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SPIS TREŚCI
CONTENTS

Od Redakcji 4
Editorial

FOOD ENGINEERING
INŻYNIERIA ŻYWNOŚCI

1. **KOWALSKA M., A. ŻBIKOWSKA, M. STACHOWICZ:**
Physical and chemical properties of emulsions containing different kind of fat and different content of an innovative protein with algae 5
Właściwości fizykochemiczne emulsji zawierających różny rodzaj tłuszczu i różną zawartość innowacyjnego białka z alg.

2. **KOWALCZUK I.:**
Consumer attitudes towards novel technologies implemented in food production across selected regions of Poland 16
Postawy konsumentów wobec nowych technologii wykorzystywanych w produkcji żywności w wybranych regionach Polski.

3. **AUGUSTYŃSKA-PREJSNAR A., Z. SOKOŁOWICZ:**
Effect of the addition of oat and wheat fiber on the quality of poultry burgers 22
Wpływ dodatku błonnika owsianego i pszennego na jakość burgerów drobiowych.

4. **SZWEDZIAK K., E. POLAŃCZYK, A. CHEŁPA, P. DOLEŻAL:**
Management of innovative evaluation techniques selected quality parameters in industry food 27
Zarządzanie innowacyjnymi technikami oceny wybranych parametrów jakości w przemyśle spożywczym.

5. **PAŁACHA Z., Ł. MIKOŁAJCZEWSKI:**
Właściwości sorpcyjne wybranych herbat 33
Sorption properties of selected tea.

6. **ФАТЫХОВ Ю.А., В.А. НАУМОВ, О.В. АГЕЕВ, D. DUTKIEWICZ, A. DOWGIAŁŁO:**
Влияние фрикционных характеристик на виброориентирование рыбы 41
Wpływ charakterystyki tarcia ryb na ich orientację przestrzenną podczas procesu wibracji.

7. **PIELAK M., A. GŁUCHOWSKI, P. SAŁEK, E. CZARNIECKA-SKUBINA, I. KRAUJUTIENE:**
The knowledge of principles of good catering practice (GCP) by the staff of kindergarten canteens 47
Znajomość zasad dobrej praktyki gastronomicznej (GCP) przez personel stołówek przedszkolnych.

8. **BILLER E., B. WASZKIEWICZ-ROBAK, E. BOSELLI, M. OBIEDZIŃSKI:**
Zastosowanie warzyw jako źródła smaku słodkiego w produkcji ciast z ograniczonym dodatkiem sacharozy 57
The usage of vegetables as a source of sweetness in the production of cakes with limited addition of sucrose.

9. **JANOWICZ M., S. GALUS, A. CIURZYŃSKA, M. KUREK, M. MICHALSKA:**
Evaluation of selected properties of products (leather fruits) based on fruit puree 64
Ocena wybranych właściwości produktów (leather fruits) otrzymanych na bazie puree owocowych.

10. **KUCHARCZYK K., T. TUSZYŃSKI, K. ŻYŁA:**
The influence of selected technological parameters of the beer wort fermentation process produced on an industrial scale on the filtration properties of beer 74
Wpływ wybranych parametrów technologicznych procesu fermentacji brzeczki piwnej produkowanej w technologii wielkozbiornikowej na właściwości filtracyjne piwa.

11. **ANDERS A., E. KOLANKOWSKA, P. MARKOWSKI, Z. KALINIEWICZ, D. CHOSZCZ, K. JADWISIEŃCZAK, M. SZUBARTOWSKI:**
Modeling the shape of materials and food products on the example of peanut fruit (*Arachis Hypogaea* L.) 79
Modelowanie kształtu surowców i produktów spożywczych na przykładzie owoców orzechy podziemnej (Arachis Hypogaea L.).

12. **WASZKIEWICZ-ROBAK B., K. KULIK:**
Food additives in confectionery 87
Dodatki do żywności w wyrobach cukierniczych.

13. **MIESZKALSKI L., K. TUCKI, K. KULPA, R. SIEJKA, I. KURIC:**
The use of the Arduino module in controlling the vegetable industry equipment on the example of a weighing-packing machine 95
Zastosowanie modułu Arduino w sterowaniu urządzeniami przemysłu warzywniczego na przykładzie wagoworkownicy.

14. **SZWEDZIAK K., E. POLAŃCZYK, D. HALKIEWICZ, P. DOLEŻAL:**
Production technology and quality assessment of fermented drinks 105
Technologia produkcji i ocena jakości napojów fermentowanych.

15. **POLAK-ŚLIWIŃSKA M.:**
Determination of aflatoxin M1 contamination levels in milk and milk products by HPLC-FLD with post - column derivatization 110
Oznaczanie poziomów zanieczyszczenia aflatoksyną M1 mleka i produktów mlecznych metodą HPLC-FLD z derywatyzacją pokolumnową.

ANALYTICAL REVIEW ARTICLES
ARTYKUŁY ANALITYCZNO-PRZEGLĄDOWE

16. **HURKO-ROMEYKO I., J. KOWALSKA, I. POCHITSKAYA:**
Cocoa powder as source of phenolic compounds, determining factors - a review 117
Proszek kakaowy jako źródło związków fenolowych, czynniki determinujące – przegląd.

17. KRÓLIKOWSKI T., K. DEPTUŁA:
Game meat in a well-balanced diet as an attractive alternative to livestock meat 125
Dziczyzna w zbilansowanej diecie jako atrakcyjna alternatywa dla mięsa zwierząt hodowlanych.

18. SKOLMOWSKA D., A. KOŁOTA, M. STACHOŃ, K. LACHOWICZ:
Health-promoting properties of bioactive compounds of tea and the influence of method of infusion preparation and time on their content 131
Właściwości prozdrowotne związków bioaktywnych występujących w herbacie oraz wpływ sposobu i czasu parzenia na ich zawartość.

19. KOŁOTA A., D. SKOLMOWSKA, K. LACHOWICZ, M. STACHOŃ:
Characteristic of phenolic compounds of wine and the influence of raw material and production process on their content 142
Charakterystyka związków fenolowych występujących w winie oraz wpływ zastosowanego surowca i procesu produkcji na ich zawartość.

20. DUTKIEWICZ D., B. SŁOWIŃSKI, Ю.А. ФАТЫХОВ:
Process, systemic and dialectical aspects inventiveness in the food production industry 158
Procesowe, systemowe i dialektyczne aspekty wynalazczości w przemyśle produkcji żywności.

21. LACHOWICZ K., M. STACHOŃ, A. KOŁOTA, D. SKOLMOWSKA:
Processed legume seed products and their significance in the prevention of cardiovascular diseases 168
Przetwory z nasion roślin strączkowych i ich znaczenie w profilaktyce chorób układu sercowo-naczyniowego.

22. Małgorzata STACHOŃ M., K. LACHOWICZ, D. SKOLMOWSKA, A. KOŁOTA:
Phytoestrogens from legume seeds and their role in the prevention of osteoporosis in postmenopausal women 185
Fitoestrogeny z nasion roślin strączkowych i ich rola w zapobieganiu osteoporozie u kobiet w wieku postmenopauzalnym.

23. KABZIŃSKI M.:
The impact of the High-Pressure Homogenization on some microorganisms and enzymes – a review 195
Wpływ homogenizacji wysokociśnieniowej na wybrane mikroorganizmy i enzymy – przegląd publikacji.

24. GRUCHELSKI M., M. GRUCHELSKI, K. PORĘBSKA:
The use of pascalization in the Polish food industry - characteristics and prospects 203
Zastosowanie paskalizacji w polskim przemyśle spożywczym – charakterystyka i perspektywy.

MANAGEMENT IN FOOD PROCESSING
ZARZĄDZANIE W PRZETWÓRSTWIE SPOŻYWCZYM

25. WIZA P.L.:
The dairy industry in Poland during the coronavirus pandemic 209
Branża mleczarska w Polsce w czasie pandemii koronawirusa.

26. PAWŁOWSKI M., A. KUŁAKOWSKA:
Porównanie innowacyjności w różnych gałęziach polskiego przemysłu z uwzględnieniem produkcji artykułów spożywczych 216
Comparison of innovation in different branches of the polish industry with the production of food products.

LISTA RECENZENTÓW 231

OD REDAKCJI

Przekazujemy do rąk Szanowanych Czytelników pięćdziesiąty siódmy numer naszego czasopisma. Dwudziesty dziewiąty rok działamy na rynku naukowych wydawnictw periodycznych, promując postęp techniczny 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 1120 artykułów.

W bieżącym numerze znajdą Państwo dwadzieścia sześć artykułów.

Trudno jest omówić każdy z nich, choć wszystkie są interesujące, dlatego sygnalizuję tylko niektóre.

Personel stołówek przedszkolnych odpowiedzialny za przygotowanie posiłków dla dzieci w warszawskich przedszkolach, nie w pełni zna i realizuje zasady dobrej praktyki gastronomicznej (GCP), twierdzi Zespół pracowników Instytutu Nauk o Żywieniu Człowieka SGGW w Warszawie. Na podstawie badań stwierdzono potrzebę edukacji osób odpowiedzialnych za przygotowanie posiłków w placówkach przedszkolnych.

Pracownicy Instytutu Biotechnologii Przemysłu Rolno-Spożywczego w Warszawie działając we współpracy z Uniwersytetem w Bolzano (Włochy) informują, że istnieje możliwość ograniczenia zawartości cukru w ciastach poprzez wprowadzenie do ich składu warzyw o naturalnym smaku słodkim. Najbardziej zbliżone cechy do próby kontrolnej uzyskiwano po zastosowaniu słodkich ziemniaków. Pozwoliło to na zmniejszenie ilości cukru przewidzianego w podstawowej recepturze do 50%.

Z badań prowadzonych w Instytucie Nauk o Żywności SGGW w Warszawie we współpracy z Uniwersytetem w Zagrzebiu (Słowacja) wynika, że wszystkie przebadane rodzaje przecierów owocowych (z czarnej porzeczki, śliwki, jabłka i jabłka ze skórką) można wykorzystać do opracowania zdrowych przekąsek (leather fruits).

Zespół Badawczy pracowników Instytutu Nauk o Żywieniu Człowieka SGGW w Warszawie po analizie wyników badań krajowych i zagranicznych stwierdza, że zwierzyna łowna w porównaniu z mięsem zwierząt hodowlanych jest zdecydowanie bardziej wskazana dla zdrowia ze względu na swój skład odżywczy, w szczególności wysoką zawartość witamin i składników mineralnych oraz korzystny profil kwasów tłuszczowych.

Analiza wyników badań krajowych i zagranicznych przeprowadzona przez pracowników Instytutu Nauk o Żywności SGGW w Warszawie we współpracy z Narodową Akademią Białorusi (Mińsk) pozwala na stwierdzenie, iż zalecane dzienne spożycie 200 mg flawonoli kakaowych można osiągnąć jedząc 2,5 łyżeczki proszku kakaowego o wysokiej zawartości flawonoli lub 10g gorzkiej czekolady. Proszek kakaowy jest cennym źródłem związków mineralnych, a także alkaloidów poprawiających pracę mózgu, a szczególnie koncentrację. Zawiera on więcej flawonoli niż czerwone wino, czy zielona herbata.

Sposób i czas parzenia decydują o zawartości właściwości prozdrowotnych związków bioaktywnych występujących w herbacie, informują pracownicy Katedry Dietetyki SGGW w Warszawie po analizie wyników badań krajowych i zagranicznych w tym zakresie.

Z kolejnego artykułu w/w Zespołu Badawczego dowiadujemy się, że spożywanie roślin strączkowych powinno być w Polsce bardziej powszechne i zalecane w profilaktyce pierwotnej chorób układu krążenia – jako sposób na ograniczenie czynników ryzyka chorób sercowo-naczyniowych.

Panie, jedzcie nasiona roślin strączkowych! – apelują naukowcy zatrudnieni w katedrze Dietetyki SGGW w Warszawie. Zawarte w nich składniki poprawiają gęstość kości i zmniejszają ryzyko osteoporozy u kobiet w okresie okołomenopauzalnym.

Dziękuję Autorom i Recenzentom – krajowym i zagranicznym, Członkom Rady Redakcyjno-Programowej oraz Zespołowi Redakcyjnemu i zachęcam zarówno ich, jak też nowych Autorów i Recenzentów do współpracy z naszym czasopismem.

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PHYSICAL AND CHEMICAL PROPERTIES OF EMULSIONS CONTAINING DIFFERENT KIND OF FAT AND DIFFERENT CONTENT OF AN INNOVATIVE PROTEIN WITH ALGAE®

Właściwości fizykochemiczne emulsji zawierających różny rodzaj tłuszczu i różną zawartość innowacyjnego białka z alg®

Celem pracy przedstwionej w artykule jest określenie wpływu rodzaju tłuszczu oraz zmiennej zawartości białka z alg na wybrane właściwości fizykochemiczne emulsji decydujące o stabilności układu. *Emulsje tłuszczowe wytworzono w trzech następujących wariantach: na bazie oleju konopnego, na bazie mieszaniny oleju konopnego i łoju baraniego (1:1) oraz na bazie tej samej mieszaniny tłuszczowej, ale poddanej procesowi enzymatycznego przeestryfikowania (1:1). Zakres eksperymentalnej części pracy obejmował przygotowanie tłuszczu zwierzęcego (łoju baraniego) przez poddanie go procesowi bielenia, a następnie przeestryfikowanie enzymatyczne z olejem konopnym. Następnie przygotowano 9 wariantów emulsji zawierających odpowiednio olej konopny, mieszaninę tłuszczową nieprzeestryfikowaną oraz mieszaninę tłuszczową przeestryfikowaną. Każda z emulsji zawierała inną zawartość białka z alg w ilości od 0.4 do 1,2% w stosunku do masy emulsji. Tak przygotowane emulsje poddano badaniom po 24 godzinach od ich sporządzenia oraz po 1 miesiącu przechowywania. Przeprowadzono ocenę następujących parametrów emulsji: barwy, tekstury, lepkości, struktury mikroskopowej oraz dokonano pomiaru intensywności światła wstecznie rozproszonego przez próbkę w czasie, z wykorzystaniem urządzenia Turbiscan Lab. Zauważono, że wraz ze wzrostem zawartości białka z alg w emulsjach, nastąpił wzrost wartości parametru b* odpowiadającego za żółty kolor dla wszystkich wariantów tych emulsji. Nastąpił również wzrost wielkości kropel w badaniu mikroskopowym i zmniejszenie stabilności emulsji na bazie tłuszczów przeestryfikowanych. Nie zauważono jednoznacznego wpływu białka z alg na następujące parametry: adhezyjność, lepkość oraz twardość emulsji.*

W pracy nie udało się wytypować emulsji o wysokiej stabilności, ani wskazać wyraźnego wpływu białka na właściwości reologiczne wytworzonych emulsji bez względu na

The aim of the work presented in the article is to determine the effect of the type of fat and the variable protein content of algae on selected physicochemical properties of emulsions determining the stability of the disersion systems. *Fat emulsions were prepared in the following three variants: based on hemp oil, based on a mixture of hemp oil and mutton tallow (1: 1) and based on the same fat mixture, but subjected to the enzymatic interesterification process (1: 1). The experimental part of the work included the preparation of animal fat by subjecting it to the bleaching process, and then enzymatic interesterification with hemp oil. Then, 9 variants of emulsions containing hemp oil, nonesterified fat mixture and interesterified fat mixture, respectively, were prepared. Each emulsion had a different algal protein content ranging from 0.4 to 1.2% by weight of the emulsion. The emulsions prepared in this way were tested 24 hours after their preparation and after 1 month of storage. The following parameters of the emulsion were assessed: color, texture, viscosity, and microscopic structure, and the intensity of the light backscattered by the sample was measured with the use of the Turbiscan Lab device. It was noticed that with the increase in the protein content of algae in the emulsions, there was an increase in the value of the b * parameter corresponding to the yellow color for all variants of these emulsions. There was also an increase in droplet size in microscopic examination and a decrease in the stability of the emulsions based on the interesterified fats. There was no unequivocal influence of the algae protein on the following parameters: emulsion adhesiveness, viscosity and hardness.*

In the study, it was not possible to select an emulsion with high stability, nor to indicate a clear influence of protein on the rheological properties of the emulsions produced, regardless of the type of fat used. In order to produce more stable systems, research should be extended to change the amount or type

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rodzaj zastosowanego tłuszczu. W celu wytworzenia bardziej stabilnych układów należy rozszerzyć badania w kierunku zmiany ilości lub rodzaju białka, czy wytypowania innego modyfikatora lepkości, który z białkiem z alg jest w stanie stworzyć układ synergistyczny oddziaływujący stabilizująco na wytworzone układy dyspersyjne.

Słowa kluczowe: emulsja, stabilność, białko z alg, Turbiscan test.

of protein, or to select a different viscosity modifier which, together with the algae protein, is able to create a synergistic system that stabilizes the dispersion systems produced.

Key words: emulsion, stability, alge protein, Turbiscan test.

INTRODUCTION

Currently, in times of advanced knowledge and technology, scientists are trying to meet the growing expectations of consumers regarding emulsion products on the market. On the basis of many experiences, researchers create more and more innovative products, as well as additions to tchem [1]. Natural ingredients are more and more often used in cosmetics, food or pharmaceutical products, which is dictated by the current trends in creating healthy products with more attractive properties. Due to their various applications, emulsions are a frequent subject of research aimed at improving the nutritional, performance and functional properties of these systems [3]. One of the key components of fat emulsions is fat. In recent years, due to the promotion of healthy eating, a decrease in the consumption of animal fats has been observed in favor of the consumption of vegetable fats. Vegetable oils provide the body with valuable unsaturated fatty acids (SFA), vitamins and do not contain cholesterol [2]. A common solution is to use the fat interesterification process which allows to change the rheological, nutritional and functional properties of the obtained fat [14]. Carrying out this process is related, inter alia, to the introduction of valuable unsaturated fatty acids derived from vegetable oils into the molecules of triacylglycerols of animal fat, i.e. tallow, mutton or lard [10]. By preparing such a fat mixture, it is often possible to obtain the fat phase of an emulsion ready for use in the formation of fat emulsions. As a result of the interesterification process, new triacylglycerols (TAGs) are obtained. The process management depends on the applied chemical catalyst or selective lipase and the application of appropriate process parameters.

An important vegetable oil recently chosen by scientists is hemp oil [13]. Due to its beneficial properties related to the presence of unsaturated fatty acids and bioactive compounds, this oil is a valuable component of cosmetic preparations with health and care properties, and can also be used for direct consumption. Despite the current trend of consuming unrefined oils and replacing animal fats with them, such fats appear in the food industry, often being a waste of this industry. Mutton tallow can be such fat [7]. This fat contains 52–64% of saturated fatty acids, 3–4% of trans fatty acids, including the valuable CLA acid. It consists of both symmetrical and unsymmetrical unsaturated triacylglycerols. The dominant fatty acids of mutton tallow are palmitic acid (C16: 0), stearic acid (C18: 0) and oleic acid (C18: 1).

The quality of emulsion food products depends on the proper selection of ingredients (oil, emulsifiers, thickeners, flavors, vitamins), as well as on the properly conducted production process (homogenization, pasteurization), and then storage and transport [12].

To obtain a stable emulsion, it is necessary to add an emulsifier, i.e. a substance that accumulates at the interface, reducing the surface tension and stabilizing the system [9]. Its presence in the system ensures that the particles of the dispersed phase are separated from each other, so that they do not merge with each other. The amount of emulsifier in the system must be sufficient to form films around all the beads. If it is not enough, the films will be too thin and the emulsion will be unstable.

Hydrocolloids are also added to increase the stability of the emulsion [6]. They are high molecular weight hydrophilic biopolymers. They are used as functional additives to products to improve their structure and stability. Hydrocolloids can regulate the stability of the emulsion by increasing the viscosity of the continuous phase as well as acting as a surfactant forming a thick film around the emulsion droplets [6]. Thanks to viscosity modifiers, it is possible to obtain a product with an acceptable viscosity for technical or commercial requirements. Commonly, these substances are divided into: natural and synthetic polymers, surfactants and inorganic compounds. In order to protect the natural environment, it is desirable to use biodegradable compounds.

Proteins can also be classified as viscosity modifying substances. One that is increasingly used in emulsion systems is algae protein. Algae are a source of valuable ingredients for the human body. They contain large amounts of proteins, lipids, carbohydrates, vitamins and microelements, essential fatty acids (EFAs), polyphenols, biogenic compounds and natural dyes [4]. Proteins found in algae constitute about 7-15% of their dry weight. They mainly include glycoproteins and metalloproteins containing essential amino acids. Algae are used in the food, pharmaceutical and cosmetic industries [4].

The aim of the presented study was to evaluate the stability of fat emulsions containing different types of fat and different algal protein content.

MATERIALS

Cold-pressed hemp oil (Oleofarm, Wrocław, Poland), mutton tallow (donated from Meat-Farm Radosław Łuczak, Stefanowo, Poland), lipase from *Rhizomucor miehei*, immobilized on immobead 150, ≥ 300 U/g (Sigma Aldrich, Saint Louis, Missouri, United States) were used at the interestrification process. Carboxymethylcellulose (Pronicel, Pionki, Poland), protein from algae, sunflower lecithin (Lasenor) and sodium benzoate (Orff Food Easter Europe) were used as additions into the emulsions (Table 1).

PROCEDURE

Mutton tallow bleaching

Tallow was bleached and deodorized before the reaction. The fat was melted, placed in a two-neck round-bottom flask and 2% wt. of bleaching earth was added. The mutton tallow was heated under reflux condenser at 80°C for 1 h. After that time sorbent was filtered at 70°C using paper filter.

Enzymatic interestrification

Emulsions' fat bases were prepared by mix of fats and enzymatic interesterification of mutton tallow (MT) and hemp seed oil (HO) blends in the following mass ratio (1:1). The fat blends were placed in a shaker equipped with a water bath (SWB 22N, Labo Play, Poland) at reaction temperature (60°C) for 15 min. After this time, enzymatic catalyst - lipase from *Rhizomucor miehei* was added to the blends, in the amount corresponding to 5% w/w of the fat blend mass and water was calculated and added in the amount of 22% w/w of the enzyme mass. Water was added to the reaction system to increase the catalytic activity of a lipase at a lipid-water interface to increase the content of mono and diacylglicerols in the fat blends, which were used as the only emulsifiers in dispersion systems (only then when interestrified fat was used as a fat base). The process was carried out for 6 h, the reaction was terminated by filtering the enzyme on a Büchner funnel at 60°C.

Emulsion preparation

The aqueous phase of each emulsion was prepared by dispersing an appropriate amount of carboxymethylcellulose (CMC) in water, while the oil phase (fat base) was respective oil, mixed fat or interesterified fat blend according to Table 1. Both phases were heated to about 50–55°C, combined and then homogenized. Sunflower lecithin was added when the fat phase of the emulsion was hemp oil and blended fat. Each formulation was prepared in duplicate and homogenized mechanically. Homogenization was carried out for 4 minutes at 18 500 rmp using a rotor stator homogenizer, model T18 digital ULTRA-TURRAX equipped with S18G-19G dispersing head (IKA, China). During homogenization, the appropriate amount of algae protein (producer Solazyme) was gradually added to each of the emulsions. Sodium benzoate was added to the thus prepared and cooled emulsions.

METHODS

Colour determination of emulsions

Colour determination was done using a Konica Minolta chromameter CR-400 (Konica Minolta Sensing Inc., Milton Keynes, UK) (Fig. 1a) after standardization with a white calibration plate. CIEL*a*b* system was used with following parameteres:

– L* – defined as lightness of the sample ranging from 0 (black) to 100 (white),
– a* and b* represents two perpendicular color axes, with the values ranging from -60 to +60. Parameter a* when (-) represents greenness, when (+) redness. Whereas b*, blueness when (-) and yellowness when (+)[15].The measurements were taken in triplicate.

Texture measurements

Emulsions were evaluated for the following texture parameters: hardness and adhesiveness using CT3 Texture Analyzer (Brookfield Eng. Laboratories, USA) (Fig 1b.). Following measurement parameters were applied: nylon sensor with a diameter of 25.4 mm, target 10 mm, trigger load 0.1 g, test and return speed 0.2 mm/s, temperature 20°C. The test was performed 24 hours after the emulsion was prepared and was repeated after a month of storage of the emulsion. The results were presented as a mean value of three measurements.

Viscosity determination of emulsions

The viscosity of the emulsions was determined using Brookfield DV-III Ultra rheometer, model HA with helipath spindle set (Brookfield Engineering laboratories, USA) (Fig 1c.). Measurements were carried out at a constant rotational spindle speed of 5 rpm using T-bar spindle no. 92 (T-B). The

Table 1. Compositions of the emulsions

Tabela 1. Skład emulsji

Component	Emulsion								
	E1	E2	E3	E4	E5	E6	E7	E8	E9
	HO			NIC			EIC		
Fat% wt.	24.8	24.8	24.8	24.8	24.8	24.8	30	30	30
Lecitin% wt.	5.2	5.2	5.2	5.2	5.2	5.2	-	-	-
CMC% wt.	0,6								
AP% wt.	0.4	0.9	1.2	0.4	0.9	1.2	0.4	0.9	1.2
Preservative% wt.	0.3								
Water% wt.	Up to 100.0								

Legend/Legenda:
NIC – non interestrified fat hemp oil and muton tallow (1:1)
NIC – mieszanina fizyczna oleju konopnego i łojo baraniego (1:1)
EIC – interestrified fat hemp oil and muton tallow (1:1)
EIC – mieszanina enyzmatycznie przeestryfikowana oleju konopnego i łoju baraniego (1:1)

Source: Own study

Źródło: Opracowanie własne

measurements were performed at 20°C in triplicate. The test was performed 24 hours after the emulsion was prepared and was repeated after a month of storage of the emulsion.

