. These references were systematically searched against databases: PubMed, Web of Science, Scopus and Google Scholar with a keywords: microwave heating, microwave, microwave oven, technological process. To search for maximum relative references, the keyword was set as "microwave oven and microwave heating" and restricted to 1998–2022 years. The statistical data concerning the equipment of Polish households with microwave ovens in the years 1995–2021 was analyzed.

CHARACTERISTIC OF MICROVAWE HEATING

A microwave oven works by absorbing energy by dipolar molecules in the ionic components of the raw material, and then generating energy, which is then converted for heating [61]. The generation of heat therefore depends on the dielectric properties of the food. The dielectric properties are dependent on the temperature, humidity and composition of the food, as well as the microwave frequency [59]. Another important factor is the packaging material of the food being treated, as it can serve as a strong or weak absorber, or reflect microwaves without generating heat [14].

Compared to other heating methods (e.g. hot air heating, infrared heating etc.), microwave heating is more efficient and faster due to the volume heat [36, 45, 89]. Due to the uneven heating and the difficulty in obtaining browning, the optimal parameters of the microwave heating process are still sought, adapted to the form of the raw material, taking into account the appropriate power and time while maintaining the highest quality [51]. The uneven temperature distribution during the process has been widely discussed by many authors. Uneven distribution of the electromagnetic field in dielectric materials causes uneven temperature and humidity, e.g. the appearance of "cold" or wet points, which causes the survival of pathogens and accelerates food spoilage. On the other hand, the appearance of hot or dry places causes charring, cracking or hardness of the food materials [45, 68,72]. This variation in heating capacity sometimes raises questions about food quality and safety, as the microorganisms are not inactivated in cold places [85]. The heterogeneity of the heating process may be related to the texture, geometry and dielectric properties of the food, and the packaging used. These issues represent challenges for microwave ovens manufacturers as well as technologists who develop food products intend for the microwave oven [16, 23, 91].

Research on the relationship between parameters, e.g. temperature or humidity, and process variables, e.g. size, shape or dielectric properties, is of key importance in better understanding the microwave heating process and obtaining high quality of the obtained product. Process efficiency is influenced by many factors, including shape or size, properties and position of food in microwave ovens, as well as attributes of microwave ovens. Modifying the design of microwave devices, combining with other heating methods, optimizing the process and designing heated semi-finished products increase the heating efficiency in a microwave oven. Designing the appropriate shape and distribution of ingredients in a multi-element dish, intended to be prepared in a microwave oven, can affect even heating and higher quality of the product [9, 10, 30, 91, 92, 93, 98]. The conducted research shows that the shape and size of the raw material, especially the thickness, affect the heating efficiency, which is higher in the case of samples with small volumes and weights [7, 10, 11, 30, 73, 88, 95]. It was shown that the shape of a vertical cylinder has the highest uniform temperature distribution [9]. The concentration of microwave energy occurs in the center or on the corners of products of various shapes subjected to the heating process [10,13].

THE USE OF MICROVAWE HEATING IN FOOD INDUSTRY

Microwave heating is successfully applied in many areas of food processing, including drying processes (e.g. dry potatoes chips, pasta and snacks), lyophilization, pasteurization, extraction of bioactive compounds and enzyme inactivation, as well as microbiological disinfection [14, 15, 47, 54, 55, 66, 72, 75], due to the beneficial effects on many properties of the final products [41, 71, 77].

Microwave (MW) drying

When drying with the use of microwave heating of a product with high humidity, the microwave energy is supplied directly to the entire volume of the product, which causes a rapid increase in product temperature and immediate evaporation of water inside the product [47]. The internal pressure increases, bringing the water to a liquid state towards

the product surface. This reduces drying time for many products - up to five times compared to air drying. The increase in internal pressure prevents the food from shrinking and hardening the surface during drying, positively influencing the texture of the microwave-dried product. It also affects the greater porosity of the product and increases the rehydration capacity [47]. In the case of microwave drying, an additional preservative effect can be observed due to the rapid increase in temperature of products rich in water, causing thermal shock in thermally sensitive microorganisms. The authors [46] found that by drying onions with air and using microwave, they found a tenfold greater reduction in total microbial count with microwave drying (a reduction approximately one to two logs).

This is an important advantage of microwave drying compared to conventional drying. However, due to the rapid saturation of the surrounding air, the efficiency of microwave drying is limited, therefore, in order to improve water transfer over the product surface, MW drying is often combined with a flow of hot air. When drying MW, excessive surface temperature may also occur, especially at the edges. This can carbonize the product and produce unpleasant off-flavors, especially in the final stages, as opposed to hot air drying where the surface temperature does not exceed a controlled ambient air temperature, e.g. when drying aromatic plants at 30-40°C. In combination with other conventional methods, microwave drying improves the drying efficiency and the quality of the dried product. Combined drying applications are mainly MW assisted hot air (HA) drying, MW vacuum drying and MW freeze drying [47].

Dried foods, including vegetables, fruits, seafood and meat, have an extended shelf life, a lower weight-to-volume ratio, which makes them easier to store or transport over long distances. In many studies, researchers focus on the use of microwave ovens for microwave drying, due to the speed and uniformity of the process, energy efficiency and obtaining a higher quality product compared to conventional hot air drying [17, 25]. Zielińska and Michalska (2016) [99] report that the berries vacuum-dried in a microwave (1.3 W / g microwave power at a pressure of 4-6 kPa, 6 rpm) showed a significant increase in color intensity change, as well as density and chewiness, which were desirable qualities of the fruit. The authors also report an improvement in color when using a domestic microwave oven with a rotating system for the drying process to improve uniformity (1000 W and a frequency of 2450 MHz) [58].

Extraction with the use of microwave heating

Microwave Assisted Extraction (MAE) is an attractive alternative in functional food development [49].

Functional food contains bioactive compounds such as antioxidants, antimicrobials, immunomodulators, enzymes, probiotics, prebiotics, fibers, phytosterols, peptides, proteins, isoflavones, saponins, and others [4]. Traditional techniques for the extraction of bioactive compounds, such as the Soxhlet method, or liquid-liquid or solid-liquid extraction, are time consuming and less efficient than microwave assisted extraction. Therefore, MAE may have the potential to be used in the extraction of fluid-soluble products from a wide variety of food matrices with minimal use of solvents [4, 8].

Microwave pasteurization and sterilization

To extend the shelf life of most food products, the pasteurization and sterilization processes are commonly used. This is due to the destruction of vegetative pathogenic microorganisms and the deactivation of certain enzymes in food. The pasteurization temperatures and the treatment time used vary depending on the pH and nature of the product and the type of microorganism. In pasteurization, most processes heat food to 60-85°C for a few seconds to an hour [2]. In semi-solid or solid products, heat transfer mainly takes place by conduction from the surface to the center, known as the "cold" point. Reaching the target temperature at the "cold" point can be demanding and may result in overcooking the surface and deterioration of quality. Maximizing bacterial inactivation while minimizing nutrient degradation is a challenge for producers and technologists. The use of microwaves seems to be a good solution to the limitations of slow thermal diffusion of conventional processes due to the direct and volumetric interaction between microwave heating and food.

Microwave sterilization of food is caused by the heat generated as a function of the food medium and the temperature achieved in the various parts of the food. De-La Vega et al. (2012) demonstrated good product quality (no loss of color) and inactivation of 5.1 log cycles of Salmonella Typhimurium, after inoculating fresh jalapeño peppers with it, then immersing them in water and subjecting them to a 950 W (2450 MHz) microwave temperature 63°C (25s) before cooling [21].

In another study [52] reduced by 2 logarithmic cycles the population of Salmonella enterica in tomatoes using microwaves (700W for 59s). Also in the case of eggs, the use of microwaves resulted in a reduction of *Salmonella enteritidi*s by 2 log cycles without any significant negative impact on the quality [48]. On the other hand, Zeinali et al (2015) [90] reported a reduction of 6 log cycles of L. monocytogenes inoculated in chicken thighs after 60 s exposure in a domestic microwave oven.

In summary, many studies have shown the effectiveness of using MW heating for pasteurization and sterilization of food [31, 65, 70]. Various strains of microorganisms have been inactivated by the use of microwaves: *Bacillus cereus, Campylobacter jejuni, Clostridium perfringens, Escherichia coli, Enterococcus faecalis, Listeria monocytogenes, Staphylococcus aureus and Salmonella* [27, 97].

A serious problem, however, is the heterogeneity of heating, which can lead to incomplete inactivation of the microorganisms. Several studies have shown the survival of pathogens in microwave-heated food, np. *Salmonella spp.* [37] and *L. monocytogenes* [24]. Non-uniform heating also deteriorates the quality of the product. Local overheating often results in irreversible color changes, where the temperature is highest, mainly at the corners and edges due to wave reflection [78]. The localization of "cold" points can also be a problem when using microwaves. In a conventional thermal process, the "cold" point is well-defined and is often at the center of the product. During MW pasteurization, single-point monitoring of the temperature in the product is not sufficient to ensure complete food safety [34]. Schnepf & Barbeau [67] investigated the inactivation of *Salmonella* in poultry and showed that the measurement of the internal temperature

during the MW treatment did not reflect the inactivation of the surface, the temperature of which was lower. However, the method of chemical markers can be used to locate a "cold" point [12, 43, 62]. In combination with experimental research, numerical simulations are recommended to find cold spots and obtain accurate research to develop a reliable decontamination process for explosives [33, 34, 56].

The food industry is constantly looking for new solutions that are characterized by greater efficiency and effectiveness, ensuring food safety while maintaining product quality. One such solution is the use of microwave assisted thermal sterilization (MATS), developed by Washington State University [78]. Worldwide license for this technology is owned by 915 Labs. The development of the MATS method at Washington State University has shown great potential in providing commercial sterilization and pasteurization with minimal nutrient loss [79]. Microwave Assisted Heat Sterilization (MATS) is becoming an increasingly popular technology for sterilizing packaged food. In this system, packaged food is sterilized by simultaneous heating to 120°C via a pressure hot water bath and microwave energy at 915 MHz, and then rapidly cooled [78]. This method has been approved by the Food and Drug Administration (FDA) for the sterilization of mashed potatoes (2009), processed meats (2010), and salmon fillets (2012) [6, 78]. The MATS system differs from conventional microwave technology in that it primarily uses water as an interface for heating followed by the heating process in a microwave oven. The combination of technology and the use of water as a medium allows for more uniform heating and at the same time reduces the time of exposure to high temperature compared to conventional sterilization [6, 78].

THE USE OF MICROVAWE HEATING IN HOUSEHOLDS

Due to its wide range of applications, microwave heating has gained a lot of interest from food producers now, but it was not until the 1940s that the possibility of using a microwave oven for cooking was discovered [74]. A domestic microwave oven is the most common device among consumers that uses the thermal effect of an electromagnetic wave, and its common operating frequency is 2.45 GHz [45, 68, 72].

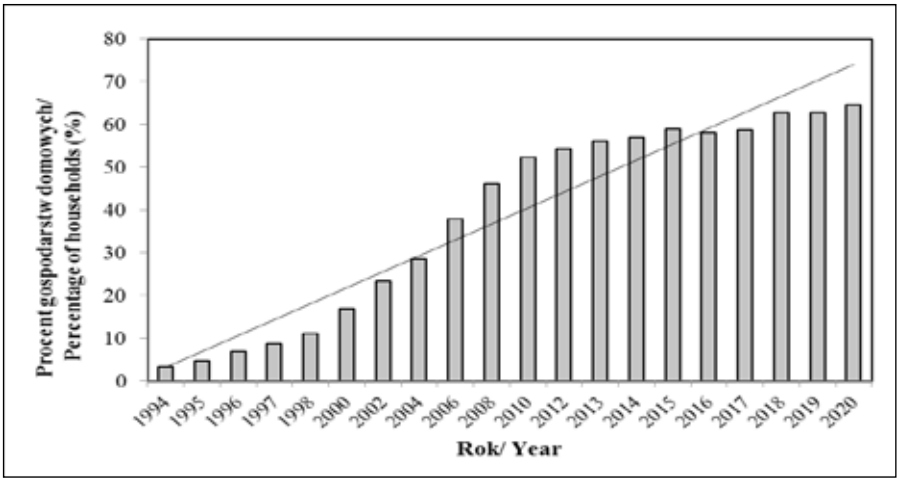

Fig. 1. Percentage of Polish households equipped with microwave ovens.
Rys. 1. Procent polskich gospodarstw domowych wyposażonych w kuchenki mikrofalowe.

Source: Own elaboration based on literature [29]

Źrodło: Opracowanie własne na podstawie literatury [29]

Microwave heating is used in gastronomy and at home, mainly for such processes as: cooking and thawing [14, 15, 54, 55, 66, 72, 75].

The microwave oven allows for quick heat transfer, which translates into a short heating time, high energy efficiency and ease of use compared to the conventional heating process, as well as the ability to immediately turn off the device to stop the process [65, 96]. Changing the lifestyle of consumers and limiting the time for preparing meals contributed to the popularization of the use of microwave ovens in households. In recent years, consumer interest in microwave ovens has increased in Poland. In 1994, only about 3% of households were equipped with them, while in 2020 it was 64.6% (Figure 1) [29]. By comparison, according to the US Bureau of Labor Statistics in 1994 67% of American household owned a microwave oven, and now it is 90% of households [84].

Food safety and safety of use microwave oven

Food cooked in a microwave oven is as safe as food cooked in a traditional cooking methods, but it raises concerns for consumer safety. The main difference between the two cooking methods is that microwave energy penetrates deep into the food and reduces heat conduction in the food, thus reducing the overall cooking time [83]. Consumer knowledge about the safe use of microwave ovens is low causing food safety concerns, especially microbiological hazard of microwaved heated food. This is confirmed by a study conducted among Malaysian consumers (n = 329) on the knowledge and practice of microwave oven safety and attitudes towards food safety. As many as 57.4% of respondents showed a low level of knowledge about the safety of a microwave oven, despite the knowledge of microwave oven usage standards. In addition, consumers also demonstrated a low level of practice of microwave safety [60].

Studies indicated that microwave heating at a high-power level can cause more acrylamide formation in food than traditional heat treatment due to differences in its formation during microwave heating and conventional methods. In contrast, short-term exposure to microwaves (during blanching and thawing) at low power may even reduce acrylamide formation during the final heat treatment [57].

In the research conducted by Czarniecka-Skubina et al. (2016), most respondents assessed the quality of food prepared in the microwave as good or average, but the taste as worse than in traditionally prepared dishes. Most of the respondents (73.6%) considered the microwave oven safe for health, and only a small percentage of respondents were afraid of radiation and the possibility of developing cancer [20].

Some authors report that the safety of microwave ovens is related to the

Table 1. Advantages and disadvantages usage of microwave heating in household and food industry

Tabela 1. Wady i zalety stosowania ogrzewania mikrofalowego w gospodarstwie domowym i przemyśle spożywczym

Household		Food industry	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
– cooking time is short / krótki czas gotowania – limited nutrients destruction / ograniczone straty składników odżywczych – no physical change of food / brak fizycznej zmiany żywności – the melting process is easy / łatwy proces topienia – possibility to obtain a sterilization effect / możliwość uzyskania efektu sterylizacji – the heat treatment is easy / obróbka cieplna jest łatwa	– the constraint uses a metal container / oraniczone użycie metalowego pojemnika – heat force control is difficult / utrudniona kontrola siły grzewczej – big water evaporation from food / duże parowanie wody z żywności – a closed container is dangerous because it could be burst / zamknięty pojemnik w trakcie użycia może pęknąć – surface toasting is impossible / niemożliwe opiekanie powierzchni – attention in using a microwave oven is needed / należy zachować ostrożność w trakcie użycia – if it is used improperly, they can leak harmful radiation, posing a risk of cancer and other diseases / jeśli jest używana niewłaściwie, może przepuszczać szkodliwe promieniowanie, stwarzając ryzyko zachorowania na raka i inne choroby	– positive effect on the texture of the dried product / pozytywny wpływ na teksturę suszonego produktu – fast heating efficiency / wysoka wydajność ogrzewania – reduction energy consumption of the process / zmniejszenie energochłonności procesu – inactivation of microorganisms / inaktywacja mikroorganizmów – the use of combined methods to obtain a high-quality product / stosowanie łączonych metod w celu uzyskania wysokiej jakości produktu – no limitation of heat diffusion can be used for many processes i.e., pasteurization, sterilization, drying, cooking, extraction / brak ograniczenia dyfuzji ciepła – może być stosowana w wielu procesach tj. pasteryzacja, sterylizacja, suszenie, gotowanie, ekstrakcja	– uneven temperature distribution / nierównomierny rozkład temperatury – local overheating of food / lokalne przegrzanie jedzenia – difficult localization of "cold" points / trudna lokalizacja „zimnych" punktów – the need to modify microwave ovens / konieczność modyfikacji kuchenek mikrofalowych – the need to optimize process parameters / konieczność optymalizacji parametrów procesu

Source: Own elaboration based on literature [22].

Źródło: Opracowanie własne na podstawie literatury [22]

leakage of waves and thus the health risk to the people who operate them. The effects of electromagnetic radiation from microwave ovens on the health of the workers (n = 28) who are exposed to microwave radiation during their work at cafeterias in four higher educational institutions in northern part of Palestine were studied. Measurable health parameters (heart pulse rate, blood oxygen saturation, tympanic temperature, systolic and diastolic blood pressure) were used to detect the effect on workers' health. The authors indicated that there is no dangerous health effects of microwave radiation from microwave ovens used in university cafeterias [32].

Quality of the products obtained and nutritional value

A literature review suggests that the quality of food prepared in a microwave oven differs from that of food prepared with conventional heating. The authors report both the highest and average sensory quality of vegetables prepared in a microwave oven [44] and good maintenance of nutrients [18]. Microwave-heated tea also had a higher sensory quality than oven-heated tea [39].

Research on the effect of microwave heating on the quality of prepared raw materials took into account the effect on the content of vitamin C, reporting significant losses of up to 40% [50, 86]. Cooking in a microwave oven helps to preserve vitamin C due to the short processing time and the limitation of the amount of water used. By carrying out the process in a microwave oven, intensive boiling of the solution is additionally eliminated, which protects the tissue and vegetable cells from tearing. This results in a reduction in the amount of leached vitamins and minerals into the solution [18].

In the case of microwave baking, the product may show a lower sensory quality by reducing the Maillard reaction products by 50%, but with a higher nutritional value by reducing the formation of heterocyclic aromatic amines and polycyclic aromatic hydrocarbons [80].

Moreover, cooking in the microwave oven changes in the content of chemical impurities in root vegetables [18, 19, 26], as well as the effect on the change in the content of substances antinutritional in legume sprouts [5].

Losses of B vitamins and minerals in microwave-cooked chickpeas were lower than in conventional cooking or autoclaving. The improvement in vitamin retention when cooking in the microwave oven could have been the result of the shorter cooking time. Chickpea protein is rich in essential

amino acids such as isoleucine, lysine, total aromatic amino acids, and tryptophan, so it is a good complement to those protein sources that are low in lysine and tryptophan. It was shown that the conventional cooking process and microwave cooking resulted in a slight increase in the total amount of essential amino acids, in addition to the autoclave thermal process. Conventional cooking and autoclaving lowered lysine concentrations, with the exception of microwave cooking [3].

Results of studies confirms the possibility of using microwave treatment as an alternative to conventional oven heating, as demonstrated with flaxseed. The influence of microwave heating and conventional heating in an oven on the amount of hydrogen cyanide, properties of oil and protein, and volatile compounds in linseed were assessed. It was shown that all the heating treatments effectively reduced the content of hydrogen cyanide.

Microwave heating (860 W for 8 minutes) also slightly increased the peroxide value, while heating in an oven (150°C for 30 minutes) increased it more than 10 times. Both methods of heating significantly increased the types and amounts of volatile substances such as pyrazines, alkanes and aldehydes. Further comprehensive quality analysis using principal component analysis (PCA) showed similar properties [38].

Moreover, changes in the quality of poppy seeds were shown, including the content of bioactive compounds, fatty acids, tocopherols and phenol composition [28]. Microwave heating, due to different process conditions, such as time, power, and amount of added water, resulted in the composition of vegetables in different ways [50]. An example is reducing the glucosinolate content of broccoli [42, 86], caused by the high rate of water evaporation, which affected the leaching of glucosinolates [50]. Microwave cooking also had a differential effect on high aliphatic glucose losses as well as indole / aromatic nolana levels, both of which high decreases in broccoli [86] and increases in red cabbage (by 78%) were determined during microwave heating [87].

The authors [82, 94] noticed that with increasing microwave heating time of broccoli and cabbage, the content of polyphenols and their antioxidant activity decreased, which was comparable to conventional cooking. Other authors [76] report that cooking in a microwave oven caused both an increase in the content of flavonoids in juices from various apple varieties, greater than as a result of traditional cooking, and a comparable level of these compounds in both methods.

In conclusion, changes in the content of nutrients, including polyphenols, due to microwave heating are product dependent [81]. The total content of phenolic compounds after culinary treatment was for: pepper – 126%, green beans – 129%, broccoli – 125%, spinach 109%, pumpkin 67%, peas – 83%, leek – 82% in relation to fresh vegetables. Similarly, in the case of antioxidant activity in vegetables, except for peas, an increase was found (from 106% to 188%) [81], as well as a decrease in antioxidant activity in potatoes by 11% [69]. In contrast, microwave-heated fennel seeds were richer in fatty and phenolic acids and had a higher antioxidant activity than after oven treatment [35]. Microwave heating resulted in the even solubility of the protein and minimized the activity of enzymes responsible for the "bean flavor" [35, 40].

The combination of microwave heating (5.7 kW at 180° C) with baking in a steam oven (35 kW at 180°C) reduced the heating time and improved the tenderness and color of beef compared to conventional baking [64].

It was also shown that microwave heating (20 kW, 120°C for 12 s) compared to the pasteurization process (90°C for 15 min) resulted in better preservation of the quality of strawberry puree [54]. Conventional pasteurization resulted in greater degradation of total polyphenols (7%), anthocyanins (20%) and vitamin C (48%) compared to microwave treatment at 120° C. However, no color change was shown. In addition, a product with better "freshness" attributes was obtained in the microwave oven [54].

Other authors have come to similar conclusions [63]. During the microwave assisted pasteurization of carrots (915 MHz) compared to conventional pasteurization, they found no significant differences in texture and carotenoid retention in carrots, but the processing time was significantly reduced, which had a positive effect on the quality attributes. Moreover, the influence of high-frequency radiation on the quality in terms of mechanical strength of bakery products with a low moisture content was demonstrated. Biscuits baked in a convection oven compared to biscuits baked in the same way and additionally subjected to microwave treatment (power 700 W for 30 seconds) had a worse structure, which deteriorated during storage. It has also been found that biscuits which are additionally heated in a microwave oven are less susceptible to the effects of high ambient humidity [1].

SUMMARY

Conventional heat treatment for preserving food generally reduces the quality of the product. Additionally, these methods are not optimized for solid foods due to the slow transfer of heat from the surface to the "cold" point that often occurs in the center of the product. The goal of modern food processing technologies is undoubtedly to improve the organoleptic properties, while obtaining the minimum loss and nutritional value of food in combination with food safety. Microwave (MW) heating has advantages that allow it to break down barriers such as the slow thermal diffusion of conventional heating. This technology is also characterized by fast heating efficiency, at the same time meeting the needs of the industry. It can be successfully used for drying and disinfecting food. However, the main disadvantage of this technology is the heterogeneity of heating, which still poses challenges for technologists and producers. However, the combination of MW heating with other conventional methods significantly improved both microbiological safety and drying efficiency which resulted in higher quality of various products. The use of physical models and simulations as well as further research on an industrial scale to optimize the MW heating process remains a challenge.

CONCLUSIONS

1. The quality of the product subjected to microwave heating depends on the type of product, its shape and size.
2. Microwave (MW) heating overcomes the limitation of slow thermal diffusion compared to conventional heating.

3. Microwave heating technology is also characterized by fast heating efficiency, which meets the needs of the industry.
4. Due to high heating efficiency, microwave heating can be used for pasteurization, sterilization, cooking, extraction, drying. The combination microwave heating with other conventional methods improves process efficiency and higher product quality, as well as microbiological safety.
5. Consumers' interest in microwave ovens and their equipment in households is growing. In 1994, only about 3% of households in Poland had a microwave oven, while in 2020 it was 64.4% of households. While 90% of US households equipped with a microwave oven.

WNIOSKI

1. Jakość produktu poddanego ogrzewaniu mikrofalowemu zależna jest od rodzaju produktu, jego kształtu i wielkości.
2. Ogrzewanie mikrofalowe (MW) przezwycięża ograniczenie powolnej dyfuzji cieplnej w porównaniu do konwencjonalnego ogrzewania.
3. Technologia ogrzewania mikrofalowego charakteryzuje się również szybką wydajnością grzewczą, wpasowując się w potrzeby przemysłu.
4. Ze względu na wysoką wydajność grzewczą ogrzewanie mikrofalowe może być stosowane do pasteryzacji, sterylizacji, gotowania, ekstrakcji, suszenia. Połączenie ogrzewania mikrofalowego z innymi konwencjonalnymi metodami poprawia wydajność procesu, wpływa na wyższą jakość produktu, a także bezpieczeństwo mikrobiologiczne.
5. Wzrasta zainteresowanie konsumentów kuchenkami mikrofalowymi i ich wykorzystaniem w gospodarstwach domowych. W 1994 roku tylko około 3% gospodarstw domowych w Polsce posiadało kuchenkę mikrofalową, podczas gdy w 2020 roku było to już 64,4% gospodarstw domowych. Natomiast 90% amerykańskich gospodarstw domowych jest wyposażonych w kuchenkę mikrofalową.

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Dr Marek PAWŁOWSKI
European University in Warsaw, Poland
Europejska Uczelnia w Warszawie, Polska
Dr inż. Ewelina PAŁUCKA, prof. WSEiZ
University of Ecology and Management in Warsaw, Poland
Wyższa Szkoła Ekologii i Zarządzania w Warszawie, Polska
Dr Artur PIĄTKOWSKI
Halina Konopacka University of Physical Education and Tourism in Pruszkow, Poland
Wyższa Szkoła Kultury Fizycznej i Turystyki im. Haliny Konopackiej w Pruszkowie, Polska

INNOVATIONS IN THE FIELD OF SUSTAINABLE DEVELOPMENT IN THE DAIRY INDUSTRY ON THE EXAMPLE OF THE 10 LARGEST POLISH COMPANIES®

Innowacje z zakresu zrównoważonego rozwoju w branży mleczarskiej na przykładzie 10 największych polskich firm®

Key words: innovation, dairy industry, binary variables, clusters, District Dairy Cooperatives.

The article attempts to assess the use of innovations in the dairy industry in the area of sustainable development in this sector. By analyzing the available literature, articles and magazines, trends and barriers to the use of preferred innovations in the dairy sector were identified.

Słowa kluczowe: innowacja, branża mleczarska, zmienne binarne, klastry, Okręgowe Spółdzielnie Mleczarskie.

W artykule dokonano próby oceny wykorzystywania innowacji w branży mleczarskiej z obszaru zrównoważonego rozwoju w tym sektorze. Analizując dostępną literaturę, artykuły i czasopisma wskazano trendy i bariery stosowania preferowanych innowacji w sektorze mleczarskim.

INTRODUCTION

The contemporary food market, which is characterized by high risk and uncertainty, is constantly changing. Consumer preferences and the aggressive competition of food processing companies have a particular impact on the dynamics of changes in this area. Companies wishing to remain competitive, to develop and be expansive on the domestic and global market, are obliged to implement innovations covered by the sustainable development program[1].

Obtaining up-to-date and objective information on systemic consumer behavior in the market is a path leading to the development of companies in a dynamic environment. In order to compete in a turbulent environment, food processing companies must evaluate their products from the perspective of consumers and competitors. Inspired by the recommendations of the sustainable development program, they should constantly monitor their offers and improve them by implementing new technologies and techniques that improve and eliminate undesirable properties of products, important for a potential consumer.

The evolution of the concept of innovation has resulted in a broader definition of innovation. In subsequent editions of the Oslo Manual [8, 9, 10], innovation is understood as the introduction of a new or significantly improved product (good or service), process, new marketing method or a new organizational method to the work environment or external relations of the organization. Such activities can be considered innovative when the product, process, marketing or organizational method is new or significantly improved on the enterprise scale [6, pp: 159–164].

In the source literature [1, 4, 7, 11] the most common are divisions of innovation into product and process, but since the publication of the Oslo Manual [8], more and more attention has been paid to organizational and marketing innovations.

Analysis of the potential effects of using key organizational and technical innovations in food processing

AH Jasiński [4, p. 6] distinguishes three basic types of innovation: (1) product (new products), (2) process (new production processes) and (3) service (new services).

The Oslo Manual [8, 9, 10, 11, 12] also distinguishes organizational innovations that consist of changes in the organization and management of a company or changes in

1 Work on new products begins with the so-called basic research, which consists in determining the basic technical properties of a product (its basic functions) and the technology that will allow to obtain these properties [15, p. 10].

Corresponding author – Adres do korespondencji: Marek Pawłowski, European University in Warsaw, ul. Modlińska 51. 03-199 Warszawa, e-mail: marek.pawlowski@europejskauczelnia.edu.pl

the organization of work. Their purpose may be to reduce costs, increase labor productivity or gain access to scarce assets. Jasiński and his team [5] believe that organizational innovations relate to, inter alia, to employee training systems, principles of learning and sharing knowledge within the company, creating new business models and managing in the enterprise. L. Białoń [1] and AH Jasiński [4] define organizational innovations as management innovations. The Oslo Manual [8, 9, 10, 12] also distinguishes between marketing innovations that are not of interest in this article.

On the other hand, organizational and technical innovations can be defined as organizational innovations supported by new technologies or with technical support [4, p. 7]. The authors of the article believe that the group of key organizational and technical innovations in food processing includes the following modern logistics concepts and management solutions:

1. Introduction of a logistic solution to prevent and counter extreme weather conditions and their degradation,
2. Unification, at the European Union level, of measures to prevent the collapse of bee colonies,
3. Creating a platform to fight global speculation on the commodity markets, causing an increase in food prices, which implies a crisis situation in poor regions of the world, using the logistic concept of the Control Tower,
4. Statutory transfer, to the domain of the EU Government Center, of responsibility for food safety,
5. Intensification of research and development works towards the development of oil substitutes, which will eliminate the uncontrolled increase in food prices,
6. Protection against chemical soil contamination to prevent the killing of plants, animals and trees,
7. Producing genetically modified food friendly to the human body.

In the constructed model of food processing management, the initiator of the introduction of key organizational and technical innovations that affect the organization and functioning of the Polish food industry should be the National Government Center.

From the perspective of time, research seems to be quite important for our considerations[2]and analyzes [3] carried out by M. Chądrzyński. They allowed the author to formulate, inter alia, such a conclusion that the examined dairy cooperatives[2] in the years 2004-2012 they focused their innovative activities mainly in the area of production, purchase, distribution and product, and to a lesser extent on packaging and marketing. The dairy cooperatives analyzed by him mainly implemented technological, technical and packaging innovations. They implemented the least organizational and marketing innovations.

MATERIALS AND METHODOLOGY OF RESEARCH

The main research instrument was a critical comparative analysis of materials, studies and reports of 10 Polish milk processing companies, which together have the vast majority of the milk processing market in Poland (data from 2020). The subjects of the research sample (dairy cooperatives and commercial law companies) were selected on the basis of the sales volume data submitted for 2020 to the National Court Register. It includes (in order of sales volume): MLEKOVITA Group, Mlekpol SM, Piątnica OSM, Polmlek Group, Danone Sp. z o. o., Łowicz OSM, Zott Polska Sp. z o. o., Lactalis Polska Sp. z o. o., Koło OSM , Sierpc OSM.

Based on the available data presented by the 10 Polish milk processing companies of the research sample, 11 binary dependent variables reflecting complexity were defined and the versatility of innovations aimed at implementing sustainable development in the surveyed organizations.

The dependent binary variables are defined and grouped as follows:

- three binary variables representing product innovations (bv_prod_1 - bv_prod_3), where:
  - bv_prod_1 means the production of new, innovative products consistent with the principles of sustainable development,
  - bv_prod_2 represents the implementation of significantly improved, innovative products consistent with the principles of sustainable development,
  - bv_prod_3 concerns the use of innovative components from the production process of products consistent with the principles of sustainable development,
- four binary variables representing process innovations (bv_proc_1 - bv_proc_4), where:
  - bv_proc_1 means the implementation of a new or improved innovative production process consistent with the principles of sustainable development,
  - bv_proc_2 represents the use of new or improved innovative manufacturing techniques consistent with the principles of sustainable development,
  - bv_proc_3 concerns the application of new, innovative technologies in the process of sustainable production,
  - bv_proc_4 represents the application of new, innovative technologies aimed at the implementation of sustainable development in the auxiliary activities of the enterprise,
- two binary variables representing marketing innovations (bv_market_1, bv_market_2), where:
  - bv_market_1 concerns innovative changes in the design of a sustainable product,
  - bv_market_2 represents innovative changes in packaging aimed at achieving sustainable development,
- two binary variables representing organizational innovations (bv_org_1, bv_ org _2), where:
  - bv_org_1 means innovative organizational methods regarding internal, sustainable principles of the company's operation,
  - bv_ org _2 concerns innovative organizational methods in the field of corporate relations with the environment in the field of sustainable development.

Each of the binary variables is assigned a value of 1 if the analyzed organization introduces innovations in the field of sustainable development in the studied area or 0 otherwise.

2 32 dairy cooperatives participated in the research, the time scope covered the years 2004–2012.

The total number of points collected using 11 binary variables allows to determine the level of consistency or differentiation of the research sample and to categorize each result in one of five possible clusters[3]:

- cluster 1: 10 – 11 points - excellent level of implementation of innovations in the field of sustainable development,
- cluster 2: 8 – 9 points - very good level of implementation of innovations in the field of sustainable development,
- cluster 3: 6 – 7 points - good level of implementation of innovations in the field of sustainable development,
- cluster 4: 4 – 5 points - satisfactory level of implementation of innovations in the field of sustainable development,
- cluster 5: 0 – 3 points - insufficient level of implementation of innovations in the field of sustainable development.

The main limitation of the analysis was the inconsistency in the reporting and presentation of data in the analyzed categories by the research sample organizations. It should also be remembered that non-financial reporting in the field of sustainable development is not obligatory in Poland and that none of the surveyed entities is a public joint-stock company, which results in limited access to sources of information and data on research sample entities and their activities in the studied area.

ANALYSIS AND RESEARCH RESULTS

None of the analyzed organizations was included in the highest cluster (No. 1). 2 out of 10 surveyed enterprises (which constitutes 20% of the research sample) were classified to the second cluster - representing a very good level of implementation of innovations in the field of sustainable development. In this cluster, there are Piatnica OSM and Danone Sp. z o. o., both entities achieving a score of 8 out of 11 possible points in the same categories of binary variables, i.e. bv_prod_1, bv_prod_2, bv_proc_2 - bv_proc_4, bv_market_2 and bv_org_1 and bv_ org _2. In the category of innovations applied in the organizations assigned to this cluster, the following deserve special attention: the implementation of ISO 9001 and ISO 14001 standards, the food safety system according to HACCP and the environmental management system, as well as the international certificate International Food Standard, which contribute to the implementation of innovations in the field of sustainable development. Moreover, high rates of waste recovery and recycling, as well as the use of electricity from renewable energy sources both in the production process itself and in the auxiliary activities of enterprises, contributed to obtaining the best result in the tested sample.

Most enterprises – 40% of the research sample, i.e. 4 out of 10 surveyed organizations, were qualified to cluster no. 3, representing a good level of implementation of innovations in the field of sustainable development. This cluster includes: Łowicz OSM, Zott Polska Sp. z o. o., Lactalis Polska Sp. z o. o. and Polmlek Group. The first three entities obtained a score of 7 out of 11 possible points in the adopted categories of binary variables, the last of them by 1 point less. In this cluster, the diversity of scoring in individual categories of binary variables is much greater than in the case of cluster 2. The only consistent categories of binary variables in which all entities obtained points are: bv_prod_2, bv_proc_2 and bv_org _2. In the category of innovations applied in the organizations assigned to this cluster, it deserves special attention to solutions for product innovations consisting in the development of new products, taking into account their impact on the natural environment by reducing the consumption of natural resources, reducing waste and pollutant emissions, as well as created in accordance with the principles of organic and certified farming in this regard.

In terms of the use of new or improved innovative manufacturing techniques consistent with the principles of sustainable development, improving the efficiency of production machines in order to increase the productivity and quality of products while reducing the harmful environmental impact, including emission of pollutants to soil, water and air and reducing CO□ emissions deserve special attention. In addition, it is important to improve energy efficiency through the use of electricity from renewable sources (wind), which will allow the complete elimination of CO□ emissions in the milk processing.

The greatest commitment of the surveyed entities is observed in the category of packaging innovation:

- the introduction of aluminum-free packaging, thus reducing the consumption of fossil raw materials and increasing the share of renewable raw materials in the packaging,
- reducing the amount of packaging materials and using materials that have a lower impact on the environment,
- introduction of packaging 100% suitable for recycling,
- responsibility for collection and recycling of packaging,
- leading research on the possibility of using mono-foil in packaging in order to minimize the impact on the natural environment.

The surveyed entities also attach great importance to communication with internal and external stakeholders in the field of sustainable development.

Another 20% of the respondent companies dealing with milk processing (Mlekovita Group and Sierpc OSM) achieved a satisfactory level in the implementation of innovations in the field of sustainable development and were qualified to cluster no. 4, achieving respectively a score of 5 and 4 out of 11 possible. The activities of the Mlekovita Group with an environmentally friendly approach to product packaging result in the reduction of the grammage of plastics in the packaging. In terms of application of new, innovative technologies aimed at the implementation of sustainable development in the company's auxiliary activities, environmentally friendly boiler houses and combined heat and power plants have been implemented.

3 definition of M Porter: „[...] a geographic concentration of interconnected firms, specialized suppliers, service providers, companies operating in related sectors and related institutions (for example universities, standardization bodies and industry associations) in specific fields competing with each other, but also cooperating "[13]; normative definition in the Polish legal system: „a cluster is understood as the spatial and sectoral concentration of entities operating for economic development or innovation, and at least ten entrepreneurs operating in one or more neighboring voivodeships, competing and cooperating in the same or related industries and connected with an extensive network of formal and informal relationships.

OSM Sierpc, on the other hand, has implemented and is implementing a number of pro-ecological innovations in the production process, including: modernization of the energy management of the cheese department, change of production processes to reduce the water consumption rate, construction of an automated water treatment station which goal is to meet all restrictive savings standards in filter rinsing. OSM Sierpc has also taken a number of activities aimed at reducing water consumption, including:

– modernized and stable media management: water, sewage,
– continuous analysis of water consumption enabling the control of its use in the plant,
– the use of the most efficient production technologies in terms of the use of water,
– reuse of water, e.g. for washing devices, machines,
– modernization of the sewage treatment plant.

OSM Sierpc also uses new, innovative technologies aimed at implementing sustainable development in the production and auxiliary activities of the enterprise:

– use of energy tanks to recover heat from whey and cold from milk - stored at 4˚C, which allows for energy savings for pasteurization and subcooling of products,
– construction of own sewage biogas plant and a system for generating thermal energy exclusively from biogas produced from sewage, which is a pioneering solution in the Polish dairy industry,
– construction of a water boiler room with economizers allowing the use of flue gas to heat the plant premises.

As a result, the production plant leaves almost no carbon footprint, which is unique among milk processing companies.

The remaining 2 surveyed organizations, i.e, Koło OSM and Mlekpol SM, were qualified to the insufficient level cluster no. 5 and obtained respectively 3 and 2 points out of 11 possible.

CONCLUSIONS

The conducted analysis (taking into account its limitations described earlier) clearly shows the awareness of the surveyed entities about the need to implement innovations in the field of sustainable development. Nevertheless, the level of implementation leaves room for progress. It should be taken into account that innovative investments aimed at the implementation of sustainable development are both costly and time-consuming, hence the full effects of this action may only be observed in the future. The analysis also shows that in the case of most of the surveyed entities, the implemented innovations relate to: the use of new or improved innovative manufacturing techniques consistent with the principles of sustainable development (9 out of 10 surveyed entities), the implementation of significantly improved, innovative products consistent with the principles of sustainable development and the use of new, innovative technologies aimed at the implementation of sustainable development in ancillary activities of the enterprise (in both cases 8 out of 10 surveyed entities) and the use of new, innovative technologies in the process of sustainable production (7 out of 10 surveyed entities). However, none of the companies in the research sample made innovative marketing changes in the sustainable product design. This means that enterprises focus on cost-intensive and time-consuming process and product innovations instead of reaching for “low-hanging fruit” in the form of marketing or organizational innovations. innovative technologies in the process of sustainable production (7 out of 10 surveyed entities). However, none of the companies in the research sample made innovative marketing changes in the sustainable product design. This means that enterprises focus on cost-intensive and time-consuming process and product innovations instead of reaching for “low-hanging fruit” in the form of marketing or organizational innovations.

WNIOSKI

Przeprowadzona analiza (biorąc pod uwagę jej ograniczenia opisane wcześniej) jednoznacznie wskazuje na świadomość badanych podmiotów o konieczności wdrażania innowacji z zakresu zrównoważonego rozwoju. Niemniej poziom wdrażania pozostawia przestrzeń do postępów. Należy wziąć pod uwagę fakt, że inwestycje innowacyjne mające na celu wdrażanie zrównoważonego rozwoju są zarówno kosztowne, jak i czasochłonne stąd pełne efekty tego działania mogą zostać zaobserwowane dopiero w przyszłości. Analiza wskazuje także, że w przypadku większości badanych podmiotów wdrażane innowacje dotyczą: wykorzystania nowych lub ulepszonych innowacyjnych technik wytwarzania zgodnych z zasadami zrównoważonego rozwoju (9 z 10 badanych podmiotów), wdrożenia znacząco ulepszonych, innowacyjnych produktów zgodnych z zasadami zrównoważonego rozwoju oraz zastosowanie nowych, innowacyjnych technologii mających na celu wdrożenie zrównoważonego rozwoju w działalności pomocniczej przedsiębiorstwa (w obu przypadkach 8 z 10 badanych podmiotów) oraz zastosowania nowych, innowacyjnych technologii w procesie zrównoważonej produkcji (7 na 10 badanych podmiotów). Żadne z przedsiębiorstw próby badawczej nie dokonało natomiast innowacyjnych zmian marketingowych w projekcie produktu zrównoważonego. Oznacza to, że przedsiębiorstwa koncentrują się na kosztochłonnych i czasochłonnych innowacjach procesowych i produktowych zamiast sięgnąć po „nisko wiszące owoce” w postaci innowacji marketingowych czy organizacyjnych.

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Msc Eng. Anna IGNACZAK[1]
Msc Eng. Agnieszka SALAMON[2]
PhD, DrSc. Jolanta KOWALSKA[1], prof. of WULS
PhD, DrSc. Hanna KOWALSKA[1], prof. of WULS
[1]Department of Food Engineering and Process Management, Institute of Food Sciences, Warsaw University of Life Sciences WULS, Warsaw, Poland
Katedra Inżynierii Żywności i Organizacji Produkcji, Instytut Nauk o Żywności, Szkoła Główna Gospodarstwa Wiejskiego SGGW, Warszawa, Polska
[2]Department of Grain Processing and Bakery, Institute of Agriculture and Food Biotechnology – State Research Institute, 36 Rakowiecka St. 02-532 Warsaw, Poland
Zakład Przetwórstwa Zbóż i Piekarstwa, Instytut Biotechnologii Przemysłu Rolno-Spożywczego- Państwowy Instytut Badawczy, Rakowiecka 36, 02-532 Warszawa, Polska

THE USE OF REDUCED PRESSURE IN METHODS OF DRYING FOOD®

Zastosowanie obniżonego ciśnienia w metodach suszenia żywności®

Key words: vacuum drying, freeze-drying, microwave-vacuum drying, fruit, vegetables.

Currently, in addition to the attractive appearance of dried plant materials, the nutritional and health-promoting value also determine their choice by consumers. Appropriate drying methods and parameters play a key role in shaping the properties of the product with the desired quality characteristics. The article shows the beneficial aspects of drying with the use of reduced pressure, especially with microwave assistance. Despite the difficulties in selecting drying conditions for various raw materials, the use of reduced pressure and microwaves allows to obtain the desired quality of droughts and significantly shorten the drying time, which is also important in sustainable food production.

Słowa kluczowe: suszenie próżniowe, liofilizacja, suszenie mikrofalowo-próżniowe, owoce, warzywa.

Obecnie oprócz atrakcyjnego wyglądu suszonych surowców roślinnych, także wartość odżywcza i prozdrowotna decydują o ich wyborze przez konsumentów. Odpowiednie metody i parametry suszenia odgrywają kluczową rolę w kształtowaniu właściwości produktu o pożądanych cechach jakościowych. W artykule wykazano korzystne aspekty suszenia z zastosowaniem obniżonego ciśnienia, zwłaszcza ze wspomaganiem mikrofalowym. Pomimo trudności w doborze warunków suszenia dla różnych surowców, zastosowanie tej metody pozwala otrzymać susze o pożądanej jakości i znacząco skrócić czas suszenia, co jest ważne również w zrównoważonej produkcji żywności.

INTRODUCTION

Due to the seasonality of harvesting many raw materials and the limited availability in the fresh state, it is necessary to process fruit and vegetables to make them available to consumers all year round. It is especially recommended to process raw materials with a delicate and unstable structure. Dried fruit and vegetables are attractive to consumers, including as snacks or as components of many products, as they are rich in nutrients and health-promoting substances such as carbohydrates, amino acids, vitamins, minerals, and dietary fiber. They are also sensory attractive. Crunchiness, taste, and aroma are especially appreciated [20, 38, 48].

Drying is one of the most popular and oldest methods of food processing and preservation. It consists in supplying the heat needed to evaporate the water, thus reducing its content in the dried material. The low water content (water activity < 0.6) of these products means that they can be stored for a long time. Limiting the availability of water contributes to inhibiting the development of harmful microflora and ensuring microbiological stability, as well as slowing down the rate of chemical reactions and physical changes in dried food [26, 48]. As a result of the removal of water, the mass and volume of the obtained dried material are significantly reduced compared to the raw material, which reduces the costs of transport and storage. This process also allows the utilization of plant raw materials in periods of production surplus [8].

The methods and conditions of drying determine the physicochemical properties, especially in terms of shaping the sensory features, as well as the chemical composition and nutritional value [38]. The processing of fruit and vegetables is expected to be gentle, resulting in attractive, high-quality products that could be an alternative to many of the less valuable snacks on the market.

Corresponding author - Adres do korespondencji: Hanna Kowalska, Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Instytut Nauk o Żywności, Katedra Inżynierii Żywności i Organizacji Produkcji, ul. Nowoursynowska 159c, 02-776 Warszawa, e-mail: hanna_kowalska@sggw.edu.pl

The physicochemical properties and the quality of the dried product determine the two most important closely related factors. The first is the type and quality of the processed raw material, the second is the process conditions. The drying process is influenced by changes in the material, and at the same time, the process parameters determine the degree of changes taking place in the drought [47]. Apart from changes in the nutritional value and health-promoting value of dried products, one of the most important features influenced by the process conditions is the color of the dried material, which is a direct indicator of the quality of the drought. During drying, pigment degradation (eg. chlorophylls, anthocyanins, carotenoids) and browning may occur due to both enzymatic and non-enzymatic reactions [54, 59]. Pre-osmotic dehydration in fruit juices or concentrates in combination with innovative drying methods allows for eliminating color changes and even enriching with bio-components (natural antioxidants, organic acids, vitamins, etc.) and thus increase the attractiveness of the obtained droughts [36]. Therefore, to obtain high-quality dried material, it is necessary to select an appropriate method and drying conditions. The most important parameters are the temperature, time of the process, and the flow rate of the drying agent. Currently, drying methods using reduced pressure deserve special attention. The most important advantage of these techniques is the possibility of creating low-temperature conditions, which, in addition to increasing the efficiency of the process and saving energy, compared to other techniques, has a very positive effect on the quality of the product. Many interesting design solutions with the use of reduced pressure include vacuum (VD), microwave-vacuum (MVD), and freeze-drying (FD) dryers. Depending on the type of dryer, especially within the MVD system, the selection of drying conditions is more complex. In addition to temperature and time, microwave pressure and power (possibly frequency) are important, as well as food composition and dielectric properties.

In many publications, the influence of the application of different pressure, the drying time of food on the properties of the obtained dried material, was analyzed, e.g. from strawberries [10, 51], calabash and quince [29, 30], beetroot [42], sweet cherry [62], bamboo [43], sohiong (Prunus nepalensis) fruit [17], papaya [15], pomegranate skins [56], and also green malt [5].

The aim of the article is to review the current state of knowledge on the use of food drying methods using reduced pressure, with particular emphasis on freeze-drying, vacuum, and microwave-vacuum drying.

DRYING MECHANISM AT DIFFERENT PRESSURE

The use of different pressure in the drying process is primarily related to the possibility of effective drying of food at a moderate temperature, allowing the preservation of thermolabile ingredients. Compared to atmospheric pressure, the use of reduced pressure for drying food results in a lower boiling point of water, and thus the phase transformation necessary to ensure the drying of the material [60]. The lower the pressure value, the lower the boiling point of the water in the drying material. Moreover, the presence of dissolved substances in the water contained in the material may increase the boiling point [60]. Is observed that at the beginning of drying, the temperature of the material is close to the boiling point of water at the corresponding pressure value. In the course of the process, as the moisture decreases, the surface temperature of the material increases. At the end of drying, when a significant part of the water has evaporated, the temperature of the material increases [19].

Ciurzyńska et al. [10] presented the effect of applying different pressure during vacuum drying on the rehydration properties of dried strawberries. Vacuum drying carried out at a lower pressure of 4 kPa resulted in obtaining a product with greater rehydration capacity compared to the dried material obtained at a pressure of 16 kPa. After rehydration, the dried samples were characterized by higher water content and a greater weight gain. This is explained by greater damage to the structure of the material at higher pressure during drying. Observations were also carried out on the influence of abrupt pressure change on the quality of dried material. Two variants were used, consisting in reducing and increasing the pressure value. The step change in pressure from 16 to 4 kPa resulted in the improvement of the rehydration capacity of the dried material, which results from the increase in its porosity. However, when the pressure was changed from 4 to 16 kPa the obtained dried material had a lower water absorption capacity [10]. Wu et al. [64] investigated the effect of different pressure during vacuum drying on the amount of drying shrinkage of eggplant. With increasing pressure in the drying chamber, the material shrinkage increased. This phenomenon results from the pressure imbalance between the inside of the dried material and the outside environment, which causes stresses leading to shrinkage. As a result of the application of the reduced pressure, a much smaller pressure difference between the inside of the dried material and the external environment was observed than in the case of drying under atmospheric pressure [64].

In food processing, microwaves used in the frequency range 915 MHz – 3 GHz are easily absorbed by water, fat, and sugars contained in food [7, 25]. At this frequency range, variable movement of polar molecules is generated, and their inversion 2450 times in 1 s. This is due to the action of microwaves and electrodynamic forces causing rotation and positioning of the dipoles, depending on the variable electric field, causing the rotation of the charges and the constant movement of the dipoles. The result is intermolecular rubbing leading to the release of thermal energy in the entire material [30]. Thus, as a result of stimulating the material particles with microwaves, energy is generated in the entire volume of the material. There is also the phenomenon of electroosmosis causing the flow of a stream of liquid water to the surface, which facilitates evaporation.

Using microwave drying in an atmosphere of reduced pressure, the energy generated by the electromagnetic field causes accelerated movement of water molecules, and the force caused by the reduced pressure causes water molecules to quickly migrate from the material to the surface and evaporate. On the other hand, the vacuum system in the chamber reduces the concentration of water vapor and lowers the boiling point of water inside the chamber, thus enabling drying of the products at a lower temperature than at atmospheric

pressure [25]. In addition to reduced process time and energy efficiency, the operation of microwaves and reduced pressure can improve the formation of the desired structure of the dried products. According to Anli [2], a vacuum helps evacuate water as gas molecules pass through the pores of the material; increasing the surface for mass transfer and phase transition at a lower temperature, which is extremely beneficial in drying heat-sensitive foods. Many studies show that obtaining an appropriate MVD drying effect depends on the type of raw material and the selection of drying conditions. It is often quite difficult because the individual parameters are related to each other. Process conditions are controlled by various parameters such as microwave power, pressure, temperature, as well as degree of moisture loss, as well as food composition, and dielectric properties, ie the ability to absorb and convert electrical energy into heat [25, 53], making the process complicated. The dielectric properties are important because in foods with a high dielectric loss and moisture content, the dipolar rotation in water molecules and the conversion of electromagnetic energy into heat energy increases. In materials with a low loss coefficient, called "transparent" to microwaves, microwaves do not generate heat, they tend to pass without absorption [25]. Moreover, depending on the food matrix, the effect of microwaves is related to the physical phenomenon of absorption and reflection of electromagnetic radiation, which is referred to as the resonant cavity [16, 25]. This is one of the most important issues that should be investigated because a properly designed resonance cavity can improve the distribution and homogeneity of the electromagnetic field.

As a design solution, MVD drying systems include static, rotating systems, with more than one wave generator (magnetron) and with different designs of vacuum chambers [25]. For food, mainly rotating systems are used to obtain an even distribution of radiation.

LOW-PRESSURE DRYING METHODS

Freeze-drying (FD)

Freeze-drying is the removal of water from previously frozen material by sublimation, i.e. a direct transition from solid (ice) to vapor, omitting the liquid phase. The process can take place under atmospheric pressure, but reduced pressure (below 200 Pa) is used more often [21, 34]. To ensure the proper course of drying, it is necessary to supply the heat of sublimation which is the sum of the heat of vaporization of water and the latent heat of melting ice, but without the possibility of defrosting the material, and maintaining pressure difference through the discharge of water vapor. The high quality of the dried products obtained with this method is conditioned by factors such as low temperature and the lack of oxygen. Freeze-drying allows for maintaining the shape and structure of the dried tissue. Particularly valuable are the features of drought, such as high nutritional value, natural color, intense taste, and aroma, as well as crunchiness, porosity, and the ability to rehydrate [38].

Freeze-drying is a complex process. In the first stage, the raw material is frozen, most often at a temperature of -20 to -40ºC [38]. The speed of freezing is important. Because the faster this process takes place, the smaller ice crystals are formed and the structure of the material is not damaged. The process of freezing the raw material, which precedes the freeze-drying stage, may take place under atmospheric pressure or be self- freezing as a result of lowering the pressure in the drying chamber. The latter method is usually used in freeze dryers on an industrial scale [34]. In the next stage, the phenomenon of ice sublimation occurs, which usually takes place under reduced pressure, 60–70 Pa, and lasts from 12 to 24 hours. At this stage, it is important to constantly supply the right amount of heat, as well as remove water vapor by freezing it on the cold walls of an ice condenser between the vacuum pump and the drying chamber [27, 34]. The process temperature at this stage plays an important role in shaping the structure of the lyophilized products. The use of too high a temperature may defrost the dried material, and thus the breakdown of the dry structure [11]. The first stage of drying continues until no more ice is deposited on the surface of the condenser. In the second phase of drying, non-freeze bound water is removed from the material by desorption. This stage takes place under conditions of increased temperature and reduced pressure. Its purpose is to dry the product to the desired humidity [22]. The final stage of drying significantly affects the quality of the dried material. Because, as a result of the increased temperature, there is a risk of losing many valuable thermolabile food ingredients at this stage. Therefore, this process in the case of products containing ingredients sensitive to high temperature is carried out in the temperature range of 10–35ºC, and in products with higher thermal resistance at temperatures above 50ºC. The pre-drying stage is considered complete when the dried products reach a humidity of approx. 2% and all water vapor present in the dried material is evaporated [27]. The course of lyophilization and the quality of the obtained products depend on factors such as the type of raw material (composition, humidity, maturity), the rate of freezing the raw material and the heat flux supply to the system, process parameters (temperature, pressure, time) and the method of storing lyophilisates [22, 33].

Despite many positive aspects, freeze-drying has certain disadvantages. First of all, it is a time-consuming and cost-intensive process, as the cost of freeze-drying is 4 to 8 times greater than that of convection drying [55, 63]. The high costs of the process are related to the long duration of the process, reaching even 72 hours. Moreover, the porous structure of the lyophilisates promotes oxidation processes, therefore these products should be packed without contact with oxygen and moisture [58].

Vacuum drying (VD)

Vacuum drying is characterized by a faster drying rate, resulting from a lower boiling point of water in the product under reduced pressure than at atmospheric pressure [26]. Compared to drying techniques in which the material is in direct contact with a drying agent, e.g. a stream of hot air, heat during vacuum drying is transferred by conduction through the contact of the material with the heated surface of the dryer shelf. Unlike convection drying, it is carried out at a lower temperature and with limited oxygen access, which results in the high quality of the dried material [44, 49]. Changes in color, taste, smell, and shape are limited, as well as the degradation of nutrients and health-promoting ingredients [3]. The changes in the color of carrots dried under reduced pressure were about 21% lower than during convection drying [23]. Another positive feature of this method is energy saving [3]. It is an

economical and environmentally friendly method. The use of low temperatures makes it possible to use this method to dry fruits and vegetables which contain thermolabile compounds [26]. To increase the efficiency of drying under reduced pressure they are combined with microwaves [26, 58].

Microwave-vacuum drying (MVD)

Microwave-vacuum drying is a relatively new and effective technology for drying food, which allows for obtaining high-quality dried products. There are three periods of drying with the MVD method. First, the drying rate is increased in a short time, with the product reaching the boiling point of water due to the efficient transfer of microwave energy. In the constant rate step, free water is removed from the material at a constant rate. The temperature of the product during this period is relatively stable. The evaporation of the water at a constant rate can be carried out to a lower moisture level than with conventional drying. This extension of the area of constant drying rate allows for the reduction of the time of the conducted process. The final stage is a period of slowing down of the drying rate, during which the drying rate is reduced due to the removal of bound water. This step is often the longest for conventional methods as well. The use of microwave-vacuum drying allows to shorten its duration, not only due to the loss of moisture in the permanent drying period but also the evaporation of water "in situ", i.e. "in place", therefore it is faster than the diffusion of liquid water occurring during traditional drying [6, 60].

Sharma and Prasad [61] proved that drying garlic using this MVD method allowed to shorten the drying time by about 80% compared to convection drying. A comprehensive review article by González-Cavieres et al. [25] presents a lot of information about MVD, including the fact that it allows shortening the drying time by 70-90% compared to the methods of hot air drying and freeze-drying. The combination of reduced pressure and the effect of microwaves increases the drying efficiency and the possibility of producing attractive products with favorable properties and requires a lower energy demand [12, 18, 38]. The reduced pressure contributes to a relatively quick mass transfer and the microwave effect of a quick heat transfer in the entire volume of the dried material. As a result of the phase change of water to steam, an internal pressure gradient is created within the material, which causes the water to flow from the inside to the surface and then to the outside of the material. The phase transformation of water into a gas state increases the volume of the material, and the action of the reduced pressure accelerates its removal from the sample, creating the "puffing" effect. Under these conditions, a stable structure is created, also resulting from the amorphous transformation of tissue components [24, 38]. This allows obtaining a product with much lower drying shrinkage or its elimination, and with better rehydration properties than in convection drying. Such a product may be light and porous, similar to that of a freeze-dried one, but is usually harder. Moreover, many of these dried products are less sensitive to moisture than lyophilisates. The intensity of this phenomenon depends on many factors. The type of dried material is of great importance, especially its initial moisture content, but also the content of food ingredients that affect the amorphous transformation and drying conditions, such as microwave power, vacuum level, and drying time. It has been shown that the product with the "puffing" effect is obtained with higher microwave power and lower pressure [32, 35, 46]. Dai et al. [15] for various thicknesses of papaya slices (3–12 mm), tested the microwave power density in the range of 6–12 W/g, temperatures in the range of 50–70°C, and vacuum degree in relative pressure in the range from 75 to 90 kPa. The optimal technological parameters were established at a microwave power density of 10 W / g, a vacuum degree of 90 kPa, a drying temperature of approx. 55°C, and a slice thickness of 6 mm.

One of the most important disadvantages of microwave drying is the uneven heating of the material, resulting e.g. from the inhomogeneous distribution of the electromagnetic field inside the drying chamber and the inhomogeneous distribution of moisture in the material. This may cause some parts of the dried food to burn. Uniform drying can be achieved through a properly constructed microwave chamber, installation of wave mixers, a rotating drum, or temperature control with power modulation. Setting the dried material in constant motion averages the effect of the electromagnetic field on each part of the dried material, and as a result, more homogeneous heating [45]. Moreover, the moisture content may not be the same in different parts of the final product. In order to improve the process, it is recommended to combine microwave-vacuum drying with preliminary convection drying [38].

EFFECT OF SELECTED PARAMETERS ON MICROWAVE-VACUUM DRYING

In the case of microwave-vacuum drying, the microwave power, temperature, pressure, and process time have a significant impact on the process and the quality of the obtained dried products. The influence of microwave power on microwave-vacuum drying has been the subject of research by many researchers. Jałoszyński et al. [30]confirmed that with the increase in microwave power the duration of the process is shortened. Drying quince fruit using the lowest microwave power, 240 W, took the longest and lasted 51 minutes. After increasing the power to 360 W, the drying time was reduced to 39 minutes. In the case of the highest microwave power of 480 W, the process took 27 minutes. The doubling of the power reduced the processing time by 47%. The maximum material temperatures during drying depending on the power of the applied microwaves were also examined. The rapid increase in the temperature of the samples was observed in the first 3 minutes of the process. The authors confirmed the effect of increasing the microwave power on increasing the maximum temperature of the dried material. In the fruit dried at the lowest power (240 W), their temperature was 55°C. Increasing the microwave power to the level of 360 and 480 W increased the maximum material temperature to 70 and 77°C, respectively. A clear temperature stabilization was observed at the final drying stage at all three levels of microwave operation. A significant effect of the microwave power on the final drying shrinkage of the product was also observed. The highest volume shrinkage occurred when using the lowest microwave power, it was at the level of 75%. Increasing the microwave power to 360 and 480 W limited the drying shrinkage to 68 and 62%, respectively. The study showed no significant effect of the microwave power used on the antioxidant activity and the total polyphenol content

in the final product. However, slightly higher values of these determinants were observed in the case of using the highest microwave power [30].

In studies conducted by Lech et al. [40], it was shown that higher microwave power increased the drying rate of beetroot slices, which resulted in a shorter process duration. The longest time was observed at a microwave power of 120 W; it was 104 minutes. With a power of 480 W, drying was the shortest to 16 minutes. Moreover, the dried obtained as a result of drying with the use of higher microwave power was characterized by a higher maximum temperature. The lowest temperature (81°C) was achieved by the dried material obtained with the use of 120 W, and the highest (138°C) was achieved by the material dried at 480 W [40]. Too high microwave power may cause a local temperature increase in the material and its local burning.

The negative effect of fixing the material by drying is the loss of heat-sensitive compounds. In the studies by Lech et al. [40] it was confirmed that the bioactive potential of dried beetroots was reduced in terms of the content of polyphenols and antioxidant activity in relation to fresh material. However, increasing the microwave power had a positive effect on both the content of polyphenols and the antioxidant activity, which was explained by a significant reduction in the drying time of the material. On the other hand, in beetroot samples subjected to initial osmotic dehydration in chokeberry juice, the increase in microwave power resulted in a significant reduction in the total content of polyphenols and antioxidant activity. This was explained by the fact that the initial osmotic dehydration increased the maximum temperature of the dried material [40].

In the case of solutions using rotary systems during microwave-vacuum drying, the rotational speed of the drum is an important parameter influencing the structure of the material. It is a variable that can prevent uneven temperature distribution during drying, as well as irreversible changes caused by electric arcs, i.e. the accumulation of excess moisture from the product on the walls of the resonance cavity or in the vacuum chamber. The research on drying pork showed that despite the use of the different rotational speeds of the drum in the range from 9 to 11 rpm, it was not possible to obtain a product without visible damage to the structure of muscle fibers. When selecting the rotational speed of the drum, an important element is to pay attention to the composition of the food undergoing drying [25], because higher rotation speeds may contribute to the formation of damage in the structure due to the collision of pieces of material, as well as the accumulation of sugars on the surface of the product, causing sticking or sticking to the walls dryers.