Determination of the emulsion structure

The emulsion structure was determined using the Delta Pro Trino optical microscope by DELTA Optical (Fig 1d). The test was performed by applying a small amount of the emulsion to a glass slide and covering it with a coverslip. The samples prepared in this way were observed under a microscope at a magnification of 400x. Photos of the tests were taken with a camera using the DLTCamViewer software. The test was performed 24 hours after the emulsion was prepared and was repeated after a month of storage in the fridge.

Determination of emulsion stability

Stability determinations of the produced emulsions were made using the Turbiscan LabCooler by Formulaction in which cylindrical glass measuring vials containing the appropriate variant of the emulsion were placed (Fig 1e). The possibility of occurrence at a very early stage of physicochemical phenomena (creaming, coalescence, sedimentation, flocculation, particle migration, particle size change) that could not be observed with the naked eye was analyzed. The instrument's measuring head scanned the slides from the bottom to the top of the vial. The test results are presented on the charts generated by the Turbisoft program. The examination was performed twice a week for one month. The samples were stored at room temperature.

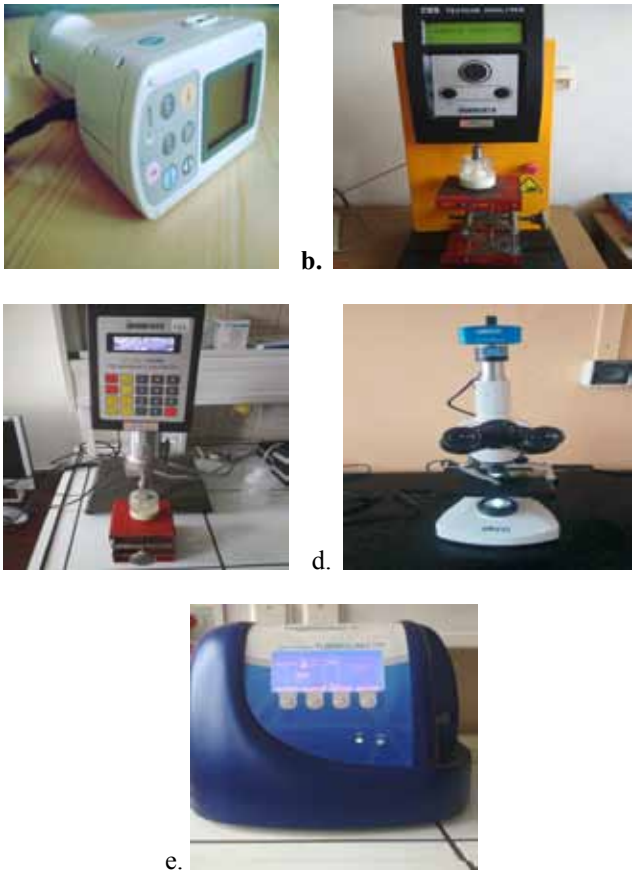

Fig. 1. Apparatus and devices used in research.
Rys. 1. Aparaty i urządzenia wykorzystane w badaniach.
Source: Own study
Źródło: Opracowanie własne

RESULTS AND DISCUSSION

Change of emulsion colour is one of the important determinants that inform about processes occurring in the product and can indicate destabilization changes [11].The results of the L * parameter recorded after 24h indicated that the emulsions based on the esterified fat were the brightest. After the storage period, an increase in the L* parameter was recorded in emulsions containing hemp oil or a mixture of non-esterified fats, which indicated a lighter shade of the emulsion. On the other hand, for samples with interesterified fat, a decrease in the value of the L* parameter was noted, indicating a darker color of these emulsions. No changes in the L* parameter values were found for emulsions containing different amounts of algae protein.

The analysis of the obtained results for the value of the a * parameter suggests that after manufactouring the emulsions had a green hue. Over time, the value of this parameter was higher, which suggested that the shade of green deepened. The least pronounced green color was observed for emulsions containing mixed fat. On the other hand, emulsions with interesterified fat showed a more intense shade of green. No clear effect of the addition of algae protein on the value of this parameter was observed.

Changes in the b* parameter value towards the yellow shade were observed for all emulsions. The smallest changes during the entire storage period were observed for the emulsions based on the interesterified fat. Moreover, within the emulsions containing the same fat base, the highest value of this parameter was observed when the protein content was higher. Thus, it can be assumed that the amount of protein contributed to the more pronounced yellow color of the emulsion. Emulsion 9 was the most intense in the shade of yellow.

Table 2. CIELAB L*, a*, b* values of the emulsions after manufactoring (24h) and stored 1 month

Tabela 2. Wartości CIELAB L*, a*, b* dla emulsji wytworzonych po 24 godzinach i przechowywanych przez 1miesiąc

Time	24h			1 month		
Emulsion	L*	a*	b*	L*	a*	b*
E1	13,91	-1,20	1,76	20,23	-1,63	4,65
E2	14,05	-1,26	2,02	19,41	-1,54	4,69
E3	19,42	-1,28	5,36	18,34	-1,49	4,27
E4	14,10	-1,01	1,77	18,48	-1,23	4,71
E5	15,50	-0,93	2,44	18,04	-1,43	4,73
E6	15,35	-1,11	3,13	19,23	-1,19	5,03
E7	22,07	-1,45	3,72	19,67	-2,00	4,79
E8	21,92	-1,70	5,15	21,17	-2,08	5,32
E9	21,56	-1,80	5,57	18,78	-2,24	6,42

Source: Own study
Źródło: Opracowanie własne

Texture is a group of physical properties of the body resulting from its structure. Measurement of texturometric properties makes it possible to objectively evaluate and compare features such as brittleness, hardness, ductility and

tackiness, which are usually determined subjectively by the senses. In the conducted texture study, the hardness and adhesiveness of the prepared emulsions were determined (Figure 2).

Analyzing the obtained results, it was found that the freshly prepared emulsions were characterized by higher hardness than those after a month of storage, especially in the case of emulsions (E3-E9). The lowest hardness values among the prepared preparations were characteristic for emulsions based on hemp oil (E1-E3), and the highest values for emulsions based on a physical mixture of fats (E4-E6). Emulsions whose fat base was an esterified mixture of fats (E7-E9) had comparable values of this parameter as emulsions based on hemp oil. Only one emulsion with the lowest algae protein content represented higher hardness values. The analysis of this parameter only shows that the interesterification process decreased the hardness of the blended fat. However, no effect of the amount of protein addition on the emulsion hardness was observed. However, it was observed that in an emulsion with a mixed fat 24 hours after production where the algae protein content was the lowest, the hardness parameter was the highest.

Sample adhesiveness can be identified as its' stickiness [8]. The analysis of the obtained results shows that emulsions based on mixed fats showed the highest values of adhesiveness of emulsions (Figure 3). The lowest values of this parameter were recorded for emulsions based on hemp oil. For the first four emulsions E1-E4, it was observed that after the indicated storage period (30 days), the value of this parameter decreased. However, for samples containing more algae protein and mixed fat, this parameter remained unchanged. Therefore, it can be concluded from the above data that the amount of protein in these emulsions had no influence on this parameter. On the other hand, when analyzing the values of this parameter for emulsions containing interesterified fat, its increase or not changing (E8) after the storage period was observed.

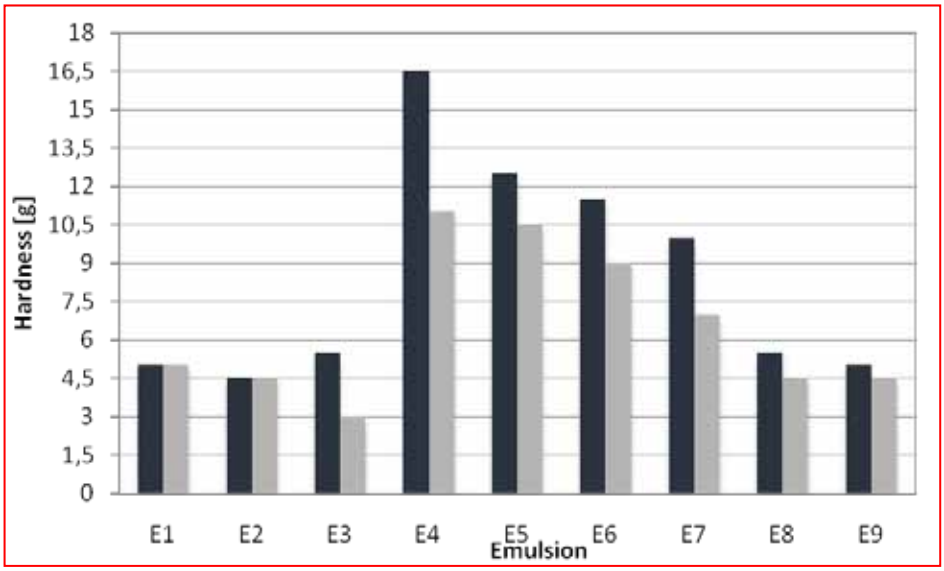

Fig. 2. Hardness of examined emulsions after 24 h and 30 days of storage.
Rys. 2. Twardość emulsji po 24 godzinach i 30 dniach przechowywania.
Source: Own study
Źródło: Opracowanie własne

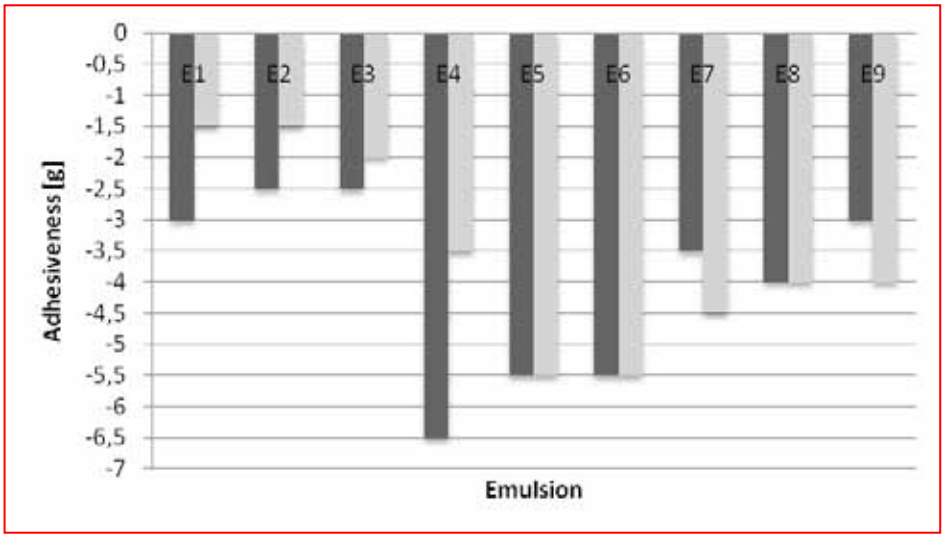

Fig. 3. Adhesiveness of examined emulsions after 24 h and 30 days of storage.
Rys. 3. Przyczepność emulsji do próbnika po 24 godzianch i 30 dniach od wytworzenia.
Source: Own study
Źródło: Opracowanie własne

Another parameter which was evaluated was the emulsions viscosity. The general factor affecting the emulsion viscosity value was the type of fat used as the base fat component. The emulsions containing the physical mixture of fats were characterized by the highest viscosity values (Figure 4). Their viscosity results were in the range of 52,533 – 68,400 cP. Emulsions based on the interesterified mixtures showed lower values of this parameter and ranged from 6667-12800 cP. On the other hand, the lowest values of this parameter were recorded for emulsions based on hemp oil. They ranged from 4,533 to 5,600 cP.

After one month of storage, a decrease in viscosity was observed for the following emulsions (E1, E2, E3 and E4, E5, E6). For emulsions containing interesterified fats, an upward trend of this parameter was observed. The study did not show a clear effect of the amount of protein from algae in the system on the value of the viscosity parameter. The emulsion E5 with 0.9 g of protein, containing mixed fat was characterized by the highest viscosity value.

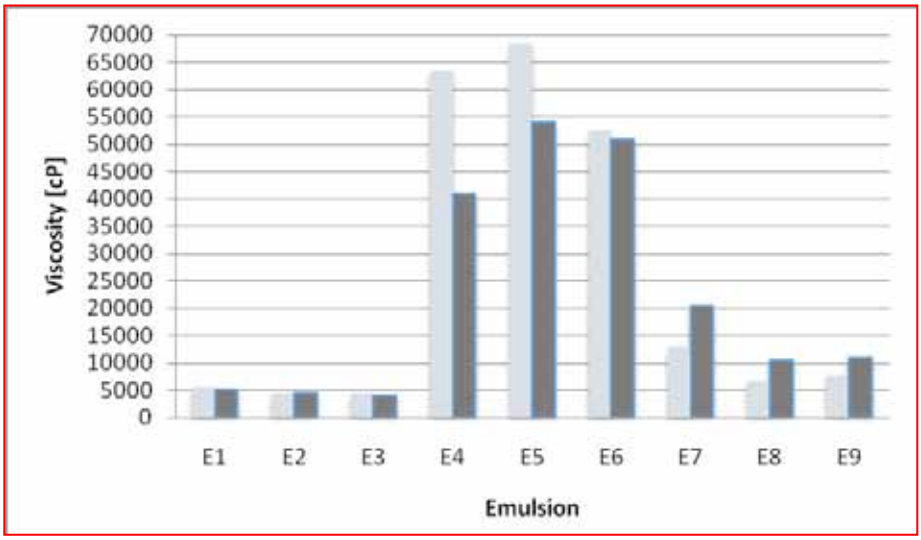

Fig. 4. Viscosity of the emulsions after 24 h from their manufacturing and 30 days of storage.

Rys. 4. Lepkośc emulsji po 24h od ich wytworzenia oraz po 30 dniach przechowywania.

Source: Own study

Źródło: Opracowanie własne

The microscopic analysis of the emulsion allows the observation of changes in the structure of the emulsion, e.g. changes in particle size. For an emulsion to be considered stable, it must have small droplets of similar size [5]. Figures 5,6,7 show photographs of the microscopic structure of the emulsion taken after 24 hours and after one month of storage.

Hemp oil emulsions (E1, E2, E3) were characterized by droplets of the smallest diameter after 24 hours from production. After one month of storage, no significant changes in droplet size were observed for these emulsions.

When analyzing the size and distribution of the dropets of emulsions containing mixed fat, it was observed that the emulsion dropets had a larger size than the dropets of the hemp oil-based emulsion (Figure 6). Numerous dropet clusters were also observed in the emulsions as a result of the merging of smaller individual drops. The droplet size was not affected by the amount of algae protein added to the emulsion.

The droplet size in the E7-E9 emulsions was also varied (Figure 7). The dropets had a different size after 24 hours from preparation and additionally changed their size after the storage period. The shape of the droplets after the storage period was definitely irregular and heterogeneous. The E8 and E9 emulsions were characterized by large dropets both after 24 hours and after one month of storage. The variant of the E7 emulsion was characterized by the smallest dropets among other emulsions based on interesterified fats. This emulsion contained the lowest amount of algae protein. On the other hand, the greatest heterogeneity of the system was observed for the emulsion with the highest addition of protein (1.2 g).

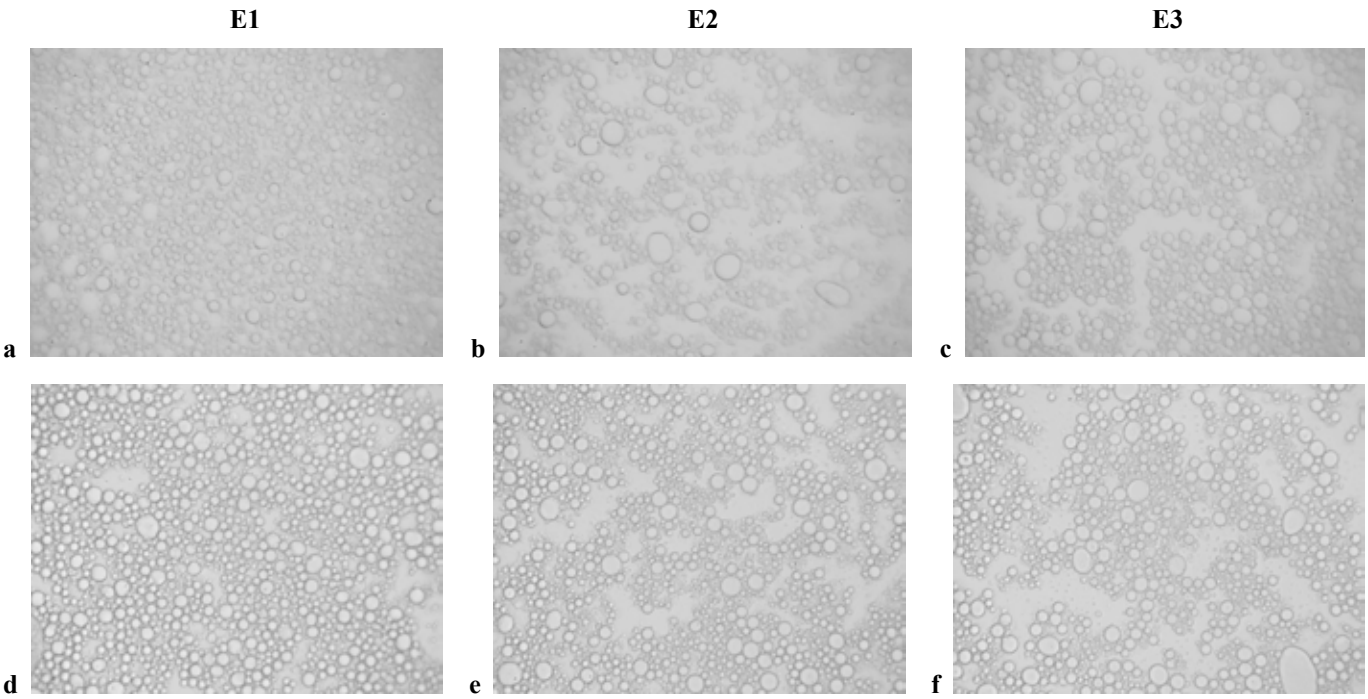

Fig. 5. Microphotographs of the prepared emulsions (E1, E2, E3) (G x 400) (a, b, c – after 24h from manufactoring and d, e, f – after 30 days).

Rys. 5. Zdjęcia emulsji (E1, E2, E3) wytworzonych po 24 godzinach (a, b, c) i po okresie 30 dniowym (d, e, f) (G x 400).

Source: Own study

Źródło: Opracowanie własne

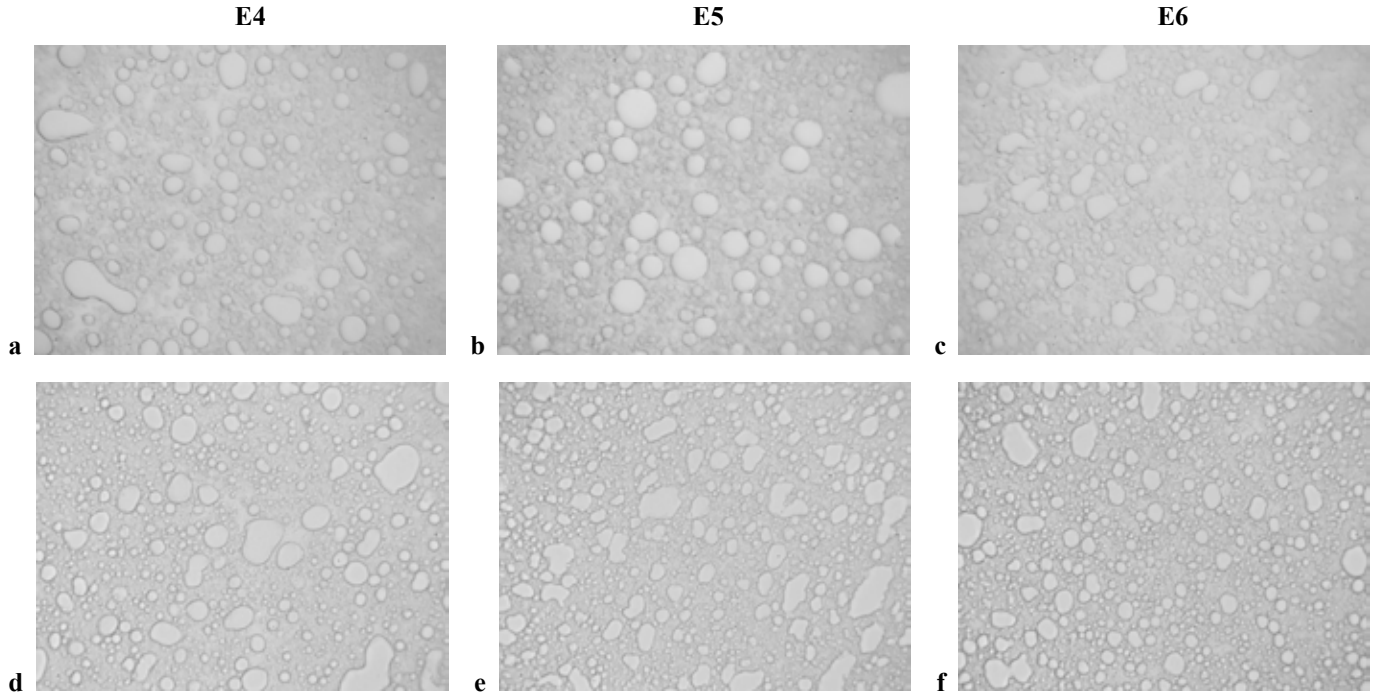

Fig. 6. Microphotographs of the prepared emulsions (E4, E5, E6) (G x 400) (a, b, c – after 24h from manufactoring and d, e, f – after 30 days).

Rys. 6. Zdjęcia emuslji (E4, E5, E6) wytworzonych po 24 godzinach (a, b, c) i po okresie 30 dniowym (d, e, f) (G x 400).

Source: Own study

Źródło: Opracowanie własne

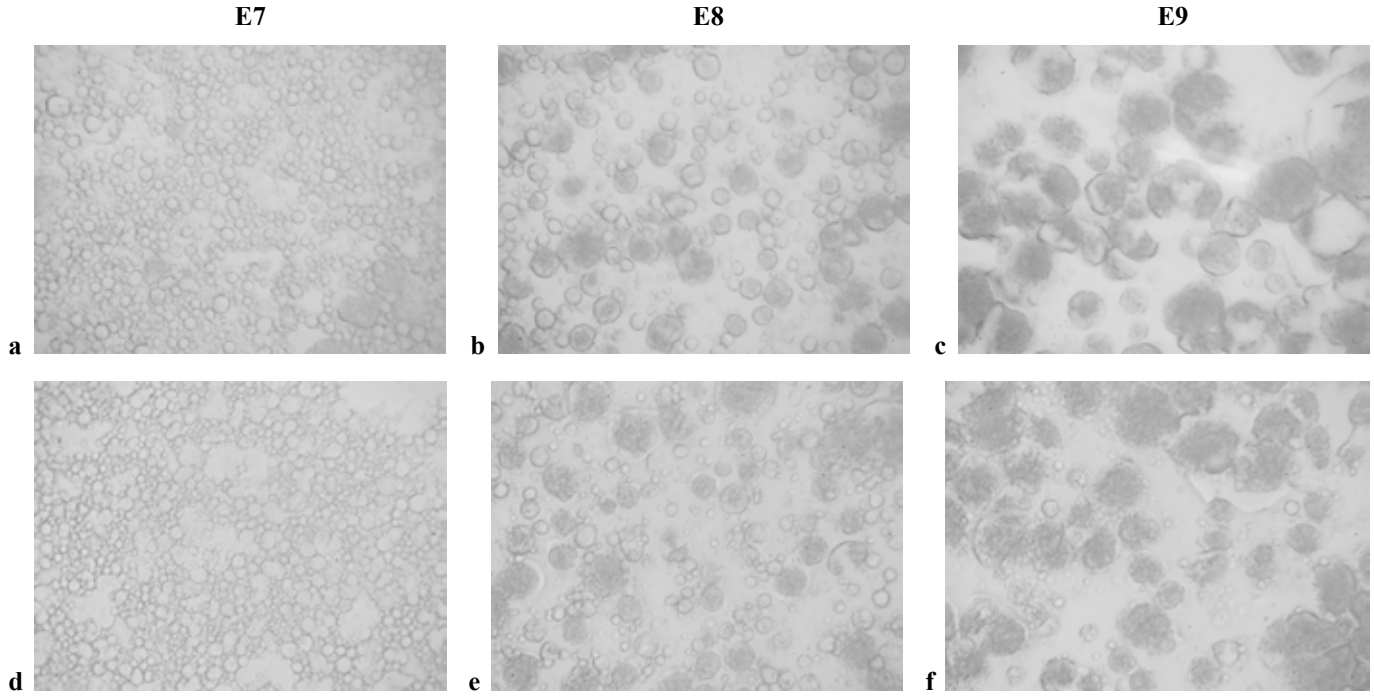

Fig. 7. Microphotographs of the prepared emulsions (E7, E8, E9) (G x 400) (a, b, c – after 24h from manufactoring and d, e, f – after 30 days).

Rys. 7. Zdjęcia emulsji (E7, E8, E9) wytworzonych po 24 godzinach (a, b, c) i po okresie 30 dniowym (d, e, f) (G x 400).

Source: Own study

Źródło: Opracowanie własne

The stability of the dispersion system is one of the most important parameters determining the possibility of its introduction to the market. Testing the emulsion with the Turbiscan test allows you to detect any instabilities in the early phase that are invisible to the naked eye. Turbiscan determinations, based on transmitted (T) and backscattered (BS) light intensity was used to analyze the stability or any instabilities occurring in manufactured emulsions. Figures 7,8,9,10 show backscattered light intensity profiles of the all emulsions. The backscattered light intensity is related to the stability of an emulsion – more precisely to the physical processes occurring during storage. The profiles are presented in a reference mode, which means that the initial scan is presented as a baseline (ΔBS = 0%). When analyzing the intensity of the backscattered light for the emulsions E1, E2, E3, a decrease in the intensity was observed, especially in the lower part of the vial (Figure 7). There was light transmission through the vial. Such changes determine creaming type instabilities. Generally, the destabilization process for all the mentioned emulsions started on the fifth day on average. The following days, with different dynamics, deepened these changes. There was no effect of protein content for these systems. The confirmation of the destabilization changes that occurred for these systems was the visual assessment, which showed a clear delamination of the emulsions E1, E2, E3 after a 30-day storage period (Figure 8).