Effect of convective drying and osmotic pre-treatment

Initial reduction of the material moisture content by convection drying or during osmotic dehydration with slight changes in structure is a favorable method of preparing the material for drying using the microwave-vacuum method. In the studies by Kowalska et al. [35] already at the stage of pre-treatment with the use of sucrose solution or with the addition of 5% concentrated chokeberry juice, strawberries were characterized by no shrinkage and were distinguished by an attractive appearance. Fruits subjected to MVD drying underwent the puffing effect much more easily than the samples not subjected to this osmotic treatment. On the other hand, the opposite tendencies were observed during the drying of strawberries by the freeze-drying method; fruits were most easily dried without pretreatment. Also in the studies by Piotrowski et al. [50] it was shown that preliminary osmotic dehydration resulted in obtaining significantly higher values of water activity of freeze-dried strawberries as compared to the dried strawberries without preliminary drainage. Moreover, in the case of strawberries obtained by the hybrid method, the water activity after storage decreased. For the lyophilized samples, an inverse relationship was obtained [35]. Kowalska et al. [37] showed that the use of convection drying at 50°C in the first stage, and then microwave-vacuum drying (microwave power 400 W, pressure 3.5 kPa) contributed to the production of high-quality products in terms of the preservation of many polyphenolic compounds.

EFFECT OF THE APPLICATION OF DRYING UNDER LOW-PRESSURE CONDITIONS ON THE PROPERTIES OF DRIED PRODUCTS

The use of various methods of drying fruit and vegetables in an atmosphere of reduced pressure has a significant and varied impact on the physicochemical properties, analyzed with both instrumental and sensory methods, as well as the nutritional and health-promoting value. Low pressure reduces the phase transition temperature of the water, therefore water from the material can be removed under milder conditions than under atmospheric pressure. This method of conducting the process may reduce overheating of the material and the loss of thermolabile components. Drying without air access is also beneficial [1, 29]. The main advantage of freeze-drying is obtaining a product with properties similar to the raw material in terms of nutritional value and sensory values. However, both freeze-drying and microwave-vacuum drying allow for the removal of significant amounts of water, up to 95–99%, but the lyophilisates are more delicate, crunchy, and highly hygroscopic, and those dried by the MVD method are harder and less hygroscopic [38]. On the other hand, their crispness and hygroscopicity make it difficult to pack, store and transport them [9, 21]. The low temperature of the FD process allows for the preservation of natural food ingredients, e.g. vitamins, dyes, but the short drying time using the MVD method at a higher temperature may result in obtaining similar or higher contents of some ingredients, e.g. polyphenolic compounds [35, 38]. Taking into account the possibilities related to the lower energy demand in the MVD method, in the next part of the article, the properties of droughts obtained with this method will be discussed in more detail.

Jałoszyński et al. [28] observed in microwave and vacuum dried rosehips an almost 3 times higher degree of vitamin C preservation compared to convection dried material. Cui et al. [12] proved that, compared to freeze-drying, the use of microwave-vacuum drying at a similar level allowed to maintain the content of carotenoids in carrot slices and chlorophyll in chives. In the studies of Chong et al. [6], it was shown that microwave-vacuum drying allows for maintaining high antioxidant activity, polyphenol content, and attractive

appearance of dried apples. Cranberries dried using this method at low microwave power turned out to be a good alternative to convective dried products in terms of color and the content of bioactive ingredients, such as polyphenols and flavonoids [65]. Similarly, MVD-dried carrot slices proved to be better in terms of beta-carotene content, vitamin C, delicate texture, and rehydration properties, compared to samples prepared by the convection method [41]. Calín-Sánchez et al. [4], examining the influence of the drying method on changes in the sensory characteristics of fruit, found that microwave-vacuum drying of chokeberry allows to obtain a high-quality product, e.g. in terms of porosity, but low hardness and bulk density, and relatively low intensity of sour taste, bitterness and astringency.

The shape change (shrinkage) and increasing the hardness of the material have a negative impact on the acceptability of dried food snacks [14]. One of the most important problems during drying is the so-called drying shrinkage, which is influenced by the structure and composition of the raw material as well as the conditions and method of drying. The shrinkage determines the quality of the dried material, because it determines its texture, limits the wettability and the ability for water adsorption, and therefore has a negative impact on the rehydration and hygroscopic properties of the product. The increasing moisture gradient in the dried material causes internal stresses and structural damage, which result, among others, from reducing the diameter of capillaries through which water flows. The gradual increase in the concentration of soluble components in the plant tissue results in the stiffening of its cell walls and the change in the properties of the material from viscoelastic to brittleness. The porosity and density of the material are closely related to the phenomenon of shrinkage; higher porosity, i.e. lower product density, conditions the occurrence of lower drying shrinkage. The products dried by the microwave-vacuum method are characterized by the high porosity of the structure, which in turn contributes to higher values of rehydration coefficients [1]. Jałoszyński et al. [31] observed a significant influence of the drying method and process parameters on the drying shrinkage of the scorzonera root. The highest shrinkage occurred in the case of traditional drying, it was 91%. Microwave-vacuum drying significantly reduced material shrinkage. Depending on the microwave power used, the shrinkage was in the range of 52–74%, with the lowest value occurring at the highest microwave power, and the highest at the lowest microwave power. Monteiro et al. [44] presented the influence of various drying methods on the rehydration of dried pumpkins. During rehydration at 25°C, the product of microwave-vacuum drying was characterized by a higher moisture content after rehydration than that obtained by lyophilization and convection. When using a higher temperature (80°C), microwave-vacuum dried samples showed lower values of the rehydration coefficient compared to lyophilisates, but higher than in the case of convection droughts.

According to the research by Kowalska et al. [38] strawberries dried by MVD without pre-treatment were too soft. It was probably difficult to choose the right parameters to obtain a texture similar to that of freeze-dried samples. The authors concluded that there was probably not enough (there was not enough) an ingredient that would strengthen the structure of the dried fruit, such as sugar. As a result, the samples were unevenly dried, burnt in places, especially inside, and damp in places. However, the hardness of dried strawberries increased depending on the amount of concentrated chokeberry juice added (5 or 15%) to the sucrose solution (from 48.3 to 56.8 N). Conversely, freeze-dried samples were characterized by lower hardness but greater brittleness, and those after initial dehydration became more flexible and soft. Initial freeze-drying of the dehydrated osmotic fruits was difficult. The more stable and higher hardness of dried strawberries obtained by the method with pre-osmotic treatment should be explained by the difference in the mechanism of both methods of drying. In dehydrated and MVD-dried samples, a stable structure arises as a result of an amorphous transformation of plant tissue components. It was favored by factors such as temperature, increased content of carbohydrate components that had penetrated from the osmotic solution [57]. The fruit tissue filled with the osmotic substance has become more resistant to shape changes caused by the collapse of the cell walls. In the freeze-drying method, sublimation of ice occurs in the frozen material with a high sugar content, which may be difficult, e.g. due to the entrapment of water in a concentrated, highly viscous liquid phase. Also, too high lyophilization temperature may cause the collapse of the structure of the material, which may be associated with exceeding the critical temperature at which the glass transition took place [39]. Similarly, when the temperature is too low, the drying rate of the material is not fast and efficient enough [55]. In the studies by Prosapio et al. [52] it was shown that initial osmotic dehydration allowed to keep the structure of strawberries dried by freeze-drying, compared to non-osmotically dehydrated samples. It was also shown that samples with medium moisture content formed less ice, and the presence of sugar causes the formation of smaller crystals because under such conditions it promotes the nucleation process and not the growth of ice crystals.

Cui et al. [13] attempted to combine microwave-vacuum drying with freeze-drying in order to obtain dried carrots and apples. This hybrid drying system proved to be an excellent alternative in which high-quality dried samples were obtained. The combination of both drying techniques allowed for the preservation of a higher content of vitamin C and carotene in the dried material, as well as obtaining favorable color, texture, and rehydration properties. At the same time, despite the multi-stage nature of freeze-drying, the combination of both methods of drying allowed to shorten the drying time compared to freeze-drying.

CONCLUSIONS

Drying is important in food production in the era of developing production including the production of fruit and vegetable snacks (chips), which are more and more common on the market. common on the market. The choice of food processing methods, and especially the drying of plant raw materials, should respond to the growing awareness of consumers in terms of nutritional and health-promoting quality. Sensory qualities are also always important. In the case of snacks in the form of dried fruit or vegetables, crunchiness is important in addition to the outside appearance. The qualitative features of the obtained droughts are shaped by both the appropriately selected method and the parameters of the process itself. Drying methods using reduced pressure,

especially with microwave support, often considered innovative, should be used more widely. They allow for obtaining high-quality dried products in terms of sensory features, nutritional value, and microbiological stability. These technological solutions are also important for energy savings, especially in sustainable production. Despite the difficulties in selecting the appropriate drying parameters, depending on the type of raw material, the use of reduced pressure and microwaves allows to significantly shorten the drying time and obtain products of the desired quality.

WNIOSKI

Suszarnictwo ma istotne znaczenie w produkcji żywności, w tym do wytwarzania coraz bardziej powszechnych na rynku przekąsek (chipsów) owocowych i warzywnych. Dobór metod przetwarzania żywności, a zwłaszcza suszenia surowców roślinnych, musi stanowić odpowiedź na wzrastającą świadomość konsumentów odnośnie jakości żywieniowej i prozdrowotnej. Zawsze ważne są również cechy sensoryczne. W przypadku przekąsek w postaci suszonych owoców lub warzyw oprócz wyglądu zewnętrznego, ważna jest chrupkość. Cechy jakościowe otrzymanych suszy kształtuje zarówno odpowiednio dobrana metoda, jak i parametry samego procesu. Metody suszenia z zastosowaniem obniżonego ciśnienia, zwłaszcza ze wspomaganiem mikrofalowym, często uznawane za innowacyjne, powinny być szerzej wykorzystywane. Pozwalają one uzyskać susze wysokiej jakości pod względem cech sensorycznych, wartości odżywczej i trwałości mikrobiologicznej. Te rozwiązania technologiczne ważne są również ze względu na oszczędności energetyczne, zwłaszcza w produkcji zrównoważonej. Mimo trudności w doborze odpowiednich parametrów suszenia, zależnie od rodzaju surowca, zastosowanie obniżonego ciśnienia i mikrofal pozwala znacząco skrócić czas suszenia i otrzymać susze o pożądanej jakości.

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*Dr inż. Katarzyna ŚWIĄDER
Inż. Aleksandra LIPSKA
**Prof. Nadiya BOYKO
*Institute of Human Nutrition Sciences, Warsaw University of Life Sciences – SGGW Warsaw, Poland; Polish Society of Nutritional Sciences, Warsaw, Poland
** Department of Molecular Microbiology and Mucosal Immunology
Uzhhorod National University, Uzhhorod, Ukraine
*Instytut Nauk o Żywieniu Człowieka, Szkoła Główna Gospodarstwa Wiejskiego SGGW Warszawa, Polska; Polskie Towarzystwo Nauk Żywieniowych, Warszawa, Polska
** Katedra Mikrobiologii Molekularnej i Immunologii Śluzówkowej, Użhorodzki Uniwersytet Narodowy, Użhorod, Ukraina

NOVEL SWEETENERS: ISOMALTULOSE, D-TAGATOSE, TREHALOSE AND SUCROMALT – THEIR DESCRIPTION AND PROPERTIES®

Nowe substancje słodzące: izomaltuloza, D-tagatoza, trehaloza i sukromalt – ich opis i właściwości®

Key words: novel food, novel sweeteners, isomaltulose, D-tagatose, trehalose, sucromalt.

The food and pharmaceutical industries are still looking for sweeteners that could be suitable alternatives to sucrose. Substances that will impart a sweet taste but at the same time have a sufficiently low Glycemic Index so that they can be used in products aimed at diabetics, among others. Noteworthy are the new sweeteners classified as novel foods under the Regulation (EU) 2015/2283 of the European Parliament and of the Council on novel foods. These substances include isomaltulose, D-tagatose, trehalose and sucromalt. The objectives of this study were to characterize these substances and discuss their physical and chemical, nutritional and health properties, safety of use, and applicability in products. The discussed new sweeteners are characterized by a lower sweetness in comparison to sucrose, therefore, in order to obtain the same sweetness in products, they should be used in appropriately larger concentrations. However, the new sweeteners do not raise blood glucose levels quickly and cause less insulin secretion than glucose, so they are recommended for use in products aimed at diabetics.

Słowa kluczowe: nowa żywność, nowe substancje słodzące, izomaltuloza, D-tagatoza, trehaloza, sukromalt.

Przemysł spożywczy i farmaceutyczny nadal poszukuje substancji słodzących, które mogłyby być odpowiednią alternatywą dla sacharozy. Substancji, które będą nadawały słodki smak, ale jednocześnie będą miały odpowiednio niski indeks glikemiczny, tak aby mogły znaleźć zastosowanie w produktach skierowanych między innymi do diabetyków. Na uwagę zasługują nowe substancje słodzące, zaliczane do nowej żywności zgodnie z rozporządzeniem Parlamentu Europejskiego i Rady (EU) 2015/2283 w sprawie nowej żywności. Do substancji tych zaliczamy izomaltulozę, D-tagatozę, trehalozę i sukromalt. Celem pracy było dokonanie charakterystyki tych substancji oraz omówienie ich właściwości fizycznych i chemicznych, odżywczych i zdrowotnych, bezpieczeństwa stosowania oraz możliwości aplikacyjnych w produktach. Omówione nowe substancje słodzące charakteryzują się niższą słodyczą w porównaniu do sacharozy, dlatego aby uzyskać w produktach identyczną słodycz należy je zastosować w odpowiednio większych stężeniach. Nowe substancje słodzące nie podnoszą szybko poziomu glukozy we krwi i powodują mniejsze wydzielanie insuliny w porównaniu z glukozą, dlatego rekomendowane jest stosowanie ich w produktach skierowanych dla diabetyków.

INTRODUCTION

Novel food is food or a food ingredient which, until May 1997, was rarely or not at all consumed in the European Union. 1997 was the year in which the first rules on novel foods in the EU came into force in the form of Regulation (EC) No 258/97 [28, 29].

Novel foods are new food sources or foods that are newly developed, innovative, produced with new technologies and production processes and traditionally consumed outside the EU but not within it [12].

Examples of food ingredients or foods categorized as novel foods are agricultural products from third countries, e.g.

Corresponding author- Adres do korespondencji: Katarzyna Świąder, Institute of Human Nutrition Sciences, Warsaw University of Life Sciences – SGGW, Nowoursynowska Sreet 159C, 02-776, Warsaw, Poland, e-mail: katarzyna_swiader@sggw.edu.pl

chia seeds; plant extracts, e.g. rapeseed protein; a new food production process, e.g. subjecting bread, mushrooms or milk to UV light to increase their vitamin D content; new sources of nutrients, e.g.: microalgae oil rich in docosahexaenoic acid (DHA).

On 30 December 2017, Commission Implementing Regulation (EU) 2017/2470 of 20 December 2017 establishing an EU list of novel foods in accordance with Regulation (EU) 2015/2283 of the European Parliament and of the Council on novel foods [5] was published. The list lists all novel ingredients and novel foods authorised for use in the European Union. The type of ingredient is indicated, together with an indication of which products it may be added to and in what quantities. It also lists contra-indications to their use and the information that the manufacturer using them should indicate on the packaging label.

Noteworthy among them are the new sweeteners such as isomaltulose, D-tagatose, trehalose and sucromalt. The aim of the study was to characterize these substances and discuss their physical and chemical properties, nutritional and health properties, safety of use and possible applications in products.

NOVEL SWEETENERS: DESCRIPTION AND PROPERTIES

ISOMALTULOSE (PALATINOSE)

Definition

Isomaltulose, also known as palatinose (6-O-α-D-glucopyranosyl-D-fructofuranose), is an isomer of sucrose that may be a valuable alternative to it (Table 1.) [5]. It is a reducing disaccharide composed of glucose and fructose linked by an α-1,6 glycosidic bond [22]. It occurs naturally in small amounts in honey and sugarcane juice [33]. The Table 1 shows chemical name and formula, as well as formula weight of isomaltulose but also the other new sweeteners.

Physical and chemical properties

Palatinose is a white fine crystalline powder, looks and tastes like sucrose but is half as sweet as it [15]. Sawale and colleagues [31] report that the sweetness intensity of this sugar is in the range of 0.3–0.4 with respect to sucrose considered as 1, while McNutt and Sentko [25] describe that, in a 10% solution, its sweetening power is 50–60% of sucrose. According to Sentko and Willibald-Ettle [32], its sweetening power relative to sucrose is 0.48. In addition, it has no foreign aftertaste, imparts a slight cooling effect and masks the unpleasant odours of intense sweeteners [32] (Table 2). The Table 2 shows calorie value, GI and sweetness of isomaltulose but also all descripted novel sweeteners [26].

Isomaltulose melts at a lower temperature (123-124° C) compared to sucrose (160-185 °C) and is more stable under acidic conditions [22]. It is soluble in water, although its solubility is lower than that of sucrose and increases with increasing temperature, reaching 85% of the yield of sucrose at around 80°C [10].

Manufacturing

Isomaltulose can be obtained from sucrose by enzymatic bioconversion. For industrial purposes, it is produced with the help of bacteria: *Klebsiella singaporensis, Serratia plymuthica* [31], *Erwinia rhapontici, Klebsiella planticola, Pseudomonas mesoacidophila, Protaminobacter rubrum* and *Enterobacter sp.* [42].

Metabolism and absorption

Isomaltulose is metabolized completely in the human body. The digestion process proceeds much slower than that of sucrose, and this is due to the greater durability of the α-1,6 glycosidic bond than that present in sucrose [14, 18, 22]. After ingestion, it is slowly broken down by enzymes (saccharidases), the rate of hydrolysis being 26-45%, compared to sucrose. The hydrolysis products formed, i.e. glucose and fructose, are

Table 1. Description of novel sweeteners

Tabela 1. Opis nowych substancji słodzących

	Isomaltulose	D-Tagatose	Trehalose	Sucromalt
Chemical name	6-O-α-D-glucopyranosyl-D-fructofuranose, monohydrate	D-tagatose	α-D-glucopyranosyl-α-D-glucopyranoside, dihydrate	n.a.
Chemical formula	$C_{12}H_{22}O_{11} \cdot H_2O$	$C_6H_{12}O_6$	$C_{12}H_{22}O_{11} \cdot 2H_2O$ (dihydrate)	n.a.
Formula weight	360,3 (monohydrate)	180,16 (g/mol)	378,33 (dihydrate)	n.a.

Source: Own elaboration based on [5]

Źródło: Opracowanie własne na podstawie [5]

Table 2. Calory value, GI and sweetness of novel sweeteners

Tabela 2. Wartość kaloryczna, indeks glikemiczny i słodycz nowych substancji słodzących

	Isomaltulose	D-Tagatose	Trehalose	Sucromalt
Calory value (kcal/g)	4	3	4	4
GI	32	3	72	53
Sweetness	0.48	0.92	0.48	0.7

Source: Own elaboration based on [3, 5, 8, 11, 13, 14, 17, 21, 31, 32, 37, 39]

Źródło: Opracowanie własne na podstawie [3, 5, 8, 11, 13, 14, 17, 21, 31, 32, 37, 39]

Table 3. The designation of the novel food (sweetener) on the labelling of the foodstuffs containing it

Tabela 3. Oznaczenie nowej żywności (substancji słodzącej) na etykietach zawierających ją środków spożywczych

Isomaltulose*	D-Tagatose*	Trehalose*	Sucromalt*
The designation of the novel food on the labelling of the foodstuffs containing it shall be:			
'Isomaltulose'	'D-Tagatose'	'Trehalose' and shall be displayed on the labelling of the product as such or in the list of ingredients of foodstuffs containing it.	'Sucromalt'
The designation of the novel food on the labelling shall be accompanied by indication that the:			
'Isomaltulose is a source of glucose and fructose'.	D-Tagatose exceeds 15 g per serving and all beverages containing greater than 1 % D-Tagatose 'excessive consumption may produce laxative effects'	'Trehalose is a source of glucose'	product is a source of glucose and fructose
*Specified food category and Maximum levels are not specified			

Source: Own elaboration based on [5]

Źródło: Opracowanie własne na podstawie [5]

absorbed and metabolized identically to those after ingestion of normal sugar. However, due to the slow hydrolysis of palatinose and the slow absorption of glucose into the blood, insulin levels also rise slowly and do not reach the same high levels as after consuming sucrose. The slow carbohydrate absorption is determined by isomaltulose's low glycemic index of 32 [11, 14]. Its caloric value is 4 kcal/g [31] (Table 2).

Nutritional and health value

The European Food Safety Authority (EFSA) considers it as a food ingredient that can regulate postprandial glycaemia. It does not cause aggressive increases in blood sugar and does not contribute to tooth decay [7].

Safety of use and application

Isomaltulose has been used in Japan since 1985 [15]. In the US, it has been recognized as GRAS (Generally Recognized as Safe) by the Food and Drug Administration (FDA) [31]. All claims for isomaltulose were positively reviewed by EFSA in a fourth series of opinions published in April 2011. These claims, address two issues: dental health concerns and glycaemic-reducing effects. Isomaltulose was placed on the market in the European Union in 2005 and was granted the status of Novel Food [4]. It has also been approved as a food in Australia and New Zealand [33]. Currently, isomaltulose is used as a substitute for other sugars and maltodextrins in foods and beverages, including sports drinks, energy drinks, breakfast cereals, cereal bars, dairy products, cakes, toppings, chocolates, jelly beans and chewing gum [31]. Isomaltulose is successfully added to sports drinks up to 7% and in energy and nutritional bars up to 15%. The addition of isomaltulose in chocolates is about 25%, similarly in breakfast cereals (30%), and in energy tablets up to 97% [37]. In Table 3 the designation of the novel sweetener on the labelling of the foodstuffs containing it is presented.

D-TAGATOSE

Definition

D-tagatose is a ketohexose with a similar chemical structure to fructose [6] (Table 1). The only structural difference between tagatose and fructose is the reverse orientation of the hydroxyl group on the fourth carbon [20].

D-tagatose is a simple sugar naturally found in trace amounts in dairy products (sterilised UHT milk, yoghurt and some cheeses) [19, 27, 39] and some fruits [6, 20].

Physical and chemical properties

D-tagatose is a white, odourless, anhydrous crystalline solid [6] with a melting point of 134°C [20]. It is a compound that is well soluble in water, stable at pH 2-7 and exhibits a sweet taste. The sweetness of tagatose is equal to 92% of that of sucrose with a simultaneously lower caloric content. The high sweetness and low calorific value make tagatose attractive as a substitute for sucrose and sugar alcohols used in the food industry as low-calorie sweeteners. In addition, this sugar has a synergistic effect with synthetic sweeteners such as aspartame or acesulfame K, enhancing their sweetness while reducing their bitterness. It enhances mint, lemon, cream and toffee flavours [39] (Table 2).

Manufacturing

Production of tagatose on an industrial scale can be carried out by chemical or enzymatic methods. The chemical method consists in the isomerization of D-galactose to D-tagatose under strongly alkaline conditions by the addition of calcium hydroxide and in the presence of a catalyst. The precipitating complex is neutralized with acid, liberating the tagatose. The insoluble calcium salt formed is removed by filtration and the D-tagatose remaining in solution is concentrated and crystallized. The enzymatic method is carried out by isomerization of D-galactose to D-tagatose using arabinose isomerase, an enzyme found in mesophilic (e.g. *Escherichia coli, Bacillus halodurans*), thermophilic bacteria (e.g. *Geobacillus, Thermoanaerobacter, Thermotoga, Thermus*). The isomerisation reaction requires considerable energy to heat the reaction mixture and the enzymes require the presence of heavy metal ions to maintain high activity and stability [39].

Metabolism and absorption

Tagatose is poorly absorbed in the small intestine. Approximately 75% of this sugar enters the cecum and colon, where it is completely fermented to short-chain fatty acids (SCFAs), which are then absorbed and metabolized [23, 40].

EFSA [8] based on human data showing that the average absorption of D-tagatose is 80% and excretion in urine is 1% or 5%, and that the remaining 20% of D-tagatose that is not absorbed in the small intestine is fermented in the colon, estimated the energy conversion factor for D-tagatose at 3 kcal/g (12,5 kJ/g) (Table 2).

D-tagatose has a very low glycemic index of 3, and many studies in healthy subjects have shown a positive effect after consumption of tagatose compared to glucose [11] (Table 2).

Nutritional and health value

D-tagatose has a low caloric value due to poor absorption in the human small intestine. The advantages of consuming tagatose include the intensification of the development of normal intestinal microflora and safety for diabetics, as it does not cause a sharp rise in blood sugar levels. Additionally, it does not cause diarrhoea, as is the case with excessive consumption of sugar alcohols [39].

Safety of use and application

The labels of products with levels of D-tagatose greater than 15 g per serving and all beverages containing more than 1 % D-tagatose (as consumed) contain the phrase „excessive consumption may have a laxative effect" [5] (Table 3).

In the United States, tagatose has GRAS status under Food and Drug Administration (FDA) regulations, thus allowing its use, as a sweetener in foods and beverages, health foods and dietary supplements [24]. It is approved for use in food in the European Union, Australia, New Zealand, South Africa, Korea and Brazil [1, 36].

The main aim of developing D-tagatose was to use it as a sugar substitute that could be used in products for energy and weight control [8]. D-tagatose is currently used as a low-energy sweetener in soft drinks and yoghurt [8], as well as in the production of low-calorie sweets, beverages, breakfast cereals and jams. Due to its resistance to high temperatures, it can be used for baking, cooking and for sweetening tea or coffee [39].

D-tagatose can be used without any restrictions on the amount [5] (Table 3) but their use is limited by its high production cost [11].

TREHALOSE

Definition

Naturally occurring trehalose consists of two glucose molecules linked by an α-1,1'-O-glycosidic bond [2]. Their chemical name is α-D-glucopyranosyl-α-D-glucopyranoside, dihydrate [5] (Table 1).

Trehalose is widely distributed in nature. It is present in bacteria, fungi, plants and in many invertebrates such as nematodes, crustaceans and insects. Although its biosynthesis in mammals is unknown, significant amounts of trehalase, an enzyme that cleaves trehalose has two glucose molecules, have been found in the human small intestine [2].

Physical and chemical properties

Trehalose is a non-reducing sugar. It occurs as a white odourless, hygroscopic powder. Its sweetness equals 45% of that of sucrose [21]. Korzeniowska-Ginter [17] reports that the sweetness of trehalose is equivalent to 45–50% of that of sucrose while having an identical caloric value 4 kcal/g, and the sweet taste profile shows a rapid onset of sweetness sensation with longer persistence than sucrose. Characteristic features are the clean and balanced sweet taste time profile and the absence of extraneous aftertaste. From the point of view of food technology, it has many advantageous characteristics: it has no reducing properties, is chemically and thermally stable, has good solubility, reduces water activity and lowers the freezing point shows high hydrophilicity and a high glass transition temperature [38] (Table 2). It does not undergo caramelization or non-enzymatic browning. It protects protein and starch substances from retrogradation during drying and freezing – trehalose reduces or even eliminates changes in the hydration layer of proteins, stabilizing them in the case of significant dehydration or increase in product temperature or freezing [34].

Manufacturing

The industrial production of trehalose is carried out by an enzymatic method, where the substrate is inexpensive and easily available maltose syrups. Synthesis Trehalose synthase (maltose α-D-glucosyltransferase – EC 5.4.99.16) is an enzyme that catalyses the isomerization of the α-1,4-glycosidic bond found in maltose to the α-1,1-glycosidic bond characteristic of trehalose. This enzyme is found in some bacteria of the genus *Thermus, Pimelobacter* sp. R48 and *Pseudomonas* sp. F1 [16].

Metabolism and absorption

The metabolism of trehalose is comparable to that of other disaccharides [26]. In the human body, trehalose is digested in the small intestine by the enzyme trehalase, resulting in the formation of two α-D-glucose molecules. Trehalase is an enzyme synthesized in the renal tubular epithelial brush cuticle of the intestine, where it hydrolyses trehalose to two glucose molecules [35].

Nutritional and health value

Trehalose reduces the pH value of dental plaque to a lesser extent than sucrose, which reduces the risk of dental caries. Due to its weaker insulin response, it allows for a longer time of energy availability, resulting in better so-called mental awareness. The aforementioned properties predispose to the use of trehalose in the production of products alleviating stress and fatigue [17]. GI of trehalose is 72 [37] whereas ingestion of trehalose, compared to ingestion of glucose, did not cause a sharp rise in blood glucose levels, and insulin secretion [41] (Table 2).

Safety of use and application

Trehalose was first produced in Japan in 1994 and was approved as a food additive a year later. Since then, it has been used without restriction in hundreds of Japanese products such as confectionery, beverages, processed fruits and vegetables, bakery products and frozen foods. In Japan, Europe and the United States, trehalose is used in the cosmetics industry and in personal care products. In 1991 in the UK trehalose was approved for industrial use as a protectant in freeze-dried foods at concentrations of no more than 5% of the product. As a food ingredient, it was approved for unrestricted use in Korea and Taiwan in 1998 [9]. In the USA, it was Generally Recognized as safe as a food ingredient (GRAS) in 2000,

and in 2001 it achieved the same status in European Union countries. Currently the use of trehalose in the food industry is limited only by Good Manufacturing Practice (GMP). Current global regulations allow the addition of trehalose to food and its daily intake is not restricted to date [30] (Table 3).

SUCROMALT

Definition

Sucromalt is a concentrated aqueous solution of saccharides of different chain lengths obtained by an enzymatic reaction between sucrose and maltose. The final product contains fructose (35–45%), leucrose (7–15%), other mono and disaccharides (<5%) and 40 to 60% oligosaccharides [13].

Physical and chemical properties

The sweetness of sucromalt corresponds to 70% of that of sucrose (Table 2). It is soluble in water, has a clean sweet taste, low hygroscopicity, and is resistant to heat and acidic environments. Sucromalt is a reducing sugar and is involved in Maillard browning reactions [3].

Manufacturing

Suromalt is produced from sucrose and maltose (or high maltose corn syrup). These substrates are treated with an enzyme produced by a strain of *Leuconostoc citreum* bacteria or a recombinant strain of *Bacillus licheniformis* [13]. The resulting oligosaccharides are characterized by the presence of α- (1, 6) and α- (l, 3) glycosidic compounds. The overall product is a syrup, in addition to oligosaccharides, containing mainly fructose, but also the disaccharide leucose and other disaccharides [5].

Metabolism and absorption

When digested, sucromalt breaks down into its primary components, glucose and fructose. Its glycemic index is 53 and its caloric value is equal to 4.0 kcal /g [13] (Table 2).

Safety and use

There are no risks associated with the consumption of sucromalt in humans, and it is well digested by both children and adults. When comparing sports drinks sweetened with sucromalt and those sweetened with sucrose, there were no differences in gastrointestinal discomfort, aftertaste, sweetness, acidity or bitterness. It can be used as a food ingredient in a wide range of foods according to current good manufacturing practices (GMP). This includes: bakery products, beverages, cereal products, dairy products and substitutes, desserts, dessert toppings and fillings, fats and oils, foods for special dietary purposes, fruit juices, jams, jellies and marmalades, miscellaneous, sauces, dips, dressings and condiments, snacks, sugars and confectionery [13] (Table 3).

CONCLUSIONS

Novel sweeteners can provide an alternative to sucrose. Apart from giving a sweet taste to products, they can also have positive effects on human health. The novel sweeteners do not rapidly raise blood glucose levels and cause less insulin secretion than glucose They can be used in a variety of foods, especially those dedicated to diabetics. However, their specific properties must always be taken into account.

WNIOSKI

Nowe substancje słodzące mogą stanowić alternatywę dla sacharozy. Oprócz nadawania słodkiego smaku produktom, mogą one mieć również pozytywny wpływ na zdrowie człowieka. Nowe substancje słodzące nie podnoszą gwałtownie poziomu glukozy we krwi i powodują mniejsze wydzielanie insuliny niż glukoza. Mogą być stosowane w różnych produktach spożywczych, zwłaszcza tych przeznaczonych dla diabetyków. Należy jednak zawsze brać pod uwagę ich specyficzne właściwości.

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Dr hab. inż. Jadwiga TOPCZEWSKA
Dr inż. Małgorzata ORMIAN
Dr inż. Anna AUGUSTYŃSKA-PREJSNAR
Department of Animal Production and Poultry Products Evaluation, Collage of Natural Sciences, University of Rzeszow, Poland
Zakład Produkcji Zwierzęcej i Oceny Produktów Drobiarskich, Kolegium Nauk Przyrodniczych, Uniwersytet Rzeszowski, Polska

TRADE IN SELECTED RAW MATERIALS OF ANIMAL ORIGIN IN THE EU®

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Key words: trade, meat, milk.