In turn, for emulsions containing mixed fat, changes in the size of the emulsion particles were observed. The curves recording changes from individual measurements did not overlap. The center of the graphs clearly indicated the separation of individual lines, which confirmed that with each measurement of the particle size it increased. The graphs for the individual emulsions E4, E5, E6 looked similar, therefore it can be assumed that the variable content of protein from algae did not affect the stability of these systems. However, the above changes were not observable during the visual evaluation of these emulsions (Figure 10).

When analyzing the graphs for emulsions (E7, E8, E9), a decrease in the intensity of backscattered light was observed, similarly to the first three emulsions (Figure 11).

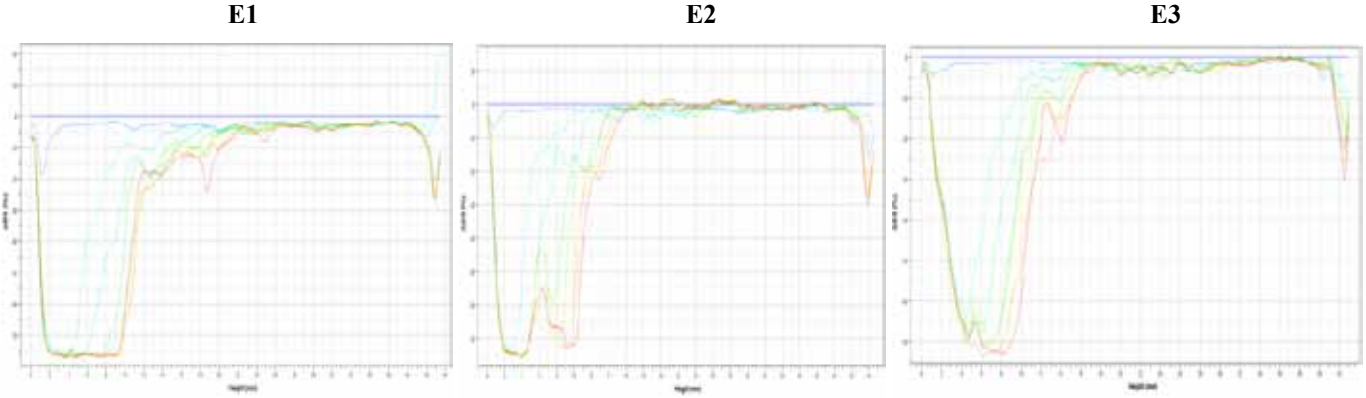

Fig. 8. Backscattered light intensity profiles of the prepared emulsions in reference mode E1, E2, E3.
Rys. 8. Krzywe przedstawiające natężenie światła wstecznie rozproszonego dla emulsji E1, E2, E3.
Source: Own study
Źródło: Opracowanie własne

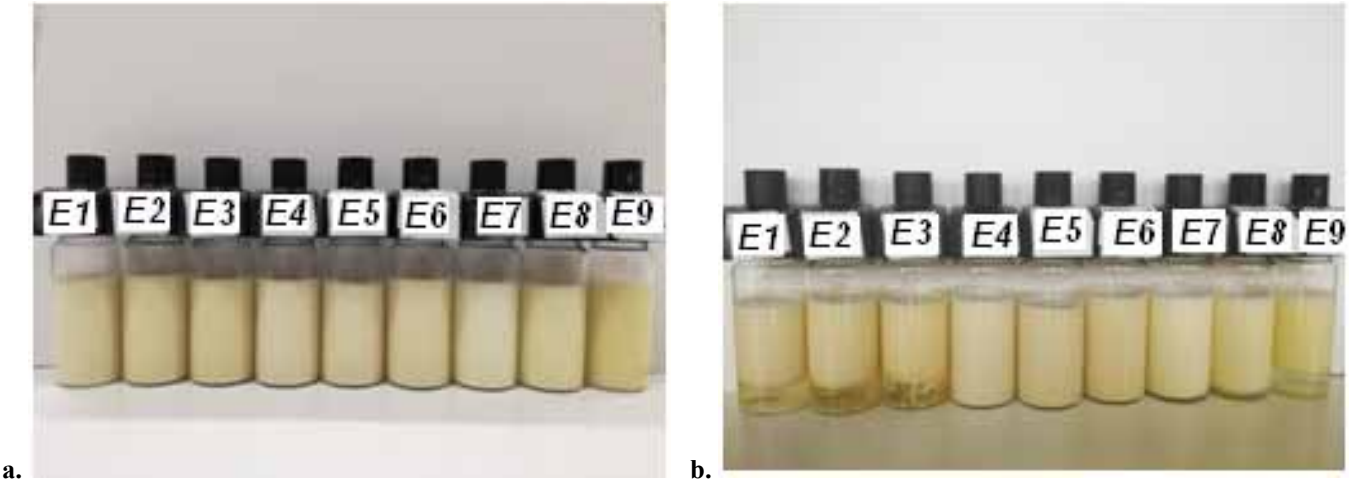

Fig. 9. Visual appearance of the emulsions a) after 24h, b) after 30 days of storage.
Rys. 9. Wizualna ocena emulsji a) po 24h b) po 30 dniach przechowywania.
Source: Own study
Źródło: Opracowanie własne

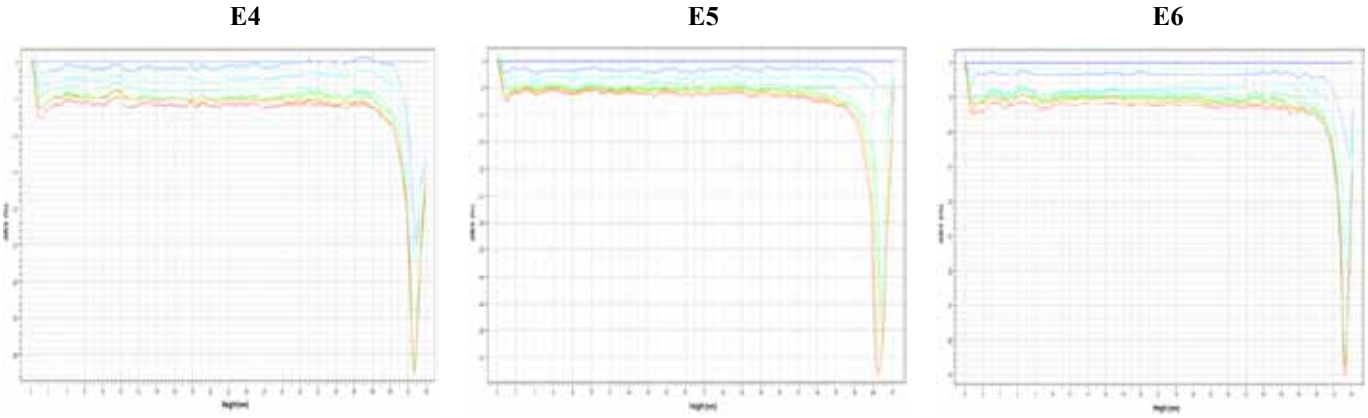

Fig. 10. Backscattered light intensity profiles of the prepared emulsions in reference mode E4, E5, E6.
Rys. 10. Krzywe przedstawiające natężenie światła wstecznie rozproszonego dla emulsji E4, E5, E6.
Source: Own study
Źródło: Opracowanie własne

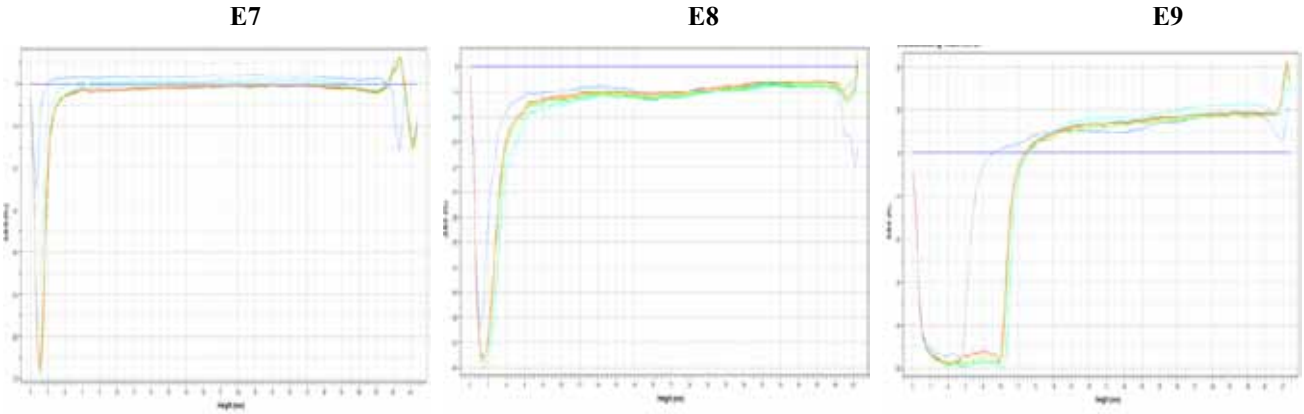

Fig. 11. Backscattered light intensity profiles of the prepared emulsions in reference mode E7, E8, E9.
Rys. 11. Krzywe przedstawiające natężenie światła wstecznie rozproszonego dla emulsji E7, E8, E9.
Source: Own study
Źródło: Opracowanie własne

For emulsions E7 and E8, these changes are subtle and poorly perceptible during visual assessment (Figure 8). On the other hand, the record for emulsion 9 is synonymous with the creaming process started early and it is deepened during subsequent determinations (increase in the transmission of light transmitted through the vessel, in the lower part). For emulsions where the fat phase was interesterified fat, the worse stability was observed when the protein content was the highest, i.e. 1.2 grams. Thus, the higher algae protein content was not a good stabilizer or viscosity modifier for these systems.

SUMMARY AND CONCLUSIONS

The colorimetric examination showed that all emulsion variants showed a distinct shade of green. As the algae protein content in the emulsions increased, the color approached yellow.

The highest hardness values among the prepared preparations had emulsions based on mixed fats, and the lowest ones based on hemp oil. In emulsions with the lowest content of algae protein (0.4 g) apart from E3 emulsion, the hardness was the highest.

The highest values of the adhesion force were characteristic for emulsions based on mixed fats, which means the best application properties of these systems. The lowest values were recorded for hemp oil-based emulsions. The variable amount of added algae protein to the emulsion had no major impact on this parameter.

The emulsions containing mixed fat as the fat base were characterized by the highest viscosity values. On the other hand, the lowest values of this parameter were recorded for emulsions based on hemp oil. The unequivocal effect of the algae protein in the systems on the viscosity was not determined.

In the microscopic examination, the dropets of the fat phase of the E7 emulsion containing the interesterified fat and 0.4 g of protein had the smallest particle. The droplet size increased with the addition of protein in all emulsions.

The analysis of the backscattered light intensity showed that all hemp oil based emulsions showed destabilization characteristics throughout the storage period. On the other hand, the results of the analysis of the turbiscan test for emulsions based on mixed fats showed an increase in the size of the emulsion particles over time, although no clear destabilization

of these systems was recorded. Poor emulsion stability was also observed for emulsions containing interesterified fats. Changes in the „creaming" type were observed in all systems. The higher addition of algae protein significantly worsened the stability of these systems.

The study did not manage to select an emulsion with high stability, therefore, in order to create more stable systems, the research should be extended to change the amount or type of protein, or to select a different viscosity modifier.

PODSUMOWANIE I WNIOSKI

Badanie kolorymetryczne wykazało, że wszystkie warianty emulsji wykazywały wyraźną tonację zabarwienia zielonego. Wraz ze wzrostem zawartości białka z alg w emulsjach barwa zbliżała się do żółtej.

Najwyższymi wartościami twardości spośród przygotowanych preparatów charakteryzowały się emulsje na bazie mieszaniny fizycznej, zaś najniższymi emulsje na bazie oleju konopnego. W emulsjach z najmniejszą zawartością białka z alg (0,4 g) poza emulsją E3, twardość była najwyższa.

Najwyższymi wartościami siły adhezji charakteryzowały się emulsje sporządzone na bazie tłuszczów mieszanych, co oznacza najlepsze właściwości aplikacyjne tych układów. Najniższe wartości zanotowano dla emulsji na bazie oleju konopnego. Zmienna ilość dodanego białka z alg do emulsji nie miała kluczowego wpływu na ten parametr.

Najwyższymi wartościami lepkości charakteryzowały się emulsje zawierające jako bazę tłuszczową mieszaninę fizyczną oleju konopnego z łojem baranim. Natomiast najniższe wartości tego parametru zanotowano dla emulsji na bazie oleju konopnego. Nie udało się określić jednoznacznego wpływu białka z alg w układach na wartość lepkości.

W badaniu mikroskopowym krople fazy tłuszczowej emulsji E7 zawierającej tłuszcz przeestryfikowany i 0,4g białka, posiadały najmniejszą cząstkę. Rozmiar kropel wzrastał wraz z dodatkiem białka we wszystkich emulsjach.

Analiza natężenia światła wstecznie rozproszonego wykazała, że wszystkie emulsje na bazie oleju konopnego wykazywały cechy destabilizacji w całym okresie przechowywania. Z kolei rezultaty analizy testu turbiscan dla emulsji na bazie tłuszczów mieszanych wykazały przyrost wielkości cząstek emulsji w czasie, aczkolwiek nie zarejestrowano wyraźnej destabilizacji tych układów. Słaba stabilność emulsji również została zaobserwowana dla emulsji zawierających tłuszcze. We wszystkich układach zaobserwowano zmiany typu „śmietankowania". Wyższy dodatek białka z alg wyraźnie pogorszył stabilność tych układów.

W pracy nie udało się wytypować emulsji o wysokiej stabilności, dlatego w celu stworzenia bardziej stabilnych układów należy rozszerzyć badania w kierunku zmiany ilości lub rodzaju białka, bądź wytypowania innego modyfikatora lepkości.

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CONSUMER ATTITUDES TOWARDS NOVEL TECHNOLOGIES IMPLEMENTED IN FOOD PRODUCTION ACROSS SELECTED REGIONS OF POLAND®

Postawy konsumentów wobec nowych technologii wykorzystywanych w produkcji żywności w wybranych regionach Polski®

The objective of the research was to determine the degree of and conditions for food technology neophobia among consumers in selected regions of Poland. The research was conducted in 2019 in Podkarpackie (150 people), Mazowieckie (161) and Zachodniopomorskie (149) voivodeships, using a survey method. The results obtained show a difference in the respondents' attitudes towards novel technologies depending on the region. The highest level of neophobia was observed among the residents of Podkarpackie voivodeship, with moderate levels displayed in Zachodniopomorskie voivodeship and the people of Mazowieckie voivodeship being the most accepting of novel food technologies. Different conditions for consumer attitudes towards novel food technologies have been observed in the analysed regions as well.

Key words: food technology neophobia, Polish consumers.

Celem przeprowadzonych badań było określenie poziomu i uwarunkowań food technology neophobia wśród konsumentów z wybranych regionów Polski. Badania przeprowadzono w roku 2019 na terenie województw Podkarpackiego (150 osób), Mazowieckiego (161) i Zachodniopomorskiego (149) metodą ankietową. Uzyskane w efekcie badań wyniki świadczą o zróżnicowaniu postaw respondentów w stosunku do nowych technologii produkcji żywności w zależności od regionu. Najbardziej neofobiczni okazali się być mieszkańcy województwa Podkarpackiego, umiarkowanie wysoki poziom food technology neophobia stwierdzono w grupie badanych z województwa Zachodniopomorskiego, a najwyższy poziom akceptacji dla nowych technologii wyrazili mieszkańcy województwa Mazowieckiego. W analizowanych regionach stwierdzono także odmienność uwarunkowań postaw respondentów w odniesieniu do nowych technologii.

Słowa kluczowe: neofobia technologiczna, polscy konsumenci.

INTRODUCTION

Novel technologies used in food production spark different reactions from consumers [2, 13]. Consumer attitudes towards products manufactured with novel technologies can be illustrated with two extremes. The first one is approval of novel products, while the other consists in denial of the new and exhibiting preference for conventional products [6, 11]. A majority of consumers lack sufficient knowledge regarding the technologies used in food production, which in turn significantly hinders the acceptance of said technologies [3, 10]. A positive consumer attitude towards novel technologies depends on the perceived risks and benefits attached to it [1]. Some technologies, such as genetic engineering, cause consumer backlash due to being perceived as a source of unknown and dangerous risk [12], which corresponds in a negative manner to the approval and willingness to consume the product [15].

Food Neophobia Scale (FNS) was used to assess consumer attitudes towards novel food products [9, 14]. However, it is not designed to measure the degree of approval for novel food production technologies [7]. That is why, under the Food Futures National Research Flagship Project, Cox and Evans [5] have developed the Food Technology Neophobia Scale (FTNS) - a psychometric tool for measuring the level of technology neophobia. The final 13 item scale was developed from studies on almost one thousand Australian consumers. It was later tested [10] and found to be stable over time. The scale comprises 13 items with which participants are asked to agree or disagree using a seven-point bi-polar scale anchored 'totally disagree' to 'totally agree', with a labelled mid-point of 'neither agree nor disagree'. Higher scores indicate greater neophobia. Items 10, 11, 12, and 13 need to be reverse-scored.

The body of research into measuring food technology neophobia and, consequently, knowledge on its conditioning

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factors are not very extensive. The research conducted thus far has shown that food technology neophobia levels are higher among women and people living in small towns and rural areas [4], that technology neophobia increases with age and is inversely correlated to income and education level [16], and that people living in large households are more inclined towards food technology neophobia [8].

So far, there have been no attempts to measure the relationship between the region of residence and the approval for new food production technologies. Determining this link could be significant empirically, as well as in the area of practical application, e.g. for developing marketing strategies for innovative products. For this reason, research has been undertaken to determine the differences in levels of and conditions for food technology neophobia in selected regions of Poland.

MATERIALS AND METHODOLOGY

The survey was conducted in 2019 on a sample of 460 adults from the following voivodeships: Mazowieckie – in central Poland (161 respondents), Podkarpackie – in the south of Poland (150) and Zachodniopomorskie – in the north-west of the country (149). The voivodeships have been selected arbitrarily, due to their diverse geographic, economic and social characteristics. Quota sampling method was employed – the respondents were selected so that the sample structure was analogous to the respective region's in terms of gender, age and area of residence (urban/rural). Characteristics of the studied population are presented in Table 1.

Survey method was used for the research. The questionnaire consisted of 13 statements constituting a scale for measuring food technology neophobia and a set of questions to determine the demographic (gender, age, area of residence), economic (income) and socio-professional (education) characteristics of the studied population. Diverse methods for questionnaire distribution were employed (on-line survey, group administered questionnaire, household drop-off survey).

As per the premise of food technology neophobia measurement, the degree of compliance with each statement was expressed by the respondents on a 7-tier scale, 1 signifying they 'totally disagree' with the statement and 7 meaning they 'totally agree' with it. Based on the assessment of compliance with each statement, individual levels of food technology neophobia were calculated; then, mean value of the sums (X) and standard deviation (Sd) were determined. On such basis, three intervals of food technology neophobia were determined for each region:

- low (neophiliac attitude): 13 pts $<X - Sd$,
- moderate (neutral attitude): $X - Sd< X +Sd$,
- high (neophobic attitude) $\geq X + SD \leq 91$.

The following statistical analyses included calculating mean values and frequencies, as well as cross tabulation. Statistical significance of differences between variables was determined with the Chi^2 test ($p<0,05$). Correlation strength between variables was determined by using Pearson correlation coefficient ($p<0,05$). The statistical analysis was performed with the SPSS 2014 program.

RESEARCH RESULTS

Analysing the agreement of the respondents from each voivodeship with the statements included in the food technology neophobia scale has shown, that respondents from Podkarpackie voivodeship exhibit the highest level of agreement across all statements. Respondents from Zachodniopomorskie voivodeship have declared moderate agreement, and those from Mazowieckie voivodeship agreed with the statements to the least degree. As a result of the recorded differences in evaluating agreement with the statements, the level of technology neophobia, too, was

Table 1. Characteristics of the studied population

Tabela 1. Chrakterystyka badanej populacji

Specification		Podkarpackie voivodeship	Mazowieckie voivodeship	Zachodniopomorskie voivodeship
Number of respondents		150	161	149
Gender (%)	Women	50.1	52	50.9
	Men	49.9	48	49.1
Age (%)	18 – 35 years old	26.4	32.8	31.6
	36 – 55 years old	32.4	33.7	33.8
	>55 years old	41.2	33.5	34.6
Education (%)	Primary and vocational	56.3	35.4	36.7
	Secondary	26.3	37.2	38.7
	Higher	17.4	27.4	24.6
Area of residence (%)	Rural	58.3	36	31.4
	Urban	41.7	64	68.6
Income (%)	<2000 zł	55.4	32.1	51.2
	2000 zł – 3500zł	25.3	39.3	30.5
	>3500 zł	19.3	28.6	18.3

Source: Own research

Źródło: Badania własne

Table 2. Mean* rating of agreement with the statements included in technology neophobia scale and level of neophobia in the studied voivodeships

Tabela 2. Średnia* ocena zgodności ze stwierdzeniami zawartymi w skali neofobii technologicznej i poziom neofobii w badanych województwach

No.	Statements	Podkarpackie voivodeship	Mazowieckie voivodeship	Zachodniopomorskie voivodeship
1.	There are plenty of tasty foods around so we don't need to use food technology to produce more	4.5	3.2	3.3
2.	The benefits of new technologies are often grossly overstated	4.8	3.5	3.8
3.	New food technologies decrease the natural quality of food	4.7	3.2	3.5
4.	There is no sense in trying out high-tech food products because the ones I eat are already good enough	4.3	4.1	4.1
5.	New foods are not healthier than traditional foods	4.2	3.9	4.1
6.	New food technologies are something I am uncertain about	4.9	4.4	4.6
7.	Society should not depend heavily on technologies to solve its food problems	3.9	3.8	3.8
8.	New food technologies may have long term negative environmental effects	4.9	3.8	3.9
9.	It can be risky to switch to new technologies too quickly	4.3	4.2	4.2
10.	New food technologies are unlikely to have long term negative health effects (R**)	4.9***	4.2***	4.6***
11.	New products produced using new food technologies can help people have a balanced diet (R)	4.8***	3.9***	4.1***
12.	New food technologies give people more control over their food choice (R)	4.3***	3.4***	3.7***
13.	The media usually provides a balanced and unbiased view of new food technologies(R)	5.1***	4.5***	4.7***
Sum (novel food technology neophobia score)		59.7 (Sd 14.2)	49.9 (Sd 11.9)	52.5 (Sd 12.5)

* the scale from 1 – I strongly disagree to 7 – I strongly agree
** (R) the assessment of compliance with the statement was re-coded
*** value after reverse scored
* w skali od 1 – zdecydowanie się nie zgadzam do 7 zdecydowanie się zgadzam
** (R) ocena zgodności ze stwierdzeniem została zrekodowana
*** wartość po zrekodowaniu

Source: Own research

Źródło: Badania własne

the highest in Podkarpackie voivodeship (59,7), and lower in Zachodniopomorskie (52,5) and Mazowieckie (49,9) voivodeships (Table 2).

Upon determining limit values of neophobia level intervals for each voivodeship, percentages of respondents within each interval were calculated. The highest percentage of respondents exhibiting neophiliac attitude (approving of novel food production technologies) was recorded in Mazowieckie and Zachodniopomorskie voivodeships (nearly ¼ of the respondents), while the lowest percentage was recorded in Podkarpackie voivodeship (14,3%). This is the region where the highest percentage of people with neutral attitudes was recorded as well (71,3%), whereas the percentage of people with such attitude in the other two voivodeships was ca. 60%. As for the percentage of respondents reporting high levels of neophobia, it was the highest in Zachodniopomorskie voivodeship (18,6%); in other regions, people disapproving of novel technologies constituted around 14% of the respondents (Table 3).

Table 3. Share of respondents showing low, moderate and high approval for new food production technologies in the surveyed voivodeships

Tabela 3. Udział respondentów wykazujących niskie, umiarkowane i wysokie aprobaty dla nowych technologii produkcji żywności w badanych województwach

Novel food technology neophobia interval	Podkarpackie voivodeship (%)	Mazowieckie voivodeship (%)	Zachodniopomorskie voivodeship (%)
Low	14.3	23.6	23.2
Medium	71.3	62.1	58.2
High	14.3	14.4	18.6

Source: Own research

Źródło: Badania własne

Analysing conditions for food technology neophobia has shown that only in the case of Podkarpackie voivodeship gender played a differentiating role in respondents' attitudes towards novel technologies – women were significantly more inclined to approve of employing novel technologies in food production compared to men (food technology neophobia levels of 55,7 and 62,9 respectively). Across all the analysed regions, age was found to affect food technology neophobia levels, with the strongest correlation between the two variables recorded in Podkarpackie voivodeship (0,437), and the weakest in Zachodniopomorskie voivodeship (0,324). It should also be noted, that in all the voivodeships food technology neophobia level among the oldest age groups was significantly higher than the levels recorded in the remaining groups. Correlation between education level and attitude towards novel food production technologies was only recorded in Podkarpackie and Mazowieckie voivodeships – neophobia was inversely correlated to the education level (correlation strength of -0,378 and -0,311 respectively) Area of residence (urban/rural) had statistically significant influence over neophobia levels among the respondents from Podkarpackie and Zachodniopomorskie voivodeships - in both cases, rural area residents exhibited more neophobic attitudes. These two voivodeships are also where income was found to affect neophobia levels – respondents with the lowest income exhibited more neophobic attitudes than those who declared medium and high income (correlation strength of -0,479 and -0,321 respectively) (Table 4).