The aim of the work presented in the article was to assess the scale of trade in raw materials of animal origin as part of trade between the European Union and third countries. The research material consisted of data published by the European Union in 2016–2020 within the TRACES system and trade data of the World Bank (World Integrated Trade Solution). Meat trade in the world far outweighs other raw materials and products of animal origin. It has accounted for no less than 43% of trade in recent years. Meat exported from the European Union is mainly beef, pork and poultry. The world dairy market is dominated by a small number of countries, with EU member states accounting for more than a third of world exports. It should be noted that international trade in animal raw materials, which amounted to 152 billion euros in 2018, is dominated by exports from several countries, including the EU.

Słowa kluczowe: handel, mięso, mleko.

Celem pracy przedstawianej w artykule była ocena skali obrotu surowcami pochodzenia zwierzęcego w ramach wymiany handlowej między Unią Europejską a krajami trzecimi. Materiał badawczy stanowiły dane publikowane przez Unię Europejską w latach 2016-2020 w ramach systemu TRACES oraz dane handlowe Banku Światowego (World Integrated Trade Solution). Obrót mięsem na świecie zdecydowanie przeważa nad innymi surowcami i produktami pochodzenia zwierzęcego. Stanowił on w ostatnich latach nie mniej jak 43% wymiany handlowej. Mięso eksportowane z Unii Europejskiej to głównie mięso wołowe, wieprzowe oraz drobiowe. Światowy rynek produktów mleczarskich jest zdominowany przez niewielką liczbę krajów, a państwa członkowskie UE mają udział w ponad jednej trzeciej światowego eksportu. Należy podkreślić, że międzynarodowy handel surowcami pochodzenia zwierzęcego, który w 2018 roku wynosił 152 mld euro, jest zdominowany przez eksport z kilku krajów, w tym z UE.

INTRODUCTION

The transport of raw materials and products of animal origin is one of the greatest logistic challenges, mainly because consumer safety depends on its proper organization. The transport of raw materials and animal products is one of the most important logistical challenges, mainly because consumer safety depends on its correct organisation. It must be carried out efficiently, in a timely manner and in compliance with the legal requirements [9]. In connection with many regulations on the transport of raw materials and animal products, the transport must take into account a number of devices and systems that protect the products during transport and marketing [10, 12]. The European Union is the world's leading exporter of animal products (32.4 billion euros in 2018 or 23% of total agro-food exports) [2].

The aim of this study was to assess the scale of trade in selected raw materials of animal origin, as part of the trade of the European Union.

MATERIALS AND METHODS

The research material consisted of data published by the European Union from 2016 to 2020 and trade data from the World Bank [13]. In terms of data from the TRACES system, the number of export certificates issued and import veterinary certificates for raw materials of animal origin, such as meat and milk, was used. TRACES is an IT system for control and notification of movements of live animals and products of animal origin across the territory of the member states of the European Union. At the same time, the system is a centralized database maintained by the Directorate General for Health and Consumer Protection of the European Commission (EC). TRACES makes it possible to certify and monitor trade [14]. It makes it possible to track the movement of live animals, raw materials and products of animal origin both from third countries and within the EU. It is a database of information for border inspection posts, allowing the exchange of data, including veterinary information, between authorized

Adres do korespondencji – Corresponding autor: Małgorzata Ormian, Uniwersytet Rzeszowski, Instytut Technologii Żywności i Żywienia, Zakład Produkcji Zwierzęcej i Oceny Produktów Drobiarskich, ul. Zelwerowicza 4, 35-601 Rzeszów, e-mail: mormian@ur.edu.pl

entities [6]. The World Bank's trade software, on the other hand, allows searching international trade databases [13]. The study determined the direction of the change and its magnitude by determining the trend line and the fit index. Statements were made using the Excel package.

RESULTS AND DISCUSSION

Analysis of raw material and animal product exports shows that EU animal product exports are mainly dairy products (52% of the total in 2018) and pork (22%). The evolution of the parity between different currencies affects the EU's ability to market (or not) its products internationally. For example, the value of the Brazilian real and the Argentine peso has fallen against the euro. Both countries have been subject to constant currency devaluation for many years, giving them an export advantage. However, the euro/dollar exchange rate has changed significantly during the period, from 0.86 in January 2002 to 1.57 in July 2008, 1.07 in January 2017, and 1.21 in December 2020 [2].

Meat is by far the most traded commodity and animal product in the world. It has accounted for no less than 43% of trade in recent years (Fig. 1). Meat exported from the European Union is mainly beef, pork and poultry Bulkowska [1], analyzing the position of animal products in the agro-food trade in Poland, found that restrictions resulting from the embargo imposed by Russia in 2014, among others on meat and dairy products, and the suspension of Polish pork imports by Asian countries as a result of the detection of ASF in Poland, affected the pork sector to the greatest extent and led to a reduction in Polish exports of this type of meat.

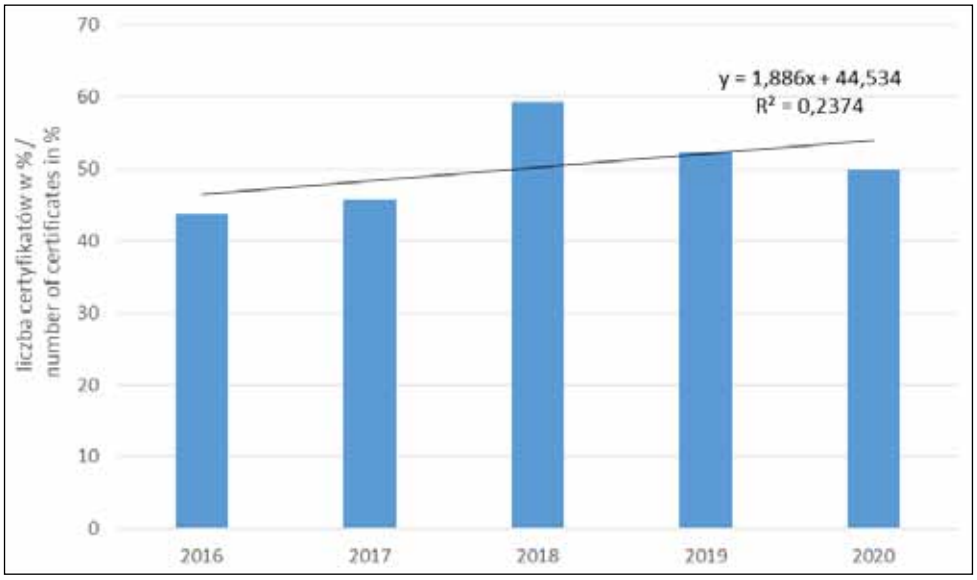

Fig. 1. TRACES certificates for meat exports from 2016 to 2020 (%).
Rys. 1. Świadectwa w systemie TRACES dla eksportu mięsa w latach 2016-2020 (%).
Source: Own elaboration based on [14]
Źródło: Opracowanie własne na podstawie [14]

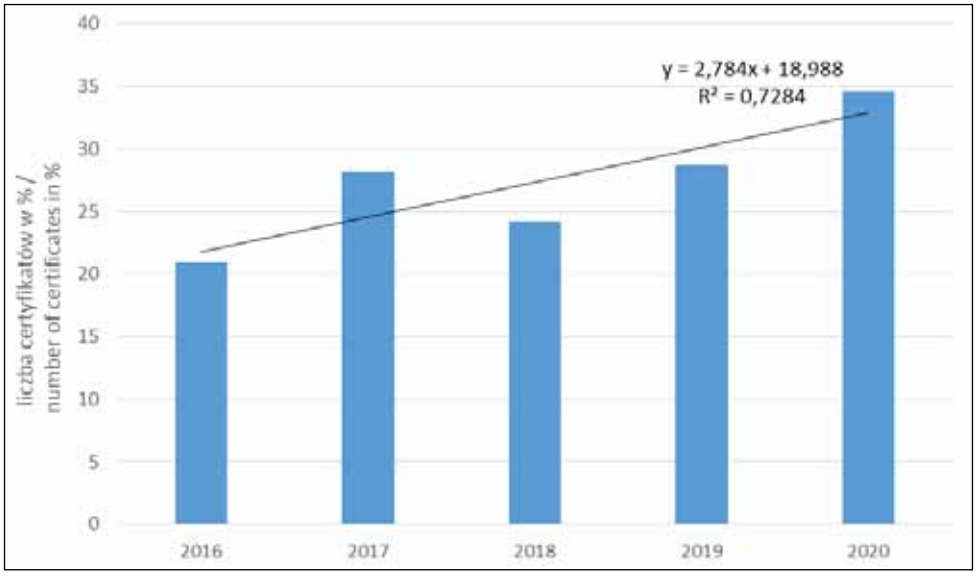

Fig. 2. TRACES issued veterinary certificates for milk exports from 2016 to 2020 (%).
Rys. 2. Świadectwa weterynaryjne wystawione w systemie TRACES dla eksportu mleka w latach 2016-2020 (%).
Source: Own elaboration based on [14]
Źródło: Opracowanie własne na podstawie [14]

Approximately two-thirds of EU animal product exports are directed to no more than 15 countries. China has become the largest customer in the European Union [13], with imports increasing tenfold between 2000 and 2018 (€7.8 billion). The country represented 24% of EU exports of animal products in 2018. This ratio is approximately 31% for pork, 26% for dairy products, 12% for poultry meat, and 17% for beef [2]. The United States is the second largest customer in terms of animal products from the European Union, accounting for 8% of total European exports. More than 55% are dairy products and 23% are pork. Japan is third (7% of EU exports), mainly due to imports of pork (65% of purchases) and dairy products (26%). Russia, on the other hand, has lost importance in trade with the EU due to the embargo [3].

Europe's milk exports have been a success, with the number of veterinary certificates issued increasing by more than 20% in five years to almost 35% and maintaining an

upward trend (Fig. 2). The European Union is a very important milk producer in the world. The cow population decreased by an average of 0.5% in the European Union in 2017 compared to 2004, which could be due to restructuring processes in the agriculture of many countries. It is estimated that mainly owners of small farms gave up milk production, while this decrease was offset by an increase in milk yields of cows. The increase in milk exports may be due to the healthy lifestyle and awareness of nutrition of consumers. Another aspect that may affect the increase in milk exports is the growing demand for milk in China and other Asian or African countries [8]. The global dairy market is dominated by a small number of countries, mainly the EU (34% of global exports by value in 2018), New Zealand (20%) and the United States (10%) [2]. In 2019, the largest exporters of dairy products for the milk and cream category (by weight) are the Netherlands ($245,180.24 thousand, 233,773 thousand kg), Saudi Arabia ($201,286.89 thousand, 216,226 thousand kg), Germany ($123,753.27 thousand, 384,184 thousand kg), Belgium ($61,349.75 thousand, 41,335,700 kg [13]. The United States, which has historically exported small amounts of dairy products, has expanded its exports primarily to neighboring countries, including Mexico [8].

International trade and the movement of goods and people allow the worldwide movement of animal diseases and zoonotic pathogens [5, 11]. Trade in animal material and live animals carries the risk of reintroduction of previously eradicated animal diseases into the European Union, since significant amounts of food products of animal origin (POAO) from endemic countries are continuously legally and illegally imported into the EU. At the same time, these products may be potential carriers of new foodborne zoonoses that pose a public health risk due to morbidity and significant mortality. Research by Jansen et al. [5] showed that *Listeria monocytogenesi* and *Staphylococcus aureus* were the pathogens most commonly detected in illegally imported meat and meat products (5% and 4.3%, respectively) and *S. aureus* in milk and milk products (7.4%). The most likely source of these zoonotic pathogens in illegally imported POAO is cross-contamination and inadequate hygiene measures during milk handling, processing and storage.

International trade in animal products, which amounted to € 152 billion in 2018, is dominated by exports from several countries, including the EU, the US, New Zealand, Brazil, and Australia. Exporters' strategies vary; for example, Brazil or New Zealand, are successful in terms of "price competitiveness", while others, including EU member states, aim to strengthen "nonprice competitiveness" (e.g., high quality or regional and/or traditional products, degree of product processing, etc.). With a trade balance of €23 billion in animal products in 2018, the EU contributes to the supply of Asian countries, which have a large deficit in this area (minus €63 billion).

Forward-looking analyses by the OECD and FAO to 2029 highlight in their projections for the global livestock sector [7] that the annual growth rate will decline over the next 10 years compared to the last decade. This will be driven by global population growth, while varying between continents and countries and being higher in developing countries. Possible changes in annual per capita calorie intake due to dietary changes are also indicated.

According to estimates, global meat production is expected to increase by approximately 12% by 2029. For dairy products, the increase in world production will be about 16%. The world meat trade is projected to increase by about 12% during the same period. In the dairy sector, trade growth is expected to be higher, with a continued high share of the three main export zones (EU, New Zealand and the United States) [2]. This is due in part to projections of population growth. The global population is projected to grow to 9.7 billion by 2050, an increase of approximately one-third compared to 2015 [4].

CONCLUSION

The analysis of the scale of trade in animal products in the European Union from 2016 to 2020 indicated differences between the different types of items entered in TRACES and fluctuations in the scale of trade. Meat exported from the European Union is mainly beef, pork, and poultry. The world market for dairy products is dominated by a small number of countries, with EU member states accounting for more than one third of world exports. It should be noted that in international trade in animal products, which amounted to 152 billion euros in 2018, EU member states had a significant share.

PODSUMOWANIE

Analiza skali obrotu produktami pochodzenia zwierzęcego w Unii Europejskiej w latach 2016-2020 wskazała na różnice między poszczególnymi rodzajami pozycji wpisywanych w system TRACES oraz wahaniami skali obrotu. Mięso eksportowane z Unii Europejskiej to głównie mięso wołowe, wieprzowe oraz drobiowe. Światowy rynek produktów mleczarskich jest zdominowany przez niewielką liczbę krajów, a państwa członkowskie UE mają udział w ponad jednej trzeciej światowego eksportu. Należy podkreślić, że w międzynarodowym handlu produktami zwierzęcymi, który w 2018 roku wynosił 152 mld euro, państwa członkowskie Unii Europejskiej miały znaczący udział.

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Mgr inż. Krystian KLIMCZAK
Dr inż. Monika CIOCH-SKONECZNY
Department of Fermentation Technology and Microbiology, Faculty of Food Technology
University of Agriculture in Krakow, Poland
Katedra Technologii Fermentacji i Mikrobiologii, Wydział Technologii Żywności
Uniwersytet Rolniczy w Krakowie, Polska

APPLICATION OF KVEIK YEASTS FOR BEER PRODUCTION®

Zastosowanie drożdży kveik do produkcji piwa®

Key words: beer, kveik, yeast.

The term kveik yeast is used to describe cultures traditionally used in Norwegian farmhouse brewing. Historically, almost every farm in Norway had its own distinct culture, of which only 24 representatives have survived to this day. From the history of their use, we can find out that these yeasts were used to ferment wort in just 2 days, using temperatures between 30-40°C. Studies of these cultures have shown that they include strains of Saccharomyces cerevisiae. Current literature indicates that these yeasts are characterized by a vigorous fermentation rate that can take place at temperatures as high as 42°C without adversely affecting the sensory characteristics of the beer. Most kveik cultures ferment the sugars present in the wort to a similar degree as commercially available cultures, ensuring adequate attenuation. Additionally, they do not produce phenolic off-flavors, exhibit a high level of flocculation, and impart a characteristic fruity aroma to the beer. Thanks to these properties, brewers are more and more willing to use these yeasts in their products. Although the knowledge of these strains is still incomplete, considerable progress has been made in this area in recent years. The article presents the current state of knowledge on the history of kveik yeast, their phylogenetic features and fermentation properties.

Słowa kluczowe: piwo, kveik, drożdże.

Terminem drożdży kveik określa się kultury tradycyjnie używane w norweskim piwowarstwie domowym. Historycznie, prawie każde gospodarstwo rolne w Norwegii posiadało swoją odmienną kulturę, z których na dzień dzisiejszy zachowanych zostało jedynie 24 przedstawicieli. Zagłębiając się w historię ich użycia, możemy dowiedzieć się, że drożdże te wykorzystywane były do odfermentowania brzeczki w zaledwie 2 dni, przy zastosowaniu temperatur z zakresu 30-40°C. Badania tych kultur wykazały, że w ich skład wchodzą szczepy Saccharomyces cerevisiae. Aktualnie dostępna literatura wskazuje, że drożdże te charakteryzują się szybkim tempem przeprowadzania fermentacji, która może odbywać się w temperaturach nawet do 42°C, bez negatywnego wpływu na cechy sensoryczne piwa. Większość kultur kveik fermentuje cukry obecne w brzeczce w podobnym stopniu jak kultury dostępne komercyjnie, zapewniając odpowiedni poziom odfermentowania. Nie wytwarzają one fenolowych aromatów, wykazują wysoki poziom flokulacji oraz nadają piwu charakterystyczny, owocowy aromat. Dzięki tym właściwościom, piwowarzy coraz chętniej sięgają po te drożdże. Mimo, że wiedza na temat tych szczepów jest wciąż niekompletna, w ostatnich latach poczyniono w tym obszarze znaczne postępy. Artykuł przedstawia aktualny stan wiedzy na temat historii drożdży kveik, ich cech filogenetycznych oraz właściwości fermentacyjnych.

INTRODUCTION

Recent decades have brought great diversity to the field of brewing. The market, hitherto homogenized by large breweries, has broken up, resulting in the emergence of many new beer styles, as well as the evolution of a number of existing ones. Commercial breweries and homebrewers look for new ways to create a product with unique sensory characteristics. Since yeasts are responsible for the entire fermentation process, using a different strain seems like a natural way to produce a different product. In recent years, the yeasts traditionally used to produce beer on Norwegian farms has become increasingly popular. They are known in Norway as *gjær*, *gjest*, *barm* and *kveik,* and it is this last name that has gained international recognizability. The history of their use goes back hundreds of years, and it is believed that until the late 1800s almost every farm had its own, often distinct yeast culture, which was used to make beer. Beer was an important part of Norwegians' lives at that time, but because of cultural and economic changes, traditional ways of production began to be abandoned, and kveik yeast fell victim to that process. By the beginning of the 21st century, only a fraction of the existing cultures have survived, while most are extinct. However, the beginning of the millennium also brought a kind of renaissance of their use. Brewers are increasingly choosing to use them because of their wide range of beneficial properties. These yeasts are characterized by

Corresponding author – adres do korespondencji: Monika Cioch-Skoneczny, Katedra Technologii Fermentacji i Mikrobiologii, Wydział Technologii Żywności, Uniwersytet Rolniczy w Krakowie, ul. Balicka 122, 30-149 Kraków; e-mail: monika.cioch@urk.edu.pl

a much faster start and rate of fermentation than commercially used cultures and are adapted to higher temperatures of the environment (traditionally these yeasts were used at temperatures in the ranges of 30–40°C). They show high flocculation, resistance to elevated alcohol concentrations and low 4-vinylguaiacol production. Beverages produced using those yeasts do not exhibit a phenolic smell and have characteristic fruit aroma. Culture analyses have shown that they consist of different strains of the *Saccharomyces cerevisiae* yeast. Initially, some critics believed that those were ordinary baker's yeast, but available publications contradict this. Genetic studies have shown that these cultures are clearly different from all commercially available *S. cerevisiae* strains [4, 13, 16]. Describing the subject of kveik yeast, it is impossible not to highlight the work of Lars Marius Garshol, who is largely responsible for the interest in this subject among the international brewing community, and has done a tremendous amount of work in, among other things, collecting cultures and researching their history.

Although knowledge of these strains is still incomplete, considerable progress has been made in recent years. This article presents the current state of knowledge on the history of kveik yeast, their phylogenetic features and fermentation properties.

HISTORY

By the mid-19th century, farms throughout northern Europe had their own yeast cultures that were used to produce beer. As mentioned earlier, most of these cultures have been lost. Nowadays, 49 distinct yeast cultures have been found preserved on northern European farms. Out of the cultures found, 2 are from Russia, 2 from Latvia, 2 from eastern Norway, many cultures are from Lithuania, but the vast majority have been found in western Norway [8]. The term kveik refers to a yeast originating from Norway. Although the term 'farmhouse ale' is mainly associated with Belgian Saison, and French *Bière de Garde*, northern Europe has its own unique beverages, such as Finnish *sahti*, Estonian *kodõlu,* Lithuanian *kaimiškas* and Swedish *gotlandsdricka* [16, 24]. In Norway, 'farmhouse ale' is referred to as *maltøl*, of which there are 3 main styles: *stjørdalsøl*, *kornøl* and *vossaøl*, of which kveik yeasts are currently only used in the latter two. These styles vary in alcohol content as well as color (from amber to dark) but have some common characteristics. Hops are used in small amounts. For mashing, instead of pure water, an infusion of juniper (whole twigs, needles, or berries) is used, which together with the hops provides an appropriate level of bitterness. For boiling, copper or iron kettles heated on hearth are used. These beers are not filtered or carbonated. Historically, the spices used in Norwegian brewing have been mainly juniper and hops, but also spices such as myrica gale, wormwood, caraway, St. John's wort, yarrow, and tansy, among others. In addition, historically *maltøl* has typically been a strong, high extract beer (up to 19.25°P), and has been brewed with self-produced malts [3, 7, 20, 22].

Since there are significant historical similarities between the yeasts from the above regions, their history will be discussed along with kveik yeast. A feature that has amazed modern brewers is the usage of remarkably high yeast inoculation temperatures. Most historical sources do not give an exact range, but a description of how to recognize it. Among such descriptors the term of human skin temperature is often mentioned, which would correspond to 33.5–36.9°C. Another common term is the temperature of freshly milked milk. This would correspond to a temperature of 35–38°C. Descriptors indicating lower temperatures (but still relatively high) are also found among reports from other regions, but those suggesting temperatures in the 35–40°C range predominate among brewers in Norway. Such high temperatures are probably related to difficulties in cooling the wort, due to lack of appropriate technology. With a typical brew size of 100–150L, it took a long time to cool the wort to 40°C. Further cooling to temperature at which top-fermenting strains are pitched today (~20°C) would take too long. During this time, unfavorable microflora could dominate the wort, not giving the yeast a chance to conduct a proper fermentation [9].

High temperatures were also used during fermentation. Most brewers fermented at temperatures above 25°C, and the most commonly mentioned temperature is, as with yeast inoculation, milk temperature. These are reports suggesting that fermentations were conducted at temperatures even higher than that at which the yeasts were inoculated. This information indicates that the brewing community has been adapting farmhouse yeasts for fermentation at high temperatures for centuries [8, 9, 17].

A distinctive feature of farmhouse ales is the short fermentation time, measured from yeast inoculation to racking beer for storage. Based on historical data, mainly from the 20th century, Garshol [9] estimated that the average fermentation time was 41 hours. After this time, the beer was almost completely attenuated. This short fermentation time, along with the high yeast pitching temperature may confirm high temperature fermentations. The wort did not have much opportunity to cool down due to exoenergetic nature of fermentation process, and given the fermentation characteristics of the kveik yeast, there was simply no need to lower the temperature. Brewers usually allowed for high wort attenuation, which combined with the short process time indicates that this yeast has a fast fermentation rate. The fast pace of a process is definitely helped by the high temperature of yeast inoculation, and the fact that kveik yeast exhibit an unusually short lag phase. However, it is worth mentioning that these strains ferment faster that those commercially available even at lower temperatures [10].

The domestication of kveik yeast and its development of the characteristics discussed in this article was likely due to the tradition of collecting yeast after fermentation and using it in subsequent fermentations. Collecting yeast after fermentation is a surprisingly old concept. Although we often downplay the knowledge of medieval artisans, evidence can be found in historical sources that people of the time were certainly aware of the existence of yeast, but most likely without knowing what it was. An example is the Pliny the Elder's description written in year 77 of how the Iberians and Gauls collected foam from fermenting beer, which was subsequently used in baking. It supposedly allowed them to obtain a better bread than other peoples [8, 10].

Due to the limited sources available, it is hard to exactly determine when the Norwegians domesticated yeasts. What we do know is that they had many ways of storing them. Due

to its unusual nature, a frequently mentioned tool is a yeast ring consisting of many interlocking wooden staves forming a circle. Another way was to use a piece of perforated log, called a *kveikstokk.* These items had a high surface area, which allowed them to collect a large amount of yeast when dipped into the beer. However, research indicates that these tools were also often used as a decoration, unrelated to brewing, so it is hard to say if their original use was to collect yeast, or if they were simply adopted for this purpose by some farmers. Other methods were less sophisticated, such as storing yeasts on a piece of cloth, brick, juniper twigs, or even on blades of grass. The yeasts collected in this way were often coated in flour, dried, and the process repeated several times. Then they were hung to dry, or sometimes hot ash was used to speed up the drying process. Almost everyone in Norway dried their yeast, but liquid yeasts were preferred for brewing. Yeast collected in this way could be stored for over a year and could be used for both brewing and baking. The preference for selecting top or bottom fermenting strains appears to be unrelated to geographic region. One farmer might use bottom-fermenting yeast, while his neighbor might choose top-fermenting ones. Farmers usually shared their yeast freely in case, when for example, a neighbor's culture spoiled, or the beers made with it began to exhibit undesirable sensory characteristics. In many places there was a saying, "You can't refuse anyone's yeast." These reports allow us to presume, that Norwegian farmers over decades took steps to enhance desirable traits in theirs yeast cultures [8, 10, 11, 21, 23].

KVEIK STRAINS

Genome studies of the cultures found in kveik yeast have shown that they belong to a distinct subfamily than other farmhouse yeasts and commercially available strains. Currently, 24 cultures identified as kveik have been found. Cultures such as Voss, Hornidal, Ebbegarden, Stranda, Årset, Midtbust and Oslo are commercially available. They inherit names from the localities in which they were found, or from the names of the owners [8, 18].

It is important to realize that traditionally available kveik cultures are usually not one particular strain, but a mixture of different yeast strains that may additionally contain bacteria. Those commercially available, consist of pure selected strain. Preiss et al. [20] studied 9 traditional kveik cultures, where the cultures contained between 1 and 9 distinct strains of *Saccharomyces cerevisiae* yeast. In the study by Aasen [1], all of 10 traditional cultures tested contained genetic sequences of bacteria belonging to the species *Lactobacillus brevis*, *Lb. backii, Lactococcus lactis* and *Aerobacter* spp. Bacterial cultures were successfully isolated from 2 of the 4 kveik yeast strains subjected to this study. Again, all the yeast strains isolated in this study belonged to the *S. cerevisiae* species. Garshol [8] in his book mentions that among the cultures he analyzed, only one of them contained a small proportion of *Pichia* spp. yeast. These studies indicate that the currently preserved kveik consist exclusively of distinct strains of *S. cerevisiae*, without the participation of so-called wild yeasts, which may seem unusual at the first glance [1, 8, 20]. However, it is mainly *S. cerevisiae* cultures that have been used for centuries to ferment beer and make bread. Available literature indicates that this yeast possesses characteristics that allow it to dominate the fermentation environment. In addition, it is now suspected that this yeast has likely developed several antagonistic mechanisms against other fungal species. An example is the study by Gobbi et al. [12], where the antagonistic properties of the *S. cerevisiae* strain against *Lachancea thermotolerans* used in mixed wine fermentation became apparent at temperatures above 30°C. Such high temperatures may bring to mind historically high *maltøl* fermentation temperatures. However, it should be noted that the decrease in *L. thermotolerans* biomass did not occur until after day 4 of fermentation, which is much longer than a typical *maltøl* fermentation. The ability to dominate the environment is well documented in wine fermentations, where non-*Saccharomyces* yeast, present in significant amounts in the grape must, develops only during the early stages of fermentation, then gets displaced by *S. cerevisiae* which completes the fermentation. Literature sources indicate that even in spontaneous fermentations, *S. cerevisiae* may account for up to 50% of the sugar consumption in the must. Thus, the presence of sole *S. cerevisiae* strains in kveik cultures seems to be a natural progression caused by repeated use of the same slurries [2, 6, 8, 12].

Genetic and phenotypic studies conducted by Gallone et al. [6] divided *S. cerevisiae* yeast into 5 clades. Most brewing yeasts used today belong to two clades, named "Beer 1" and "Beer 2". The Beer 1 clade consists of 3 subpopulations, reflecting geographically distinct German/Belgian, British and US yeast groups. These show the most pronounced domestication characteristics of all the yeasts assessed in this study. Those in the Beer 2 clade are closer to wine yeast, and no clear geographical division is apparent is this group. In a study conducted by Preiss et al. [20], the 9 strains selected by the authors from kveik cultures formed a new, distinct group within the Beer 1 clade. In the study, the authors note that phenotypes and genetic markers of domestication largely overlap with those found in commercially available ale strains. Interestingly, the authors also evaluated one strain of Lithuanian traditional yeast, which did not fit into this group. This indicates that kveik yeasts form a completely different group than the currently domesticated *S. cerevisiae* yeasts [6, 20].

It should be noted that not all cultures originating from Norway belong to kveik yeast. An example is the Muri yeast, previously considered to be representative of kveik group. This culture was used for brewing for the last time in 1991. Bjarne Muri tried to revive it when kveik yeast began to become popular. Krogerus et al. [15] isolated a strain from this culture that turned out to be a *S. cerevisiae* x *S. uvarum* hybrid. Interestingly, although beers brewed with kveik should be characterized by a lack of phenolic aromas, this aroma was very prominent when using this strain. The study showed that this strain did not fit into the kveik subgroup of Beer 1 clade. Garshol [8] explains, that the examined Muri strain turned out to be actually a commercially available White Labs WLP351 hefeweizen yeast culture, that was probably mistakenly multiplied by the owner, and taken for a kveik culture [8, 15].

APPLICATION OF KVEIK YEAST IN BEER PRODUCTION

The first striking feature of kveik cultures is their very rapid rate of fermentation initiation. In a study conducted by Preiss et al. [20], 24 hours after the pitching all of the strains isolated from the kveik cultures produced more CO_2 than the control strain WLP002. They were inoculated into 12.5°Plato wort at 30°C. The most efficiently fermenting strain produced 70.6% more CO_2 than the control sample. In a study conducted by Foster et al. [5], after 12 hours of fermentation at 30–40°C, 5/6 *S. cerevisiae* strains isolated from kveik cultures attenuated the wort (12.5°Plato extract) in 30%, while the control strains (Cali Ale, Vermont Ale, Kölsch and St. Lucifer) were still in a lag phase [15, 20].

All of the available literature seems also to confirm their extremely fast fermentation rate, and preference for higher temperatures of the process. Foster et al. [5] studied the fermentation rate of kveik yeasts at different temperature ranges, considering a final extract <2.56°Plato as the end of fermentation, fermenting a wort mentioned above. In the 22–40°C range, most cultures reached the desired extract level within 5 days. At temperatures of 30–40°C this time was only 3 days for most cultures. The authors showed that some strains have a wide range of tolerable temperatures, like Hornindal1 (15–42°C), while others like Laerdal2 prefer a narrower range (30–37°C). Overall, the authors suggests that the 30–37°C range can be adopted as the preferred range for the kveik strains they studied. In a study by Kits and Garshol [14], the authors evaluated the fermentation rates of 3 commercially available kveik strains (Escarpment Laerdal kveik, LalBrew Voss™ and Omega Lutra™), in the temperature range of 20–42°C against a control sample with US-05 yeast, fermenting a wort with an extract of 12.1–12.5°Plato. The temperature range of 20–33.5°C had no significant impact on the fermentation rate of the control strain, but the temperature of 37°C caused a complete inhibition of its growth. The situation was different with the tested kveik strains. All of them showed growth at temperatures of 20–42°C. Generally, higher temperatures resulted in faster attenuation, but the fastest fermentation took place at the optimal temperatures determined by the authors. These are respectively, for Escarpment Laerdal kveik: 28°C, LalBrew Voss™: 37°C and Omega Lutra™: 33.5°C. These temperatures are similar to the range presented by Foster et al. [5]. At these temperatures, complete attenuation occurred after less than 48 hours, which is consistent with fermentation times in traditional Norwegian brewing. Even fermentations conducted at less temperatures favorable for kveik yeast, were significantly shorter than those carried out with US-05. Different results are presented in the paper by Aasen [1], in which kveik cultures Ørjasæter, Gamlegrua and Gausemel (which were discovered relatively recently) were studied. In the study, wort with an extract of 19.3° Plato was fermented at temperatures ranging from 22–37°C, against a control sample with US-05. Most beers finished fermentation within 6–10 days, and significant differences between fermentation rates were shown by ANOVA test but were not apparent with Tukey's test. The cited studies indicate that fermentation time is not uniform among all kveik cultures. Among them, there are cultures that ferment very efficiently, as well as those that ferment similarly to commercially available yeast [1, 5, 14].