SUMMARY AND CONCLUSIONS

The conducted research has shown diverse attitudes towards novel food production technologies among the respondents depending on the region. Residents of Podkarpackie voivodeship have been found to exhibit the highest levels of neophobia, with moderate levels of food technology neophobia among the respondents from Zachodniopomorskie voivodeship, and the highest level of approval for novel food production technologies in Mazowieckie voivodeship.

Analysing the structure of neophobia level intervals has shown, that in Podkarpackie voivodeship, the largest percentage of respondents (compared to other regions) exhibited a moderate level of neophobia, with the smallest percentages representing low and high levels. In turn, Zachodniopomorskie voivodeship has the largest percentage of respondents in the high level interval, and the smallest percentage within moderate level interval. Mazowieckie voivodeship stood out with the largest percentage of respondents representing low neophobia level interval.

The recorded differences could be partially explained by distinct structure of the examined voivodeships in regard to gender, age, area of residence, education and income levels; however, the analyses conducted have shown that the influence of these factors on food technology neophobia in each voivodeship varies. Gender was a statistically significant factor differentiating neophobia levels only in Podkarpackie voivodeship; age – across all the analysed regions (positive correlation); education level – in Podkarpackie and Mazowieckie voivodeships (negative correlation); area of residence and income (negative correlation) – in Podkarpackie and Zachodniopomorskie voivodeships. Therefore, it can

Table 4. Conditions for technology neophobia level in the surveyed voivodeships

Tabela 4. Uwarunkowania poziomu neofobii technologicznej w badanych województwach

Specification		Podkarpackie Voivodeship		Mazowieckie voivodeship		Zachodniopomorskie voivodeship	
		Neophobia level	r*	Neophobia level	r*	Neophobia level	r*
Gender	Women	55.7a**		49.8a		52.7a	
	Men	62.9a		50.1b		52.3b	
Age	18 – 35 years old	56.3a		47.3a		49.9ab	
	36 – 55 years old	57.5b	0.437	48.5b	0.401	51.4b	0.324
	>55 years old	62.8ab		53.7ab		54.8a	
Education	Primary and vocational	62.4ab		52.6ab		52.1a	
	Secondary	56.5b	-0.378	48.7b	-0.311	52.9b	
	Higher	54.2a		47.9a		52.4c	
Area of residence	Rural	63.5a		50.9a		56.3a	
	Urban	54.2a		49.2b		50.7a	
Income	>2000 zł	62.3ab		50.5a		54.1ab	-0.321
	2000zł – 3500zł	57.1b	-0.379	49.9b		51.2b	
	< 3500 zł	56.3a		49.3c		51.1a	

* Pearson correlation coefficient ($p<0,05$)

** values in the cell marked with the same letter differ with statistical significance, Chi^2 test, $p<0,05$

* współczynnik korelacji Pearsona ($p<0,05$)

** wartości w komórce oznaczone tą samą literą różnią się istotnie statystycznie, test Chi2, $p <0,05$

Source: Own research

Źródło: Badania własne

be inferred that the differences in perception of novel food production technologies in the examined voivodeships are to a significant degree caused by worldview and psychological factors.

Due to its sample not being representative, the research may be considered a poll; however, its results might inspire further exploration of the problem it tackles, particularly conducting research on larger, representative populations, accounting for psychographic aspects of consumer behaviors and referencing specific types of technological innovations.

PODSUMOWANIE I WNIOSKI

Przeprowadzone badania wykazały zróżnicowanie postaw respondentów w stosunku do nowych technologii produkcji żywności w zależności od regionu. Najbardziej neofobiczni okazali się być mieszkańcy województwa Podkarpackiego, umiarkowanie wysoki poziom food technology neophobia stwierdzono w grupie badanych z województwa Zachodniopomorskiego, a najwyższy poziom akceptacji dla nowych technologii w produkcji żywności wyrazili mieszkańcy województwa Mazowieckiego.

Analiza struktury przedziałów neofobii wykazała, że na Podkarpaciu największy odsetek respondentów (w stosunku do pozostałych regionów) charakteryzował się średnim poziomem neofobii, zaś najniższe odsetki reprezentowały przedziały niski i wysoki. Z kolei w województwie Zachodniopomorskim największy odsetek badanych zaliczony został do przedziału wysokiego, a najniższy do średniego. Województwo Mazowieckie wyróżniał najwyższy odsetek badanych reprezentujących niski przedział neofobii.

Stwierdzone różnice można byłoby częściowo wyjaśnić odmienną strukturą badanych województw ze względu na płeć, wiek, miejsce zamieszkania, poziom wykształcenia i dochodu, jednakże przeprowadzone analizy wykazały, że oddziaływanie tych determinant na poziom food technology naophobia w poszczególnych województwach jest zróżnicowane. Płeć istotnie statystycznie różnicowała poziom neofobii jedynie w województwie podkarpackim, wiek we wszystkich analizowanych regionach (korelacja pozytywna), poziom wykształcenia w województwach podkarpackim i mazowieckim (korelacja negatywna), zaś miejsce zamieszkania i dochód (korelacja negatywna) województwach podkarpackim i zachodniopomorskm. Można więc wnioskować, że przyczyną różnic w postrzeganiu nowych technologii wytwarzania żywności w badanych województwach są w istotnym stopniu względy o charakterze psychologicznym i światopoglądowym.

Przeprowadzone badanie ze względu na brak reprezentatywności próby można uznać za sondażowe, jednakże jego wyniki mogą stanowić inspirację do dalszej eksploracji podjętej problematyki, w tym szczególnie realizacji badań na większych, reprezentatywnych populacjach, uwzględniających aspekty psychograficzne zachowań konsumentów oraz odnoszących się do specyficznych rodzajów innowacji technologicznych.

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EFFECT OF THE ADDITION OF OAT AND WHEAT FIBER ON THE QUALITY OF POULTRY BURGERS®

Wpływ dodatku błonnika owsianego i pszennego na jakość burgerów drobiowych®

The article presents the results of research concerning the assessment of the effect of adding oat and wheat fiber on the quality of poultry burgers with a constant raw material composition. The physical and sensory characteristics of three product variants were assessed after baking and 24 hours of storage. It was shown that the addition of 3% wheat and oat fiber in non-hydrated form to the recipe composition resulted in an increase in yield, increased shear force and color differentiation, positively affecting the intensity of smell and taste and increasing the product hardness.

Key words: oat fiber, wheat fiber, poultry burgers, quality.

W artykule przedstawiono prezentację wyników badań dotyczących wpływu dodatku preparatu błonnikowego owsianego i pszennego na jakość burgerów drobiowych o stałym składzie surowcowym. Cechy fizyczne i sensoryczne trzech wariantów produktów oceniono po upieczeniu i 24 godzinnym przechowywaniu. Wykazano, że wprowadzenie do składu recepturowego 3% błonnika pszennego i owsianego w postaci nieuwodnionej spowodowało wzrost wydajności, zwiększenie siły cięcia i zróżnicowanie barwy, wpływając pozytywnie na natężenie zapachu i smaku oraz zwiększając twardość produktu.

Słowa kluczowe: błonnik owsiany, błonnik pszenny, burgery drobiowe, jakość.

INTRODUCTION

In recent years, there has been an increase in consumer interest in functional food, which is related to the growing awareness of consumers about the proper diet and concern for their own health [1, 4, 8, 10]. In the Polish meat industry, measures are taken to improve the health quality of processed meat by introducing changes to the recipe composition. An ingredient approved for use in food processing is dietary fiber which is the residue of plant cell walls resistant to the action of digestive enzymes [3, 16]. It is a complex of heterogeneous substances such as digestible carbohydrates, lignin, oligosaccharides, polysaccharides, celluloses, hydrocolloids and gums found in plants [12, 14]. Dietary fiber been used in meat processing not only due to its technological properties (the ability to bind water, fat, reducing thermal leakage), but primarily due to the health and dietary properties of the meat product [11, 13 16]. The fiber preparations used in convenient meat products are oat and wheat fibers [5, 6, 7, 14].

The aim of this paper is to present the results of research on the assessment of the effect of adding oat and wheat fiber on the quality of poultry burgers.

MATERIAL AND METHODS

Two experimental series were performed in which three variants of burgers with a constant composition were produced: thigh muscles of slaughter turkeys and, in relation to the weight of the meat raw material: water 7%, salt 1%, pepper 0.5%. The burgers differed in the additives applied in the form of oat and wheat fiber preparation (Look Food, Poland), calculated in relation to the meat mass, water and spices. The choice of meat was made due to the high nutritional value of turkey meat and its high usefulness in the production of ground poultry products. The raw meat came from the same producer. Raw materials were purchased once. The raw meat was ground in a meat grinder (Gastropuls, Poland) using a mesh with 3.5 mm hole diameter. The stuffing was mixed in a blender (Kenwood Major Titanium, USA), starting with mixing the raw meat, spices and water. The meat mass was divided into 3 parts. Burgers made from the mass without the addition of the fiber preparation made the control group, 3% of wheat and oat fiber in non-hydrated form were added to the other two parts. The meat masses were again mixed with the fibers applied. Burgers (about 80 g) were formed from the prepared meat masses using a manual molding machine, giving them the shape of flat discs with a diameter of about 80 mm and a height of 8 mm. Processing of the burgers was carried out in a hot-air electric oven at 180°C up to reaching 75°C at the product center, then cooling at room temperature for 24 hours, followed by a qualitative assessment. The assessment of physical properties took into account: the product yield using the gravimetric method, pH measurement made with a Hanna Polska pH meter (HIV° 99163), measurement of the shear force of 8×20×80 [mm] product samples using

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a Zwick/Roell testing machine (Zwick CmbH&Co.KG. Ulm, Germany), equipped with a Warner-Bratzler flat shear blade with a pre-force of 0.2 N and a head speed of 100 mm/min. The measurement of the color parameters on the surface of the burgers was done by the reflection method in the CIE colorimetric system (L*, a*,b*) using the Chroma Meter colorimeter (Konica Minolta Osaka, Japonia) standard parameter, observer D_{65}, 2º. The applied parameters of instrumental measurements were determined based on the preliminary tests results, each measurement was performed in triplicate and the obtained results were averaged. The sensory evaluation of burger quality was performed according to the methodology of Baryłko-Pikielna and Matuszewska [2]. A 5-point rating on an ascending scale was used, including the following qualitative indices: intensity and desirability of taste and smell, juiciness, tenderness, bonding, texture, structure and overall desirability. The burger samples were coded and assessed in random order. The sensory evaluation was carried out by a 7-person evaluation team in duplicate. Results obtained were statistically analysed with the analysis of variance ANOVA using the Statistica 13.1 software package [18]. The arithmetic mean ($\bar{x}$) and standard deviation (SD) were determined. To indicate the significance of differences between means in groups, the Tukey's post hoc test with a level of significance $p < (0.05)$ was applied.

RESULTS AND DISCUSSION

The present study showed that the addition of oat and wheat fiber significantly ($p \leq 0.05$) increased the yield of the product after heat treatment (Table 1). It can be assumed that the vegetable fiber used in the production of poultry burgers managed to bind cell juice and added water. The results concerning the effect of cereal fibers on the yield of burger meat products are not conclusive [6, 14]. The study by Cegiełek and Młynarczyk [7] showed an increase in the yield of hamburgers obtained from chicken meat with the addition of at least 2% Vitacel® VF400 wheat fiber. In contrast, Cegiełka et al. [5] and Miazek et al. [14] showed that the addition of 3% of an oat fiber preparation in the non-hydrated form for poultry burger production and 1.5% and 2.5% addition of an oat fiber preparation to homogenized poultry sausage did not significantly increase the product yield.

The type of dietary fibre used, the degree of grinding and the fractional composition may influence the texture characteristics of the product [5, 8, 19]. The present study showed that the addition of fiber preparations strengthened the structure and increased ($p \leq 0.05$) the hardness of poultry burgers (Table 1). Dasiewicz et al. [9] showed, however, that the shear force of poultry fingers depended on the type of a wheat fiber preparation. The usefulness of various oat fiber preparations for shaping the texture of meat products is confirmed by the results obtained by Miazek et al. [14], Verma and Banerjee [9] and Cegiełka et al. [6]. According to the authors, the increase in hardness of poultry sausages, Bolognese sausage (mortadella) and pork hamburgers, respectively, was obtained by adding a fiber preparation to the stuffing in the amount of 2.5%, 3.0% and 6.0%, respectively. To shape the instrumental hardness of meat products, attempts were made to apply oat flour to low-fat chicken meat nuggets [17]. Cegiełka et al. [5], in turn, showed no effect of oat fiber addition on the texture of beef and pork hamburgers.

The color parameters of the surface of burgers with the additives used were characterized by lower color saturation towards red (a*) and higher saturation of yellow color (b*) compared to burgers without additives (Table 1). As demonstrated by Cegiełka et al. [5], the color of the surface of beef and pork hamburgers differed significantly in relation to the amount of the oat fiber preparation used. The hamburgers to which 3% and 6% oat fiber were added were characterized by a brighter color and significantly higher saturation towards yellow compared to the control products, as well as to those with the addition of 1.5% oat fiber. Similarly, Miazek et al. [14] showed a tendency to increase the color lightness of sausages with increasing the amount of an added oat fiber preparation.

The present study showed (Table 2) that the addition of oat and wheat fiber had a positive effect on the intensity of the smell and taste of poultry burgers compared to the product without additives. Moreover, poultry burgers with the addition of oat fibre were characterized by a higher intensity of smell. The fiber additives used in the recipe composition

Table 1. The effect of addition oat and wheat fiber the physical characteristics of the quality of poultry burgers
Tabela 1. Wpływ dodatku błonnika pszennego i owsianego na fizyczne wyróżniki jakości burgerów drobiowych

Parameter	Variant of burgers		
	without additionals	wheat fiber	oat fiber
Yield after heat treatment [%]	81,12b±3,18	84,34a±4,17	83,62a±5,14
pH	6,17±0,06	6,14±0,09	6,15±0,07
Shear force [N]	10,80b±2,80	14,80a±2,12	16,01a±4,10
Colour:			
L*	53,10 ±4,12	54,86 ± 3,14	56, 20 ± 3,52
a*	14,15a ±2,15	10,95b ± 2,60	11,08b ± 1,80
b*	13,10b ±3,86	18,02a ± 2,01	16,92a ± 2,53

Explanations: ($\bar{x}$ ± s) arithmetic mean±standard deviation, the mean values in rows with different letters differ significantly $p \leq 0.05$
Objaśnienia: ($\bar{x}$ ±s) średnia arytmetyczna ± odchylenie standardowe, wartości średnie oznaczone różnymi literami w wierszach różnią się statystycznie istotnie przy $p \leq 0.05$

Source: The own study
Źródło: Badania własne

Table 2. The effect of addition oat and wheat fiber on sensory quality characteristics of poultry burgers [points]
Tabela 2. Wpływ dodatku błonnika pszennego i owsianego na cechy sensoryczne burgerów drobiowych [punkty]

Traits	Variant of burgers		
	without additionals	wheat fiber	oat fiber
odour intensity	3,80b ± 0,32	4,38a ± 0,54	4,58a ± 0,38
flavour intensity	3,85b ± 0,80	4,58a ± 0,54	4,80a ± 0,65
odour desirability	3,60b ± 0,85	4,16 ± 0,48	4,80a ± 0,65
flavour desirability	3,60 ± 1,00	4,00 ± 0,93	4,38 ± 0,68
juiciness	4,38± 0,54	4,00 ± 0,80	4,00 ± 0,44
tenderness	4,62a ± 0,50	4,20b ± 0,60	4,00b ± 0,42
connection	4,16 ± 0,54	4,20 ± 0,85	4,38± 0,44
consistenc	4,62 ± 0,62	4,38 ± 0,58	4,33 ± 0,40
structure	4,38 ± 0,48	4,38 ± 0,48	4,42 ± 0,56
total desirability	3,70b ± 0,44	4,28 a ± 0,54	4,40a ± 0,70

Explanations: ($\bar{x}$ ± s) arithmetic mean±standard deviation, the mean values in rows with different letters differ significantly $p \leq 0.05$
Objaśnienia: ($\bar{x}$ ±s) średnia arytmetyczna ± odchylenie standardowe, wartości średnie oznaczone różnymi literami w wierszach różnią się statystycznie istotnie przy $p \leq 0.05$

Source: The own study
Źródło: Badania własne

reduced the tenderness of the product but did not worsen the overall sensory desirability of poultry burgers compared to the control product. The literature data [5, 6, 13, 15] show that the selection of the type and amount of a fiber preparation should be individually adjusted to the type of a meat product. A beneficial effect of the addition of 2.5% oat preparation on the smell, color and consistency of poultry sausages was demonstrated by Miazek et al. [14]. Cegiełka et al. [5] and Cegiełka et al. [6] taking into account the assessment of the structure and consistency, indicated that the amount of dietary fiber additive for hamburger stuffing with the adopted recipe composition should not exceed 3.0%. Moreover, there were no differences in the assessment of the smell, taste, juiciness and general desirability of products with and without the addition of fiber.

CONCLUSION

Poultry burgers with the addition of oat and wheat fiber were characterized by a higher yield, greater hardness and lower color saturation towards red (a*) and a higher proportion of yellow (b*) in the overall color tone compared to burgers without additives.

The additives applied in the form of oat and wheat fiber preparations had a positive effect on the intensity of smell and taste. Burgers with the addition of oat fiber were characterized by higher aroma desirability. Introduction of oat and wheat fiber to the recipe composition of poultry burgers resulted in an increase in hardness without adversely affecting the overall desirability of the product.

This study indicates the need to continue research on the use of oat and wheat fiber preparations for the production of delicatessen meat products.

PODSUMOWANIE

Burgery drobiowe z dodatkiem błonnika owsianego i pszennego cechowały się wyższą wydajnością, większą twardością oraz niższym wysyceniem barwy w kierunku czerwieni (a*) i wyższym udziałem barwy żółtej (b*) w ogólnym tonie barwy w porównaniu do burgerów bez dodatków.

Zastosowane dodatki preparatów błonnika owsianego i pszennego wpłynęły pozytywnie na natężenie zapachu i smaku. Większą pożądalnością zapachową charakteryzowały się burgery z dodatkiem błonnika owsianego. Wprowadzenie błonnika owsianego i pszennego do składu recepturowego burgerów drobiowych spowodowało zwiększenie twardości, nie wpływając negatywnie na ogólną pożądalność produktu.

Przeprowadzone badania wskazują na konieczność kontynuowania badań dotyczących wykorzystania preparatów błonnika owsianego i pszennego do produkcji mięsnych wyrobów garmażeryjnych.

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MANAGEMENT OF INNOVATIVE EVALUATION TECHNIQUES SELECTED QUALITY PARAMETERS IN INDUSTRY FOOD®

Zarządzanie innowacyjnymi technikami oceny wybranych parametrów jakości w przemyśle spożywczym®

The meat industry is looking for quick evaluation methods due to the fact that meat has a relatively short shelf life and is subject to rapid technological changes, e.g. under the influence of storage conditions. The reference methods, despite the relatively short time of analysis, do not determine the accuracy of measurements. In order to ensure the repeatable quality of meat, it is necessary to search for new evaluation methods that will eliminate, among others, subjectivity resulting from the human factor and will allow for quick results. In the case of using computer-based evaluation methods, it is important to obtain a good-quality, distortion-free image of the test sample as well as proper classification and recognition of the recorded images. The article analyzes the content of fat visible in poultry meat using the traditional method – organoleptic, and using visual techniques – computer analysis image. A computer application based on the RGB model to recognize individual colors was used for the tests.

Key words: computer image analysis, innovation management, quality assessment methods, poultry production.

Przemysł mięsny poszukuje szybkich metod ocen ze względu na to, iż mięso ma stosunkowo krótki termin przydatności do spożycia oraz szybko ulega zmianom technologicznym, np. pod wpływem warunków przechowywania. Metody referencyjne, mimo stosunkowo krótkiego czasu analiz, nie odznaczają się dokładnością pomiarów. W celu zapewnienia powtarzalnej jakości mięsa niezbędne jest poszukiwanie nowych metod oceny, które wyeliminują m.in. subiektywność wynikającą z czynnika ludzkiego oraz pozwolą na szybkie uzyskanie wyników. W przypadku wykorzystania metod oceny opartych na analizie komputerowej istotne jest pozyskanie dobrej jakości, wolnego od zniekształceń obrazu badanej próbki oraz właściwej klasyfikacji i rozpoznawania rejestrowanych obrazów. W artykule dokonano analizy zawartości tłuszczu widocznego w mięsie drobiowym metodą tradycyjną – organoleptyczną oraz za pomocą technik wizyjnych – komputerowa analiza obrazu. Do badań wykorzystano aplikację komputerową opartą na modelu RGB do rozpoznawania poszczególnych barw.

Słowa kluczowe: komputerowa analiza obrazu, zarządzanie innowacjami, metody oceny jakości, produkcja drobiu.

INTRODUCTION

In recent years, food production has shown an upward trend. In order to meet the constantly growing needs of the food market, food companies must constantly develop and use raw materials and services of other entities. They stock up on individual elements necessary for final products, and therefore depend on the state of economic development.

The animal products market is one of the main sectors of the food economy. Poultry meat, considered a source of wholesome and easily digestible protein, is the most frequently chosen type of meat by consumers. It is produced from chickens, turkeys, geese and ducks [8].

The overall quality consists of a set of features that distinguish a given food product. The appropriate quality of meat determines its attractiveness and health [9]. One of the most important characteristics of meat is its color. It is the main factor that determines the choice of the product by the consumer because it suggests that the offered product is fresh and of good quality. The color of meat is influenced by many factors. Poultry meat has a gray-pink color, which is influenced by the concentration and form of myoglobin (a heme pigment found in skeletal muscles and the heart muscle). The myoglobin content depends on the age of the poultry. The value of myoglobin is not constant and depends on the activity of the muscle. Hemoglobin also affects color,

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but to a lesser extent compared to myoglobin. Texture is another differentiator in judging the quality of poultry meat. It is expressed through the feeling of hardness, elasticity and elasticity of the meat. It depends on the structure of muscle tissue and the amount of collagen, the value of which changes with the activity of the muscles. Age plays a key role here - the muscles of young chickens have thinner muscle fibers, which increases the tenderness of the meat obtained from them [3]. Juicy is a parameter related to the water absorption of meat, i.e. the ability to retain meat juice in the muscle. The meat is characterized by better juiciness during slight losses of muscle mass. The presence of intramuscular fat enhances the feeling of juiciness. Transport and post-slaughter processing of chickens has a significant impact on the palatability – broiler stress reduces the water absorption capacity, which makes the meat less juicy [7].

One of the traditional methods of quality assessment is organoleptic assessment, which consists in verifying organoleptic characteristics with the help of the senses. It allows for an analysis of the quality of the product, e.g. its fat content, color, smell, consistency or clarity. It takes place through the sense of sight, smell, taste and touch, it is unique and unplayable. It is an immeasurable method due to the inability to maintain the objectivity of the assessment. The results are influenced, inter alia, by the health condition of the assessor and environmental conditions. This is a very important assessment, especially for a finished product, because the consumer, when making a purchase decision, determines the visual features of this product [10]. The organoleptic evaluation is used for the sensory analysis of the product.

Innovation in quality management is understood as activities consisting in improving the existing ones or introducing new solutions that will contribute to the improvement of the quality of products. It is particularly important that the new activities contribute to the optimization of the time of obtaining results and condition their credibility and value. Meeting these conditions enables the use of innovative techniques as an effective tool for food technologists and producers. It is important to methodically prepare people working with new tools so as to obtain value from the obtained results [4].

Innovations in the field of quality management have been a frequent development path chosen by representatives of food companies in recent years, which confirms the need to use innovative solutions in this area. Enterprises decided not only to implement new methods of quality assessment, but also to reorganize the tools used so far [6]. Due to the dynamic development of the sciences in the field of automation, it is also used for new methods of food evaluation. Reference methods are not preferred in in-house research centers mainly due to the time-consuming nature of analyzes. The use of vision systems turned out to be effective [2].

Computer image analysis is a research technique that allows for an unambiguous assessment of the sensory quality of food products, such as size, shape or color. The aforementioned discriminants are the key aspect that prevails in the choice of a product by the consumer [1]. This method automatically processes and analyzes the image, extracting the desired information and comparing it with the specified standards [5]. The undoubted advantages of computer image analysis are the speed, non-invasiveness and repeatability of the assessment [1].

The aim of the article was to present the application of innovative methods to assess the quality of poultry meat using computer image analysis and to compare them to traditional evaluation methods.

RESEARCH METHODOLOGY

The research material consisted of selected elements of poultry meat – thigh meat of broilers fed with standard mixtures. The weight of a single sample was about 200 g. The research material was obtained from a nearby slaughterhouse. Slaughter was carried out automatically on the slaughter lines with the sanitary requirements in force in the meat industry. After slaughter, the chicken carcasses were cooled by the air-spray method to the temperature not exceeding 3°C. Muscles were obtained from a chicken carcass automatically

Table 1. Card of the innovation process

Tabela 1. Karta procesu innowacji

Process name	The use of an innovative technique of poultry meat quality assessment in a food enterprise
process owner	Quality Management System Specialist
Process type	Management process
Purpose of the process	Searching for new methods of product quality assessment to ensure the highest sensory quality of products
Imput data	Technologists' initiative An initiative of the employees of the Quality Management Department Production Director's initiative
Ouput	An innovative method of assessing the quality of poultry meat, and in the future – also of processed meat products, e.g. sausages
Meters	The possibility of using new technologies in the product evaluation process
Process related procedures	Specification of the products Poultry meat evaluation sheet

Source: Own study

Źródło: Opracowanie własne

using a dividing line. The average pH of the meat oscillated between 5.8–6.0. The results are similar to the data given in the technological specification. The determination was carried out 24 hours after slaughter. Until the examination, the meat was stored under the conditions declared by the producer, ie at a temperature of a maximum of 4°C.

The computer application "APR" and the organoleptic evaluation sheet were chosen as the main methods for conducting effective research. The enrichment method was the innovation process chart, created for the proper conduct of the innovation management process. The design of the card is presented in Table 1.

The analytical part of the research included the organoleptic analysis of selected product quality indicators, carried out by 5 specialists:

- 2 technologists,
- 2 food quality specialists,
- 1 lab technician.

The evaluation team had experience and qualifications confirmed by training in sensory evaluations for meat and meat products.

The test was carried out under artificial, uniform lighting. The stand is equipped with a scale, a Petri dish to be used when it is necessary to collect samples for further tests, gloves and a place for cutting and visual assessment of the test sample.

The study was carried out on 20 samples of meat from broiler thighs. The meat used was free from defects and fit for consumption by consumers.

Meat evaluation sheet prepared. The team assessed the meat on a 5-point scale (1 – unacceptable quality, 5 – the highest quality rating). The external appearance of the meat was assessed: the intensity of the color and its uniformity, and whether the general appearance is as specified.

Then, samples (digital photos) of the meat were obtained with the use of lighting ensuring even light dispersion: halogen lighting (two halogen lamps, 35W each) and fluorescent lighting (one fluorescent lamp with a power of 6W). The shots were taken with a digital camera NIKON Coolpix B500 camera on a black background which has the slightest effect on the natural color of the meat. The obtained photos show the percentage of bright fields that were fat. The "APR" computer application was used in the research. The principle of operation of the "APR" computer application is based on the RGB (red – red, green – green, blue – blue) model. Photographs are presented as a collection of points - pixels that can be saved in the form of a 1-bit, 8-bit or 24-bit scale. This model uses the receiving properties of the human eye. It allows for the reproduction of about 16 million colors. The "APR" program analyzed the meat image, on the basis of which the percentage of fat content of poultry meat was obtained, which corresponds to the sensory parameter in the tested material. The saturation and brightness of the selected color in the meat were determined to obtain results.

ANALYSIS AND DISCUSSION OF THE RESULTS

The first stage of the research was to conduct an organoleptic evaluation. Based on the organoleptic evaluation it was found that the color and shape of the samples were as specified. The assessed meat did not contain any defects in appearance or texture, and the cross-sectional appearance and compactness were highly rated. In the 5-point evaluation, the tested meat obtained values from 4–5 for each parameter, which indicates its good quality. The mean values of the fat content are presented in Table 2.

The second stage included research with the use of computer image analysis. On the basis of the photographs taken, the program performed a quantitative analysis of light fields representing fat tissue on the muscle and red fields – muscles, and then calculated their percentage in relation to the total meat surface. The unidentified area has not been identified. People who performed the organoleptic evaluation of the samples, i.e. employees of the plant from which the meat for testing was obtained, participated in the research.

Table 2. Percentage of fat and meat in the tested samples

Tabela 2. Procentowa ilość tłuszczu oraz mięsa w badanych próbkach

Sample no	Fatness rating [%]					
	Technologist	Technologist	Lab technician	Food Quality Specialist	Food Quality Specialist	Sample mean value
1	15	14	12	14	13	**13,6**
2	15	13	11	13	14	**13,2**
3	18	14	15	14	15	**15,2**
4	17	15	12	15	14	**14,6**
5	12	12	13	12	13	**12,4**
6	13	14	15	13	15	**14**
7	14	15	17	13	16	**15**
8	12	11	11	13	12	**11,8**
9	15	13	12	14	14	**13,6**
10	16	15	13	13	15	**14,4**

Source: Own study

Źródło: Opracowanie własne

Fig. 1. Sample photo of the analyzed sample analysis.
Rys.1. Przykładowe zdjęcie analizy badanej próbki.
Source: Own study
Źródło: Opracowanie własne

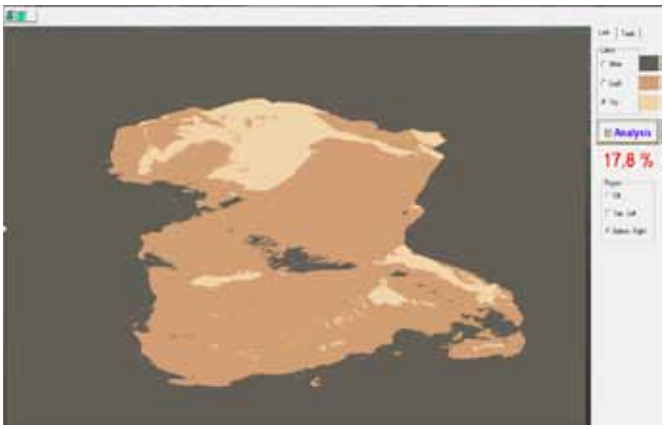

Fig. 2. Digital image analysis for sample no. 1.
Rys.2. Analiza obrazu cyfrowego dla próby nr 1.
Source: Own study
Źródło: Opracowanie własne

Table shows the percentage of fat and meat obtained after the computer image analysis.

Table 3. The percentage of fat and meat in the tested samples

Tabela 3. Procentowa ilość tłuszczu oraz mięsa w badanych próbkach

No	The amount of fat [%]	The amount of meat [%]
1	17,8	82,2
2	8,2	91,8
3	8,5	91,5
4	10,3	89,7
5	8,1	91,9
6	7,5	92,5
7	7,4	92,6
8	7,9	92,1
9	7,8	92,2

Source: Own study
Źródło: Opracowanie własne

Based on the photos taken and the computer image analysis, the mean value of body fat was 9.2%.

The share of light semi-light varieties was varied, as the tested meat differed in terms of the presence of fat, which influenced the technological properties of the meat. The degree of fatness is important for the palatability parameter – fat is the carrier of flavor. Nevertheless, the fat value should not be too high, as the meat will lose its appeal aspect, which for many customers is a key factor in determining the purchase. When the consumer sees excessive fatness of meat, it is associated with a product unhealthy for the body.

Based on the results obtained from the computer image analysis, a graph of the amount of fat was plotted and compared with the empirical method. The obtained results are shown in Figure 3.

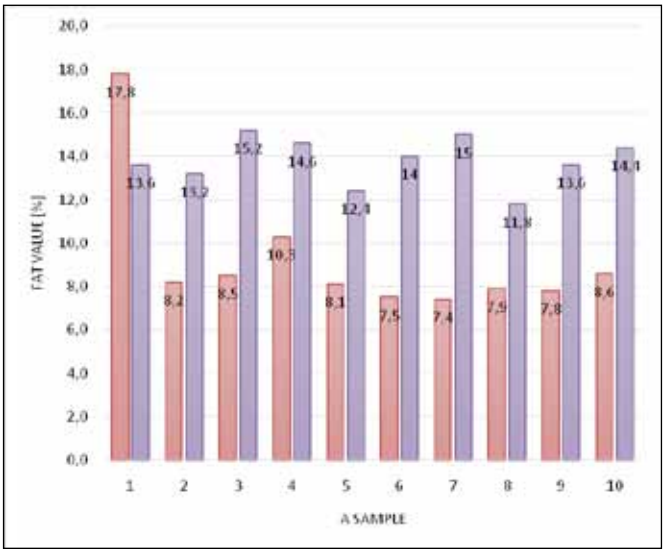

Fig. 3. Comparison of the obtained results by means of computer image analysis.
Rys. 3. Porównanie uzyskanych wyników za pomocą komputerowej analizy obrazu.
Source: Own study
Źródło: Opracowanie własne

Based on the chart, it can be concluded that the fatness value obtained by computer image analysis is generally lower than the result determined during the traditional evaluation of the tested samples. Only for the first sample is the result of the evaluation made by specialists lower. The differences result from the elimination of the subjectivity factor in computer vision techniques. The analysis of specialists may be marked with an error resulting from the personal preferences of the researcher, where he selects a more desirable sample from among the tested products. For this reason, the sensory test requires conducting it on a group of specialists in order

to consider it objective. Analyzes by one employee are not acceptable. With computer techniques, only one specialist is required to take pictures and then interpret the data received.

SUMMARY

On the basis of the performed tests and the analysis of the obtained results, the answer to the formulated main problem and specific problems was obtained. The possibility of using computer image analysis as a tool for the evaluation of fat content in poultry has been demonstrated. The combination of innovative evaluation methods along with the knowledge and competences of employees in food plants guarantees the improvement of the quality of manufactured products, which directly affects their safety. Moreover, this method seems to be promising for the evaluation of other food quality parameters, e.g. color. However, remember to maintain adequate lighting and light intensity in order to obtain the desired photos used for the analysis. A barrier to the introduction of new assessment methods may be insufficient knowledge of employees about innovative quality assessment techniques. After the research with the plant employees from the meat industry, it can be concluded that their knowledge about innovations in the field of quality assessment is small. However, after familiarizing themselves with the method, they clearly confirmed the need to use newer and newer methods of quality assessment that will eliminate the subjectivity resulting from standard measurements.

In order to meet the expectations of consumers, meat products require constant improvement in the context of quality assessment. Together with a properly developed strategy, innovative methods of food analysis enable the development of the organization and should become an integral part of the company's quality culture. Therefore, the issue of food control is still an open field of research for the food industry.

PODSUMOWANIE

Na podstawie wykonanych badań oraz analizy otrzymanych wyników uzyskano odpowiedź na sformułowany problem główny oraz problemy szczegółowe. Wykazano możliwość wykorzystania komputerowej analizy obrazu jako narzędzia oceny otłuszczenia w mięsie drobiowym. Połączenie innowacyjnych metod oceny wraz z wiedzą i kompetencjami pracowników w zakładach spożywczych gwarantuje poprawę jakości produkowanych wyrobów, co bezpośrednio wpływa na ich bezpieczeństwo. Ponadto metoda ta wydaje się być obiecująca do oceny innych parametrów jakości żywności, np. barwy. Należy jednak pamiętać o zachowaniu odpowiedniego oświetlenia i natężenia światła, tak aby uzyskać pożądane zdjęcia wykorzystywane do analizy. Barierą do wprowadzenia nowych metod oceny może być niedostateczna wiedza pracowników o innowacyjnych technikach oceny jakości. Po przeprowadzonych badaniach z pracownikami zakładu z branży mięsnej można stwierdzić, że ich wiedza dotycząca innowacji z zakresu oceny jakości jest niewielka. Po zapoznaniu się z metodą wyraźnie potwierdzili oni konieczność stosowania coraz nowszych sposobów oceny jakości, które wyeliminują subiektywność wynikającą ze standardowych pomiarów. W celu spełnienia oczekiwań konsumentów produkty mięsne wymagają ciągłego doskonalenia w kontekście oceny jakości. Wraz z właściwie opracowaną strategią innowacyjne metody analizy żywności umożliwiają rozwój organizacji i powinny stać się nierozerwalną częścią kultury jakości przedsiębiorstwa. Dlatego też problematyka kontroli żywności jest nadal otwartym polem badawczym dla przemysłu spożywczego.

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WŁAŚCIWOŚCI SORPCYJNE WYBRANYCH HERBAT®

Sorption properties of selected tea®

W pracy prezentowanej w artykule wyznaczono izotermy adsorpcji wody oraz badano kinetykę sorpcji wody dla wybranych herbat czarnych (granulowana, liściasta i sproszkowana) w temperaturze 25°C. Izotermy adsorpcji wody wyznaczono metodą statyczno-eksykatorową w zakresie aktywności wody od 0,113 do 0,932. Krzywe kinetyczne sorpcji wody wyznaczono w środowisku o zróżnicowanej wilgotności względnej powietrza (52,9, 75,3 i 100,0%). Stwierdzono, że izotermy adsorpcji wody badanych herbat miały kształt sigmoidalny i zgodnie z klasyfikacją Brunauera i współpracowników odpowiadały II typowi izoterm. Model Pelega najlepiej opisywał otrzymane izotermy adsorpcji wody (RMS < 7%). Model kinetyczny Ficka w miarę poprawnie opisywał dane sorpcyjne badanych herbat (RMS od 5,45 do 25,83%). Najmniejszą zdolnością chłonięcia pary wodnej w środowisku o wilgotności względnej 52,9 i 100,0% charakteryzowała się herbata granulowana, a największą herbata sproszkowana.

Słowa kluczowe: herbaty czarne, izotermy adsorpcji wody, kinetyka sorpcji, modele GAB, Pelega i Ficka.

In the paper water adsorption isotherms and water sorption kinetics for selected black teas (granulated, leaf and powdered) at 25°C were determined. The water adsorption isotherms were determined by the static gravimetric method in the water activity range from 0,113 to 0,932. The kinetics curves of water vapor sorption in the environment of different relative humidity of the air (52,9, 75,3 and 100,0%) were investigated. The water adsorption isotherms of the tested teas had a compatible course with second type of isotherms according to the Brunauer's classification. The Peleg model best fit to the experimental sorption data (RMS < 7%). The Fick's kinetic model accurately described the sorption data of the teas tested (RMS from 5,45 to 25,83%). Granulated tea characterized by the lowest ability to adsorb water vapor in the environment with relative humidity of 52,9 and 100%, while the highest was powdered tea.

Key words: black teas, water adsorption isotherms, sorption kinetics, GAB, Peleg and Fick models.

WSTĘP

Herbata jest jedną z najbardziej popularnych używek na całym świecie, spożywaną w postaci napoju. Światowa produkcja herbaty kształtuje się na poziomie około 3,7 mln ton rocznie. Największe spożycie herbaty – ok. 3 kg/osobę rocznie ma miejsce w Irlandii, natomiast w Polsce ilość suchej herbaty przypadająca na jedną osobę jest znacznie mniejsza i wynosi ok. 0,9 kg rocznie. Statystyczny Polak miesięcznie, w przeliczeniu na gotowe napary wypija około 40 szklanek herbaty [20, 21].

Obecnie spotyka się wiele systemów klasyfikowania i oznaczania herbaty. Najbardziej znane systemy klasyfikacji herbaty odnoszą się do kraju pochodzenia i rejonu uprawy oraz formy surowca końcowego. I tak, wyróżniamy m. in. herbaty indyjskie, chińskie, cejlońskie, brazylijskie, gruzińskie (Assam, Darjeeling, Cejlon, Madras) oraz liściaste, łamane (broken), bardzo drobne (fannings) i pył herbaciany (dust). Ponadto wyróżnia się herbaty czarne, zielone, czerwone i żółte. Herbata czarna jest liderem w obrocie handlowym na rynkach całego świata [21].

Herbata jest źródłem wielu substancji o działaniu przeciwutleniającym, a szczególnie związków polifenolowych [10]. Odpowiednia podaż tych substancji w diecie ma korzystny wpływ na gospodarkę lipidową organizmu, obniżenie podwyższonego ciśnienia krwi, co ma duże znaczenie w prewencji chorób serca i czynników ich ryzyka, a także chorób nowotworowych. Ponadto napar herbaciany pomaga w leczeniu wielu dolegliwości takich jak: cukrzyca, infekcje i stany zapalne, problemy trawienne, bezsenność, osłabienie układu kostnego [11, 12].

Ważnym kryterium dla producentów jak i konsumentów herbaty jest uzyskanie wysokiej jakości produktu o dużej stabilności w czasie transportu i przechowywania. W tym celu niezwykle ważne jest poznanie właściwości sorpcyjnych suchej herbaty. Wyznaczone izotermy sorpcji wody jak i krzywe kinetyczne procesu sorpcji stanowią cenny materiał na podstawie którego można określić optymalną i krytyczną wilgotność produktu oraz ustalić optymalne warunki przechowywania i opakowania suchej herbaty [13, 14]. W dostępnej polskiej literaturze, niewiele jest informacji na temat izoterm adsorpcji i przebiegu krzywych kinetycznych procesu sorpcji wody dla suchej herbaty. Poniższe rozważania będą stanowiły uzupełnienie wiedzy na ten temat.

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Celem artykułu jest przedstawienie wyników badań dotyczących określenia właściwości sorpcyjnych wybranych herbat czarnych na podstawie wyznaczonych izoterm i przebiegu krzywych kinetycznych procesu adsorpcji wody w temperaturze 25°C oraz ich analizy.

METODYKA BADAŃ

1. Materiał badawczy

Do badań użyto 3 rodzaje herbaty czarnej: granulowaną „Irving" (Amber Spark S.A.), liściastą „Irwing" (Amber Spark S.A.) i sproszkowaną „Saga" (Unilever Polska Sp. z o.o.).

2. Metody analityczne

2.1. Oznaczenie początkowej zawartości wody

Początkową zawartość wody w herbatach oznaczano metodą suszenia pod obniżonym ciśnieniem w suszarce próżniowej Horyzont Spt-2000. Próbki materiału suszono w temperaturze 70 ±1°C, pod ciśnieniem 0,266 kPa, przez 24 godziny [1]. Oznaczenie wykonano w 3 równoległych powtórzeniach.

2.2. Oznaczenie początkowej aktywności wody

Początkową aktywność wody w herbatach zmierzono przy użyciu aparatu Rotronic Hygroskop DT w temperaturze 25,0 ± 0,5°C. Pomiar przeprowadzono w 3 równoległych powtórzeniach.

2.3. Wyznaczenie izoterm adsorpcji wody

Izotermy adsorpcji wody wyznaczono metodą statyczno -eksykatorową [18], stosując nasycone roztwory soli jako czynniki higrostatyczne (LiCl, CH_3COOK, $MgCl_2$, K_2CO_3, $Mg(NO_3)_2$, $NaNO_2$, NaCl, $(NH_4)_2SO_4$ i $(NH_4)H_2PO_4$) [6, 7, 16]. W eksykatorach z roztworami o większej aktywności wody (NaCl, $(NH_4)_2SO_4$ i $(NH_4)H_2PO_4$ umieszczono naczynka z tymolem, w celu ochrony przed rozwojem mikroflory w materiale. Przed procesem adsorpcji próbki herbat o masie ok. 1 g suszono w suszarce próżniowej w temperaturze 70°C, przy ciśnieniu 0,266 kPa, w czasie 24 godzin. Tak przygotowane próbki materiału przeniesiono do eksykatorów z roztworami soli o a_w od 0,113 do 0,932. Czas przetrzymywania próbek wyniósł 3 miesiące. Badania wykonano w temperaturze 25 ±0,5°C w 3 powtórzeniach.

2.4. Wyznaczenie kinetyki procesu adsorpcji wody

Do wyznaczenia kinetyki procesu adsorpcji wody w herbatach w warunkach nieustalonych wykorzystano układ pomiarowy, którego zasadniczym elementem była waga analityczna RADWAG WAS 220/C/2 znajdująca się w pomieszczeniu o stałej temperaturze 25°C, podłączona do komputera z oprogramowaniem Pomiar-Win v.3.0.24 (Radwag) [19]. Jako czynniki higrostatyczne zastosowano dwa nasycone wodne roztwory soli ($Mg(NO_3)_2$ i NaCl) oraz wodę destylowaną, które gwarantowały w otoczeniu badanej próbki stałą wilgotność względną powietrza na poziomie 52,9, 75,3 i 100,0% [6]. Materiał, po otworzeniu opakowania, poddano suszeniu pod obniżonym ciśnieniem zgodnie z metodyką podaną w p. 2.3. Suchy materiał umieszczono w naczynku pomiarowym wykonanym z folii aluminiowej (masa próbki ok. 1 g). Z kolei, naczynko z próbką wstawiono na szalkę wagi, montowano pojemnik z czynnikiem higrostatycznym i natychmiast zapisywano początkową masę próbki oraz uruchamiano program komputerowy. Program komputerowy rejestrował przyrost masy próbki z dokładnością ±0,0001 g co 5 minut i gromadził dane przez 48 h. W celu sprawdzenia reprezentatywności pomiaru, wykonano go w dwóch powtórzeniach dla każdej wilgotności względnej środowiska.

3. Metody obliczeniowe

3.1. Obliczenie równowagowej zawartości wody

Równowagową zawartość wody w herbacie po procesie adsorpcji obliczono ze wzoru [8]:

$$u = \left[\frac{d}{c\frac{b}{a}} - 1 \right] \cdot 100 \qquad (1)$$

gdzie: u – równowagowa zawartość wody, g wody/100 g s.s.,
a – początkowa masa próbki z eksykatora z $CaCl_2$, g,
b – końcowa masa próbki, po trzymiesięcznym przetrzymywaniu w eksykatorze z $CaCl_2$ (po suszeniu w temperaturze 70°C, pod obniżonym ciśnieniem, przez 24 h), g,
c – początkowa masa próbki z eksykatora z określonym roztworem, g,
d – końcowa masa próbki, po trzymiesięcznym przetrzymywaniu, z eksykatora z określonym roztworem, g.

3.2. Obliczenie zawartości wody w materiale po czasie τ

Zawartość wody w herbacie, przeliczona na 100 g suchej substancji, obliczono ze wzoru [19]:

$$u_\tau = \frac{m_\tau - m_o}{m_o} \cdot 100 \qquad (2)$$

gdzie: u_τ – zawartość wody po czasie τ, g wody/100 g s.s.,
m_0 – pierwotna masa próbki suchej, g,
u_τ – masa próbki po czasie τ, g.

3.3. Opis izoterm adsorpcji wody herbat

Do opisu izoterm adsorpcji wody herbat zastosowano dwa modele:

- model GAB [3]

$$u = \frac{u_m C k a_w}{(1 - k a_w)\left[1 + (C - 1) k a_w\right]} \qquad (3)$$

- model Pelega [15]

$$u = A a_w^{\ B} + D a_w^{\ E} \qquad (4)$$

gdzie: a_w – aktywność wody,
u – równowagowa zawartość wody, g wody/100 g s.s.,
u_m – zawartość wody w monowarstwie, g wody/100 g s.s.,
A, B, C, D, E i k – stałe.

Aproksymację izoterm przeprowadzono na bazie wszystkich punktów pomiarowych (3 powtórzenia). Programu Table Curie 2D (Jandel Scientific) użyto do dopasowania testowanego modelu do danych doświadczalnych.

3.4. Wyznaczenie parametrów modelu kinetycznego

Parametry kinetyczne procesu adsorpcji wody wyznaczono z modelu Ficka [5] wykorzystując program komputerowy TableCurve™ 2D v.5.01.01:

$$\frac{u_r - u_\tau}{u_r - u_o} = F \cdot \exp(-K \cdot \tau) \quad (5)$$

gdzie: u_0 – początkowa zawartość wody, g wody/100 g s.s.,
u_r – równowagowa zawartość wody, g wody 100 g s.s.,
F – współczynnik kształtu (stała),
K – stała powiązana ze współczynnikiem dyfuzji,
τ – czas, min.

3.5. Obliczenie średniego błędu kwadratowego (RMS)

Przydatność modeli GAB, Pelega i Ficka do opisu danych doświadczalnych adsorpcji wody oceniono na podstawie średniego błędu kwadratowego (RMS) wyrażonego w % [9]:

$$RMS = \sqrt{\frac{\Sigma\left(\frac{u_e - u_p}{u_e}\right)^2}{N}} \cdot 100 \quad (6)$$

gdzie: u_e – doświadczalna równowagowa zawartość wody, g wody/100 g s.s.,
u_p – prognozowana równowagowa zawartość wody, g wody/100 g s.s.,
N – liczba danych.

OMÓWIENIE I DYSKUSJA WYNIKÓW

1. Charakterystyka badanych herbat

W tabeli 1 przedstawiono średnią początkową zawartość i aktywność wody w badanych herbatach.

Tabela 1. Początkowa zawartość wody i aktywność wody w badanych herbatach

Table 1. Initial water content and water activity in studied teas

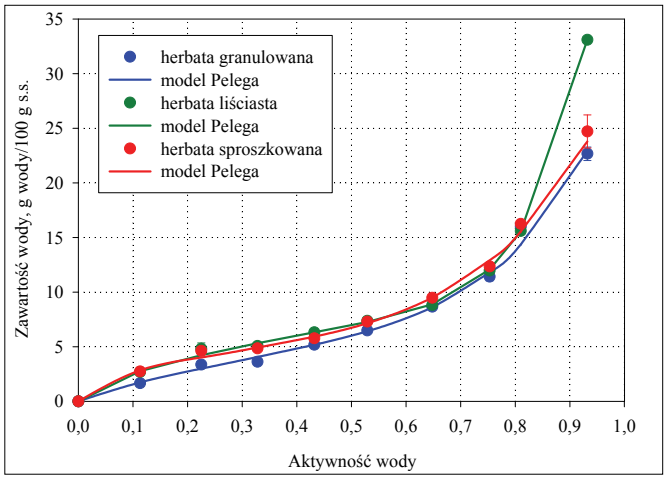
Rodzaj herbaty	Zawartość wody [%]	Aktywność wody [-]
Granulowana	4,64 ± 0,07	0,361 ± 0,003
Liściasta	8,30 ± 0,03	0,593 ± 0,014
Sproszkowana	5,71 ± 0,02	0,410 ± 0,004

Źródło: Badania własne

Source: The own study

Stwierdzono, że największą początkową zawartość i aktywność wody posiadała herbata liściasta (8,30%, 0,593), natomiast, najmniejszą miała herbata granulowana (4,64%, 0,361). Herbaty granulowana i sproszkowana, ze względu na poziom aktywności wody, zalicza się do żywności o niskiej zawartości wody, ponieważ mieszczą się w przedziale a_w od 0 do 0,55 [13]. Tym niemniej, wartości aktywności wody wszystkich badanych herbat poniżej 0,6 świadczą o pełnej ich stabilności mikrobiologicznej [14].

2. Izotermy adsorpcji wody



Rys. 1. Izotermy adsorpcji wody herbaty granulowanej, liściastej i sproszkowanej.

Fig. 1. Water adsorption isotherms of granulated, leaf and powdered tea.