What appears to be a universal characteristic of kveik yeast is their significant resistance to the high temperatures of the fermentation environment. Among yeast cells, this ability is determined by a number of factors, including increased synthesis of trehalose and glycerol. In a study conducted by Foster et al. [5], kveik yeast produced 1.5-2x more of this disaccharide at 30°C and began its production much earlier than control strains. Additionally, they maintained high levels of trehalose longer than control strains. The authors suggests that this may be due to dysfunction of the trehalase enzyme. The evaluated kveik strains were also characterized by faster glycerol production during the initial 24 hours of fermentation, especially at 35–40°C. In fermentations of 15°Plato wort at 25°C, conducted by Kawa-Rygielska et al. [13] beers obtained with kveik yeast had noticeable higher glycerol content, compared to the control sample fermented with US-05 yeast (1.51 g/L and 1.12 g/L, respectively). These results suggest that these two mechanisms may be an important part of their ability to ferment at high temperatures. Additionally, in the study by Preiss et al. [20], more than half of the cultures tested showed growth in an environment with 16% of alcohol [5, 13, 17].

All available literature sources indicate that most kveik yeasts produce alcohol levels similar to those produced by commercially used *S. cerevisiae*, with apparent attenuation rates in the 60–90% range. Only in the study by Aasen [1] the alcohol levels produced by the kveik cultures were lower than those of the control sample fermented with US-05 at 22°C and 30°C. At 37°C it was the kveik cultures that produced more alcohol. Maltose and maltotriose are the sugars present in the wort in the highest amounts (~60% and ~20% of all sugars available in the wort, respectively), hence their efficient attenuation is crucial if only from economic aspects. According to studies conducted by Foster et al. [5] and Preiss et al. [20], most cultures efficiently utilize maltose over a wide range of temperatures. Some strains like Ebbegarden utilize it to a lesser extent at the extremes of their temperature ranges (15°C and 42°C). In a study by Foster et al. [5] all evaluated strains utilized maltotriose, but to a lesser extent than the control strains, leaving 20-25% of the original content of this sugar. An important factor determining the utilization of this sugar was the fermentation temperature, where temperatures closer to the optimum provided higher utilization. Different results were obtained by Kawa-Rygielska et al. [13], where authors found no differences in residual maltose and maltotriose content between the kveik and US-05 strains used. Commercially available beers contain 0.8–17 g/L residual maltotriose, hence the utilization rate of this sugar by kveik cultures should not be a problem for their use in the fermentation industry. These results indicate that maltotriose consumption is a variable trait among kveik strains. Another important factor for the usage of yeast in brewing industry is the flocculation capacity. Exhibiting high levels of flocculation is considered as one of the characteristic traits of yeast domestication. In a study by Preiss et al. [20] half of the strains showed high levels of flocculation (more than 80%), and 4 of the 24 strains showed low levels (<20%). Interestingly, in most kveik cultures containing more than one *S. cerevisiae* strain, at least one of the strains showed high flocculation, suggesting that coflocculation may occur between these strains [1, 13, 19, 20, 25].

As mentioned earlier, beers brewed with kveik yeast are characterized by a fruity, tropical aroma. In a study by Kawa-Rygielska et al. [13] panelists preferred beers brewed with kveik due to those aromas. The authors indicate that these yeasts produce higher amounts of esters than the control strain US-05, especially ethyl capronate (tropical, pineapple), ethyl caprylate (tropical, apple), ethyl decanoate (apple) and isoamyl acetate (banana), which were present above their sensory threshold. In the case of the study conducted by Preiss et al. [20], only the first 3 mentioned compounds were present in higher amounts compared to the control sample, but the authors found no significant differences in their concentrations. Similar results were obtained by Kits and Garshol [14]. This suggests that these esters may be partly responsible for the fruity character of beers produced with this yeast. In a study by Aasen [1], all kveik cultures produced higher amounts of esters than a control sample with *S. cerevisiae* US-05. Studies by all the authors mentioned above agree that kveik cultures produce overall low amounts of higher alcohols. Depending on the kveik strain used, and the fermentation conditions, the levels of esters and fusel alcohols are lower or higher than those produced by commercial strains. It however should be noted, that even at high fermentation temperatures these cultures do not produce excessive amounts of esters and higher alcohols, which in high concentrations are responsible for beer sensory defects. For most commercially available yeasts, the temperatures used in in fermentations with kveik yeast are too high, which manifests itself, among other things, in exaggerated production of the aforementioned volatile compounds. This necessitates maintaining lower fermentation temperatures and cooling the wort. Such actions seem not to be necessary with kveik cultures [1, 13, 14].

Beers obtained using kveik cultures do not have phenolic aftertastes, making these cultures POF (–). As for now, β-glucosidase activity, terpenoid biotransformation ability, and sensitivity to hop-derived compounds have not been evaluated among kveik cultures [20].

CONCLUSION

The currently available literature confirms historical reports on the fermentation properties of kveik yeasts. These strains are characterized by a vigorous rate of fermentation, which can take place over a very wide range of temperatures, without negatively affecting the sensory characteristics of the beer. However, it seems that the most suitable range for most kveik strains is 30–37°C. Beverages obtained using those yeasts are characterized by a tropical, fruity aroma. These strains ferment the sugars present in the wort to a similar degree as commercially available cultures, ensuring an adequate level of attenuation. The fact that the kveik yeast are genetically affiliated to the group of *S. cerevisiae* strains domesticated by man, produce no phenolic off-flavors, express appropriate fermentation abilities and most of them have high level of flocculation confirms that over the centuries brewers in Norway have managed to obtain cultures with completely different properties than those previously known. Due to their properties, these cultures are rapidly gaining popularity among the homebrewing community as well as beginning to appear in commercially available products.

PODSUMOWANIE

Aktualnie dostępna literatura potwierdza historyczne doniesienia dotyczące właściwości fermentacyjnych drożdży kveik. Szczepy te charakteryzują się szybkim tempem przeprowadzania fermentacji, która może odbywać się w bardzo szerokim zakresie temperatur, bez negatywnego wpływu na cechy sensoryczne piwa. Wydaje się, że najbardziej odpowiednim zakresem temperatur fermentacji dla większości szczepów z tej grupy jest zakres 30–37°C. Napoje otrzymane z ich użyciem charakteryzują się tropikalnym, owocowym aromatem. Szczepy te fermentują cukry obecne w brzeczce w podobnym stopniu jak kultury dostępne komercyjnie, zapewniając odpowiedni poziom odfermentowania. Brak produkcji fenolowych aromatów, wysoki poziom flokulacji większości szczepów, odpowiednie zdolności fermentacyjne oraz przynależność genetyczna do grupy szczepów *S. cerevisiae* potwierdzają, że na przestrzeni stuleci piwowarom w Norwegii udało się uzyskać kultury o zupełnie innych właściwościach, niż te dotychczas znane. Dzięki swoim właściwościom, kultury te zdobywają szybką popularność wśród społeczności piwowarów domowych, jak i zaczynają pojawiać się w produktach dostępnych komercyjnie.

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Dr hab. Antoni PLUTA, prof. SGGW
Dr Monika GARBOWSKA
Dr hab. Lidia STASIAK-RÓŻAŃSKA
Dr hab. Anna BERTHOLD-PLUTA
Zakład Technologii Mleka, Katedra Technologii i Oceny Żywności
Instytut Nauk o Żywności
Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Polska
Division of Milk Technology, Department of Food Technology and Assessment
Institute of Food Science Warsaw University of Life Science, Poland

BIOAKTYWNE PEPTYDY Z BIAŁEK MLEKA®

Bioactive peptides from milk proteins®

Słowa kluczowe: mleko, peptydy, bioaktywność, właściwości prozdrowotne.

Najliczniejszymi białkami mleka są α-kazeina, β-kazeina, κ-kazeina, β-laktoglobulina i α-laktoalbumina. Poza wysoką wartością odżywczą, białka mleka mają ogromny wpływ na właściwości technologiczne mleka, takie jak między innymi: stabilność cieplną, podatność na koagulację pod wpływem podpuszczki, zdolności emulgujące czy pianotwórcze. Białka te są także głównym źródłem składników bioaktywnych w mleku. Bioaktywne peptydy pochodzące z białek mleka cieszą się dużym zainteresowaniem naukowym i aplikacyjnym ze względu na ich różnorodność i potencjalne korzyści zdrowotne. Peptydy te wykazują m.in. aktywność przeciwnadciśnieniową, immunomodulującą, przeciwnowotworową, przeciwzakrzepową, przeciwbakteryjną i cytotoksyczną. Ze względu na wiele znanych i domniemanych korzyści dla zdrowia ludzkiego, bioaktywne peptydy z mleka są stosowane jako składniki nutraceutyków.

Key words: milk, peptides, bioactivity, health-promoting properties.

The most abundant milk proteins are α-casein, β-casein, κ-casein, β-lactoglobulin and α-lactalbumin. In addition to the high nutritional value, milk proteins have a huge impact on the technological properties of milk, such as, among others, heat stability, susceptibility to rennet coagulation, emulsifying and foaming abilities. These proteins are also the main source of bioactive ingredients in milk. Bioactive peptides derived from milk proteins are of great scientific and application interest due to their diversity and potential health benefits. These peptides show, inter alia, antihypertensive, immunomodulating, antitumor, anticoagulant, antibacterial and cytotoxic activity. Due to many known and alleged benefits to human health, bioactive milk peptides are used as ingredients in nutraceuticals.

WPROWADZENIE

Mleko i produkty mleczne są pokarmem dla ponad 6 miliardów ludzi na całym świecie [12]. Ogromną większość mleka produkowanego na świecie stanowi mleko krowie (81%), a następnie mleko bawole (15,2%), kozie (2,3%), owcze (1,4%) i wielbłądzie (0,4%) [13]. Mleko zawiera praktycznie wszystkie niezbędne składniki odżywcze, w tym białka, węglowodany (laktozę), tłuszcze, składniki mineralne i witaminy. Produkty mleczne będące bardzo dobrym źródłem wapnia oraz wartościowych i wielofunkcyjnych białek nabierają coraz większego znaczenia żywieniowego w przeciętnej diecie nie tylko w krajach rozwiniętych ale szczególnie w krajach rozwijających się pomimo wielu kampanii „antymlecznych". Wśród różnych składników odżywczych białko jest jednym z najbardziej zróżnicowanych funkcjonalnie mlecznych składników odżywczych, a jego zawartość i właściwości funkcjonalne różnią się między gatunkami ssaków. Pod względem funkcjonalnym białka mleka zapewniają charakterystyczną strukturę, rozpuszczalność, wiązanie wody, lepkość i właściwości stabilizacji cieplnej mleku i produktom mlecznym.

Wyróżnia się trzy grupy białek mleka: kazeiny, białka serwatkowe i białka otoczki fosfolipidowo-białkowej kuleczek tłuszczowych [20]. Kazeiny a głównie αs-kazeina (αs1 i αs2), β-kazeina i κ-kazeina, stanowią około 78% białek mleka krowiego [19]. Białka serwatkowe, takie jak β-laktoglobulina, α-laktoalbumina, laktoferryna, immunoglobuliny, albumina serum krwi, glikomakropeptydy, enzymy i czynniki wzrostu stanowią kolejne około 18% [28], podczas gdy białka wchodzące w skład otoczek kuleczek tłuszczowych, przykładami których są mucyna-1 czy dehydrogenaza/oksydaza ksantyny, stanowią mniej niż 4% białka [27, 30]. Udział poszczególnych frakcji białkowych różni się w zależności od gatunku zwierzęcia, np. mleko owcze na ogół zawiera więcej kazein, β-laktoglobuliny, α-laktoalbuminy, albuminy serum i laktoferryny w porównaniu do mleka krowiego, bawolego czy koziego (Tabela 1).

Corresponding author – Adres do korespondencji: Anna Berthold-Pluta, Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Instytut Nauk o Żywności, Zakład Technologii Mleka, Katedra Technologii i Oceny Żywności, ul. Nowoursynowska 159c, 02-776 Warszawa, e-mail: anna_berthold@sggw.edu.pl

Tabela 1. Frakcje białek mleka (g/l) różnych przeżuwaczy
Table 1. Protein fractions (g/l) in various ruminants milk

Białko	Mleko krowie	Mleko owcze	Mleko kozie	Mleko bawole
Frakcje kazeiny				
α_{s1}-kazeina	8 – 10,7	15,4 – 22,1	0 – 13,0	8,9
α_{s2}-kazeina	2,8 – 3,4	15,4 – 22,1	2,3 – 11,6	5,1
β-kazeina	8,6 – 9,3	15,6 – 17,6	0 – 29,6	12,6 – 20,9
κ-kazeina	2,3 – 3,3	3,2 – 4,3	2,8 – 13,4	4,1 – 5,4
γ-kazeina	0,8	-	-	-
Białka serwatkowe				
β-laktoglobulina	3,2 – 3,3	6,5 – 8,5	1,5 – 5,0	3,9
α-laktoalbumina	1,2 – 1,3	1 – 1,9	0,7 – 2,3	1,4
Albumina serum	0,3 – 0,4	0,4 – 0,6	0,31 – 0,42	0,29
Proteozy i peptony	0,8 – 1,2	-	0,97 - 1	3,31
Laktoferryna	0,02 – 0,5	0,8	0,02 – 0,2	0,03 – 3,4
Lizozym	(70-600) $\times 10^{-6}$	100 $\times 10^{-6}$	250 $\times 10^{-6}$	(120-152) $\times 10^{-6}$
Immunoglobuliny				
IgG	0,91	0,87	0,73	0,37 – 1,34
IgA	0,05 – 0,14	-	0,03 – 0,08	0,01 – 0,04
IgM	0,58	0,38	0,41	0,04 – 1,91
Stosunek kazeina/białka serwatkowe	4,7	3,1	3,5	4,6

Źródło: Na podstawie [49]
Source: On the source [49]

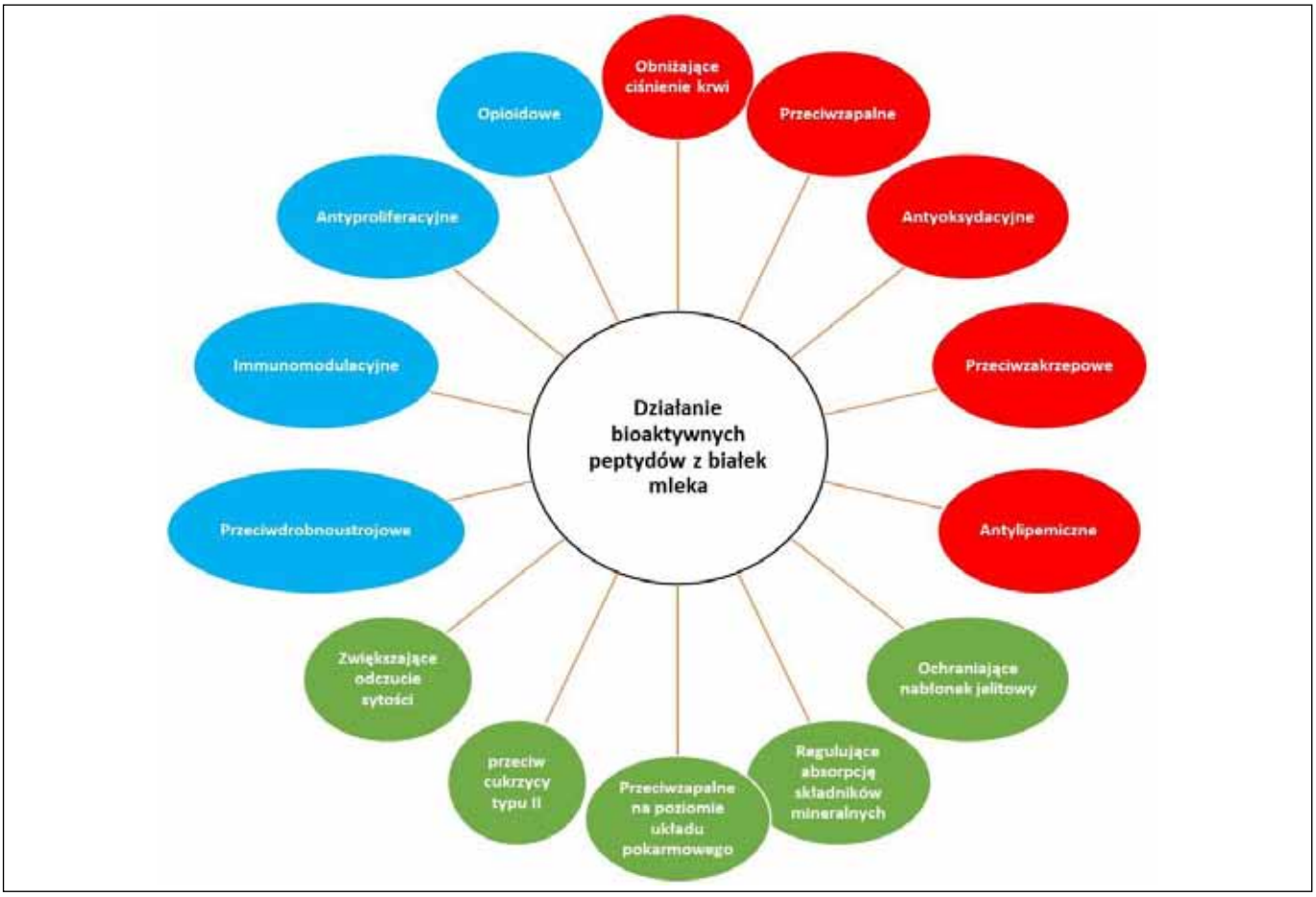
Białka mleka mogą działać jako prekursory bioaktywnych peptydów, które mają wielkość od 2 do 20 aminokwasów. Te odrębne sekwencje aminokwasowe są nieaktywne w macierzystej cząsteczce białka i pozostają „utajone". Są uwalniane dopiero przez działanie proteaz obecnych w mleku, enzymów trawiennych i enzymów wytwarzanych przez mikrobiotę jelitową w organizmie człowieka lub przez enzymy proteolityczne bakterii kwasu mlekowego (kultur starterowych) podczas fermentacji mleka. Wszystkie z frakcji białek mleka są źródłem bioaktywnych peptydów, czyli potencjalnych składników prozdrowotnych w żywności funkcjonalnej [18, 43].

Podczas trawienia enzymy trawienne hydrolizują białka z pokarmu do peptydów i aminokwasów. Na transport i wchłanianie peptydów w przewodzie pokarmowym wpływa kilka czynników: wielkość peptydu, pH środowiska i pK_a. Stwierdzono, że peptydy większe niż di- i tri-peptydy nie są łatwo wchłaniane przez zdrowych ludzi, z wyjątkiem stanów takich jak stres lub choroba, gdy zwiększa się przepuszczalność jelit [11]. Zaobserwowano, że błona śluzowa jelita nie jest szczelną barierą i różne peptydy mogą przenikać przez nabłonek jelitowy, natomiast mechanizm tego transferu nadal nie jest jasny. U ssaków istnieją cztery różne systemy transportu peptydów (PTS-1, PTS-2, PTS-3 i PTS-4), w tym peptydów pochodzących z żywności, z układu krwionośnego do ośrodkowego układu nerwowego przez barierę krew-mózg [16].

W niniejszym artykule dokonano przeglądu piśmiennictwa z zakresu badań nad peptydami pochodzącymi z białek mleka, które budzą zainteresowanie w kierunku wykorzystania ich w nowej żywności funkcjonalnej ze względu na potencjalny korzystny wpływ na zdrowie człowieka.

PROZDROWOTNA AKTYWNOŚĆ BIOAKTYWNYCH PEPTYDÓW Z MLEKA

Białka mleka są uważane za główne źródło peptydów o szerokim zakresie funkcji fizjologicznych. Pierwszymi bioaktywnymi peptydami odkrytymi już w latach 50-tych XX w. w hydrolizatach kazeiny były fosfopeptydy. Szybki postęp wiedzy na temat bioaktywnych peptydów rozpoczął się w latach 70-tych XX w. od wydzielenia z kazeiny i scharakteryzowania peptydów podobnych do opioidów – związki te nazwano kazomorfinami [1]. Od tego czasu scharakteryzowano wiele bioaktywnych peptydów z białek mleka o różnej aktywności m.in. przeciwnadciśnieniowej, przeciwlipemicznej, przeciwutleniającej, przeciwzakrzepowej czy wzmacniającej odpowiedź immunologiczną (Rys. 1). Należy zwrócić uwagę na równomierny rozkład aktywności bioaktywnych peptydów białek mleka w obrębie trzech układów sercowo-naczyniowego, pokarmowego i odpornościowego.



Rys. 1. Wpływ bioaktywnych peptydów z białek mleka na zdrowie człowieka (czerwony – aktywność w obrębie układu sercowo-naczyniowego, zielony – aktywność w obrębie układu pokarmowego, niebieski – aktywność w obrębie układu odpornościowego).

Fig. 1. Influence of bioactive peptides from milk proteins on human health (red - activity within the cardiovascular system, green - activity within the digestive system, blue - activity within the immune system).

Źródło: Opracowanie własne

Source: Own study

Choroby sercowo-naczyniowe kojarzone są z niezdrową dietą bogatą w nasycone kwasy tłuszczowe, tłuszcze trans (uwodornione tłuszcze przemysłowe), sól oraz dietą ubogą w owoce i warzywa [29]. W przeszłości wiele chorób sercowo -naczyniowych wiązano również z pełnotłustymi produktami mlecznymi, jednak w ostatnich latach wykazano, że spożywanie pełnotłustych produktów mlecznych, w tym mleka, serów i mlek fermentowanych, może być odwrotnie skorelowane z występowaniem tych chorób. Stwierdzono także, że obecne w tych produktach bioaktywne peptydy mogą przyczynić się do zmniejszenia częstości występowania chorób sercowo-naczyniowych [22].

Jedną z najczęściej opisywanych właściwości bioaktywnych peptydów mleka jest ich działanie przeciwnadciśnieniowe [40]. W szczególności u wielu bioaktywnych peptydów mleka stwierdzono właściwość obniżania ciśnienia tętniczego poprzez hamowanie enzymu konwertującego angiotensynę (ACE, z ang. angiotensyn converting enzyme), który odgrywa kluczową rolę w regulacji ciśnienia krwi. Aktywność enzymatyczna reniny powoduje powstanie angiotensyny I z angiotensynogenu, a ta z kolei jest katalizowana przez ACE do angiotensyny II, silnego środka zwężającego naczynia. Dodatkowo ACE dezaktywuje bradykininę, substancję rozszerzającą naczynia krwionośne, przyczyniając się dodatkowo do wzrostu ciśnienia krwi [26]. Hamowanie aktywności ACE uznaje się za jedną ze strategii leczenia nadciśnienia. Ong i Shah [35] opisali, że zastosowanie *Lactobacillus acidophilus* LAFTI L®10 jako dodatkowej kultury starterowej przy produkcji sera zwiększa uwalnianie bioaktywnych peptydów hamujących ACE (np. kazeiny κ (f 96–102), kazeiny αs1 (f 1–9), kazeiny αs (f 1–7), kazeiny αs1 (f 1–7), kazeiny αs1 (f 24–32) i kazeiny β (f 193–209)). Podobnie Sahingil i wsp. [42] wykorzystali *Lactobacillus helveticus* jako kulturę pomocniczą przy produkcji serów solankowych w celu zwiększenia zawartości bioaktywnych peptydów o właściwościach hamujących ACE. W piśmiennictwie podaje się, że tego typu aktywność wykazują peptydy Ile-Pro-Pro (IPP) i Val-Pro-Pro (VPP) [5, 9]. Z badań Iwaniak i wsp. [21] wynika, że zastosowanie mleka o zwiększonej zawartości β-kazeiny do produkcji serów typu Gouda powoduje zwiększenie zawartości peptydów o aktywności inhibitorów ACE w czasie dojrzewania serów w porównaniu do serów z mleka o typowym składzie. Garbowska i wsp. [14, 15] podjęli badania mające na celu określenie możliwości tworzenia bioaktywnych peptydów o właściwościach przeciwnadciśnieniowych przez wybrane szczepy bakterii

mlekowych z rodzaju *Lactobacillus* (*Lb. casei* 2639, *Lb. acidophilus* 2499, *Lb. rhamnosus* 489 i 490) oraz *Lactococccus* (*Lc. lactis* 11454, *Lc. lactis* 2379, *Lc. lactis* 476) w modelach serów podpuszczkowych dojrzewających otrzymanych z ich udziałem. Inhibicję ACE powyżej 90% po 5 tygodniach dojrzewania stwierdzili we wszystkich modelach serów z badanymi dodatkowymi szczepami bakterii mlekowych.

Peptydy pochodzące z αs-kazeiny wykazują aktywność wymiatania wolnych rodników i hamowania enzymatycznego i nieenzymatycznego utleniania lipidów [39]. Peptydy o aktywności antyoksydacyjnej zidentyfikowano również we frakcjach β-kazeiny i β-laktoglobuliny mleka koziego [2, 23]. Za właściwości antyoksydacyjne białek serwatkowych odpowiedzialny jest obecny w ich cząsteczkach aminokwas siarkowy – cysteina, która wzmacnia syntezę glutationu będącego naturalnym antyoksydantem komórki [44].

Nadwaga i otyłość to nieprawidłowe i nadmierne nagromadzenie tłuszczu, który negatywnie wpływa na stan zdrowia. Uznaje się, że odczucie sytości jest jednym z kluczowych czynników, które pomagają zapobiegać otyłości. Sytość pojawia się po spożyciu pokarmu i zwiększeniu objętości żołądka a także dzięki uwolnieniu substancji anorektycznych, czyli takich które hamują uczucie głodu. Jedną z nich jest hormon cholecystokinina syntetyzowany w jelicie cienkim [49]. Wydzielanie cholecystokininy może być stymulowane przez glikomakropeptyd [38], czyli fragment κ-kazeiny uwalniany pod wpływem działania chymozyny (enzym preparatu podpuszczki) w czasie otrzymywania serów podpuszczkowych. Glikomakropeptyd stanowi 20–25% wszystkich białek obecnych w produktach otrzymanych z serwatki, takich jak proszek serwatkowy oraz izolaty i koncentraty białek serwatkowych. Dlatego uważa się, że spożywanie białek serwatkowych jako naturalnego źródła glikomakropeptydu może ograniczać ilość spożywanego pokarmu, a tym samym ograniczyć nadwagę [25, 32].

Cukrzyca jest chorobą przewlekłą. W 2018 r. w Polsce było 2,9 mln dorosłych chorych na cukrzycę, czyli co jedenasty dorosły [31]. Choroba ta występuje albo w wyniku autoimmunologicznego zniszczenia wydzielających insulinę komórek β trzustki (cukrzyca typu I) albo w wyniku insulinooporności w narządach obwodowych, co powoduje rozregulowanie wydzielania insuliny i ewentualną niewydolność komórek β (cukrzyca typu II). Według Pasin i Comerford [37] wpływ spożywania produktów mlecznych na wydzielanie insuliny i kontrolę poziomu cukru we krwi wynika z: dużej ilości niezbędnych aminokwasów i bioaktywnych peptydów, które stymulują wydzielanie insuliny; specyficznych kombinacji makroskładników i mikroskładników odżywczych w mleku; unikalnych szczepów probiotycznych; oraz bioaktywnych peptydów występujących w mlecznych produktach fermentowanych. Podawanie zwierzętom laboratoryjnym bioaktywnych peptydów z mleka (Val-Ala-Gly-Thr-Trp-Tyr) i sera typu Gouda (Leu-Pro-Gln-Asn-Ile-Pro-Pro-Leu) powodowało obniżenie stężenia glukozy w osoczu krwi gryzoni, co prawdopodobnie wynikało z hamowania dipeptydylopeptydazy-4 (DPP-4), czyli kluczowego enzymu regulującego wytwarzanie insuliny [47, 48]. Sugeruje się więc, że spożywanie produktów mlecznych bogatych w β-kazeinę, hamuje DPP-4, a co za tym idzie stymuluje sekrecję insuliny, co może mieć korzystny wpływ u osób z zaburzonym jej wydzielaniem.

Bioaktywne peptydy z mleka, takie jak β-kazokininy, β-kazomorfiny i laktoferycyna B stymulują odpowiedź immunologiczną organizmu człowieka [10]. Podkreśla się, że szczególnie peptydy pochodzące z różnych frakcji kazein stymulują proliferację limfocytów, aktywność makrofagów a ponadto przyczyniają się do ochrony przed infekcjami bakteryjnymi, wirusowymi i pasożytniczymi, zmniejszają procesy zapalne o podłożu autoimmunologicznym i zapobiegają odrzucaniu przeszczepów [17]. Szeroko już opisana laktoferyna oprócz zdolności chelatowania żelaza, pośrednio uczestniczy w aktywacji limfocytów B, hamuje proces powstawania granulocytów w krwiotwórczym szpiku kostnym i zwiększa aktywność komórek NK (z ang. natural killer) [26]. Laktoferyna ma również właściwości bakteriostatyczne i bakteriobójcze, gdyż uszkadza zewnętrzną błonę komórkową bakterii Gram -ujemnych powodując uwalnianie lipopolisacharydów, które aktywują odpowiedź immunologiczną organizmu [49].

Wspomniany już wyżej peptyd VPP, zmniejsza adhezję monocytów do śródbłonka objętego stanem zapalnym, zmniejszając stan zapalny i przyczyniając się do zapobiegania procesom miażdżycowym [3]. Podobnie β-kazomorfina hamuje ACE, który inaktywuje bradykininę, silny czynnik wazoaktywny powodujący niedociśnienie i wzmacniający odpowiedź immunologiczną. Dlatego wydaje się, że spożywanie produktów mlecznych bogatych w tripeptyd VPP pośrednio wzmacnia odpowiedź immunologiczną poprzez zmniejszenie hamowania bradykininy przez ACE [10].

Depresja, lęk i stres są częścią istotnych problemów zdrowotnych na świecie. Stres jest zespołem reakcji zachodzących w organizmie mających na celu przywrócenie równowagi homeostatycznej. Ale te same reakcje zachodzące w czasie przedłużającego się stresu mogą powodować uszkodzenia komórek/tkanek lub prowadzić do stanów chorobowych. Przedłużający się lub uporczywy stres przyczynia się do podwyższenia poziomu hormonów, takich jak „hormon stresu" – kortyzol oraz zmniejszenia poziomu serotoniny i innych neuroprzekaźników w mózgu (np. dopaminy), co uznaje się za dodatnio skorelowane z depresją. Kiedy te biochemiczne systemy regulacji działają prawidłowo, kontrolują procesy biologiczne, takie jak sen, apetyt i popęd seksualny oraz umożliwiają wyrażanie normalnych nastrojów i emocji. Jeśli jednak reakcja na stres nie zanika, może to prowadzić do depresji u osób podatnych a pojawiające się zaburzenia snu – do problemów, takich jak zmniejszenie apetytu, problemy ze skupieniem uwagi, niestabilny nastrój i zmęczenie. Dostępne terapie farmakologiczne zaburzeń związanych ze stresem, wiążą się z różnymi skutkami ubocznymi, takimi jak wymioty, zawroty głowy, otępienie polekowe i nudności [46]. Dlatego wszelkie dane świadczące o możliwości wykorzystania jako nutraceutyków egzogennych peptydów opioidowych występujących w żywności, są bardzo obiecujące ale wymagają wciąż wielu badań, aby dokładnie zrozumieć mechanizmy ich aktywności w organizmie człowieka.

Egzogenne peptydy opioidowe (znane jako egzorfiny) o aktywności podobnej do morfiny mogą pochodzić z różnych produktów spożywczych zawierających białko zarówno pochodzenia zwierzęcego np. mleka lub roślinnego np. soi. Egzogenne peptydy opioidowe wykazują podobieństwo strukturalne do opioidów endogennych, czyli tych tworzonych przez organizm. Coraz więcej badań sugeruje, że receptory

opioidowe nie rozróżniają niektórych peptydów egzogennych od endogennych, co wskazuje, że pewne peptydy egzogenne mogą wykazywać się aktywnością fizjologiczną. Większość egzogennych peptydów opioidowych uwalnianych jest w czasie procesów trawienia białka i następnie wchłanianych do krwiobiegu. Są one oporne na rozkład przez proteazy jelitowe i mogą przekraczać barierę krew-mózg [46].