Źródło: Badania własne

Source: The own study

Na rysunku 1 przedstawiono przebieg i kształt izoterm adsorpcji wody badanych herbat. Uzyskane izotermy adsorpcji wody, bez względu na rodzaj herbaty, posiadały typowy kształt sigmoidalny, charakterystyczny dla izoterm typu II, zgodnie z klasyfikacją Brunauera i wsp. [4]. Stwierdzono, że najniżej przebiegała izoterma adsorpcji wody herbaty granulowanej w całym badanym zakresie aktywności wody. Oznacza to, że herbata granulowana była najmniej higroskopijna i adsorbowała najmniejszą ilość wody. Przebieg izoterm adsorpcji wody herbat liściastej i sproszkowanej w przedziale aktywności wody 0,00 – 0,75 (na poziomie mono- i wielowarstwy) był bardzo podobny, świadcząc o zbliżonej higroskopijności obu herbat. Po przekroczeniu aktywności wody 0,75 izoterma adsorpcji wody herbaty liściastej zdecydowanie odbiegała ku górze. Prawdopodobnie świadczy to o bardziej intensywnym procesie pęcznienia zachodzącym w tym materiale. Rozwinięcie struktury wewnętrznej, uaktywnienie się nowych miejsc adsorpcji wody spowodowało większy przyrost adsorpcji wody w porównaniu z innymi herbatami.

Podobny przebieg i kształt izoterm adsorpcji wody dla herbat granulowanej i sproszkowanej stwierdzili Sinija i Mishra [17], a dla herbaty liściastej Arslan i Toğrul [2].

3. Dopasowanie modeli GAB i Pelega do danych adsorpcji wody

Do opisu izoterm adsorpcji wody badanych herbat wykorzystano modele GAB i Pelega. W tabeli 2 zestawiono obliczone parametry odnoszące się do 3 rodzajów herbat w zastosowanych modelach izoterm adsorpcji oraz pokazano zgodność dopasowania tych modeli, wyrażoną przez współczynnik determinacji (R^2) i średni błąd kwadratowy (RMS).

Tabela 2. Obliczone parametry modeli GAB i Pelega izoterm adsorpcji wody badanych herbat

Table 2. Calculated parameters of GAB and Peleg models of water adsorption isotherms of studied teas

Model/ parametry	Herbaty		
	Granulowana	Liściasta	Sproszkowana
GAB			
u_m, g wody/100 g s.s.	4,280	3,467	4,287
k	0,881	0,960	0,883
C	4,885	57,190	11,908
R^2	0,988	0,997	0,989
RMS, %	7,22	10,39	6,36
Peleg			
A	9,747	10,555	22,010
B	0,794	0,616	4,819
D	20,516	44,123	8,398
E	5,756	9,255	0,498
R^2	0,992	0,999	0,993
RMS. %	6,80	4,89	5,59

Źródło: Badania własne

Source: The own study

Przeprowadzona analiza danych wskazuje, że znacznie lepszym kryterium zgodności dopasowania jest średni błąd kwadratowy. Stwierdzono, że model Pelega najlepiej opisywał dane sorpcyjne badanych herbat. Wartości RMS kształtowały się na poziomie od 4,85% (herbata liściasta) do 6,80% (herbata granulowana). Nieco wyższe wartości RMS stwierdzono dla modelu GAB, które kształtowały się na poziomie od 6,36% (herbata sproszkowana) do 10,39% (herbata liściasta). Graficzne dopasowanie danych uzyskanych z modelu Pelega do izoterm adsorpcji wody badanych herbat przedstawiono na rysunku 1. Najlepsze dopasowanie modelu Pelega do danych sorpcyjnych herbat granulowanej, liściastej i sproszkowanej potwierdziły badania Sinija i Mishry [17] oraz Arslana i Toğrula [2].

Wartości stałych (tab. 2), uzyskane z modelu GAB dla badanych herbat, tj. zawartość wody w monowarstwie (u_m) oraz C i k związane z energią oddziaływań między pierwszą a dalszymi adsorbowanymi cząsteczkami wody przez indywidualne centra adsorpcji matrycy, poprawnie opisują sigmoidalny kształt izotermy [9].

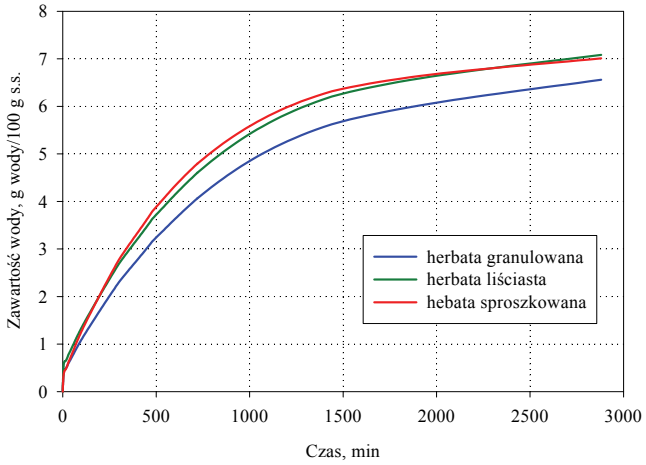
Największą zawartość wody w monowarstwie w procesie adsorpcji wody stwierdzono dla herbat sproszkowanej (4,287 g wody/ 100 g s.s.) i granulowanej (4,280 g wody/ 100 g s.s.). Natomiast herbata liściasta posiadała zawartość wody na poziomie monowarstwy mniejszą o ok. 19% od u_m tych herbat.

Stała C odzwierciedla wartość czystego izosterycznego ciepła adsorpcji wody na poziomie monowarstwy [13]. Określa ona dodatkowy nakład energii (oprócz ciepła parowania) jaki musi być dostarczony do materiału, aby usunąć z niego wodę. Pośrednio, określa więc siłę wiązania wody przez matrycę materiału na poziomie monowarstwy. Z przytoczonych danych wynika (tab. 2), że najmocniej woda była związana z suchą matrycą w herbacie liściastej (C = 57,190), znacznie słabiej w herbacie sproszkowanej (C = 11,908), a najsłabiej w herbacie granulowanej (C = 4,885).

Wartości stałej k herbat granulowanej i sproszkowanej były prawie identyczne i wyniosły odpowiednio 0,881 i 0,883, a dla herbaty liściastej wartość stałej k była o ok. 9% wyższa.

4. Przebieg krzywych kinetycznych adsorpcji wody

Na rysunkach 2-4 przedstawiono przebieg krzywych kinetycznych adsorpcji wody dla herbat granulowanej, liściastej i sproszkowanej w środowisku o różnej wilgotności względnej.

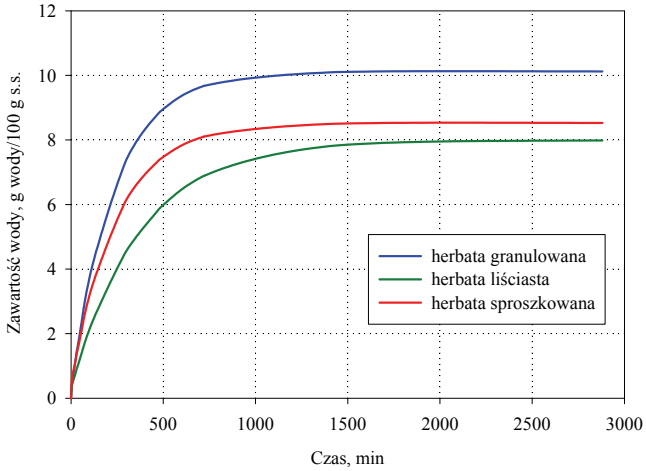


Rys. 2. Krzywe kinetyczne adsorpcji wody w herbatach w środowisku o wilgotności względnej 52,9% (aw = 0,529).

Fig. 2. Kinetic curves of water adsorption in teas in an environment with a relative humidity of 52,9% (aw = 0,529).

Źródło: Badania własne

Source: The own study

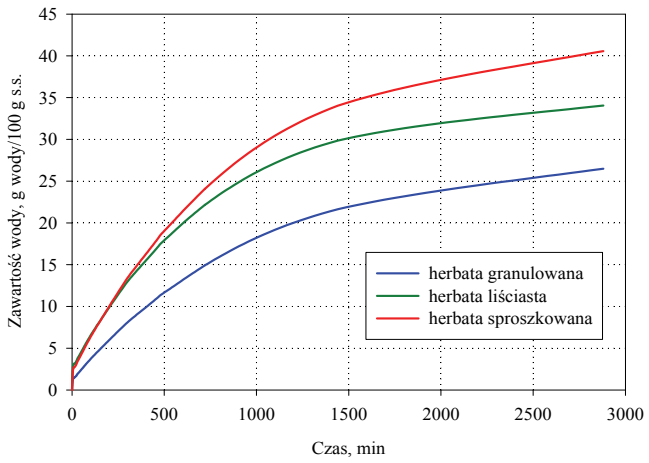


Rys. 3. Krzywe kinetyczne adsorpcji wody w herbatach w środowisku o wilgotności względnej 75,3% (aw = 0,753).

Fig. 3. Kinetic curves of water adsorption in teas in an environment with a relative humidity of 75,3% (aw = 0,753).

Źródło: Badania własne

Source: The own study



Rys. 4. Krzywe kinetyczne adsorpcji wody w herbatach w środowisku o wilgotności względnej 100,0% (aw = 1,000).

Fig. 4. Kinetic curves of water adsorption in teas in an environment with a relative humidity of 100,0% (aw = 1,000).

Źródło: Badania własne

Source: The own study

W środowisku o najniższej wilgotności względnej 52,9% (rys. 2) największą zdolnością adsorpcji wody, a tym samym największą higroskopijnością, wykazały się herbaty sproszkowana i liściasta, których krzywe kinetyczne przebiegały najwyżej i były bardzo zbliżone do siebie. Natomiast, znacznie słabiej chłonęła wodę herbata granulowana i była najmniej higroskopijna. W środowisku o wilgotności względnej 75,3% stwierdzono zależność odwrotną (rys. 3). Zdecydowanie największą higroskopijność wykazała herbata granulowana, znacznie mniejszą higroskopijnością cechowała się herbata sproszkowana, a najmniejszą higroskopijność posiadała herbata liściasta.

W środowisku o największej wilgotności względnej 100% (rys. 4) ponownie zauważono tendencję jak na rysunku 2, przy czym różnice w przebiegu krzywych kinetycznych były bardziej wyraźne. Najmniejszą ilość wody chłonęła herbata granulowana, znacznie większą herbata liściasta, a największą herbata sproszkowana.

Ogólnie, bez względu na wilgotność względną środowiska, największą zdolność adsorpcji wody przez herbaty stwierdzono w czasie do 1000 minut procesu sorpcji. Po tym czasie, krzywe kinetyczne zbliżały się do stanu równowagi wilgotnościowej.

5. Dopasowanie modelu Ficka do danych sorpcyjnych

W tabeli 3 zestawiono obliczone parametry kinetyczne modelu Ficka oraz pokazano zgodność dopasowania modelu, wyrażoną przez współczynnik determinacji (R^2) i średni błąd kwadratowy (RMS).

Ponownie przeprowadzona analiza danych wskazuje, że znacznie lepszym kryterium dopasowania jest średni błąd kwadratowy. Najmniejsze wartości RMS dla wszystkich badanych herbat stwierdzono w środowisku o wilgotności względnej 75,3% (wartości RMS < 8%), natomiast w środowisku o wilgotności względnej 52,9 i 100,0% wartości RMS były znacznie większe i mieściły się w przedziale od 12,70 do 25,83%.

Tabela 3. Parametry modelu Ficka dopasowanego do danych sorpcyjnych badanych herbat

Table 3. Parameters of the Fick's model fitted to the sorption data of studied teas

Rodzaj herbaty	Parametry modelu Ficka	Wilgotność względna środowiska, ϕ [%]		
		52,9	75,3	100,0
Granulowana	ur	6,760	10,121	28,000
	F	0,946	0,979	0,960
	K	0,0012	0,0043	0,0010
	R2	0,992	0,979	0,994
	RMS, %	12,70	6,84	25,83
Liściasta	ur	7,241	7,988	34,815
	F	0,929	0,963	0,927
	K	0,0013	0,0027	0,0013
	R2	0,988	0,990	0,985
	RMS, %	28,53	7,93	15,91
Sproszkowana	ur	7,099	8,526	42,261
	F	0,956	0,951	0,950
	K	0,0015	0,0041	0,0011
	R2	0,983	0,990	0,986
	RMS, %	21,44	5,45	18,04

Źródło: Badania własne

Source: The own study

Ogólnie, najniższe wartości równowagowej zawartości wody (u_r), bez względu na rodzaj herbaty, zanotowano w środowisku o wilgotności względnej 52,9%, a najwyższe w środowisku o φ = 100%. W środowisku o φ = 52,9% najwyższą wartość u_r posiadała herbata liściasta 7,241 g wody/100 g s.s.. Wartości u_r dla herbaty sproszkowanej były o 2%, a dla herbaty granulowanej o 6,6% niższe od wartości u_r dla herbaty liściastej.

W środowisku o φ = 75,3% największą wartość u_r stwierdzono w herbacie granulowanej 10,121 g wody/100 g s.s., mniejszą o 15,8% w herbacie sproszkowanej, a najmniejszą w herbacie liściastej (o 21,1%).

W środowisku o φ = 100% największą wartość u_r stwierdzono w herbacie sproszkowanej 42,261 g wody/100 g s.s., znacznie mniejszą w herbacie liściastej i granulowanej, odpowiednio o 17,6 i 33,7%.

Stała F (współczynnik kształtu) posiadała zbliżone wartości na poziomie 0,95 dla herbaty sproszkowanej, bez względu na wilgotność względną środowiska (tab. 3). Wartości stałej F dla herbat granulowanej i liściastej były bardziej zróżnicowane, przy czym wilgotność względna środowiska nie miała jednoznacznego wpływu na jej wartości. Z kolei, na wartość parametru K, powiązanego ze współczynnikiem dyfuzji, bez względu na rodzaj herbaty, wilgotność względna środowiska ponownie nie wykazała jednoznacznego wpływu.

W tabeli 4 dokonano porównania wartości równowagowej zawartości wody (u_e) uzyskanych w metodzie statyczno-eksykatorowej z prognozowanymi wartościami u_r wyznaczonymi z modelu Ficka. Stwierdzono, że w środowisku o wilgotności względnej 52,9% wartości u_e były bardzo zbliżone do wartości u_r dla wszystkich badanych herbat.

Tabela 4. Wartości równowagowej zawartości wody wyznaczone metodą statyczno-eksykatorową (ue) oraz obliczone z modelu Ficka (ur) przy aktywności wody 0,529; 0,753 i 1,000

Table 4. The equilibrium water content values determined by the static gravimetric method (ue) and calculated from the Fick model (ur) at 0,529, 0,753 and 1,000 water activity

Rodzaj herbaty	a_w = 0,529		a_w = 0,753		a_w = 1,000	
	u_e	u_r	u_e	u_r	u_e	u_r
Granulowana	6,482	6,760	11,407	10,121	-	28,000
Liściasta	7,370	7,241	11,965	7,988	-	34,815
Sproszkowana	7,292	7,099	12,344	8,526	-	42,261

Źródło: Badania własne

Source: The own study

Świadczy to o tym, że po 48 godzinach procesu adsorpcji wody materiał praktycznie osiągnął stan równowagi wilgotnościowej, natomiast, w środowisku o wilgotności względnej 75,3% wartości u_r były znacznie mniejsze od wartości u_e dla wszystkich badanych herbat. Wynika z tego, że czas 48 godzin był za krótki, aby materiał zbliżył się do stanu równowagi wilgotnościowej z otaczającym go środowiskiem. Wydłużenie czasu w metodzie dynamicznej, prawdopodobnie doprowadziłoby do zbliżenia wartości u_r do u_e.

WNIOSKI

1. Izotermy adsorpcji wody wszystkich badanych herbat czarnych należały do II typu izoterm, zgodnie z klasyfikacją Brunauera i współpracowników.
2. Na podstawie przebiegu izoterm adsorpcji wody za najbardziej higroskopijną uznano herbatę liściastą, a za najmniej higroskopijną herbatę granulowaną w całym badanym zakresie aktywności wody.
3. Model Pelega najlepiej opisywał dane sorpcyjne badanych herbat. Obliczony średni błąd kwadratowy nie przekroczył wartości 7%.
4. Największą zawartość wody na poziomie monowarstwy wyznaczoną z modelu GAB posiadały herbaty sproszkowana i granulowana, a najmniejszą herbata liściasta.
5. W środowisku o wilgotności względnej 52,9 i 100,0% najmniejszą zdolnością chłonięcia pary wodnej charakteryzowała się herbata granulowana, a największą herbata sproszkowana.
6. Model kinetyczny Ficka w miarę poprawnie opisywał dane sorpcyjne badanych herbat. Obliczony średni błąd kwadratowy mieścił się w przedziale od 5,45 do 25,83%.
7. Badane herbaty po 48 godzinach procesu sorpcji wody w środowisku o wilgotności względnej 75,3% nie osiągnęły stanu równowagowej wilgotnościowej.

CONCLUSIONS

1. The water adsorption isotherms of the tested black teas belonged to second type of isotherms according to the Brunauer's classification.
2. On the basis of the course of the water adsorption isotherms, leaf tea was considered the most hygroscopic, and granulated tea the least hygroscopic in the all tested range of water activity.
3. The Peleg model best described the sorption data of the tested teas. The calculated root mean square error did not exceed 7%.
4. Powdered and granulated teas had the highest water content at the monolayer level determined from the GAB model, and leaf tea the lowest.
5. In the environment with 52,9 and 100,0% relative humidity, granulated tea was characterized by the lowest capacity to adsorb water vapor, and powdered the highest.
6. The Fick's kinetic model described the sorption data of the teas tested relatively correctly. The calculated root mean square error ranged from 5,45 to 25,83%.
7. The tested teas after 48 hours of the water sorption process in an environment with a relative humidity of 75,3% did not achieved the equilibrium moisture state.

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ВЛИЯНИЕ ФРИКЦИОННЫХ ХАРАКТЕРИСТИК НА ВИБРООРИЕНТИРОВАНИЕ РЫБЫ®

Wpływ charakterystyki tarcia ryb na ich orientację przestrzenną podczas procesu wibracji®

Предлагается решение дифференциального уравнения движения рыбы на виброплоскости численным методом, который дает возможность оценить путем виртуального эксперимента влияние фрикционных характеристик рыбы на динамику процесса. Установлен наиболее рациональный режим виброперемещения, разработаны рекомендации по подбору фрикционной пары «рыба-материал технологической поверхности» с коэффициентом трения в области малых значений.

Ключевые слова: рыба, фрикционные характеристики, виброориентирование.

W artykule zaproponowano rozwiązanie równania różniczkowego ruchu ryb na płaszczyźnie wibracyjnej metodą numeryczną, co umożliwia ocenę za pomocą wirtualnego eksperymentu wpływu cech tarcia ryb na dynamikę procesu. Ustalono najbardziej racjonalny tryb przemieszczania drgań, opracowano zalecenia dotyczące wyboru pary ciernej „materiał rybny -powierzchnia technologiczna" o współczynniku tarcia w obszarze małych wartości.

Słowa kluczowe: ryby, charakterystyki tarcia, proces wibracyjny.

ВВЕДЕНИЕ

Рост производительности рыбообрабатывающих машин ограничивается возможностями ручной ориентированной загрузки рыбы в кассеты приемного транспортера. При обслуживании машины тремя рабочими ее производительность составляет 120 рыб/мин. Основным способом механизированной загрузки рыбы является ее ориентирование на горизонтальной колеблющейся плоскости.

Способ ориентирования рыбы на виброплоскости основан на использовании следующих ее морфометрических и фрикционных свойств. У промысловых рыб веретенообразной формы центр тяжести располагается выше оси хребтовой кости и ближе к голове. Поэтому, попадая в зону загрузки виброплоскости, рыба стремится из-за возникающего момента занять устойчивое положение, ориентируясь спинкой вниз и вдоль желоба поверхности, соответствующего клиновидному профилю поперечного сечения рыбы. При определенных параметрах работы виброплоскости (круговой частоте т амплитуде колебаний) рыбе инерционной силой сообщается ускорение, обеспечивающее устойчивое относительное ее движение головой вперед. Это связано с различием фрикционных характеристик (коэффициентов трения) для рыбы, ориентированной в противоположных направлениях – головой или хвостом вперед. Причем, коэффициенты трения покоя и скольжения у рыбы, ориентированной хвостом вперед, существенно выше, чем их сопоставимые значения при движении головой вперед. Таким образом, в одном желобе виброплоскости образуются два потока рыбы, движущейся головой вперед, но в противоположных направлениях. При развороте одного из потоков на 180° в горизонтальной или вертикальной плоскости один желоб виброплоскости на выходе из загрузочного устройства образует два ручья с ориентированной головой вперед рыбой. В указанном алгоритме реализуется системная связь между свойствами сырья, способом выполнения технологического процесса и конструктивными особенностями загрузочных ориентирующих устройств [5].

Основной тенденцией совершенствования и конструирования загрузочных устройств является использование методов и средств мехатроники [1]. Современные системы технического зрения позволяют получить с высокой разрешающей способностью и скоростью видеокомпьютерное изображение объекта обработки, содержащее информацию о его форме и геометрических размерах. Этих

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данных достаточно для того, чтобы с помощью быстродействующих управляющих и исполнительных органов правильно позиционировать рыбу в нужном направлении. В работе [2] предлагается методика и алгоритм для автоматического анализа морфометрических параметров рыбы и определения наилучших линий резания с целью обеспечения ресурсосбережения. В работе [4] исследованы различные способы сортирования и ориентирования рыбного сырья, учитывающие профили тушек, а также показаны достоинства и недостатки различных методов. Разработаны алгоритм и устройство для быстрого сортирования и ориентирования морских рыб с учетом особенностей строения тела и широким применением математических методов. Статья [8] описывает подход к анализу физико-механических характеристик различных частей тела рыбы, используемых в пищевых целях. В работе [9] предложены методики для определения морфометрических параметров рыб, которые могут использоваться при машинном сортировании, ориентировании и загрузке сырья.

Теоретический анализ движения рыбы на горизонтальной виброплоскости впервые изучался С.И.Брилем [3] и Ю.В.Поспеловым [7] в 90-х годах прошлого столетия. Из-за отсутствия компьютерных технологий исследования проводились графоаналитическим методом, носили приближенный характер и не опирались на достоверно установленный массив по фрикционным характеристикам основных видов промысловых рыб, для которых применяются машинные методы ориентирования и загрузки в приемные кассеты рыбообрабатываюих машин. Как показано в работе [6], графоаналитический метод анализа может привести к неверным выводам и некорректной оценке влияния параметров виброориентирования.

Целью настоящего исследования является установление методом математического и компьютерного моделирования динамики относительного движения по горизонтальной виброплоскости рыбы и влияние на параметры процесса ее фрикционных свойств.

МЕТОДОЛОГИЯ ИССЛЕДОВАНИЯ

Как правило, привод виброплоскости осуществляется исполнительным механизмом по синусоидальному или близкому к нему закону. Рыба занимает в желобе виброплоскости устойчивое положение и движется с относительной скоростью с головой вперед в двух противоположных направлениях. Перед загрузкой в кассеты рыбообрабатывающей машины, после разворота на 180° в горизонтальной или вертикальной плоскости, каждый желоб образует два ручья с одинаковой, головой вперед ориентацией. Дифференциальное уравнение прямолинейного движения рыбы имеет вид:

$$m \cdot x = F + A \cdot m \cdot \omega^2 \cdot \sin(\omega t),\ |F| = f \cdot mg \quad (1)$$

Где: m – масса рыбы

F – сила трения;

f – коэффициент трения;

ω и A – круговая частота и амплитуда колебаний виброплоскости.

Аналитическое решение второй задачи динамики тела, описываемой уравнением (1) невозможно, так как в ней не заданы зависимости коэффициентов трения от скорости и направления. На основании анализа массива существующих экспериментальных данных примем качественный вид этой зависимости, соответствующий изображенному на рис.1.

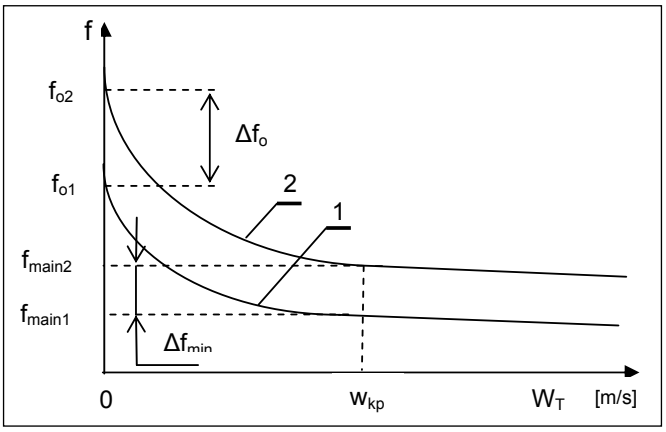

Рис. 1. Общий вид зависимости коэффициента трения рыбы от скорости движения по поверхности.

Rys. 1. Schemat ogólny zależności współczynnika tarcia od szybkości ruchu ryby po powierzchni.

Источник: Собственногое исследование

Źródło: Opracowanie własne

На рис.1 выделяем две области: в первой области при изменении скорости скольжения рыбы от 0 до $W_{кр}$ зависимости 1 (скольжение рыбы головой вперед) и 2 (скольжение рыбы хвостом вперед) коэффициенты трения изменяются от f_0 до f_{min} по закону, близкому к гиперболическому. Во второй области при $W > W_{кр}$ коэффициенты трения численно различаются незначительно (в пределах 3-5%), практически не зависят от скорости и процесс направленного относительного движения по виброплоскости становится невозможным. Анализ массива экспериментальных данных по фрикционным характеристикам различных видов рыб показал, что критическое значение скорости можно принять [6] равным 0,5м/с.

Решение дифференциального уравнения (1) осуществлялось численным методом в компьютерной среде MathCad. Характер зависимости 1 и 2 на рис.1 задавался по опорным точкам: коэффициентам трения покоя f_{01} и f_{02} и коэффициентам трения скольжения f_{min1} и f_{min2}, соответствующих значению скорости $W_{кр}$. Виртуальный эксперимент заключался в варьировании параметров f_{01}, f_{02}, f_{min1}, f_{min2} и разницы между ними $Df_0=f_{02}- f_{01}$; $Df_{min}=f_{min2}-f_{min1}$ при постоянных значениях w и A. При таком методологическом подходе становится возможным оценить влияние коэффициентов трения на динамику относительного движения рыбы.

Постоянные значения параметров виброплоскости A=10мм и w =25,0c^{-1} приняты по результатам установления рационального виброориентирования рыб среднего размера (скумбрия, ставрида), перемещающихся по поверхности из нержавеющей стали с опорными значениями коэффициентов трения: f_{01}=0,25; f_{min1}=0,18; f_{02}=0,43; f_{min2}=0,23 [6].

РЕЗУЛЬТАТЫ И ОБСУЖДЕНИЕ

На рис.2 представлена расчетная зависимость изменения относительной скорости рыбы при постоянных параметрах колебаний виброплоскости (A=10мм и w =25,0c^{-1}) и переменные коэффициентов трения, опорные значения которых указаны в таблице 1.

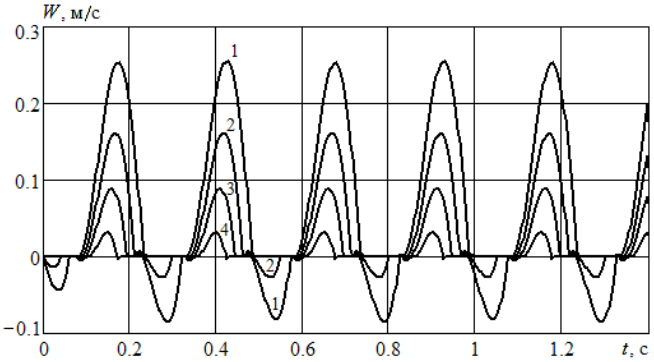

Рис. 2. Изменение относительной скорости рыбы при A=10мм, w =25,0c-1 и переменных коэффициентов трения.

Fig. 2. Zmiana względnej prędkości ryb przy A=10mm, w =25,0s-1 i zmiennych współczynnikach tarcia.

Источник: Собственногое исследование

Źródło: Opracowanie własne

Таблица 1. Значения опорных коэффициентов трения

Tabela 1. Wartości referencyjnych współczynników tarcia

Номер кривой на рис.2	f_{01}	f_{min1}	f_{02}	f_{min2}	Δf_0	Δf_{min}
1	0,25	0,18	0,43	0,23	0,18	0,05
2	0,35	0,28	0,53	0,33	0,18	0,05
3	0,45	0,38	0,63	0,43	0,18	0,05
4	0,55	0,48	0,73	0,53	0,18	0,05

Источник: Собственногое исследование

Źródło: Opracowanie własne

Как видно из данных табл.1 в виртуальном эксперименте изменялись значения опорных коэффициентов трения, но разница между ними сохранялась постоянной.

При значениях фрикционных характеристик, соответствующих кривой 4 на рис.2 видно, что функция движения рыбы по виброплоскости является прерывистой и осуществляется по циклу «остановка-движение головой вперед-остановка». Очевидно, что возникающей инерционной силы, переданной колебаниями виброплоскости, недостаточно для того, чтобы преодолеть силу трения при движении рыбы хвостом вперед. Суммарное время рыбы превышает время скольжения головой вперед.

Характер зависимости 3 на рис.2 качественно не отличается от описанного для кривой 4. Однако интенсивность процесса вибротранспортирования несколько возрастает.

Относительное скольжение рыбы по виброплоскости, соответствующее зависимости 2 на рис.2 осуществляется по полному циклу: «остановка-движение головой вперед-остановка-движение хвостом вперед». Причем интенсивность движения рыбы головой вперед существенно выше, чем при обратном движении.

Характер зависимости 1 на рис.2 также показывает, что относительное скольжение рыбы, ориентированной головой вперед, осуществляется по полному циклу. Этапы скольжения рыбы головой и хвостом вперед по времени почти одинаковы, при этом остановки между этапами очень кратковременны.

Эффективность процесса вибротранспортирования рыбы можно определить по средней скорости поступательного перемещения рыбы $W_{ср}$, а следовательно, и по производительности виброплоскости. На рис.3 представлены зависимости, характеризующие изменение координат рыбы по времени и соответствующие зависимостям на рис.2.

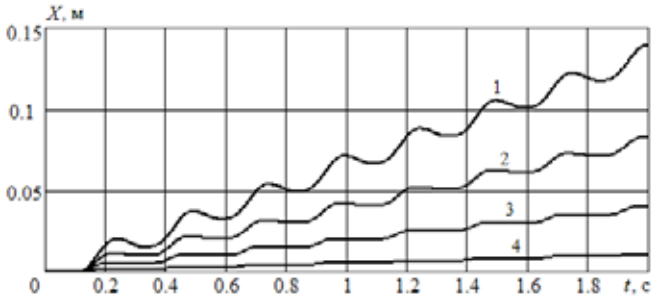

Рис. 3. Изменение координат рыбы при исходных данных, соответствующих данным на рис. 2.

Rys. 3. Zmiana współrzędnych ryby na dane początkowe odpowiadające danym na rys. 2.

Источник: Собственногое исследование

Źródło: Opracowanie własne

По данным рис.3 скорость $W_{ср}$ определяется как отношение перемещения рыбы x за время t. Для кривой 4 она составляет 0,005 м/с; для кривой 3 - 0,025 м/с; для кривой 2 – 0,04 м/с; для кривой 0,07 м/с. При этом, рассчитанная для рыб среднего размера теоретическая производительность виброплоскости, соответствующая условиям, отраженным зависимостью 4, составит для одного желоба ориентатора 33,6 рыб/мин [6]. Таким образом, виброплоскость с четырьмя желобами полностью обеспечит механизированную загрузку и работу большинства современных рыбообрабатывающих машин.

Из анализа зависимостей, представленных на рис. 2, 3, можно сделать два важных вывода:

- наиболее эффективным является полный цикл скольжения рыбы по виброплоскости с двумя кратковременными (почти мгновенными) остановками;
- уменьшение коэффициентов трения рыбы приводит к увеличению ее относительной скорости перемещения по виброплоскости.

В таблице 2 представлены значения опорных коэффициентов трения, когда для виртуального эксперимента варьировались не только их величины, но и разница между ними.

Таблица 2. Значения опорных коэффициентов трения

Tabela 2. Wartości referencyjnych współczynników tarcia

Номер кривой на рис.4	f_{01}	f_{min1}	f_{02}	f_{min2}	Δf_0	Δf_{min}
1	0,25	0,18	0,43	0,23	0,18	0,05
2	0,35	0,28	0,63	0,43	0,28	0,15
3	0,45	0,38	0,83	0,63	0,38	0,25
4	0,55	0,48	1,03*	0,83	0,48	0,35

Источник: Собственное исследование

Źródło: Opracowanie własne

*Экспериментально установлено, что коэффициент трения покоя у рыб, ориентированных хвостом вперед, может превышать 1,0.

На рис.4, 5 показаны аналогичные рис.2, 3 зависимости, полученные для исходных данных табл.2

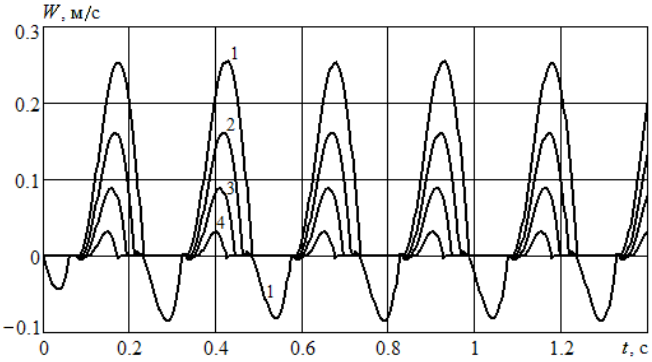

Рис. 4. Изменение относительной скорости рыбы при A=10мм, w =25,0c-1 и переменных коэффициентов трения.

Rys. 4. Zmiana względnej prędkości ryb A=10mm, w =25,0s-1 i zmiennych współczynników tarcia.

Источник: Собственное исследование

Źródło: Opracowanie własne

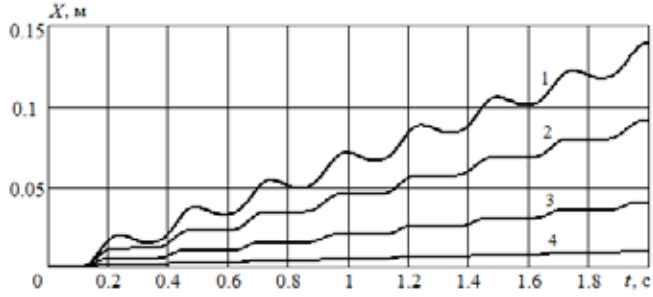

Рис. 5. Изменение координат рыбы при исходных данных, соответствующих данным на рис. 4.

Rys. 5. Zmiana współrzędnych ryby na dane początkowe odpowiadające danym na rys. 4.

Источник: Собственное исследование

Źródło: Opracowanie własne

По зависимостям, приведенным на рис.4, 5, можно видеть качественную аналогию с характером зависимостей, изображенных на рис.2, 3. Отличием является следующее. Разница между соответствующими коэффициентами трения влияет на динамику ее относительного перемещения по виброплоскости: с уменьшением разницы средняя скорость перемещения возрастает. Увеличение разницы между коэффициентами трения приводит к большим остановкам между этапами цикла. Полный цикл относительного перемещения рыбы характерен только для зависимости 4, причем параметры вибротранпортирования оказывается наиболее рациональными.

Учитывая тенденцию к улучшению условий виброориентирования в области малых значений коэффициентов трения и разницы между ними, проведем виртуальный эксперимент по исходным опорным значениям коэффициентов трения, приведенным в табл.3.

Таблица 3. Значения опорных коэффициентов трения

Tabela 3. Wartości referencyjnych współczynników tarcia

Номер кривой на рис.6	f_{01}	f_{min1}	f_{02}	f_{min2}	Δf_0	Δf_{min}
1	0,04	0,02	0,08	0,04	0,04	0,02
2	0,10	0,05	0,20	0,10	0,10	0,05
3	0,20	0,10	0,40	0,20	0,20	0,10

Источник: Собственное исследование

Źródło: Opracowanie własne

На рис.6 показаны аналогичные рис.2, 4 зависимости, а на рис.7 – аналогичные рис.3, 5, полученные для исходных данных табл.3.

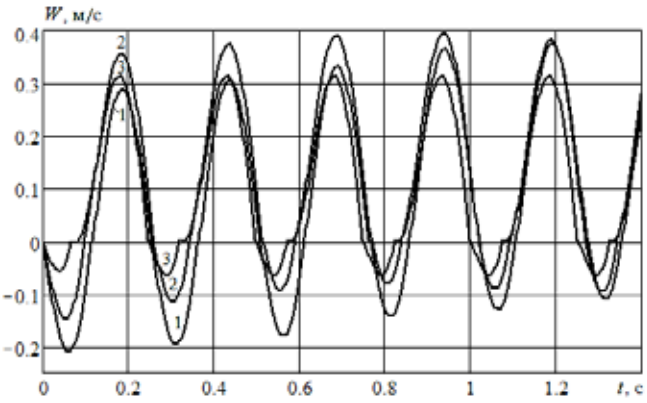

Рис. 6. Изменение относительной скорости рыбы при A=10мм, w =25,0c-1 и малых значениях коэффициентов трения.

Rys. 6. Zmiana względnej prędkości ryb przy A=10mm, w =25,0s-1 i małych współczynnikach tarcia.

Источник: Собственное исследование

Źródło: Opracowanie własne

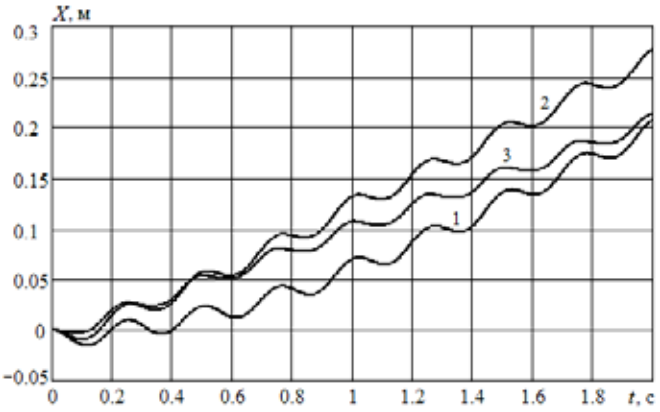

Рис. 7. Изменение координат рыбы при исходных данных, соответствующих данным на рис.4.

Rys. 7. Zmiana parametrów ryby przy danych wyjściowych zgodnych z rys. 4.

Источник: Собственногое исследование

Źródło: Opracowanie własne

Из рассмотрения рис.6 видно, что для всех зависимостей характерно наличие полного цикла вибротранспортирования со всеми этапами. Однако наиболее рациональные (оптимальные) условия процесса отражает зависимость 2 на рис. 6 и 7. Вероятно, что чрезмерное уменьшение коэффициентов трения и разницы между ними приведет к «стоянию рыбы на месте», а их увеличения – к уменьшению скорости относительного перемещения рыбы на виброплоскости.

По данным рис. 6, 7 можно сделать вывод о том, что ранее изложенные в научной литературе рекомендации (например, [3, 7]) об увеличении шероховатости поверхности виброплоскости за счет искусственного нанесения мелкодисперсного материала, представляется неверным. Наоборот, с практической точки зрения нужно подбирать трущуюся пару «рыба-материал поверхности» как можно с меньшей шероховатостью. Это возможно или за счет подбора материала виброплоскости с маленькой шероховатостью (нержавеющая сталь; оргстекло; пластмассы, допускаемые для пищевого машиностроения), или за счет шлифования поверхности виброплоскости.

ВЫВОДЫ

1. Решение дифференциального уравнения движения рыбы на горизонтальной виброплоскости позволило установить влияние её фрикционных характеристик на динамику относительного движения головой вперед.
2. Установлено, что наиболее рациональным режимом виброперемещения является полный цикл, включающий этапы движения рыбы головой и хвостом вперед с двумя мгновенными остановками.
3. С уменьшением коэффициентов трения увеличивается скорость относительного перемещения рыбы. В области малых коэффициентов трения установлены их рациональные значения.
4. С практической точки зрения выбор рациональных параметров виброперемещения осуществляется также за счет оптимального сочетания фрикционной пары «рыба-материал технологической поверхности».

WNIOSKI

1. Rozwiązanie równania różniczkowego ruchu ryb na poziomej płaszczyźnie wibracyjnej pozwoliło ustalić wpływ właściwości ciernych na dynamikę ich względnego ruchu w kierunku głową do przodu.
2. Ustalono, że najbardziej racjonalnym rodzajem ruchu wibracyjnego jest pełny cykl, który obejmuje etapy poruszania głową i ogonem ryby do przodu za pomocą dwóch natychmiastowych zatrzymań.
3. Wraz ze spadkiem współczynników tarcia rośnie względna prędkość ryby. Korzystny obszar współczynników tarcia to ten o małych wartościach.
4. Z praktycznego punktu widzenia wybór racjonalnych parametrów przemieszczenia drgań odbywa się również dzięki optymalnemu połączeniu pary ciernej: „materiał rybny- powierzchnia technologiczna”.

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THE KNOWLEDGE OF PRINCIPLES OF GOOD CATERING PRACTICE (GCP) BY THE STAFF OF KINDERGARTEN CANTEENS®

Znajomość zasad dobrej praktyki gastronomicznej (GCP) przez personel stołówek przedszkolnych®

The aim of the study was to determine the knowledge of the correct production operations during preparation of meals for children in Warsaw's kindergartens. A survey was conducted among 220 people preparing meals in kindergarten canteens. It was stated, that respondents don't understand GCP principles, despite declaring proper technological practices. The correctness of pretreatment of potatoes and vegetables, as well as meat was confirmed, respectively by about 60% and 78–92% of respondents. Technological incorrectness declared by respondents were related to skipping vegetable washing after peeling, long soaking of peeled potatoes, not used proper rules when meat thawing and chops coating. A significant percentage of respondents (over 60%) declared cooking potatoes starting with cold water, which contributes to the loss of vitamin C, as well as the cooking of green vegetables in a small amount of water, which effects in lower sensory quality. Estimation of the end of the meat roasting process by temperature measuring was used by a small percentage of respondents (33%). Identified the lack of technological knowledge and non-application of HACCP rules in practice, which indicates the need to educate canteen personnel.

Key words: technological process, canteens in kindergarten, GCP, personnel.

Celem pracy przedstawionej w artykule jest określenie wiedzy na temat prawidłowego postępowania technologicznego podczas przygotowywania posiłków dla dzieci w warszawskich przedszkolach. Przeprowadzono badania ankietowe wśród 220 osób przygotowujących posiłki w stołówkach przedszkolnych. Stwierdzono, że respondenci nie w pełni rozumieją zasady GCP, mimo iż deklarują właściwe wykonywanie wielu procesów technologicznych. Prawidłowe prowadzenie obróbki wstępnej ziemniaków i warzyw deklarowało około 60% ankietowanych, natomiast mięsa 78–92%. Błędy technologiczne wskazane przez respondentów dotyczyły nie stosowania mycia warzyw po obieraniu, długiego moczenia obranych ziemniaków, nieprawidłowego rozmrażania mięsa i panierowania kotletów. Znaczny odsetek (ponad 60% osób) deklarował rozpoczynanie procesu gotowania ziemniaków od zimnej wody, co przyczynia się do strat witaminy C oraz gotowanie warzyw zielonych w małej ilości wody co ma wpływ na ich jakość sensoryczną. Koniec procesu pieczenia mięsa poprzez pomiar temperatury stosowało niewiele osób (33%). Stwierdzone braki wiedzy technologicznej i niestosowanie zasad HACCP w praktyce, wskazują na konieczność edukacji personelu stołówek.

Słowa kluczowe: proces technologiczny, stołówki w przedszkolu, dobra praktyka gastronomiczna, personel.

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INTRODUCTION

Institutional children's nutrition requires special responsibility in terms of providing high nutritional and sensory quality meals and their food safety. Ensuring the proper quality of prepared dishes in mass catering establishments is possible only within the implementation of Good Hygienic Practice (GHP) and Good Manufacturing Practice (GMP)' principles referred as Good Catering Practice (GCP), as well as HACCP rules [26].

The quality of food offered by catering establishments is closely related to proper food preparation in accordance with technological rules. It includes both the correct selection of foodstuffs, processes, and operations to be used in the production of dishes, as well as physicochemical and biological changes that occur in the raw materials during processing [11].

According to authors [10] personnel in Polish catering establishments still uses inappropriate technological and hygienic practices in food production.

In 2018, there were 408 canteens in Warsaw, which constituted approximately 15.2% of the total number of catering establishments in Warsaw [39]. They were under the supervision of the State Sanitary Inspection in the capital city of Warsaw among a group of 2,563 mass catering establishments. In 2016, in a group of 15 controlled establishments, poor sanitary and hygienic conditions that posed a threat to food safety were found. During the inspection, the sale of out-of-date products, digestive system ailments after eating meals delivered from catering establishments to schools and kindergartens, food storage at incorrect temperatures, lack of hygiene, and other issues were noted. Assessment of the catering services provided in school and kindergarten canteens showed a number of incorrectness in menus planning, including an insufficient variety of meals and too small proportion of fruit and vegetables in relation to consumed fats [36, 41]. In other research [44, 50], analysis of food safety compliance in 55 Warsaw nurseries demonstrated conformity with the GMP/ GHP and HACCP standards. However, the level of compliance with the standards to the documentation of the food safety system was higher than their use in practice [44].

Most of the published studies on canteens concern an assessment of food safety and hygienic behavior of staff, while only a small number explores technological practices (GMP) of the staff [5, 9, 22, 29, 44, 47]. It should be emphasized that improper technological behavior may lead to providing end products of poor quality [25]. The shaping of the technological process is closely related to health safety aspects. From the consumer's health point of view, it is important to obtain a microbiologically, chemically, and physically safe product, which could be achieved by the implementation and application of food safety systems [4, 15, 26]. Importantly, the catering industry can be a potential source of food poisoning for a big group of people. In the European Union, the percentage of noted food poisoning outbreaks after eating meals in catering establishments is over 60%, and in the USA it is nearly 80%, while the number of food poisonings caused by improper preparation of dishes at home is 21–30% [19, 20, 49].

The aim of the study was to determine the knowledge of catering practices during the preparation of meals for children by people responsible for the nutrition in Warsaw educational institutions on the basis of their declarations.

MATERIAL AND METHODS

Research on the implementation of GMP in kindergarten canteens was carried out using the direct interview method with staff responsible for nutrition in educational institutions.

The research was conducted among 220 people working in Warsaw kindergartens. Most of the respondents were women (92.7%). Three-quarters of the group (72.3%) were between 41 and 60 years old, 16.8% were 25–40 years old, and 10.9% of the respondents were under the age of 25. Almost half of the respondents (48.2%) had secondary education, 26.8% – vocational education, 2.7% – primary education, and 10% – higher education. The rest of the group did not declare their degree of education. More than half of the respondents were employed as a cook (50.5%) or as a kitchen manager (16.4%); 19.1% as manciples, the rest worked in different positions. They were mainly people who prepared meals directly.

The research tool was an original, validated questionnaire used in previous research [12, 31, 45]. The survey consisted of 16 questions about good catering practice during meal preparation and 4 questions about the characteristics of the respondents (gender, age, education, job position). The questions were closed-ended and related to the good manufacturing practices (GMP) during pre-treatment and thermal processing of plant and animal origin ingredients.

Statistical package STATISTICA v.13.0 was used to perform the statistical analysis. The comparison of the given qualitative features was performed using the one-way analysis of variance (ANOVA), which showed no statistically significant differences between catering practices in dependence of gender, age, and education of respondents.

RESULTS AND DISCUSSION

Manufacturing practices during pre-treatment of vegetables and potatoes

Operations related to the preparation of raw materials for heat treatment of vegetables and potatoes have a significant impact on the quality of the dishes obtained from them [11], therefore, the respondents were asked about the procedure during pre-treatment (Table 1). To eliminate physical, chemical and microbiological contaminants from the vegetable surface, proper pre-treatment procedure is recommended, i.e. root vegetables and potatoes should be washed, peeled, and then rinsed.

Most of the respondents (62.7%) declared the correct pre-treatment procedure (Table 1). Some respondents declared making mistakes by skipping the rinsing (16.8%) and soaking [root] vegetables in cold water for a long time before cooking (10.5%). There is a noticeable greater variation in declared handling methods of potatoes. The largest number of respondents (31.8%) declared, they soak the potatoes in cold water maximally <0.5h before cooking. Some (28.6% of surveyed workers) cook potatoes immediately after pre-treatment. Every fifth person (20%) conducted this process

incorrectly, and 23.3% of the group too long soaked the potatoes after peeling.

Table 1. Methods of vegetables and potatoes pre-treatment declared by canteens personnel (n=220)

Tabela 1. Metody obróbki wstępnej warzyw i ziemniaków deklarowane przez obsługę stołówek (n=220)

Pre-treatment method		Percentage of responses (%)	
		Root vegetables	Potatoes
wash, peel with a knife (for vegetable or chef's) and rinse		62.7	28.6
peel it with a knife and rinse it		16.8	20.0
wash, peel, rinse and soak in cold water (<0.5h)		17.3	31.8
wash, peel, rinse, soak in cold water until cooking (about 0.5-1h)		10.0	17.3
wash, peel, rinse, soak in cold water (for a few hours or more)		0.5	5.0
Peeling methods			
Manual		66.4	
Mechanical		47.3	
mechanical and manual		13.7	
The method of soaking the seeds of legumes			
„cold"	12 h at room temperature	38.2	
	12h at low temperature <10°C	44.1	
„hot"	12 h, pouring boiling water	4.1	
	3-4h, pouring boiling water	13.6	

Source: The own study

Źródło: Badania własne

Undesirable changes in color can influence consumer acceptability of the product. Enzymatic browning is an indicator of the quality deterioration of many fresh and processed fruits and vegetables such as banana and potato [2]. The chemical substances (e.g. sulfide) use, heat treatment, cold storage, and other advanced techniques are the methods that inhibit the browning.

Correct pre-treatment of root vegetables and potatoes allows for a short subsequent soaking in cold water after peeling to prevent their color darkening, which is caused by the browning reaction. The process is caused by the oxidation of phenolic compounds (mainly tyrosine) induced by endogenous polyphenol oxidase (o-diphenol oxidase, EC 1.10.3.1) in the presence of oxygen, to a brown compound called o-Quinones, which then polymerize to produce deep dark polymers (melanin) [2, 11]. Short-term soaking of the peeled vegetables in cold water or in weak salt solution are the methods commonly used in food service. Indeed, they reduce the activity of enzymes responsible for browning reactions (salt) and reduces the access of oxygen (water), but the too-long process may lead to minerals and vitamin C loss [28], as well as deterioration of sensory quality due to the leaching of flavor compounds [11, 46].

The surveyed workers declared (61%), that they usually peel the vegetable mechanically using a washer-peeler or combine mechanical with manual peeling (Table 1). Interestingly, many canteen workers (66.4% of respondents), declared manual peeling which in the case of preparing a large number of meals may have an impact on the quality of the produced dishes. Commercially pre-peeled vegetables (both potatoes and root ones) were not used by respondents in their canteens. Mechanical peeling is recommended to shorten the time of contact of the freshly cut vegetable' surface with oxygen or water (during soaking in water), thus reducing the nutrients lixiviation and cross-contamination possibility, as well as due to the smaller amount of food waste, and increased yield of the process [11]. Meal preparation personnel is becoming the most important factor influencing the generation of food waste in schools [7].