W 1979 r. wykazano, że mleko ma aktywność opioidową a rok później z mleka wyizolowano morfinę w stężeniach od 200 do 500 ng/l [46]. Wśród frakcji białek mleka najbogatszym źródłem egzogennych peptydów opioidowych są β-kazeina i α-kazeina (Tabela 2). Natomiast β-kazomorfina 7 z bydlęcej β-kazeiny była pierwszym zidentyfikowanym peptydem opioidowym i jest najsilniejszym peptydem opioidowym wśród wszystkich β-kazomorfin [7]. Obecność proliny w łańcuchu β-kazomorfin nadaje tym związkom wysoką oporność na rozkład pod wpływem enzymów trawiennych w żołądku dzięki czemu mogą przetrwać pasaż żołądkowy bez degradacji. β-Kazomorfiny izolowano z mleka spożywczego [33], mlek fermentowanych i serów podpuszczkowych dojrzewających [4, 24, 34]. Związki te wykazują potencjalny wpływ na funkcje mózgu, wywołują uspokojenie i senność u niemowląt, a także niwelują niektóre zachowania np. lęk [6].

W badaniach na myszach oraz prowadzonych w warunkach *in vitro* wykazano właściwości przeciwnowotworowe β-kazomorfiny oraz κ-kazecydyny, co przypisuje się wywoływaniu cytotoksyczności wobec komórek nowotworowych (wobec komórek białaczki, komórek czerniaka, komórek raka piersi) [41]. Peptydy te mają zdolność przenikania bariery jelito-krew i dzięki temu docierania do miejsc docelowych (komórek nowotworowych). Wykazano, że jogurty zawierające β-kazomorfiny i κ-kazecydynę zmniejszały proliferację komórek nowotworowych, co łączy spożywanie jogurtu ze zmniejszoną częstością występowania raka okrężnicy [45]. W piśmiennictwie dostępne są dane informujące o przeciwnowotworowej aktywności bioaktywnych peptydów pochodzących z białek serwatkowych. Zaobserwowano, że ekspresja kaspazy-3 znacznie wzrosła w komórkach czerniaka linii B16F10, gdy hodowano je w pożywce zawierającej izolat białek serwatkowych [8]. Kaspazy to enzymy odpowiedzialne za prowadzenie apoptozy, czyli naturalnego i przebiegającego pod kontrolą procesu destrukcji komórek w organizmie wielokomórkowym. Mechanizm apoptozy jest konieczny dla homeostazy i zapobiegania szkodliwej proliferacji komórek organizmu, w tym szczególnie procesom kancerogenezy [49].

PODSUMOWANIE

Produkty mleczne są jednym z najważniejszych źródeł białek o wysokiej wartości biologicznej a także będących nośnikiem bioaktywnych peptydów. Bioaktywne peptydy z mleka mogą mieć korzystny wpływ na szereg procesów fizjologicznych a przez to potencjalnie stanowić czynniki zapobiegające różnym stanom chorobowym. Potencjalne korzyści zdrowotne bioaktywnych peptydów z mleka wzbudziły w ostatnich latach rosnące zainteresowanie. W różnych badaniach, zarówno na modelach zwierzęcych jak i w badaniach klinicznych, wykazano wpływ peptydów z białek mleka na układ nerwowy, funkcjonowanie przewodu pokarmowego oraz zwiększenie zużycia energii, co wskazuje na możliwości ich zastosowania jako nutraceutyków do łagodzenia bólu, poprawy pamięci, redukcji stresu, wydłużenia pasażu jelitowego, zwiększenia poziomu cukru we krwi, leczenia otyłości, obniżenia ciśnienia krwi, czy wspomagania układu odpornościowego.

Tabela 2. Wybrane sekwencje peptydowe o aktywności opioidowej z białek mleka krowiego

Table 2. Selected peptide sequences with opioid activity from cow's milk proteins

Białko macierzyste	peptyd	Sekwencja aminokwasowa
αs-kazeina	αs1-kazeino-egzorfina	Arg-Tyr-Leu-Gly-Tyr-Leu-Glu
β-kazeina	β-kazomorfina-4	Tyr-Pro-Phe-Pro
	β-kazomorfina-5	Tyr-Pro-Phe-Pro-Gly
	β-kazomorfina-6	Tyr-Pro-Phe-Pro-Gly-Pro
	β-kazomorfina-7	Tyr-Pro-Phe-Pro-Gly-Pro-Ile
	Neokazomorfina-6	Tyr-Pro-Val-Glu-Pro-Phe
κ-kazeina	kazoksyna A	Tyr-Pro-Ser-Tyr-Gly-Leu-Asn-Tyr
	kazoksyna B	Tyr-Pro-Tyr-Tyr
	kazoksyna C	Tyr-Ile-Pro-Ile-Gln-Tyr-Val-Leu-Ser-Arg
α-laktoalbumina	α-laktorfina	Tyr-Gly-Leu-Phe
β-laktoglobulina	β-laktorfina	Tyr-Leu-Leu-Phe
Albumina serum	serorfina	Tyr-Gly-Phe-Asn-Ala
Laktoferyna	laktoferoksyna A	Tyr-Leu-Gly-Ser-Gly-Tyr-OCH_3
	laktoferoksyna B	Arg-Tyr-Tyr-Gly-Tyr-OCH_3
	laktoferoksyna C	Lys-Tyr-Leu-Gly-Pro-Gln-Tyr-OCH_3

Źródło: Na podstawie [11, 36, 46]

Source: On the base [11, 36, 46]

Istnieją jednak także doniesienia sugerujące, że peptydy pochodzące z żywności mogą mieć negatywny wpływ na zdrowie człowieka. Po dokonaniu przeglądu dowodów naukowych na ewentualny związek β-kazomorfiny-7 (BCM7), sekwencji peptydowej obecnej w β-kazeinie, z chorobami takimi jak autyzm, choroby układu krążenia i cukrzyca typu I, Europejski Urząd ds. Bezpieczeństwa Żywności (EFSA) [11] stwierdził, że nie można wykazać związku przyczynowo -skutkowego między doustnym przyjmowaniem BCM7 lub pokrewnych peptydów a etiologią i przebiegiem tych chorób.

Większość publikacji dotyczących bioaktywnych peptydów nadal opiera się na badaniach *in vitro* a rzeczywisty wpływ tych peptydów na zdrowie człowieka pozostaje nie do końca poznany. W związku z tym istnieje potrzeba długotrwałych badań *in vivo* w celu dostarczenia silniejszych danych potwierdzających pozytywny wpływ bioaktywnych peptydów z mleka na zdrowie człowieka.

SUMMARY

Dairy products are one of the most important sources of proteins with high biological value and also being a carrier of bioactive peptides. Bioactive peptides from milk can have a beneficial effect on a number of physiological processes and thus potentially act as preventers of various disease states. The potential health benefits of bioactive milk peptides have aroused increasing interest in recent years. In various studies, both in animal models and in clinical trials, the effect of peptides from milk proteins on the nervous system, the functioning of the gastrointestinal tract and the increase in energy consumption has been shown, which indicates the possibility of their use as nutraceuticals for pain relief, memory improvement, stress reduction, prolongation intestinal transit, increasing levels of glucose in blood, treating obesity, lowering blood pressure, or supporting the immune system.

However, there are also reports suggesting that food-derived peptides may have a negative impact on human health. After reviewing the scientific evidence for a possible association of β-casomorphine-7 (BCM7), a peptide sequence present in β-casein, with diseases such as autism, cardiovascular disease and type I diabetes, the European Food Safety Authority (EFSA) [11] concluded that no cause-and-effect relationship could be demonstrated between the oral intake of BCM7 or related peptides and the etiology and course of these diseases.

Most publications on bioactive peptides are still based on *in vitro* research, and the actual impact of these peptides on human health remains not fully understood. Therefore, there is a need for long-term *in vivo* studies to provide stronger data supporting the positive effect of bioactive milk peptides on human health.

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Dr n. wet. inż. Magdalena POLAK-ŚLIWIŃSKA
Chair of Commodity Science and Food Analysis, Department of Food Science
University of Warmia and Mazury in Olsztyn, Poland
Katedra Towaroznawstwa i Badań Żywności, Wydział Nauki o Żywności
Uniwersytet Warmińsko – Mazurski w Olsztynie, Polska

OLIVE OIL: HEALTH BENEFITS AND APPLICATION OF THE GCMS TECHNIQUE AND THE LCMS TECHNIQUE FOR THE QUANTIFICATION OF THE IMPORTANT NUTRITIONAL COMPONENTS®

Oliwa z oliwek: korzyści zdrowotne oraz zastosowanie techniki GCMS i LCMS do ilościowego oznaczania ważnych składników odżywczych®

Key words: olive oil, health benefits, phenolics, fatty acids, GCMS and LCMS methods.

Olive oil is known for its health properties [88], which has translated into dietary patterns favouring higher consumption, especially in Mediterranean countries. Numerous studies support the claim of olive oil consumption and its potential health benefits, especially in the prevention of cardiovascular disease, diabetes and breast cancer. Olive oil is considered a nutritional product because it contains phenolic compounds (for example, oleuropein and hydroxytyrosol present in extra virgin olive oil) whose health benefits are now widely documented. Several studies have reported anti-inflammatory effects of phenolic compounds. In vitro and in vivo studies have shown, for example, that the phenols present in olive oil are potent antioxidants. Omega-6 fatty acids, which are also present in this product, are an important factor for the metabolism of the human body, for bones, healthy skin and hair. As an essential nutrient, it is necessary to take them from outside. They are found in many foods, especially vegetable oils and nuts. Commonly used techniques for the determination of beneficial substances from olive oil are GCMS and LCMS, and many of the applications already developed allow the analysis of different types of this product with a single method, which certainly makes it possible to precisely assess the levels of various compounds, including the fatty acid content of olive oil in a short time.

The aim of this work was to present recent reports related to the beneficial effects of olive oil consumption in humans and to present selected methods and applications for the analysis of several important substances responsible for the beneficial properties of this product.

Słowa kluczowe: oliwa z oliwek, korzyści zdrowotne, fenole, kwasy tłuszczowe, metody GCMS i LCMS.

Oliwa z oliwek jest znana ze swoich właściwości zdrowotnych [88], co przełożyło sę na wzorce żywieniowe, preferujące wyższe jej spożycie, zwłaszcza w krajach śródziemnomorskich. Liczne badania potwierdzają słuszność twierdzenia o spożyciu oliwy z oliwek i jej potencjalnych korzyściach zdrowotnych, zwłaszcza w zapobieganiu chorobom układu krążenia, cukrzycy i rakowi piersi. Oliwa z oliwek jest uważana za produkt odżywczy, ponieważ zawiera związki fenolowe (na przykład oleuropeina i hydroksytyrozol obecne w oliwie z oliwek extra virgin), których korzyści zdrowotne są obecnie szeroko udokumentowane. W wielu badaniach stwierdzono działanie przeciwzapalne związków fenolowych. Badania in vitro i in vivo wykazały chociażby, że fenole obecne w oliwie z oliwek są silnymi przeciwutleniaczami. Kwasy tłuszczowe omega-6, które są również obecne w tym produkcie, stanowią ważny czynnik dla metabolizmu organizmu ludzkiego, dla kości, zdrowej skóry i włosów. Jako niezbędny składnik odżywczy konieczne jest ich pobieranie z zewnątrz. Znajdują się w wielu produktach spożywczych, zwłaszcza w olejach roślinnych i orzechach. Powszechnie stosowanymi technikami oznaczania substancji korzystnie wpływających na organizmy ludzkie pochodzących z oliwy z oliwek jest technika GCMS i LCMS, a wiele z już opracowanych aplikacji umożliwia analizę różnych rodzajów tego produktu przy użyciu jednej metody, co na pewno pozwala na precyzyjną ocenę poziomu różnych związków, w tym ocenę zawartości kwasów tłuszczowych w oliwie z oliwek w krótkim czasie.

Celem pracy było przedstawienie najnowszych doniesień związanych z korzystnym wpływem spożycia oliwy z oliwek przez człowieka oraz przedstawieniem wybranych metod i aplikacji do analizy kilku ważnych substancji odpowiedzialnych za dobroczynne właściwości tego produktu.

Corresponding author – Adres do korespondencji: Magdalena Polak-Śliwińska, Chair of Commodity Science and Food Analysis, Department of Food Science, University of Warmia and Mazury in Olsztyn, Pl. Cieszyński 1, 10-957 Olsztyn; e-mail: m.polak@uwm.edu.pl

INTRODUCTION

Knowledge of natural products extracted from medicinal plants and nutrition issues have played a key role in the human health care system since the dawn of history [3]. Many societies, despite significant advances in medical knowledge, continue to use traditional plants as an alternative to medicines in the treatment of various chronic diseases and health problems, such as skin ailments, bone fractures, rheumatism gastric problems associated with asthma, diabetes, constipation, respiratory infections, colds, cough and fever, urological diseases, measles, liver and spleen diseases, typhoid fever, epilepsy, toothache, tuberculosis, anemia, hypertension, nervous system disorders [3]. The olive tree is one of the most important trees in the world due to the economic and health benefits of the oil obtained from its fruit. Due to its climatic requirements, the olive tree is found in the Mediterranean region, and seventy-five percent of the world's olive oil production comes from this area. The main producers are Spain, Italy, Greece, Turkey, Morocco and Syria [25, 41]. Olive oil in Mediterranean culture is used as a major source of fat [3, 41] because it contains a high amount of lipids that are helpful in the primary and secondary prevention of cardiovascular disease, improve lipid profile and insulin sensitivity. Characteristically, the Mediterranean diet, abundant in olive oil intake, is also abundant and diverse in the intake of plant foods (fruits, vegetables, grains, legumes, and nuts); moderate in the consumption of red wine with meals moderate in the consumption of fish and seafood, dairy products, poultry and eggs; and showing a low intake of red meat and sweets [11, 12, 25, 70], which contributes significantly to a lower incidence of cancers such as breast cancer compared to southern European countries, where mortality from breast and other cancers has been rising for years. These problems are attributed to changes in dietary patterns, including decreasing consumption of olive oil and increasing consumption of seed oils [29, 70]. Olive oil consumption increases oxidative stability, improves biomarkers of inflammation, and controls blood pressure [3, 25, 28]. More than 2000 years ago, olive oil was mainly used for religious and spiritual purposes, as evidenced by religious writings such as the Bible and the works of Homer [3, 41]. Currently, consumption of this product seems to be steadily increasing from year to year [51]. Olive oil has a low concentration (8–14%) of saturated fatty acids (SFAs) and contains a high amount of monounsaturated fatty acids (MUFAs), especially oleic acid in a proportion of about 55–83% and polyunsaturated fatty acids (4–20%) [32, 41]. Olive oil is a product that also contains 1–2% of total weight minor compounds such as phenols, triterpenes, tocopherols, some pigments and sterols with unique biological properties [3, 28]. Both the fruit, oil and leaves of the olive tree show the highest antioxidant potential, well known and repeatedly reported in the literature. Extracts obtained from olive tree by-products are used in food and pharmaceutical industries as they contain various important phenolic compounds and antioxidants that help in preventing oxidative damage such as oleuropein aglycone, hydroxytyrosol, oleuropein and tyrosol [40, 41, 55]. In the market, extra virgin olive oil (EVOO) is the most sold olive oil worldwide and is the first choice of consumers among different types of olive oil. The main part of the lipids contained in EVOO is oleic acid, followed by linoleic and α-linolenic acid and a small amount of stearic and palmitic acid (SFAs) [41]. In recent years, much attention has been paid to the potential health benefits of olive oil and the effects of various EVOO components [3, 42, 55, 87]. The nutraceutical industry uses EVOO [78, 79] because it acts as a cardiovascular and cerebrovascular protector, prevents neurodegenerative diseases, has anti-inflammatory effects, and plays an important role in some types of cancer. It also affects some human metabolic syndromes and is a general detoxifier. All of these properties make EVOO an essential health food ingredient [41]. Virgin olive oil (VOO) is considered a healthy fat. The European Food Safety Authority (EFSA) has granted health claims regarding the beneficial effects of the lipid profile and polyphenol content of VOO [16, 34, 35, 70].

The specific composition of olive oil depends on its quality and many other parameters such as growing area, variety, environmental conditions, harvest time and system, extraction methods or storage conditions [55, 78]. For example, fruits harvested in cold regions have more MUFAs [28, 78]. Thus, the popularity of olive oil is mainly due to its anti-inflammatory and antioxidant properties that definitely help to prevent various ailments in humans [29, 41].

The aim of this study was to present recent reports on the beneficial effects of olive oil consumption in humans and to present methods and applications for the analysis of several important substances responsible for the beneficial properties of this product.

OLIVE OIL AND ITS MAJOR COMPONENTS

Nowadays, it is very important to know in detail the composition of varietal oils [78] and to know the specific role played by their most noble components in terms of health care (Table 1). The role of olive oil in preventive medicine is gaining more importance and is always associated with healthy behavioral habits. It is still very important to have a deeper knowledge about the specific role of the components in oils [16, 75], especially in the aspect of combating chronic diseases such as atherosclerosis, heart disease [28], Parkinson's disease [56], regulation of plasma cholesterol, obesity and control of hypertension [60], etc. Therefore, the active ingredient especially in monograde oils is essential [7, 81].

The fatty acid profile comprising the main fraction of a typical olive oil (the saponifiable fraction, accounts for more than 98% of the total weight of the oil, and includes triacylglycerols and their derivatives) is represented by MUFA oleic acid and palmitoleic acid; palmitic and stearic acids, saturated fatty acids; n-6 PUFA linoleic acid; n-3 PUFA linolenic acid; and small amounts of other fatty acids (myristic, 14: 0; margaric, 17:0; margaric, 17:1n9; arachidic, 20:0; eicosene, 20:1n9; docosanoic, 22:0; lignoceric, 24:0) [12, 41, 42, 53, 70, 73, 83, 99]. Many authors [50, 91] have recently stated the need to improve our knowledge of the role of the different fatty acids present in EVOO and VOO and the relationship between them [71] in order to clarify in the deepest possible way their role as dietary supplements that promote the reduction of cardiovascular pathologies [71] and in the treatment of various pathologies of the nervous system and even multiple sclerosis [101].

Table 1. The composition of EVOO

Tabela 1. Skład EVOO

Olive Oil Compounds	Reference
Saponifiable Fraction (>98%)	[12, 24, 42, 76, 83]
Triacylglycerols and derivatives	[53, 73, 83, 99]
16:0 Palmitic acid	
16:1n-7 Palmitoleic acid	
18:0 Stearic acid	
18:1n-9 Oleic acid	
18:2n-6 Linoleic acid	
18:3n-3 Linolenic acid	
Unsaponifiable Fraction (< 2%)	[12, 24, 42, 76, 83]
Non-glyceride esters and waxes	
Aliphatic alcohols	[4, 83]
Volatile compounds: aldehydes, ketones, alcohols, acids, esters, etc.	[24, 83]
Triterpenes: erythrodiol, uvaol, oleanolic acid and maslinic acid	[62, 83]
Sterols: β-sitosterol, campesterol, stigmasterol and avenasterol	[62, 83]
Hydrocarbons	[62, 83]
Squalene	[62, 83]
n-alkanes and n-alkenes	[24, 45]
Carotenoids: β-carotene and lycopene	[8, 83]
Pigments: chlorophylls and pheophytins	[62]
Lipophilic phenolics: tocopherols and tocotrienols	[8]
Hydrophilic phenolics	[83]
Phenolic acids: gallic, vanillic, cinnamic, caffeic, coumanic and elenolic acids	[83]
Phenolic alcohols: hydroxytyrosol, tyrosol and their glucosides Secoiridoids: oleuropein and ligstroside derivates (oleocanthal and oleacein)	
Lignans: pinoresinol and acetoxypinoresinol	[76]
Flavonoids: luteolin and apigenin	

Source: Own elaboration based on source Salazar et all. [89]

Źródło: Opracowanie własne na podstawie Salazar i in. [89]

The unsaponifiable fraction of olive oil (1–2% of total weight) is characterized by chemical variability and complexity, containing: dialcohols and triterpene acids; sterols; hydrocarbons such as squalene; n-alkanes and alkenes, or carotenoids (β-carotene is most abundant; pigments; and phenolic compounds (lipophilic and hydrophilic) [40, 41, 83]. The most important lipophilic compounds are tocopherols (α-tocopherol is the most abundant in olive oil) [83]. Regarding hydrophilic phenols [83], several chemical classes have been identified, such as secoiridoses, flavonoids or lignans [76]. Other components are also present in the unsaponifiable EVOO fraction, such as aliphatic alcohols, waxes, and many volatile compounds [24, 83]. Secoiridoids are a group of compounds found in *Oleaceae* plant species and constitute the majority of bioactive polyphenols in olive oil and seeds. Oleuropein (OLE) and its biosynthetic precursor, ligstroside, are the major secoiridoids in EVOO. The structure of OLE involves a glycosylated ester of elenolic acid with hydroxytyrosol. Most of the secoiridoid phenolic derivatives in EVOO are derived from oleuropein and ligstroside [52, 70].

Oleocanthal (OC) is a decarboxylation derivative of the aglycone form of oleuropein. This phenolic compound is interesting due to its anti-inflammatory activity similar to ibuprofen, acting as a non-selective COX inhibitor [15].

Flavonoids are a group of polyphenols widely found in fruits, vegetables and traditional medicinal plants. Apigenin and its main metabolite, luteolin, are the most concentrated flavones, belonging to the flavonoid class, found in EVOO [70].

HEALTH BENEFITS OF OLIVE OIL

Currently, talking about the integral role of EVOO ingredients is important, but it is even more worthwhile to focus on the specific role of each of its components, such as hydrocortisol, oleuropein, fatty acids, especially monounsaturated ones, phytosterols, and tocopherols, almost all of them play a proven antioxidant role [41]. Numerous compounds in olive oil have been studied for their potential activity in chemoprevention. These studies were performed *in vivo* and, mainly, *in vitro* on different cell lines. *In vivo* studies have served to elucidate the potential role of these compounds as adjuvant to enhance the efficacy of some chemotherapeutics, but little data have been published about the preventive effects as dietary supplements [70].

The importance of the presence of oleic acid is related to its ability to reduce the effects of oxidative stress in the human body, controlling LDL cholesterol levels without changing HDL cholesterol levels, which reduces the risk of heart attack and other heart diseases. It contributes to better control of foam cell formation and control of macrophage accumulation in the cardiovascular system, minimizes the formation of atherosclerosis [17, 69], which explains its role in reducing cardiac problems. The proportion of monounsaturated, polyunsaturated and saturated fatty acids consumed in the diet, especially the Mediterranean diet, is also involved in preventing death or complications related to cardiac problems. Currently, the high oleic acid content of oil has been linked to its ability to act as an anti-cancer agent [19], and in particular, it has been attributed with an important role in reducing the probability of colorectal cancer or prostate cancer [41].

Polyphenols are considered to be compounds that exhibit anti-inflammatory [86], gastrointestinal anti-diarrheal [27], anti-allergic, anthelmintic, and also exhibit some antiviral activity. In addition, polyphenols are very valuable for their protective effects against cardiovascular disease, and for their ability to reduce neurodegenerative processes [41]. They are also considered to prevent cerebral ischemia and other neurotransmission problems [33], such as Huntington's disease [100], Alzheimer's disease [56], Parkinson's disease, some peripheral neuropathologies, spinal nervous system problems, and even multiple sclerosis [41]. It is important to realize that all EVOOs and VOOs intended for commercial use do not have the same polyphenol content [14, 43], which obliges manufacturers to indicate the content on the labels of these commercially available products [41].

Hydroxytyrosol (HT) and tyrosol are the main phenolic alcohols found in EVOO, whose content increases during olive oil storage due to the hydrolysis of secoiridoids [55]. Hydroxytyrosol exhibits antitumor activity in vivo and in vitro using different mechanisms. In DMBA-induced rats, HT treatment for 6 weeks with a dose of 0.5 mg/kg inhibited the growth and proliferation rate of mammary tumors and modified the tumor expression profile. It also modulated genes related to proliferation, apoptosis and the Wnt signaling pathway (increased Sfrp4 expression) [47]. HT treatment also increased total plasma antioxidant capacity and reduced DNA damage and protein oxidation. This would suggest that its combination with chemotherapeutic drugs may reduce adverse oxidative effects [36]. Apoptotic pathways are also stimulated by HT treatment [47]. The chemopreventive effect of HT is also related to its antioxidant activity with a controversial evaluation of the role of oxidative stress and its modulation by antioxidants in cancer [36, 70]. Reactive oxygen species (ROS) appear to have complex actions: promoting as well as inhibiting tumorigenesis. Increased levels of ROS are associated with tumor initiation and transformation and resistance to chemotherapy [36, 70]. However, increased ROS generation and/or decreased antioxidant defense can activate various apoptotic pathways and this is a mechanistic effect of many chemotherapeutics. Through studies in human breast cancer, it has been shown that HT supplementation can have a mitigating effect on the oxidative effects of chemotherapeutic drugs in patients [36, 70].

Oleuropein (OLE) showed inhibitory effects on viability, cell cycle, proliferation and migration, and promotion of apoptosis in multiple breast cancer cell lines. These effects were associated with different molecules and signaling pathways at different levels, as modulation of epigenetic mechanisms, transcriptome, protein levels, and protein activation were described [1, 9, 13, 26, 63, 68]. OLE acts on cancer cells probably through modulation of several signaling pathways, and its antitumor effects may vary depending on the characteristics of the cancer cell lines [49, 70, 98]. Oleocanthal (OC) has been shown to be an inhibitor of Met, a membrane tyrosine kinase receptor binding HGF growth factor [38]. In *in vivo* and *in vitro* studies, OC has inhibitory effects on breast carcinogenesis through various mechanisms, such as modulation of apoptosis and alterations in several signaling pathways [2, 10, 70, 82, 93]. In several breast cancer cell lines, OC has also demonstrated inhibitory effects on proliferation, migration, invasion and G1/S cell cycle progression [2, 38, 57]. Flavones (apigenin and its major metabolite luteolin) exhibit anticancer effects *in vivo* and *in vitro* through cellular mechanisms such as inhibition of cell growth, cell cycle arrest, stimulation of apoptosis or inhibition of angiogenesis and metastasis [70]. The antitumor effects of flavonoids in vitro have been associated with the modulation of different pathways (for instance apigenin induced G2/M cell-cycle arrest by modulating CDK1/cyclin B1, accompanied by ERK inhibition) [103]. In relation to the pro-apoptotic effect of luteolin, evidence indicates that this flavone is able to induce several pathways, such as intrinsic, extrinsic and caspase-independent apoptosis [21, 70, 77].

Many other EVOO ingredients have been studied for potential protective effects, including on cancer.

Lignans are dimeric structures consisting of two phenylpropane units: (+)-pinoresinol and 1-acetoxypinoresinol are those found in EVOO. Both lignans inhibited proliferation, induced apoptosis, blocked HER2 activity and reduced FAS levels in HER2-expressing breast cancer cell lines [65, 66, 67]. Pinoresinol also showed cytotoxic and antiproliferative effects on various breast cancer cells [22, 61, 92]. Due to the complex effects of oxidative stress on carcinogenesis, pinorezinol may prevent tumor initiation as it reduces ROS levels and DNA damage in non-cancerous cells (MCF-10A), while in cancer cells, which have higher ROS levels, when treated with H_2O_2, this lignan increases ROS levels [61, 70].

Phenolic acids are also found in EVOO [70]. Caffeic and gallic acids have demonstrated antiproliferative and pro-apoptotic effects on MCF-7 cells though gene expression

modulation of p53, Mcl-1 and p21 [84]. The major triterpenes of EVOO are uwaol, erythrodiol, oleanolic acid and maslinic acid. In MCF-7 cells, erythrodiol, uwaol, and oleanolic acid exhibited dose- and time-dependent inhibition of cell growth and proliferation. Erythrodiol stimulated apoptosis associated with ROS production and DNA damage, while the growth inhibitory effects of uvaol and oleanolic acid were associated with cell cycle arrest [5]. Tocopherols (provitamin E) are highly present in EVOO [52], involved in the cardiovascular system (avoiding or mitigating clot formation, reducing the risk of myocardial infarction, angina, stroke, but also preventing cramps), stimulate the ability to regenerate physical damage (stimulating the formation of elastin and collagen fibers in connective tissue), support the formation of cellular responses to certain infections, and stimulate the cellular immune system. Tocopherols are essential in the proper functioning of the reproductive system and fertility [70].

SELECTED METHODS FOR ANALYZING OLIVE OIL

Olive oil is a complex, multicomponent food matrix whose analysis is not a simple task; its characterization is even more difficult due to the increasingly common problem of adulteration with low-quality products [80] and, in some cases, with the addition of other cheap edible vegetable oils of uncertain origin [6]. Although the oil may be of similar quality, specific EVOOs from some countries are valued higher than those from other countries [54]. Due to the economic and political interests of the various countries involved in the EVOO market, there is growing interest in developing techniques to obtain more detailed information about the origin of this product [46, 94]. Scientific research is being conducted to identify analytical techniques to detect food fraud and guarantee the authenticity of EVOO and the presence in the market of products whose labels contain true information [18]. In recent years, more and more attention has been paid to analytical techniques that allow the evaluation of EVOO characteristics by studying its chemical-physical and organoleptic properties. Genetic methods are also used, allowing the study of the variety rather than the geographical origin of the product [72, 90]. In addition to the influence of variety, the influence of pedoclimatic conditions and agricultural practices is much better analyzed by studying the metabolic profiles of the product [30, 96, 97]. Olive trees of the same variety can be planted in several countries and the oil produced from them will be different, despite having the same genetics [20]. For this reason, notwithstanding the well established importance of genetic characterization, the evaluation of the geographic origin of EVOO is best studied using analytical techniques designed for metabolic rather than genomic profiling. Currently, two analytical techniques are used for metabolic profiling of EVOO: nuclear magnetic resonance (NMR) [30] and mass spectrometry (MS) [20, 39, 74]. These techniques are usually associated with chemometrics methods involving metabolomics with the application of statistical analysis to spectroscopic chemical data [44, 85, 102]. In the study of olive oil, liquid and gas chromatography are most commonly used to detect adulteration of this product, especially when the laboratory has GCMS and LCMS instruments [31, 37, 59]. Chromatographic methods can be used to determine the content of individual fatty acids including isomers, triacylglycerols, waxes, sterols, hydrocarbons, alcohols, tocopherols and volatile compounds [32]. The determination of these compounds can be used to assess the authenticity of individual vegetable oils as well as to distinguish vegetable oils from animal fats [64]. It has been established that fatty acid composition analysis can distinguish between sesame oil, soybean oil, rapeseed oil, coconut oil, erucic acid-reduced rapeseed oil, olive oil, and corn oil, among others [48, 58] and detect adulteration of one edible oil with another [23, 37, 58]. Chromatographic determination of fatty acid profile and triacylglycerols allows detection of as little as 5% addition of walnut oil, sunflower oil, soybean oil, sesame oil, rapeseed oil, reduced erucic acid peanut oil and mustard oil to olive oil [32]. Because of their relatively low molecular weights and sufficient volatility under high vacuum conditions, fatty acids can be studied by electron ionization or chemical ionization with direct introduction of the sample into an ion source [31]. A molecular ion is visible in the EI spectra of many of these acids, so that their molecular weight can be easily determined. Examination of fatty acids by GC or GCMS techniques is possible after they have been converted to more volatile compounds such as fatty acid methyl esters [31]. Fatty acids (simple and more complex molecules) can also be analyzed using electrospray ionization in the negative ion mode, which undergoes fragmentation to determine the structure of the carbon chain [31]. However, CID spectra recorded with triple quadrupole or Q-TOF spectrometers are not very characteristic compared to CID spectra recorded with magnetic analyzer spectrometers (fragmentation energy is much higher), which are currently less used [31]. Thus, fatty acids can be analyzed using the LCMS technique, either by recording full ESI spectra in negative ion mode or by tracking ions with masses corresponding to the anions of the acids under study. The MRM technique cannot be used in this case due to the practical lack of fragmentation. With respect to steroids, their volatility and thermal stability is usually sufficient to analyze them by the GCMS technique [31]. Analysis by the LCMS technique is possible but presents difficulties because these compounds are of low polarity and ionize poorly with electrospray. Hence, the mass spectrometer coupled to the LC instrument must operate in atmospheric pressure chemical ionization (APCI) or atmospheric pressure photoionization (APPI) mode, providing significantly higher sensitivity [31].

Another possibility to analyze the quality of olive oil is the use of fluorescence, which was already proposed in the early 20th century [95]. It was shown that extra virgin olive oils show a characteristic yellow fluorescence due to chlorophylls, while the fluorescence of refined oils is blue, due to changes in chlorophyll content during the refining process. This method was able to detect adulteration of extra virgin olive oil at a level of 5% relative to refined oil [46, 94]. Nowdays fluorescence spectroscopy is a well-known and widely used analytical tool in many fields, including food analysis [95]. Fluorescence is a type of photoluminescence, a process in which a molecule, excited to an electronically excited state by absorption of UV, VIS or NIR radiation, decays back to its ground state by emission of a photon [95]. Fluorescence is emission from an excited state in which the electron spin is equal to the spin in the ground state, and usually equal to zero. The most comprehensive characterization of

a multicomponent fluorescent system can be obtained by measuring the excitation-emission matrix, also known as the total luminescence spectrum or the fluorescence landscape [95]. Fluorescence spectra of olive oil contain information on fluorophores (tocopherols, phenolic compounds, and chlorophylls) that are important to the quality of the oil. The spectra can be used to monitor selected components or to determine the overall characteristics of the sample, which can serve as a spectral fingerprint [95]. The analytical potential of fluorescence is increased by using multivariate data analysis methods to analyze the spectra [95]. Fluorescence measurements conducted directly on olive oil samples with subsequent multivariate data analysis can be effectively used for qualitative and quantitative analysis as an important alternative to conventional chemical quality assessment methods. These methods can be used to distinguish oils and to quantify fluorescent components after appropriate calibration [95].

CONCLUSION

There is in-depth knowledge of the potential benefits of consuming EVOO and the compounds it contains on the health and prevention of serious diseases, including cancer, with the complexity of interactions between components of the human diet, individual heterogeneity and the complexity of the process of carcinogenesis making it difficult to draw firm conclusions from human studies. Caution appears to be necessary, being mindful of the effects of these compounds and their dependence on factors such as dose, exposure time, and cell type.

PODSUMOWANIE

Istnieje obszerna wiedza na temat potencjalnych korzyści płynących ze spożywania EVOO i zawartych w niej związków dla zdrowia i profilaktyki poważnych chorób, w tym nowotworów, przy czym złożoność interakcji pomiędzy składnikami diety człowieka, różnorodność osobnicza i złożoność procesu kancerogenezy utrudniają wyciągnięcie jednoznacznych wniosków z badań na ludziach. Wydaje się, że należy zachować ostrożność, pamiętając o skutkach działania tych związków i ich zależności od takich czynników, jak dawka, czas ekspozycji i typ komórki.

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Dr Jan BOGUSKI
Wyższa Szkoła Menedżerska w Warszawie, Polska
Warsaw Management University, Poland

PRZETWÓRNIA SPOŻYWCZA JAKO UCZESTNIK KLASTRA SPOŻYWCZEGO®

Food Processing as a Participant of the Food Cluster®

Słowa kluczowe: przetwórnia spożywcza, klaster spożywczy, rolnictwo, przemysł, technologia, Polska.

Celem publikacji jest przedstawienie roli i znaczenia przetwórni spożywczej w ramach klastrów spożywczych, które stanowią ważne narzędzie aktywizacji obszarów rolniczych zaniedbanych pod względem gospodarczym. Zakładane w różnych miastach, regionach i krajach klastry tworzą sieci współpracy, przyczyniając się do ich rozwoju. Dzięki ich obecności możliwe staje się przetwarzanie na miejscu surowców i materiałów oraz następnie oferowanie gotowych produktów odbiorcom - co skraca drogę towaru od wytwórcy do klienta.

Key words: food processing plant, food cluster, agriculture, industry, technology, Poland.

The aim of the publication is to present the role and importance of food processing plants within food clusters, which are an important tool for activating agricultural economically neglected areas. Clusters established in various cities, regions and countries create cooperation networks, contributing to their development. Thanks to their presence, it becomes possible to process raw materials and materials on site and then offer finished products to recipients, which shortens the path of goods from the manufacturer to the customer.

WPROWADZENIE

Polska posiada sektor spożywczy, który zalicza się do dynamicznie rozwijających się segmentów gospodarki narodowej [14]. Jest to efekt bogatej tradycji rolnej. Przez stulecia Polska była zaliczana do państw rolniczych. W wyniku industrializacji po drugiej wojnie światowej stała się krajem przemysłowo-rolniczym.

Współczesne procesy i zjawiska, które są efektem globalizacji sprawiają, że narasta potrzeba konsolidacji działań biznesu w różnych branżach – także w rolnictwie. Podyktowane jest to wzrostem ekspansji zagranicznych korporacji na krajowych i lokalnych rynkach. Proces ten dotyka również przemysłu spożywczego. Polska ma możliwości, aby wspomagać rodzimy przemysł przetwórstwa spożywczego.

Ważne jest aby wśród polskich menedżerów i właścicieli przetwórni narastało myślenie ukierunkowane na rzecz przyspieszenia tempa tworzenia skupisk biznesowych na wzór klastrów. Tego typu struktury pozwalają tworzyć wspólne kanały zaopatrzenia i reklamy oraz kreują silną grupę przetargową wobec sieci handlowych, zdolną osiągać pożądane wartości, które są poza zasięgiem pojedynczych firm.

Wspomniane konfiguracje są złożone z wielu podmiotów spożywczych oraz wspierających ich instytucji sfery okołobiznesowej. Pozwalają wytworzyć synergię w ramach współdziałających firm i przynoszą wymierne korzyści uczestnikom.

Wspomaganie rozwoju przetwórstwa spożywczego leży w interesie polskiego rolnictwa, które eksploatuje środowisko przyrodnicze. Polska posiada znaczne obszary o wybitnych walorach ekologicznych. Szczególnie ważne jest wspieranie przetwórni ekologicznych w gospodarstwach rolnych. Wymaga to jednak aktywizacji zawodowej wśród ludzi młodych. Obecność przetwórni przydomowych w ramach gospodarstw agroturystycznych nie wypełnia możliwości w tym zakresie. Potrzebne są przetwórnie ekologiczne o większej skali działania aniżeli dotychczas ma to miejsce.

PODMIOTY RYNKU SPOŻYWCZEGO

W przeszłości w każdym niemal folwarku istniały przetwórnie spożywcze. Także wiele gospodarstw rolnych wytwarzało podstawowe produkty i oferowało na rynku. Ten model sprawiał, że gospodarstwo było jednocześnie przetwórcą surowców, które uprawiało i ich sprzedawcą w miastach i miasteczkach.

W okresie międzywojennym i powojennym w miasteczkach funkcjonowały różne przetwórnie spożywcze, np.: wytwórnie wód gazowanych, gorzelnie, mleczarnie, masarnie, piekarnie, cukiernie. W latach późniejszych spółdzielcze firmy upadły lub zostały rozwiązane. Z dawnej świetności pozostało niewiele piekarni spółdzielczych.

Współczesny rynek spożywczy zajmuje w kraju silną pozycję. Znajdują się na nim krajowe i zagraniczne podmioty. Po 1989 roku pojawiły się w polskiej branży spożywczej zagraniczne firmy Danone, Heinz, Unilever, Mondelez oraz Nestle. Warto zwrócić uwagę, że obok zagranicznych marek zaczęły wyrastać rodzime firmy. W branży przetwórstwa mleczarskiego będzie to Mlekovita i Mlekpol. Wśród podmiotów wytwarzających soki, makarony i płatki Maspex oraz Hortex, który wytwarza soki. Z naszego kraju wywodzą się takie

Corresponding author – Adres do korespondencji: Jan Boguski, Wyższa Szkoła Menedżerska w Warszawie, ul. Kawęczyńska 36, 03-772 Warszawa, Polska, e-mail: jan.boguski@mac.edu.pl

marki jak Tymbark (soki), Wedel (produkty z czekolady), Pudliszki (sosy, keczupy), Winiary (przyprawy, dania gotowe) [14].

Funkcjonujące na polskim rynku przetwórnie spożywcze posiadają kluczowe atrybuty, którymi są: ludzie wyposażeni w odpowiednią wiedzę - posiadający odpowiednie know-how, receptury oraz dostęp do maszyn, urządzeń i surowców.

W pogoni za zyskiem współczesne sieci handlowe instalują w swoich sklepach urządzenia do wypieku pieczywa, bułek i innych produktów. Wspomniane działania uruchomiła znana w kraju sieć handlowa Biedronka. Pracownicy obsługują maszyny do wypieku pieczywa, które oferują klientom każdego dnia[2].

Ważne miejsce wśród produktów oferowanych na rynku spożywczym zajmuje produkt ekologiczny. Pochodzi ze środowiska, które jest przyjazne dla zdrowia człowieka. Nie zawiera konserwantów, barwników i słodzików. Uważa się, że wieloskładnikowy produkt przetworzony musi posiadać w swoim składzie co najmniej 95 procent składników pochodzących z upraw ekologicznych, oraz pozostałych 5 procent nieekologicznych pochodzenia rolniczego[16].

FENOMEN KLASTRA

Koncepcja klastrów zwanych po polsku gronami wywodzi się ze średniowiecznych skupisk rzemieślniczych. Wzdłuż dróg, które rozchodziły się od rynku miejskiego lub osiedlowego, zakładano warsztaty rzemieślnicze. Pracowali w nich rzemieślnicy określonej profesji. Oferowali konkretne usługi miejscowej ludności[4].

Kontynuację ośrodków rzemieślniczych stanowiły okręgi przemysłowe w XIX wieku. W pewnych miastach występowały skupiska firm, które miały wpływ na ich rozwój. Opisał je A.Marshall[8].

Współczesna koncepcja klastrów jest dziełem M. Portera. Postrzega je jako skupiska biznesowe na pewnym obszarze. W ich ramach mamy różne instytucje i organizacje. Działają w tych samych albo podobnych branżach. Ma miejsce współdziałanie oraz konkurencja. Należą do nich przedsiębiorstwa, stowarzyszenia, fundacje, uczelnie, banki itp.[12].

Analiza dostępnych źródeł ukazuje, że w regionie mogą funkcjonować różne klastry. Można tu wskazać na znajdującą się w Stanach Zjednoczonych Kalifornię. Posiada obszary rolnicze, na których powstał klaster winny oraz klaster informatyczny. Ten ostatni pojawił się w Santa Clara County. Rolnicze obszary zatem stanowią doskonałą bazę dla tworzenia klastrów spożywczych, co potwierdza Kalifornia[1].

Klasyczne grono przedstawił M. Porter. Opisał je na przykładzie sektora winnego w Kalifornii. Posiada ono strukturę złożoną z 3 segmentów. W skład pierwszego wchodzą winnice. Uprawia się w nich winorośl, z której uzyskuje się winogrona. Zalicza się do tego technologie nawadniania, pielęgnacji i zbioru. W przypadku drugiego mamy instytucje i organizacje, które zajmują się produkcją i wytwarzaniem maszyn, urządzeń a także butelek, beczek, etykiet, korków. Jeśli chodzi o trzeci, to w jego skład wchodzą instytucje edukacyjne w postaci uczelni, agencje rządowe, instytucje badawczo-rozwojowe[12].

Klastry odznaczają się swoją specyfiką. Siłami klastrów są podmioty biznesowe a zarządzanie w nich odbywa się poprzez realizowane przedsięwzięcia co stanowi novum w porównaniu do organizacji i instytucji, które mają swoje organy, którymi zarządzają [18].

Skupiska zwane klastrami są zakładane przez ludzi przedsiębiorczych oraz organizacje, w których jest realizowane przedsiębiorcze zarządzanie. Niezbędni są animatorzy biznesu na danym terenie. Tworzą się oddolnie inicjatywy biznesowe, w wyniku których powstają przedsiębiorstwa.

Funkcjonujące na danym terenie klastry zrzeszają firmy, które działają niezależnie obok siebie, rywalizując i kooperując pomiędzy sobą. W ten sposób uzupełniają segmenty rynkowe i nisze.

Klastry tworzą pewne skupisko przemysłowe w mieście lub regionie. Zachodzi tu efekt synergii. W ramach wspomnianego skupiska „rozlewa się wiedza". Dokonuje się to poprzez zjawisko podpatrywania rywala, nabywania jego dóbr i analizowania ich pod kątem jakości. Pracujący w nich ludzie mogą zmieniać pracodawcę, przenosząc w ten sposób know-how.

KATALIZATORY LOKALNEGO ROZWOJU PRZETWÓRSTWA SPOŻYWCZEGO

Kluczowe znaczenie dla rynku ma organizacja biznesowa. Jej obecność przyczynia się do redukcji kosztów transakcyjnych. Dzieje się tak, ponieważ wszystkie operacje i czynności nie wykonują odrębnie różni ludzie, ale firmy jako podmiot gospodarczy.

Czynione od lat obserwacje działalności klastrów pozwalają na wysunięcie wniosków, że sprzyjają kreowaniu odpowiedniego klimatu biznesowego na danym terenie. Dzięki temu przedsiębiorcze organizacje lub osoby mogą tu inwestować. Tego typu instytucje pobudzają tworzenie oraz rozwój miejscowych przetwórni spożywczych[7].

Analiza skupisk przemysłowych wskazuje, że w środowisku o dużym zagęszczeniu ośrodków miejskich jest możliwe ustanowienie środowiska, które będzie sprzyjało kreowaniu firm odpryskowych (spin-off). Odnosi się to do przedsiębiorstw przemysłowych, w wyniku których powstaje tzw. „płodna krzyżówka"[1]. Tego typu zjawisko możliwe jest w środowisku rolniczym. Zagęszczenie firm sprzyja pojawianiu się osób, które będą chciały prowadzić biznes na własny rozrachunek – również w przetwórstwie spożywczym.

Działające w klastrach firmy wyróżniają się na tle innych. Mają dostęp do nowych rozwiązań technologicznych. Pod tym względem górują jeśli chodzi o poziom innowacyjny nad pozostałymi podmiotami gospodarczymi, które do nich nie należą[11].

Klastry stają się obszarem, w którym mogą inwestować firmy krajowe i zagraniczne. Szczególne znaczenie ma obecność bezpośrednich inwestycji zagranicznych. Zachęcają one do przyjazdu specjalistów w danej branży[15].

Operujące w klastrach firmy mają większe pole manewru jeśli chodzi o działalność innowacyjną. Są w stanie zarejestrować więcej patentów i znaków towarowych, a do tego wyeksportować towarów od firm, które nie należą do nich[11].

Skupiska przemysłowe ożywiają gospodarkę lokalną i regionalną. Obecność klastrów prowadzi do redukcji asymetrii informacyjnej wśród organizacji i instytucji biznesowych[15].

UNIKALNE TECHNOLOGIE PRZETWÓRSTWA SPOŻYWCZEGO

Funkcjonujące z dawien dawna przetwórnie spożywcze są miejscem, w którym zachodzi zjawisko doskonalenia oraz przekazywania z pokolenia na pokolenie wiedzy unikalnej i cichej oraz umiejętności w zakresie wytwarzania produktów. Jest to bardzo ważne, ponieważ tego typu struktury bazują na dwóch zasadniczych filarach: lojalności i zaufaniu, które pozwalają zacieśniać relacje między sobą z pożytkiem dla wszystkich członków klastra.

Zatrudnieni w przetwórniach pracownicy kształcą się pod okiem mistrzów oraz sami rozwijają swoje umiejętności. Szczególnie ważne są receptury, na bazie których wytwarza się smaczne i zdrowe produkty spożywcze.

Wiele czynności fizycznych wykonywanych przez ludzi ma charakter unikalny. Przychodzi mi na myśl przykład wypieków pieczywa w Osaka International Hotel w Japonii. Miejscowi goście zachwycali się jego smakiem. Pewnego dnia Ikuko Tanaka postanowiła przyjrzeć się z bliska arkanom pysznego wypieku. Z kilkoma osobami terminowała u przełożonego piekarzy. Podczas obserwowania pracy piekarza zauważyła, że jego sekret tkwił w ruchach rąk. Brał do ręki ciasto a następnie rozciągał je i jednocześnie skręcał. Dzięki temu nadawał mu nowe właściwości [9].

Osoby pragnące zawodowo zająć się przetwórstwem mogą skorzystać ze wsparcia doradztwa rolniczego. Wspomniane Ośrodki Doradztwa Rolniczego mają na swoim wyposażeniu niezbędny do szkolenia sprzęt oraz wykwalifikowanych specjalistów. Są gotowi ich szkolić w zakresie przetwórstwa spożywczego. W Podlaskim Ośrodku Doradztwa Rolniczego w Szepietowie znajduje się typowa przetwórnia. Składają się na nią 4 linie technologiczne. Służą do przerobu: mleka, mięsa, owoców i warzyw na susz oraz owoców i warzyw na soki. Osoby pragnące prowadzić przetwórnię mogą poznać technologię przerobu produktów. Wspomniany ośrodek udostępnia własne linie technologiczne. Czyni to na zasadzie inkubatorów przedsiębiorczości[13].

KLASTRY SPOŻYWCZE W POLSCE

Klastry wykorzystują efekt lokalizacji. Kluczowa jest tu bliskość geograficzna[3]. Uwagę przykuwa Klaster „Dolina Ekologicznej Żywności" w województwie lubelskim. W roli koordynatora występuje Instytut Uprawy Nawożenia i Gleboznawstwa PIB w Puławach. Jego uczestnicy prowadzą produkcję produktów ekologicznych. Stawiają oni na innowacyjne rozwiązania i promocję. Wdrażając je są w stanie podnosić jakość surowców, używanych w produkcji spożywczej. Prowadzą szkolenia, w których biorą udział uczestnicy klastra[6].

Na uwagę zasługuje skupisko spożywcze określane jako „Klaster spożywczy Południowej Wielkopolski". Należące do tej sieci podmioty gospodarcze zajmują się produkcją słodyczy, napojów, przetwórstwem owoców i warzyw suszonych oraz serów. Swój akces do klastra zgłosiła Fabryka Maszyn Spożywczych „Spomasz", która specjalizuje się w budowaniu maszyn i urządzeń wykorzystywanych w przetwórstwie spożywczym. Ponadto uczestnikiem jest Uniwersytet przyrodniczy w Poznaniu, Regionalna Izba Gospodarcza w Kaliszu a także Pleszewska Izba Gospodarcza [6].

W formule klastra działa Stowarzyszenie Klaster Spożywczy „Naturalnie z Podlasia". Za cel stawia kreowanie odpowiedniego wizerunku, promocję, podniesienie innowacyjności oraz konkurencyjności produktów i usług na rynkach. Służy wzmacnianiu pozycji przedsiębiorstw na rynku krajowym i zagranicznym. Obecność wspomnianego klastra pomaga wdrażać rozwiązania o charakterze innowacyjnym. Tego typu struktura reprezentuje interesy firm wobec władz. Pomaga też w dostępie do ośrodków badawczo-rozwojowych i wsparcia know-how [5].

Wśród skupisk spożywczych należy również wyróżnić Klaster Podkarpackie Smaki założony w 2013 roku. Zalicza się do niego wytwórców produktów regionalnych, tradycyjnych a także ekologicznych. Wspiera on podmioty w pozyskiwaniu środków oraz prowadzi szkolenia. Zajmuje się promocją spożywczych produktów regionalnych, tradycyjnych i ekologicznych. Ma tu miejsce współpraca i wymiana [10].

Nie wszystkie klastry mogą poszczycić się sukcesem. Próby czasu nie wytrzymał Polski Klaster Mięsny. Pojawił się na rynku polskim w 2010 roku. Założono go z inicjatywy sześciu podmiotów. Dwa podmioty opuściły go po pewnym czasie. Miał wspierać uczestników w rywalizacji z dużymi podmiotami na rynku. Po roku pięć firm powołało do istnienia nową spółkę. Otrzymała nazwę Sufler. Mimo dobrych chęci wspomniana spółka uległa likwidacji w 2019 roku [17].

PODSUMOWANIE

Działające w naszym kraju klastry spożywcze odgrywają ważną rolę w przestrzeni lokalnej i regionalnej:

- aktywizują miejscowe środowiska wiejskie i zapewniają im podstawowy lub dodatkowy dochód;
- przyczyniają się do rozwoju innowacyjności i konkurencyjności w danym mieście i regionie;
- dzięki nim przetwarzane są surowce pochodzące z rolnictwa, generowane produkty, które oferowane są na rynku lokalnym i krajowym, a nawet zagranicznym;
- zlokalizowane w miastach, miasteczkach i po wsiach zakłady przetwórstwa spożywczego dają miejsca pracy miejscowej ludności, generują zyski w postaci podatków i wynagrodzeń;
- stwarzają lokalne zapotrzebowanie na surowce u rolników;
- sprzyjają dalszej konsolidacji polskich przetwórni w ramach klastrów;
- wyzwalają synergię oraz zapewniają dostęp do informacji, wiedzy i danych dotyczących rynku;
- jako spożywcze skupiska biznesowe klastry ustanawiają struktury sieciowe, w których poszczególni uczestnicy zachowują autonomię działania;
- mogą wzajemnie wspierać się, udzielać porad, wymieniać informacjami;
- wzmacniają współdziałanie poszczególnych podmiotów biznesowych oraz instytucji sfery okołobiznesowej;
- zapewniają operującym na rynkach przetwórniom dostęp do informacji bieżących o cenach surowców, produktów, materiałów, maszyn, urządzeń oraz danych odnośnie pozycji konkurencji w danym segmencie rynkowym lub niszy.

Środowiska, w których ma miejsce koncentracja biznesu sprzyjają wzajemnemu uczeniu się, dzieleniu wiedzą ukrytą. Możliwa staje się realizacja wspólnych projektów inwestycyjnych. W wyniku lojalności i zaufania tworzy się sieć współpracy między podmiotami.

CONCLUSIONS

The food clusters operating in our country play an important role in the local and regional space:

- activate local rural environments and provide them with a basic or additional income;
- their presence contributes to the development of innovation and competitiveness in a given city and region;
- thanks to them, raw materials from agriculture are processed, and products are generated that are offered on the local and domestic, and even foreign markets;
- processing plants located in cities, towns and villages provide jobs for the local population, generate profits in the form of taxes and wages;
- create local demand for raw materials by farmers;
- they are conducive to further consolidation of Polish processing plants within clusters;
- their presence combines the potential of companies, creates synergy and provides access to information, knowledge and data on the market;
- Seen as food clusters of business clusters establish network structures in which individual participants retain operational autonomy;
- can support each other, give advice, exchange information;
- cooperation between individual business entities and institutions from the business-related sphere takes place;
- Processing plants operating on the markets must have access to current information on the prices of raw materials, products, materials, machinery, equipment and data on the competition's position in a given market segment or niche.

The environments in which business is concentrated are conducive to mutual learning and the sharing of tacit knowledge. It becomes possible to implement joint investment projects. As a result of loyalty and trust, a network of cooperation between entities is created.

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Dr hab. Marek GRUCHELSKI Prof. WSM
Warsaw Management University, Poland
Wyższa Szkoła Menedżerska w Warszawie, Polska
Inż. Marcin GRUCHELSKI

IMPACT OF THE WAR IN THE UKRAINE ON THE FOOD SECTOR IN POLAND – PRELIMINARY FORECASTS®

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Key words: food processing, agri-food products, sustainable development, agricultural policy, management, SARS-CoV-2 pandemic, Ukraine.

The military aggression of the Russian Federation against Ukraine has significantly and drastically changed the political and economic situation in Ukraine. The outbreak of war and the justified imposition of economic sanctions on Russia by the European Union and other Western countries also has a significant impact on many sectors of the global economy, including the agri-food industry. The ongoing war in Ukraine is associated with a number of negative and long-term macroeconomic consequences for Poland and other countries, both in the area of trade and maintenance of the supply chain, as well as security of supply of energy resources.

Following the SARS-CoV-2 coronavirus pandemic, this is another economic crisis that poses a challenge for the entire agri-food sector. In the medium and long term, much depends on the timing of the end of hostilities in Ukraine. Therefore, due to dynamic changes in the political and economic situation, at present it is a priority to maintain constant and full monitoring of changes in both the Polish in the Polish economy, as well as in the world economy.

Słowa kluczowe: przetwórstwo spożywcze, produkty rolno-żywnościowe, rozwój zrównoważony, zarządzanie, pandemia SARS-CoV-2, Ukraina.

Zbrojna agresja Federacji Rosyjskiej na Ukrainę znacząco i drastycznie zmieniła sytuację polityczno-gospodarczą w Ukrainie. Wybuch wojny oraz uzasadnione nałożenie przez Unię Europejską oraz inne kraje zachodnie sankcji gospodarczych na Rosję ma również znaczący wpływ na wiele gałęzi gospodarki światowej, w tym branży rolno-spożywczej. Trwająca wojna w Ukrainie wiąże się z szeregiem negatywnych i długookresowych konsekwencji makroekonomicznych dla Polski i innych krajów, zarówno w obszarze wymiany handlowej i utrzymania łańcucha dostaw, jak też bezpieczeństwa dostaw surowców energetycznych.

Jest to kolejny, po pandemii koronawirusa SARS-CoV-2, kryzys gospodarczy, który stanowi wyzwanie dla całego sektora rolno-spożywczego. W perspektywie średnio i długookresowej wiele zależy od terminu zakończenia prowadzonych na terenie Ukrainy działań wojennych. Ze względu na dynamiczne zmiany w sytuacji polityczno-gospodarczej, obecnie kwestią priorytetową jest utrzymanie stałego i pełnego monitoringu zmian zarówno w gospodarce polskiej, jak i światowej.

INTRODUCTION

The crisis caused by the SARS-CoV-2 pandemic had a negative impact on all sectors of the economy, including the food processing sector. The majority of forecasts indicated a disadvantageous situation for Poland as they assumed recession on the main Polish export markets, mainly export of agricultural and food products [5, 7].

Although the COVID-19 crisis did not cause particularly severe damage to the EU food industry, and production volume declines volumes in any of the EU countries did not reach a double-digit level (which was the norm in in the case of many other processing sectors), the new crisis caused by the military aggression of the Russian Federation in Ukraine may result in a number of negative and long-term macroeconomic consequences for Poland and the entire European Union [5, 7]. At the same time, the impact of the war in Ukraine is already visible both in the area of trade and maintenance of the supply chain, as well as the security of supply of energy resources.

The ongoing military conflict in Ukraine is also associated with other global issues such as the immigration and food crisis and the impact of war on the sustainable development agenda [3, 9, 11].

Currently, due to dynamic changes in the economy and ongoing structural changes in the food industry, it is a priority to maintain constant and full monitoring of changes in both the Polish and global economies.

Corresponding author – Adres do korespondencji: Marek Gruchelski, Wyższa Szkoła Menedżerska w Warszawie, ul. Kawęczyńska 36, 03-772 Warszawa, Polska, e-mail: gruchelscy@tlen.pl

IMPORTS AND EXPORTS DURING THE WAR IN UKRAINE

Due to the Russian invasion, Ukrainian farmers estimate that yields will be significantly lower than in 2021. Experts predict that spring sowings in Ukraine may drop from 7.7 million hectares to 4.7 million hectares (which is a 39% decrease).

In addition, warfare has led to the destruction or impossibility of harvesting crops from about 2 million hectares of winter wheat, barley and rye, and harvesting of winter-sown cereals will probably be possible in an area limited to about 5.5 million hectares. The sown areas of sunflower, rapeseed and maize will also decrease. This will have a significant and negative impact on the markets for the production of vegetable fats and derivatives [16, 17].

Products imported to Poland from Ukraine in large quantities are sunflower oil – almost 170 thousand tons, i.e. almost 9% of all imports. Russia and Ukraine are the main producers of sunflower oil, producing about 60% of the total world production of this product and exporting about 75% of their production [17].

The final recipients of Ukrainian raw materials, mainly cereals, were not only European countries, but also Egypt and other African countries. Moreover, exports from Russia and Ukraine are a key part of the food supply structure in unstable developing countries – especially in the Middle East [16, 17].

According to experts, the war will affect food prices through two main channels. Firstly, the war could result in a strong and sustained increase in prices of cereals and oilseeds, of which both Ukraine and Russia are major exporters, including wheat (8.3% and 19.3% share in world exports), corn (13.2% and 2.2%), barley (11.8% and 17.6%) and rapeseed (13.4% and 3.8%). Higher prices for cereals and oilseeds will lead to higher feed prices and consequently higher prices of animal products (meat, dairy products and eggs). Secondly, the war in Ukraine, through increased gas prices, may lead to further increases in fertilizer prices. Higher fertilizer prices will also support an increase in the prices of cereals and oilseeds [12, 14, 15].

As early as March 2022, hostilities and economic sanctions led to disruptions in supply chains and drastic price increases. Within two weeks of the start of the conflict, grain reached record prices on Western exchanges. U.S. grain futures increased about 50% between February 25 and March 7, according to Bloomberg data. That means, that Americans will pay about $11 per bushel (about 35 liters) of grain, more than 72% more than a year ago. The International Monetary Fund (IMF) estimated a 60% increase in grain prices between September 2021 and March 22, 2022. In addition, food has become the most expensive since 1961, according to the IMF. As a result of inflation and pandemic disruptions in supply chains, grain prices were nearly double in December 2021 compared to 2019 [10].

It should be noted that Russia is the world's largest supplier of fertilizers and the second largest exporter of potash, a key component of fertilizers. The established sanctions oblige the European Union to replace the share of Russia and Belarus, respectively 60% for potash and 35% for phosphates [12].

In 2021, Russia was the seventh largest recipient of goods exported from Poland and ranked third in terms of the value of goods imported into Poland. The shares of Poland's trade with Russia in total goods exports and imports are significant, at 2.8% and 5.8% (EUR 8.0 billion and EUR 16.7 billion), respectively. The trade connections of Poland and Russia are also greater than those of Poland and Ukraine, where the shares were 2.2% and 1.1% (EUR 5.2 billion and EUR 2.5 billion), respectively. According to experts, the complete expiration of Poland's goods exports to Russia and Ukraine would lower Poland's GDP dynamics by 2.5 percentage points in the first year after the shock [14].

SUPPLY CHAIN SECURITY

The Russian-Ukrainian conflict is causing a significant increase in tension in international transport. The ongoing war has caused a complete shutdown of shipments from Ukrainian and Russian ports in the Black Sea basin and has significantly restricted the movement of other vessels in the Black Sea. Russian ships have been detained in European ports and subjected to searches. The conflict has also resulted in the re-routing of many ships. Currently, major ports in Northern Europe are heavily congested and there are significant delays in deliveries. It is estimated that the impediments cover up to 47% of global container transport (April 2022). It follows that all industries (including the agri-food sector) will face difficulties in terms of energy resources and international transport in the coming months [17].

Despite the fact that, in comparison with other sectors of industrial processing, food production is characterized by shorter supply chains due to the fact that most links are located in the country, problems in the international transport of goods and some raw materials can negatively affect the entire production process [1, 2].

It would be necessary to pay special attention to solutions that allow to diversify the sources of supply and reduce the impact of existing transport restrictions. One of the complex solutions that can stabilize the food processing process is a Short Food Supply Chain. It is an organized system of production, processing, distribution and sale of food, which consists in linking food producers from a specific region. It is a form of integrated production, distribution and sales that minimizes the number of middlemen between the buyer and the producer [4, 7]. Additionally, food produced and sold in short supply chains, due to its unique characteristics, can become a showcase of the region from which it comes [7].

A method that could help to partially reduce the import of raw materials to agri-food processing plants is market reorganization. One of the most effective solutions could be to organize, on the model of South Korean chaebols, a multi-industry conglomerate. The basic principle of the conglomerate should be to include the largest possible number of producers and customers, but these do not have to be entities belonging to the with the conglomerate through civil-law contracts. An important argument for the use of multibranch conglomerates in international trade is the ability to effectively purchase technology used to produce import-substituting products. A strong economic entity, such as a conglomerate, can obtain much more favorable conditions in negotiations for

the processing of agricultural products [6]. Moreover, the implementation of such a solution is fully compatible with the Short Food Supply Chain system.

SECURITY OF SUPPLY OF ENERGY RESOURCES

A significant threat for Poland and Europe coming from the Russian-Ukrainian conflict is significant dependence of the economy on supplies of energy resources from Russia (gas, oil and coal). Cutting off Poland from Russian coal, gas and oil will not only be a logistic challenge for Poland, but also a financial one. Poland is best prepared in the area of gas supplies. Due to the expiration of the Yamal contract at the end of 2022, Poland planned to stop importing gas from the East and replace these supplies with importing gas from the Norwegian Continental Shelf [17].

It should be remembered that basing a significant part of electricity and heat production on imported natural gas does not meet the criteria of guaranteeing both the timely supply of electricity and heat as well as maintaining prices for companies and households at an acceptable level. The reason is the excessive burden of import costs both on business entities and the balance of payments of the state and the lack of price stability [8].

Diversification of supplies of imported natural gas should eliminate the problem of interruption of natural gas supplies by Russia for political reasons after 2022. At the same time, it will not eliminate the risk of supply shortage caused by a sharp increase in gas prices on the international market.

According to the Central Statistical Office, coal imports from Russia have been steadily decreasing over the past three years, but 75% of total domestic coal imports to Poland are still imported from Russia. Russian coal is used mainly by households and small heating plants, which use this raw material for heating purposes [17].

The solution to the above problem in the medium and long term may be the use of hybrid solutions consisting in a combination of energy production based on coal technologies and RES technologies in the following proportions: 10% coal technologies and 90% RES, while assuming that due to the possibility of climate problems the final proportions of energy production from coal and RES may be respectively: 20% and 80%.

Depending on the adopted variant, the reduction in the use of coal technologies would be from 80% to 90%, which as a result:

- would allow to significantly reduce the impact of price differences between imported and domestic coal on the economics of economic entities;
- significantly reduce CO_2 emissions;
- would mean a proportionally high degree of cost reduction costs on account of climate fees and CO_2 utilization.

It should be noted that the implementation of the above concept in economic practice for the energy sector requires the development of an effective, coherent and innovative policy that takes into account the use of the potential of both the public and the private sector. The implementation of these assumptions may take different forms: from single agreements between business entities, through organized cooperation programs, or consortia operating on the principles of multi-sector conglomerates, to the possibility of creating a public-private energy holding [8].

The raw material situation in the oil market is the least favorable. At present, 66% of demand for oil in Poland is covered by the import from Russia. This problem concerns not only Poland but the whole European Union [17].

Oil is the main export product of Russia. Exported oil goes mainly to European countries – the largest importers of Russian oil in 2021 were the Netherlands (16% of the value of Russian exports) and Germany (8%). The total value of oil exports from Russia in 2021 was over US$100 billion. Profits from oil sales to the countries of the Union alone account for about 10% of the central budget of the Russian Federation. Reducing this source of funding seems necessary to inhibit further Russian expansion [13].

Diversification of crude oil supply from Russia requires diversification of its sources. Experts of the Polish Economic Institute identified three potential sources of diversification of oil supplies to the European Union [13]:

1. An agreement with Iran on reducing its nuclear program.
   Iran is currently producing 2.5 million barrels a day, of which only 0.7–1 million is destined for export. It is estimated that it would be possible to increase production by nearly 1.3 million barrels per day by the end of the year. Russia's daily production is over 10 million barrels per day, of which about 2.3 million barrels were exported to the EU in 2020. Accordingly, increasing Iran's exports would replace almost 60% of Russian oil supplies to the EU.
2. Greater use of imports from Norway.
   Oil and gas supplies accounted for 40% of the country's total exports in 2020. The largest importer of oil from Norway is China (15%), to which 0.24 million barrels of oil per day were delivered. It is highly likely that as a result of the current war in Ukraine, China will increase its imports of this crude from Russia. This will create an opportunity for the EU to make better use of the existing infrastructure connecting the old continent with Norway and will make it possible to redirect oil exports to the EU.
3. Increasing supplies from the U.S. and Kazakhstan.
   Analysts at the European Environment Agency forecast that U.S. oil production will increase from 9 to 10.4 million barrels of oil per day in 2022 and 2023. In addition, Kazakhstan plans to increase oil production.

Thus, with the implementation of the above solutions, there is a possibility to completely move away from oil supplies from Russia.

SUMMARY

The crisis caused by the SARS-CoV-2 pandemic has negatively affected all sectors of the economy, including the food processing sector. Although the crisis did not cause particularly severe damage to the EU food industry, and the decline in production volumes in any of the EU countries

did not reach a double-digit level, the new crisis caused by the military aggression of the Russian Federation against Ukraine may result in a number of negative and long-term macroeconomic consequences for Poland and the entire European Union. The impact of the war in Ukraine is already visible both in the area of trade and maintaining the supply chain, as well as in the security of supply of energy resources.

It is predicted that spring sowings in Ukraine may fall from 7.7 million ha to 4.7 million ha (which is a 39% drop). According to experts, the war will affect food prices through two main channels. Firstly, the effect of the war may be a strong and sustained increase in the prices of cereals and oilseeds, of which both Ukraine and Russia are major exporters, which in turn will affect the prices of feed, and consequently animal products. Secondly, the war in Ukraine, through rising gas prices, may lead to further increases in fertilizer prices, which will also support grain and oilseed crop prices. Additionally, Russia is the world's largest supplier of fertilizers and the second largest exporter of potash, and sanctions adopted oblige the European Union to replace the share of Russia and Belarus, 60% for potash and 35% for phosphate, respectively.

As early as March 2022, hostilities and economic sanctions led to disruptions in supply chains and drastic price increases. Within two weeks of the start of the conflict, grain reached a record price on Western exchanges – U.S. grain futures increased about 50%. According to the International Monetary Fund, food has risen the most since 1961, and due to inflation and pandemic disruptions in supply chains, grain prices were nearly double in December 2021 compared to 2019.

It should be noted that in 2021, Russia was the seventh largest customer of Polish exports and ranked third in terms of the value of goods imported into Poland. It is estimated that a complete expiration of Polish goods exports to Russia and Ukraine would reduce Poland's GDP dynamics by 2.5 percentage points in the first year after the shock.

The Russian-Ukrainian conflict caused a significant increase in tension in international transport and a complete shutdown of shipments from Ukrainian and Russian ports in the Black Sea basin. In addition, major ports in Northern Europe are heavily congested and there are significant delays in deliveries. The impediments are estimated to cover up to 47% of global container shipping (April 2022), resulting in impeded access to energy resources and international transportation, and disrupted supply chains for all industries.

Although food production is characterized by shorter supply chains compared to other industrial processing sectors, problems in the international transport of goods and certain raw materials can negatively affect the overall production process. In this respect, special attention should be given to solutions that allow diversification of supply sources and reduce the impact of transport constraints. One of the complex solutions that can stabilize the food processing process is a Short Food Supply Chain. It is an organized system of production, processing, distribution and sale of food, which consists in linking food producers from a specific region.

A method that could help reduce the import of raw materials to agri-food processing plants and is fully compatible with the Short Food Supply Chain system is market reorganization. A solution that could be implemented, following the example of the South Korean chaebols, is the creation of a multi-industry conglomerate that would include as many producers and buyers as possible. An important argument in favor of the use of multi-industry conglomerates in international trade is the ability to effectively purchase technologies used to produce import-substituting products. Moreover, a strong business entity, such as a conglomerate, may obtain much more favorable conditions in negotiations for the processing of agricultural products.A significant threat to Poland and Europe stemming from the Russian-Ukrainian conflict is also a significant dependence of the economy on supplies of energy resources from Russia. It should be remembered that basing a significant part of the production of electricity and heat on the use of imported natural gas does not meet the criteria of guaranteeing both the timely supplies of electricity and heat as well as maintaining prices for companies and households at an acceptable level. Diversification of supplies of imported natural gas should eliminate the problem of interruption of natural gas supplies by the Russian side for political reasons after 2022. In connection with the expiry of the Yamal contract at the end of 2022, Poland planned to discontinue gas imports from the East and replace these supplies with gas imports from the Norwegian Continental Shelf.

Although the import of coal from Russia has been steadily decreasing over the last 3 years, 75% of the total domestic coal imports to Poland are still coming from Russia. Russian coal is used mainly by households and small heating plants, which use this raw material for heating purposes.

In the medium and long term, a hybrid solution may be implemented, combining energy production based on coal technologies and RES in the following proportions: 10% coal technologies and 90% RES, while assuming that due to the possibility of climate problems the final proportions of energy production from coal and RES may be respectively: 20% and 80%.

Depending on the adopted variant, reduction in the use of coal technologies would be from 80% to 90%, which would make it possible to significantly reduce the impact of price differences between imported and domestic coal on the economics of economic entities, as well as to significantly reduce CO_2 emissions and would mean a proportionally high level of reduction of costs on account of climate fees and CO_2 utilization.

It should be noted that the implementation of the above concept for the energy sector in economic practice requires the development of an effective, coherent and innovative policy that takes into account the use of the potential of both the public and private sector. At the same time, the implementation of these assumptions may take different forms: from individual contracts between business entities, through organized cooperation programs, or consortia operating on the principles of multi-sector conglomerates, to the possibility of creating a public-private energy holding.

In terms of energy raw materials, the situation in the crude oil market is currently the least favourable. Currently, 66% of demand for oil in Poland is covered by imports from Russia. This problem affects not only Poland, but the entire European Union. Profits from oil sales only to the EU countries amount to about 10% of the central budget of the Russian Federation. Limiting this source of financing seems

to be indispensable in order to curb further Russian expansion, while the abandonment of oil supplies from Russia requires diversification of the sources of crude oil supplies. from Russia requires diversification of its supply sources. Experts of the Polish Economic Institute identified three potential sources of diversification of crude oil supplies to the European Union, thanks to which there is a possibility of complete withdrawal from oil supplies from Russia:

1. An agreement with Iran to reduce its nuclear program.
   Iran currently produces 2.5 million barrels per day, of which only 0.7–1 million are for export. It is estimated that it would be possible to increase production by nearly 1.3 million barrels per day by the end of the year. Russia's daily production is over 10 million barrels per day, of which about 2.3 million barrels were exported to the EU in 2020. Accordingly, increasing Iran's exports would replace almost 60% of Russian oil supplies to the EU.
2. Greater use of imports from Norway.
   Oil and gas supplies accounted for 40% of the country's total exports in 2020. It is highly likely that as a result of the current war in Ukraine, China will increase its imports of this commodity from Russia, and this will create an opportunity for the EU to make better use of the already existing infrastructure connecting the old continent with Norway and to redirect oil exports to the EU.
3. Increasing supplies from the U.S. and Kazakhstan.
   Analysts at the European Environment Agency forecast that U.S. oil production will increase from 9 to 10.4 million barrels of oil per day in 2022 and 2023. Additionally, Kazakhstan plans to increase oil production.

In the medium and long term, much depends on how quickly the military operations in Ukraine will end and what the scale of damage will be. There is a real risk that Polish and EU markets will face shortages of oilseed plants and products made from them and a significant increase in prices of other raw materials and products, of which Ukraine was a significant supplier.

To sum up, due to dynamic changes in political and economic situation, it is a priority to maintain constant and full monitoring of changes in both Polish and world economies. In a period of dynamic changes, all decisions, both on a micro and macroeconomic scale, require access to up-to-date and comprehensive information on the condition of the economy, and actions taken should be multidirectional and cover in their scope all branches of industry.

PODSUMOWANIE

Wywołany pandemią SARS-CoV-2 kryzys wpłynął negatywnie na wszystkie gałęzie gospodarki, w tym na sektor przetwórstwa spożywczego. Chociaż kryzys ten nie poczynił szczególnie dotkliwych szkód w unijnym przemyśle spożywczym, a spadki wolumenu produkcji w żadnym z krajów UE nie osiągnęły poziomu dwucyfrowego, to nowy kryzys wywołany agresją zbrojną Federacji Rosyjskiej na Ukrainę może skutkować szeregiem negatywnych i długookresowych konsekwencji makroekonomicznych dla Polski oraz całej Unii Europejskiej, a wpływ wojny w Ukrainie widoczny jest już zarówno w obszarze wymiany handlowej i utrzymania łańcucha dostaw, jak też bezpieczeństwa dostaw surowców energetycznych.

Przewiduje się, że wiosenne zasiewy w Ukrainie mogą spaść z 7,7 mln ha do 4,7 mln ha (co stanowi spadek o 39%). Zdaniem ekspertów wojna będzie oddziaływać na ceny żywności poprzez dwa główne kanały. Po pierwsze, efektem wojny może być silny i trwały wzrost cen zbóż i roślin oleistych, których zarówno Ukraina jak i Rosja są znaczącymi eksporterami, co będzie z kolei oddziaływać w kierunku wzrostu cen pasz, a w konsekwencji produktów pochodzenia zwierzęcego. Po drugie, wojna w Ukrainie poprzez wzrost cen gazu może doprowadzić do dalszego wzrostu cen nawozów, co również będzie sprzyjać wzrostowi cen zbóż i roślin oleistych. Dodatkowo, Rosja jest największym na świecie dostawcą nawozów i drugim co do wielkości eksporterem potażu, a przyjęte sankcje zobowiązują Unię Europejską do zastąpienia udziału Rosji i Białorusi, odpowiednio 60% w przypadku potażu i 35% w przypadku fosforanów.

Już w marcu 2022 roku działania wojenne i sankcje gospodarcze doprowadziły do przerw w łańcuchach dostaw i drastycznego wzrostu cen. W ciągu dwóch tygodni od rozpoczęcia konfliktu, zboże osiągnęło rekordową cenę na zachodnich giełdach – kontrakty terminowe w USA na zboże wzrosły ok. 50%. Według Międzynarodowego Funduszu Walutowego żywność podrożała najbardziej od 1961 r., a wskutek inflacji i pandemicznych przerw w łańcuchach dostaw ceny zboża były w grudniu 2021 r. niemalże dwukrotnie wyższe niż w 2019 r.

Należy zaznaczyć, że w 2021 r., Rosja była siódmym największym odbiorcą towarów eksportowanych z Polski i zajmowała trzecie miejsce pod względem wartości towarów importowanych do Polski. Szacuje się, że całkowite wygaśnięcie eksportu towarów z Polski do Rosji i na Ukrainę obniżyłoby dynamikę PKB w Polsce o 2,5 pkt. procentowego w pierwszym roku od wystąpienia szoku.

Konflikt rosyjsko-ukraiński spowodował znaczący wzrost napięcia w transporcie międzynarodowym oraz całkowite wstrzymanie wysyłek z portów ukraińskich i rosyjskich w basenie Morza Czarnego. Ponadto, główne porty w Europie Północnej są mocno zatłoczone i występują znaczne opóźnienia w dostawach. Szacuje się, że utrudnienia obejmują nawet 47% globalnego transportu kontenerowego (kwiecień 2022 r.), co skutkuje utrudnionym dostępem do surowców energetycznych i transportu międzynarodowego oraz przerwaniem łańcucha dostaw dla wszystkich branż przemysłu.

Mimo że produkcja żywności cechuje się krótszymi łańcuchami dostaw w porównaniu z innymi działami przetwórstwa przemysłowego, to problemy w międzynarodowym transporcie towarów i niektórych surowców mogą negatywnie wpływać na całokształt procesu produkcyjnego. W tej kwestii należy zwrócić szczególną uwagę na rozwiązania pozwalające na dywersyfikację źródeł dostaw oraz zmniejszenie wpływu zaistniałych ograniczeń w transporcie. Jednym z kompleksowych rozwiązań mogących ustabilizować proces przetwórstwa spożywczego jest Krótki Łańcuch Dostaw Żywności. Jest to zorganizowany system produkcji, przetwórstwa, dystrybucji i sprzedaży żywności, który polega na łączeniu producentów żywności z określonego regionu.

Metodą, która mogłaby pomóc w ograniczeniu importu surowców do zakładów przetwórstwa rolno-spożywczego jest w pełni zgodną z systemem Krótkiego Łańcucha Dostaw Żywności jest reorganizacja rynku. Rozwiązaniem, które mogłoby być wprowadzone, na wzór Południowo Koreańskich czeboli, jest utworzenie wielobranżowego konglomeratu, który objąłby jak największą liczbę producentów i odbiorców. Istotnym argumentem przemawiającym za wykorzystaniem wielobranżowych konglomeratów w wymianie międzynarodowej jest możliwość efektywnego dokonania zakupu technologii wykorzystywanych do produkcji produktów substytuujących import. Ponadto, silny podmiot gospodarczy, jakim jest konglomerat, może uzyskać znacznie korzystniejsze warunki w negocjacjach dotyczących przetworzenia produktów rolnych.

Znaczącym zagrożeniem dla Polski i Europy płynącym z konfliktu rosyjsko-ukraińskiego jest też znaczące uzależnienie gospodarki od dostaw surowców energetycznych z Rosji. Należy pamiętać, że oparcie znacznej części produkcji energii elektrycznej i ciepła na wykorzystaniu importowanego gazu ziemnego nie spełnia kryteriów gwarancji zarówno terminowych dostaw energii elektrycznej i ciepła, jak też utrzymania cen dla firm oraz gospodarstw domowych na akceptowalnym poziomie. Dywersyfikacja dostaw importowanego gazu ziemnego powinna po 2022 roku wyeliminować problem przerwania, ze względów politycznych, dostaw gazu ziemnego przez stronę rosyjską. W związku z wygaśnięciem kontraktu jamalskiego pod koniec 2022 roku, Polska planowała zaprzestać importu gazu ze wschodu, a dostawy te zastąpić sprowadzaniem gazu z Norweskiego Szelfu Kontynentalnego.

Chociaż import węgla z Rosji w ostatnich 3 latach systematycznie się zmniejszał, mimo to z Rosji sprowadzane jest nadal do Polski 75% całego krajowego importu węgla. Z rosyjskiego węgla korzystają głównie gospodarstwa domowe i małe ciepłownie, które wykorzystują ten surowiec do celów grzewczych.

Rozwiązaniem powyższego problemu w perspektywie średnio i długookresowej może być zastosowanie rozwiązań hybrydowych polegających na połączeniu produkcji energii w oparciu o technologie węglowe oraz OZE w proporcji: 10% technologie węglowe oraz 90% OZE, z jednoczesnym przyjęciem założenia, że ze względu na możliwość wystąpienia problemów klimatycznych ostateczne proporcje produkcji energii z węgla i OZE mogą wynieść odpowiednio: 20% oraz 80%.

W zależności od przyjętego wariantu, redukcja wykorzystania technologii węglowych wyniosłaby od 80% do 90%, co w rezultacie pozwoliłoby istotnie ograniczyć wpływ różnic cen węgla importowanego i krajowego na ekonomikę podmiotów gospodarczych, jak również znacznie zredukować emisję CO_2, co oznaczałoby proporcjonalnie wysoki stopień ograniczenia kosztów z tytułu opłat klimatycznych oraz utylizacji CO_2.

Implementacja w praktyce gospodarczej powyższej koncepcji dla sektora energetycznego wymaga opracowania skutecznej, spójnej oraz innowacyjnej polityki uwzględniającej w swoich założeniach wykorzystanie potencjałów zarówno sektora publicznego, jak i prywatnego. Realizacja tych założeń może przyjmować różne formy: od pojedynczych umów pomiędzy podmiotami gospodarczymi, przez zorganizowane programy współpracy, czy konsorcja działające na zasadach wielobranżowych konglomeratów, po możliwość utworzenia publiczno-prywatnego holdingu energetycznego.

W zakresie surowców energetycznych najmniej korzystnie wygląda obecnie sytuacja surowcowa na rynku ropy naftowej. Aktualnie 66% zapotrzebowania na ropę w Polsce pokrywane jest importem z Rosji. Problem ten dotyczy nie tylko Polski, ale całej Unii Europejskiej. Zyski ze sprzedaży ropy naftowej tylko do państw Unii to ok. 10% centralnego budżetu Federacji Rosyjskiej. Ograniczenie tego źródła finansowania wydaje się niezbędne do zahamowania dalszej rosyjskiej ekspansji, a odejście od dostaw ropy naftowej z Rosji wymaga dywersyfikacji źródeł jej dostaw. Eksperci Polskiego Instytutu Ekonomicznego wskazali trzy potencjalne źródła dywersyfikacji dostaw ropy naftowej do Unii Europejskiej, dzięki którym istnieje możliwość całkowitego odejścia od dostaw ropy naftowej z Rosji:

1. Porozumienie z Iranem w sprawie ograniczenia programu jądrowego.
   Iran produkuje obecnie 2,5 mln baryłek dziennie, z czego jedynie 0,7–1 mln jest przeznaczone na eksport. Szacuje się, że do końca roku byłoby możliwe zwiększenie produkcji blisko o 1,3 mln baryłek dziennie. Produkcja dzienna w Rosji wynosi ponad 10 mln baryłek dziennie, z czego w 2020 r. ok. 2,3 mln baryłek było eksportowane do UE. Zgodnie z powyższym, zwiększenie eksportu Iranu zastąpiłoby w prawie 60% dostawy rosyjskiej ropy do UE.
2. Większe wykorzystanie importu z Norwegii.
   Dostawy ropy i gazu stanowiły 40% całego eksportu tego kraju w 2020 roku. Jest wysoce prawdopodobne, że w wyniku obecnej wojny w Ukrainie, Chiny zwiększą import tego surowca z Rosji, a to stworzy możliwość dla UE lepszego wykorzystania istniejącej już infrastruktury łączącej stary kontynent z Norwegią oraz umożliwi przekierowanie eksportu ropy do UE.
3. Zwiększenie dostaw z USA i Kazachstanu.
   Analitycy Europejskiej Agencji Środowiskowej prognozują, że wydobycie ropy naftowej w USA wzrośnie w 2022 i 2023 r. z 9 do poziomu 10,4 mln baryłek ropy dziennie. Dodatkowo, Kazachstan planuje zwiększyć produkcję ropy naftowej.

W perspektywie średnio i długookresowej wiele zależy od tego jak szybko zakończą się prowadzone na terenie Ukrainy działania wojenne i jaka będzie skala zniszczeń. Istnieje realne ryzyko, iż na polskim i unijnym rynku wystąpią braki w zakresie roślin oleistych i produktów z nich wytwarzanych oraz znaczący wzrost cen pozostałych surowców i produktów, których dostawcą była Ukraina.

Reasumując, ze względu na dynamiczne zmiany w sytuacji polityczno-gospodarczej, kwestią priorytetową jest utrzymanie stałego i pełnego monitoringu zmian zarówno w gospodarce polskiej, jak i światowej. W okresie dynamicznych zmian, wszelkie decyzje, zarówno w skali mikro, jak i makroekonomicznej wymagają dostępu do aktualnej i kompleksowej informacji o stanie gospodarki, a podejmowane działania powinny być wielokierunkowe oraz obejmować w swoim obszarze wszystkie gałęzie przemysłu.

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WSPOMNIENIE O DOBRYM CZŁOWIEKU

Prof. dr inż. Daniel Dutkiewicz

W połowie listopada 2021 roku zmarł Prof. dr inż. Daniel Dutkiewicz. Jak napisano w nekrologu – Dobry i Życzliwy Człowiek. Bo takim był i tak też Go nieraz nazywaliśmy w naszych rozmowach. Daniel nie był front-manem. Wolał patrzeć i doradzać. Dla wielu z nas w Morskim Instytucie Rybackim – Państwowym Instytucie Badawczym był mentorem, doradcą. Jednocześnie, nigdy nie narzucał swojej opinii. Po prostu mówił, co myśli zostawiając decyzje każdemu z nas, często jako dyrektorom. Dwukrotnie pełnił obowiązki dyrektora Instytutu, ale nigdy nie chciał nim być. Przez lata pracy w MIR posiadł olbrzymią wiedzę nie tylko o sprawach związanych z Jego specjalizacją, ale także o ludziach i wydarzeniach z tamtych pionierskich czasów. Namawialiśmy Go, żeby te fascynujące historie przeniósł na papier, ale wolał pisać o swoich maszynach czy ostatnio bardziej filozoficznie o mechatronice w konstruowaniu maszyn przetwórstwa spożywczego. Miał dystans do siebie, ale też wielki entuzjazm i poczucie humoru. Jego powiedzonka własne, czy też cytowane, pozostaną z nami, niestety już bez Niego. Na gdańskim cmentarzu oprócz licznej rodziny (był pradziadkiem) żegnali Go pracownicy szczególnie ci starsi, którzy pamiętali Profesora z pracy w Instytucie.

Jeszcze tak niedawno Profesor uczestniczył w obchodach 100-lecia działalności MIR, będąc w bardzo dobrej formie, jak zawsze żartując i wspominając dawne czasy. Dziś niestety pozostaje już tylko we wspomnieniach. Żal.

Prof. dr inż. Daniel Dutkiewicz (1936–2021) był absolwentem Wydziału Mechanicznego Moskiewskiego Technicznego Instytutu Przemysłu Rybnego. Ukończył go w roku 1956 i krótko potem rozpoczął pracę w Morskim Instytucie Rybackim w Gdyni jako asystent w Pracowni Technologii, Zakładu Technologii Rybnej. W opinii służbowej z roku 1984 prof. Andrzej Ropelewski, dyrektor Instytutu pisał: „... od samego początku pracy w Instytucie doc. dr inż. D. Dutkiewicz dał się poznać jako doskonale przygotowany pracownik naukowo-badawczy, pracowity, sumienny o nieprzeciętnych zdolnościach, szerokim horyzoncie i inicjatywie…”. Potwierdza to w pełni Jego dorobek, bowiem był twórcą lub współtwórcą 30 patentów i zgłoszeń patentowych, w tym 8 maszyn i linii produkcyjnych wdrożonych do przemysłu. Jego największym osiągnięciem było opracowanie i wdrożenie pierwszej w skali światowej linii do odskorupiania kryla antarktycznego. Uczestniczył też w opracowywaniu założeń do budowy trawlerów przetwórni i trawlerów zamrażalni, a także oceanicznego statku badawczego Instytutu „Profesor Siedlecki”.

W roku 1967 uzyskał stopień doktora nauk przyrodniczych, w roku 1972 docenta, a Rada Państwa w roku 1984 nadała Mu tytuł profesora nadzwyczajnego.

Prof. Dutkiewicz był uznanym nauczycielem akademickim, wykładającym na Wydziale Rybackim WSR w Olsztynie, a później w Szczecinie, na Politechnice Gdańskiej i Politechnice Koszalińskiej. Wypromował wielu obecnych specjalistów przetwórstwa rybnego, był opiekunem 70 magistrów, promotorem kilku doktorów i recenzentem habilitacji. Jego osiągnięcia dydaktyczne i naukowe stawiają Go w rzędzie wybitnych, znanych w kraju i za granicą specjalistów w zakresie mechanizacji przetwórstwa rybnego.

Profesor był aktywnym organizatorem życia społeczności naukowej – zajmującej się przetwórstwem w przemyśle spożywczym oraz inicjatorem utworzenia na Politechnice Gdańskiej pierwszego w Polsce kierunku studiów – maszyny i urządzenia przemysłu spożywczego.

To między innymi z Jego inicjatywy i przy Jego współudziale powstały w ramach Komitetu Techniki Rolniczej PAN odbywające się przemiennie corocznie sztandarowe konferencje środowiska przetwórców przemysłu spożywczego – Budowa i Eksploatacja Maszyn Przemysłu Spożywczego „BEMS” i Ogólnopolska Konferencja Naukowa „Postęp w Inżynierii Produkcji”. Profesor był także znanym i zaangażowanym rzecznikiem współpracy nauki z przemysłem, czego dobitnym przykładem był Jego udział w powołaniu do życia Polskiego Towarzystwa Inżynierii i Techniki Przetwórstwa Spożywczego „Spomasz” oraz naszego czasopisma naukowego „Postępy Techniki Przetwórstwa Spożywczego”.

Wielkim wyzwaniem dla Profesora było powierzenie Mu przygotowania i kierowania Polską Pierwszą Morską Wyprawą Antarktyczną w latach 1975/1976. Z zadania tego wywiązał się znakomicie, stwarzając podstawy do kolejnych wypraw i eksploatacji rybackich zasobów Antarktyki.

W latach 1985–1998 i 2000–2002 był zastępcą dyrektora MIR ds. naukowych oraz dwukrotnie pełnił również obowiązki dyrektora Instytutu.

Za swe zasługi został odznaczony Krzyżem Kawalerskim Orderu Odrodzenia Polski, Złotym Krzyżem Zasługi, Medalem Komisji Edukacji Narodowej i wieloma odznaczeniami zawodowymi i społecznymi.

Odszedł nasz wspaniały Mentor, Przyjaciel i Kolega. Po prostu Dobry i Życzliwy Człowiek.

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- **Uwaga!** Wraz z w/w egzemplarzami artykułu należy dostarczyć płytkę z zapisanym tekstem (rysunkami) w edytorze pracującym w środowisku **Windows** drogą pocztową lub elektroniczną na adres: **ptps@mac.edu.pl**.
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- Na rysunki i tabele należy powołać się w tekście w nawiasach okrągłych, np. (rys.1), natomiast na źródła literaturowe, których zestawienie umieszczone jest na końcu artykułu, w nawiasach kwadratowych, np. [3| lub [3,4,5].
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- Prace przekazujemy na płytach CD. Wraz z przekazywanym nośnikiem, przekazujemy **wydruk pracy** (z drukarki).
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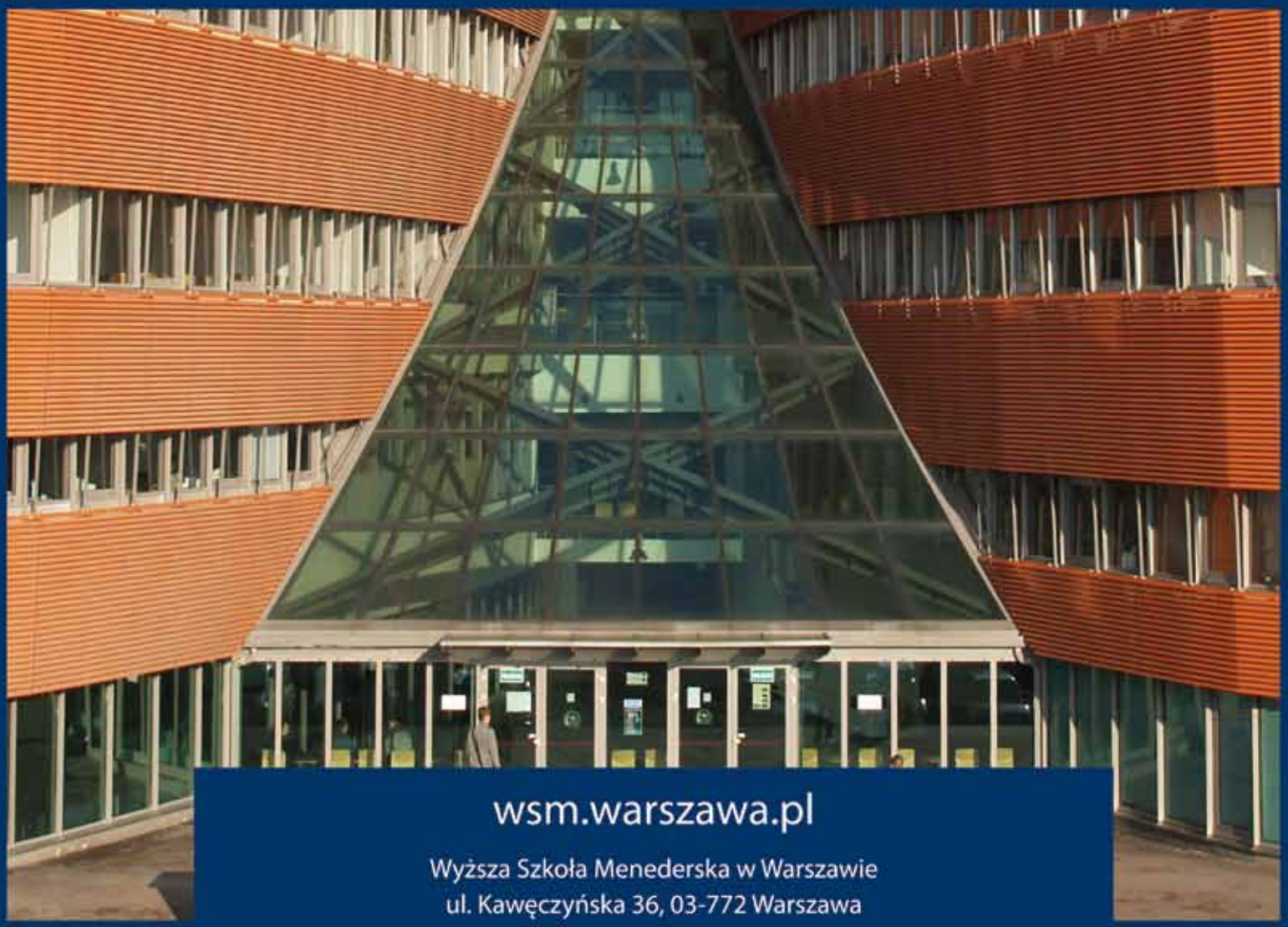

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