The nutritional recommendations indicate the need to include legume dishes in the menu. However, flatulence caused by oligosaccharides (RFO) deters consumers from eating more legumes [21]. A properly carried out culinary treatment includes soaking in water, which is usually applied prior to cooking to soften texture, significantly reduce the cooking time, and remove natural anti-nutritional substances (raffinose family of oligosaccharides - RFOs) [16]. Legume seeds can be soaked: cold (in refrigerated conditions) for about 10 hours or hot (by pouring boiling water over them) for 2-3 hours. "Hot" soaking is a more advantageous method in terms of greater removing the flatulence substances, better retention of nutrients and food safety, as higher temperature reduces initial microbial load (2-3 hours) and limits the time of staying in a dangerous temperature zone [1, 5, 16]. In our study, the majority of surveyed staff declared the use of the 'cold' method (82.3%), wherein a significant share (38.2%) improperly stores the soaked seeds at room temperature, which poses a microbiological hazard. The results of other authors also found improper food processing by the kitchen staff. In 16% of catering establishments, vegetables were processed at the same stand as other raw materials [23].

Manufacturing practices during the thawing and preparing cutlets for heat treatment

Thawing is one of the most important processes of a pre-treatment regarding meat. It should be carried out in a way allowing to minimize the risk of multiplication of pathogenic microorganisms. It is recommended to thaw the meat under refrigerated conditions and use a leak-proof package or plastic bag to isolate food from the surrounding environment. Once thawed the food cannot be re-frozen and must be cooked immediately [26].

The majority of the respondents (Table 2) declared that they thaw meat in accordance with the recommendations, i.e. thawing in cold temperature (76.4%) or directly cooking without thawing (1.8%). Some respondents (Table 2) used the cold-water thawing method at room temperature (13.2%) or under refrigerated conditions (3.6%). A small percentage of participants (3.2%) thawed meat at room temperature [37].

Table 2. Methods of pre-treatment and heat treatment of meat used by canteens personnel (n=220)

Tabela 2. Metody obróbki wstępnej i cieplnej mięsa stosowane przez personel stołówek (n=220)

Meat processing	Percentage of responses (%)
The ways to thawing meat	
in refrigerator	76.4
in cold water (packed) at room temperature	13.2
in cold water (packed) under refrigerated conditions	3.6
in hot water (packed)	0.5
directly during the heat treatment process	1.8
in a microwave oven	0.0
in the air without packaging at room temperature	3.2
Preparation cutlets to the heat treatment	
breading for cutlets immediately before pan-frying	91.8
breading for cutlets beforehand to save time and stored them after	4.1
breading for an hour in a refrigerator	1.4
breading for cutlets beforehand to save time and stored them after	0.9
breading and frying day before	0.9
Fat change after meat frying	
after each use	96.4
after use pouring fat into a jar and stores it for the next frying	2.6
the lack of answer	1.0
The end of the meat roasting process determining	
based on the processing time	34.1
assessing visually	22.3
the probe reading use	32.7
the lack of answer	10.9

Source: The own study

Źródło: Badania własne

A similar percentage of people declaring thawing the meat under refrigerated conditions was noted among staff responsible for mass catering in Ireland (63%) [6], Brazil (78.1%) [38], and Jordan (66.7%) [34]. In other Polish catering establishments, employees often do not follow the principles of GMP regarding meat and egg preparation, which can be a source of *Salmonella* sp. [26].

The surveyed workers were also tasked to indicate how long they make a breading for cutlets before pan-frying (Table 2). Most of the participants (91.8%) declared that this process was carried out, i.e. immediately before pan-frying. The rest of the group did this beforehand to save time and stored them after breading for an hour or a night in a refrigerator. Such a procedure leads to a product of low quality, and the breadcrumbs soaked with the juice of the meat may fall off during frying and burn [11].

Practices of respondents regarding the heat treatment of potatoes and vegetables

Almost all respondents boiled potatoes traditionally in a pot (Table 3), wherein most of them (64.5%) process them incorrectly, starting with cold water. This leads to increased vitamin C loss of up to 60%, whereas boiling water use reduces the loss to 41%. This is due to the inactivation of the ascorbinase enzyme at higher temperatures [11]. The recommended parameters of cooking vary depending on vegetable type, therefore the respondents answered a separate question about the thermal processing of green and other vegetables (Table 3), as well as the question about cooking vegetable stock.

Table 3. Methods of vegetables & potatoes heat treatment used by canteens personnel (n=220)

Tabela 3. Metody obróbki cieplnej warzyw i ziemniaków stosowane przez personel stołówek (n=220)

Thermal treatment methods	Percentage of responses (%)			
	potatoes	green vegetables	carrot	other
in a pot with plenty of water:				
- when starting the process with cold water	64.5	-	-	43.0
- when starting the process with boiling water	35.5	-	5.9	50.0
- without cover	-	7.7	-	-
- under cover	-	9.5	-	-
in a pot in a little water:				
- without cover	-	20.0	35.5	0
- under cover	-	40.9	45.2	0
- with the addition of fat	-	-	16.4	-
in the microwave oven:				
- in a little water	0.0	0.0	-	0.0
- in plenty of water	0.9	0.0	-	0.0
in a pressure cooker:				
- in a little water	0.5	0.0	-	2.0
- in plenty of water	0.0	0.9	-	0.0
in a pot (with perforated insert) steaming	0.0	10.9	-	5,0
in the combi steamer (steaming)	0.0	15.0	-	0.0

Source: The own study

Źródło: Badania własne

The greatest number of respondents (Table 3) declared that they usually cook green vegetables traditionally in a pot (78.1%), steam them in a pot (10.9%), and cook in a combi steamer (15%). Among kitchen workers who use traditional boiling, only 7.7% of them follow the culinary recommendations (GMP). It was found that most people cook green vegetables in a small amount of water, covered (40.9%), or without a cover (20%).

Green vegetables, that are rich in chlorophyll pigments, should be cooked as short as possible, and the process should be started with boiling water. A properly conducted cooking process is carried out in a large amount of water with a neutral

pH (dilution of organic acids), possibly with the addition of milk (neutralization of some acids), without a cover in the initial stage of heat treatment (to evaporate volatile organic acids) and without the use of increased pressure [11, 18].

A large diversification of responses was observed in the methods of carrot cooking (Table 3). Most of the respondents (97.1%) declared that they cook this vegetable in a small amount of water. Carrots are often prepared as stewed vegetables. Most consumers boil them under cover (45.2%), starting the process with both cold and hot water (22.6% each). A small percentage of surveyed (5.9%) indicated traditional boiling in a pot with a large amount of hot water as a beneficial method of processing carrots. This allows for obtaining a product with good sensory quality, good retention of carotenoid compounds, and significant removal of chemical contaminants [44]. Vegetables low contaminated with chemical residues should be cooked in a little water, which reduces the leakage of nutrients. On the other hand, vegetables that tend to accumulate chemical contaminants should be boiled in large amounts of water and with prolonged process time to remove them [13] Only 16.4% of examined workers declared fat as an additive to stewing carrots, which is used to preserve beta-carotene (Table 3).

In the case of other vegetables (Table 3), the respondents declared traditional boiling in water (93%). Half of the respondents (50%) cook vegetables correctly, starting with hot water, but a significant share (43%) boil it with a 'cold start' (Table 3). A significant percentage of the surveyed staff correctly depended boiling with „cold or hot start" on the culinary intention (stock or vegetable portion). More than half of the surveyed group (52% of indications) indicated that the vegetable stock should be cooked with a cold start, and only 20% of workers pointed out that cooked vegetable portion should be boiled with a 'hot start'. Few of the respondents declared cooking in a steam pot (5%) and in a pressure cooker (2%).

The beetroot borscht (red beet soup) is a typical national Polish dish eaten mainly in Central and Eastern Europe [48]. In Russia, Lithuania, Belarus, Ukraine, and Poland, the main ingredient is beet, which gives the soup a vivid red color [32]. Betalains, the beetroot pigments, are sensitive to high temperatures and the presence of oxygen. In gastronomic practice, to obtain the desired red color of beetroot, they should be boiled or baked in its peal, and then grated and acidified to fix the color. Boiling beets of a high degree of fragmentation (rubbing on the grater) results in obtaining unacceptable sensory experience of soup [11, 46].

In this study, almost all of kitchen staff (98.7%) declared preparation of beetroot borscht on their own, and a small percentage (1.4%) uses canned or instant soup (Figure 1).

The largest percentage of the respondents (36.4%) comminuted beets before heat treatment, rubbing them on a grater, which contributes to a significant deterioration of the color. Nearly 30% of respondents diced beetroots into cubes or slices before heat processing. Only every third respondent (34.5%) declared following the recommended procedure to maintain the desired color of borscht, i.e. roasting the beets in their peel, then shredding them and cooking them briefly to elute the dyes (Figure 1).

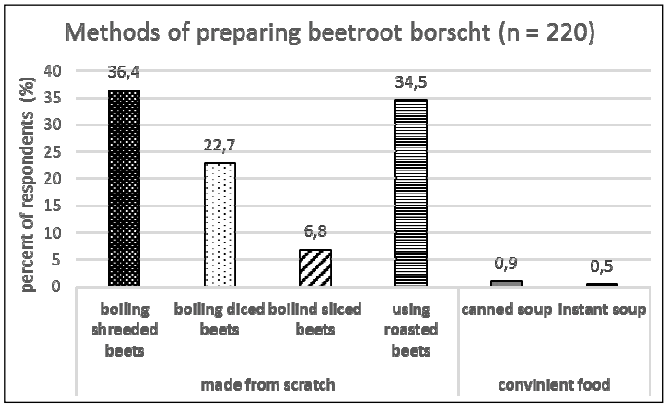

Fig. 1. Methods of beetroot soup preparation in group of canteens personnel (n=220).

Rys. 1. Sposoby przygotowywania barszczu czerwonego przez personel stołówek (n=220).

Source: The own study

Źródło: Badania własne

The process of heat treatment of meat

Frying is a heat treatment method that involves food and hot oil or fat. Hence, the quality of the frying medium, process conditions, and utensils or fryers used are critical elements in the frying process. The frying fats most frequently used by the respondents were vegetable oil (94.6%), olive oil (6.4%), and butter (2.3%). Lard and other fats were used by less than 1% of responders. The majority of participants in the study (96.4%) declared that the frying fat was changed after each use, one of those surveyed poured it into a jar and stored it for the next frying, the others did not answer this question.

The respondents (n = 220) determined the moment of oil readiness for frying in various ways. This was mainly done by the "raw potato" test (35.5%), the "water drop" test (31.4%), or used by a thermometer (24.5%). A small percentage of the respondents (5.5%) declared that they start frying when they notice the burning and smoking of fat or start the process immediately after pouring the cold fat into the pan (1.4%). Too low temperature of fat and the use of old frying fat are factors to increase its absorption into a product, which is a disadvantageous phenomenon from the technological and nutritional point of view [11].

One of the important elements in ensuring food safety is reaching the right temperature in the geometric center of the product. Meat processing temperature is a critical control point (CCP) and should be monitored and recorded [11]. Respondents were asked how they determined the end of the roasting process (Table 2). Most surveyed workers (34.1%) declared that the end of the process was determined based on the processing time or assessed visually (22.3%). The probe reading as a method of estimation was used only by 32.7% of the respondents. A similar share of kitchen workers (31.3-37.5%), who declared indication of the end of the roasting process based on temperature measurement were obtained in Brazilian study [39] and higher share (40-57%) in the Irish study [22].

The time and temperature of the heat treatment should be sufficient to inactivate pathogenic non-sporulating microorganisms. It is assumed that the temperature of beef

should be min. 63°C, pork at least 74°C (72° C for 2 minutes), and in the case of whole poultry carcasses temperature of up to 85°C. Visual assessment of the degree of doneness is not enough to accurately determine the temperature inside the meat. Determining the end of the process visually or by measuring the cooking time may lead to a reduction in the juiciness of the meat [12]. Controlling the temperature and time of the process reduces the formation of unfavorable compounds (heterocyclic aromatic amines and acrylamide) and the loss of some amino acids and minerals [9].

Food provided by catering establishments can be a significant source of many food poisonings [35]. It may be affected by improperly conducted culinary treatment, which lead to cross-contamination between ready food and the raw material; inappropriate storage conditions; incorrect cleaning procedures; lack of personnel hygiene ; use of contaminated dishes and equipment, and insufficient heat treatment [3, 24, 33]. In the past, these food safety noncompliances resulted in food poisoning caused by the presence of *Listeria monocytogenes* in food – in school catering in Italy, 2009-2012 [30]; and in school and university canteens in Greece, 2001-2004 [27]; *Bacillus cereus* in kindergarten in Belgium [14]; *Salmonella Sp.* - in Podgorica, Montenegro, where about 23,000 food poisonings were found in 2004-2015 [4]. It is worth emphasizing that young students represent a high-risk group for *L. monocytogenes* due to lower immunity, especially among children with weakened immune systems [8, 35, 43].

The performed statistical analysis did not show the influence of sociodemographic features on the technological behavior of canteen employees. This may be due to the homogeneity of the group, as most of the people delegated to the workshops were female, aged 41-60 and employed as a cook or kitchen assistant.

Summing up, digestion of nutrients, bioactive compounds bioavailability, development of changes in food, and above all, food safety may be influenced by its thermal processing and application of appropriate technological procedures [17, 40, 42]. Proper manufacturing practices, which include pretreatment and heat treatment besides ensuring food safety (e.g. internal temperature measurement, removing food contaminants) should also provide food of attractive appeal and other sensory traits (e.g. color of green vegetable, the juiciness of meats, intense flavor of vegetables), and protect nutritional value (against leaching and destruction of nutrients, absorption of undesired fat). Gaps in kitchen workers' knowledge resulting from no culinary education, as well as underinvestment of equipment in kindergarten, may reflect on a lower quality of served dishes. Further study should develop this preliminary research and be focused on hygienic aspects including the kitchen premises audits.

CONCLUSIONS

1. The staff of kindergarten canteens participating in the study does not fully know and implement the principles of good catering practice (GCP).
2. Although reaching the right temperature in the geometric center of a dish is crucial for food safety and sensory quality, only about 33% of respondents declared that the end of heat treatment of meat is determined by measuring temperature. This indicates irregularities in the hygiene of food preparation in kindergartens and in the functioning of the HACCP system.
3. About 60% of the respondents declared that the pretreatment of potatoes and vegetables was performed correctly. The rinsing of vegetables after peeling and soaking of peeled for too long was mentioned among the irregularities. Proper pre-treatment of meat was declared by the majority of respondents, e.g. defrosting the meat in accordance with the recommendations (78%) coating the cutlets immediately before frying (92%).
4. Surveyed staff declared that potatoes were improperly boiled with a cold start (64.5%), which contributes to large losses of vitamin C. Additionally, 60.9% of staff was stated as cooking green vegetables in a small amount of water, which effect reduces the products sensory quality.
5. Our findings show the need to educate people responsible for preparing meals in preschool institutions. Irregularities in the field of technological conduct can affect sensory quality, nutritional value, and food safety.

PODSUMOWANIE

1. Personel stołówek przedszkolnych, biorący udział w badaniu nie w pełni zna i realizuje zasady dobrej praktyki gastronomicznej (GCP).
2. Mimo, iż osiągnięcie odpowiedniej temperatury w geometrycznym centrum potrawy jest kluczowe dla bezpieczeństwa żywności i jakości sensorycznej, jedynie około 33% osób deklarowało, że koniec obróbki termicznej mięsa określa mierząc temperaturę. Wskazuje to na nieprawidłowości w higienie przygotowania posiłków w przedszkolach i w zakresie funkcjonowania systemu HACCP.
3. Prawidłowe wykonywanie obróbki wstępnej ziemniaków i warzyw deklarowało około 60% badanych. Wśród nieprawidłowości stwierdzono pomijanie procesu mycia warzyw po obraniu, a obrane ziemniaki były zbyt długo moczone. Poprawne prowadzenie obróbki wstępnej mięsa deklarowała większość respondentów, np. rozmrażając mięso zgodnie z zaleceniami (78%) czy panierując kotlety bezpośrednio przed smażeniem (92%).
4. W przypadku procesu obróbki termicznej, ankietowany personel deklarował nieprawidłowe gotowanie ziemniaków od zimnej wody (64.5%) co przyczynia się do dużych strat witaminy C oraz gotowanie warzyw zielonych w małej ilości wody (60.9%), co obniża ich jakość sensoryczną.
5. Na podstawie przeprowadzonych badań stwierdzono potrzebę edukacji osób odpowiedzialnych za przygotowanie posiłków w placówkach przedszkolnych. Nieprawidłowości w zakresie postępowania technologicznego mogą bowiem wpływać na jakość sensoryczną, wartość odżywczą i bezpieczeństwo żywności.

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ZASTOSOWANIE WARZYW JAKO ŹRÓDŁA SMAKU SŁODKIEGO W PRODUKCJI CIAST Z OGRANICZONYM DODATKIEM SACHAROZY®

The usage of vegetables as a source of sweetness in the production of cakes with limited addition of sucrose®

Celem pracy przedstawionej w artykule była ocena wybranych cech jakościowych ciast, w których zmodyfikowano podstawową recepturę zamieniając sacharozę i część mąki pszennej warzywami o naturalnym smaku słodkim. Materiałem do badań było siedem rodzajów ciast: ciasto kontrolne zawierające pełną zawartość cukru, trzy rodzaje ciast bez dodatku cukru, w których cukier i część mąki zastąpiono równoważną masą rozdrobnionych warzyw (marchwi, słodkich ziemniaków i dyni) oraz trzy rodzaje ciast o składzie podobnym do poprzednio wymienionych, ale z dodatkiem połowy cukru przewidzianego w recepturze podstawowej (kontrolnej). Dla każdej próbki ciasta po upieczeniu dokonano instrumentalnego pomiaru barwy, oznaczono refraktometrycznie zawartość ekstraktu ogółem oraz dokonano oceny sensorycznej wybranych cech organoleptycznych (jakość ogólną, intensywność smaku słodkiego, barwę na przekroju i powierzchni ciast). Wyniki wykazały, że wszystkie ciasta bez dodatku cukru oceniane były gorzej niż próba kontrolna, jednak uzyskane wartości dla badanych cech jakościowych nie były dyskwalifikujące, a w przypadku 50% dodatku cukru przewidzianego recepturą podstawową były nawet zadowalające. Najmniej przydatna do produkcji ciasta bez lub z ograniczoną ilością cukru okazała się dynia, natomiast najbardziej smakowite było ciasto z dodatkiem słodkich ziemniaków. Wykazano, że poprzez zastosowanie szybkiego, refraktometrycznego pomiaru ekstraktu gotowych ciast można przewidzieć pożądalność smaku słodkiego tych ciast, która w istotny sposób wpływa na ich jakość ogólną.

Słowa kluczowe: ciasta ucierane, warzywa, smak słodki, jakość ogólna, barwa ciast.

The aim of the study presented in the article was the assessment of selected quality features of cakes, in which the basic formula was modified by replacing of some quantity of sucrose and wheat flour with natural sweet vegetables. As the research material were used seven types of cakes: a control cake that contains entire amount of sucrose, three types of cakes without sucrose addition in which sucros and some amount of wheat flour were replaced with the equal mass of grated vegetables (carrot, sweet potatoes or pumpkin) and three types of cakes containing the analogue ingredients as mentioned above, though, with addition of half quantity of sucros that was listed in the control formula. In each cake sample, after thermal heating, the colour was measured instrumentally, total extract refractometrycally as well as sensory features were measured of selected organoleptic attributes (total quality, intensity of sweetness, colour of cross-section and colour of the cakes' surface). The results of investigations have shown that all cakes without addition of sucrose were lower estimated than the control cake sample, but the achieved values of the assessed quality features weren't disqualifying, and in the case of cakes containing 50% of sucrose, determined by the basic formula, were even satisfying. Nevertheless, the least suitable for the production of cakes without or with limited amount of sugar, was the pumpkin, but the most delicious was the cake with the addition of sweet potatoes. It was proven that thanks to applying of fast, refractometry measurement of the extract of ready-made cakes, it is possible to predict the desirable sweetness of these cakes that significantly influences their total quality.

Key words: grated cakes, vegetables, sweetness, total quality, colour of the cakes.

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WSTĘP

W 2018 roku Narodowy Fundusz Zdrowia opublikował raport *Cukier, otyłość – konsekwencje* [3]. Z raportu wynika, że przeciętny Polak spożywa rocznie około 40 kg cukru dodatkowo ponad ten, który zawarty jest naturalnie w surowcach, np. w owocach i warzywach. Znany jest także fakt, że głównym źródłem cukru w diecie są napoje, wyroby cukiernicze i półcukiernicze czy inne słodkie przekąski. Konsekwencją nadmiernego spożywania cukru jest wzrost liczby osób z nadwagą i otyłych, w tym dzieci. To z kolei bezpośrednio przekłada się na wzrost liczby zachorowań na różne choroby cywilizacyjne, przede wszystkim na cukrzycę.

W świetle tych niepokojących faktów poszukuje się rozwiązań ograniczających stosowanie cukru jako czystej sacharozy, wprowadzając jego zamienniki, głównie naturalne składniki o smaku słodkim. Do takich składników można zaliczyć niektóre warzywa takie jak np. marchew, dynię czy słodkie ziemniaki. Surowce te oprócz naturalnego smaku słodkiego, mogą dodatkowo stanowić źródło cennych składników odżywczych i bioaktywnych.

Według różnych źródeł 100 g marchwi, w zależności od odmiany i miejsca występowania, dostarcza od 27 do 41 kcal, przez co uznawana jest ona jako surowiec niskoenergetyczny. W jej skład wchodzi przede wszystkim woda (88 – 89,7%), węglowodany ogółem (7 – 13,5%, w tym ok. 4,7% cukrów), od 2,7 do 3,6% błonnika pokarmowego. Białko i tłuszcz występuje w marchwi w znikomej ilości (odpowiednio ok. 1% i 0,2%) [2; 7; 9; 10]. Marchew jest źródłem wielu składników bioaktywnych. W jej składzie stwierdzono obecność takich składników jak: terpeny, alkohole, aldehydy, estry, ketony, pyrazyny, związki furanowe, pyrole oraz związki fenolowe, takie jak kwas kofeinowy i jego pochodne oraz pochodne kwasu ferulowego [7]. Wiele z wymienionych związków wykazuje właściwości przeciwutleniające. Najbardziej znanymi substancjami przeciwutleniającymi zawartymi w marchwi są karotenoidy, wśród których dominuje b-karoten (8,9 – 10,5 mg/100 g) oraz a-karoten – 5,3 mg/100 g [2; 9; 10]. Ze względu na swoje działanie antyrodnikowe związki te zapobiegają chorobom układu krążenia, degeneracjom komórek, w tym katarakcie, mają działanie prewencyjne przeciwko powstawaniu nowotworów, zapobiegają utlenianiu się struktur komórkowych i ich zmianom [7].

Wartość energetyczna dyni wynosi od 18 do 28 kcal/100 g w zależności od odmiany i miejsca pochodzenia. Dynia zawiera wodę w ilości 89,9 – 94,5 g/100 g, 0,9 – 2,1 g/100 g białka, 0,29 – 0,6 g tłuszczu, 5,5 – 7,7 g węglowodanów, w tym 2,6 g cukrów, a skrobi 1,4 – 3,5 g i błonnika pokarmowego 0,5 – 2,8 g/100 g [2; 5; 9; 10]. Zawartość karotenoidów ogółem w dyni jest podawana w szerokich granicach, w zależności od odmiany i wynosi od 2,97 aż do 45,6 mg/100 g [2; 5]. Spośród karotenoidów w dyni dominuje luteina, a na drugim miejscu jest b-karoten [2]. Oprócz tego dynia zawiera również inne karotenoidy, których profil można znaleźć w literaturze [1; 8]. Spośród innych związków bioaktywnych w dyni znajdują się kwasy fenolowe, witamina C, tokoferole, kwas foliowy, witamina B1 oraz składniki mineralne: K, Ca, Mg, Na, Fe, Zn, Cu, Mg [8].

Słodkie ziemniaki są również niskoenergetyczne, 100 g dostarcza od 86 do 105 kcal [2; 10]. Zawierają one głównie wodę w ilości od 72 do 77 g/100g, białko w ilości 1,6 – 1,7 g/100g i znikome ilości tłuszczu (0,04 – 0,3 g/100 g). Węglowodany ogółem występują w ilości od 20 do 24,28 g/100g, z czego ok. 4,2 g/100 g to są cukry oraz błonnik pokarmowy w ilości ok. 3 g [2; 10]. Spośród składników bioaktywnych zawartych w słodkich ziemniakach należy wymienić również karotenoidy (głównie b-karoten w ilości ok. 6,5 mg/100 g) [2; 10]. Ponadto wg Cruz i wsp. [4] słodkie ziemniaki są bogate również w witaminę C i inne antyoksydanty, witaminę PP, kwas foliowy, tryptofan i tyrozynę oraz zawierają szereg składników mineralnych; B, Ca, Cu, J, Fe, Mg, Mn, P, K, S, Zn.

Zmodyfikowanie więc receptury ciasta przez zastąpienie części cukru i mąki pszennej warzywami, mogłoby przynieść kilka korzyści. Przede wszystkim obniżenie wartości energetycznej ciasta dzięki zastosowaniu zamiast określonej masy cukru i mąki, których wartość energetyczna w 100 g wynosi odpowiednio 400 i 350 kcal, warzyw o wartości energetycznej mieszczącej się w granicach od 18 do 105 kcal/100g. Wiązałoby się z tym obniżenie zawartości tzw. „pustych kalorii" oraz dostarczenie w to miejsce błonnika i związków bioaktywnych. **Celem przedstawionej poniżej pracy jest ocena cech jakościowych ciasta, w którym zmodyfikowano recepturę zamieniając sacharozę i część mąki pszennej warzywami jako materiałem o naturalnym smaku słodkim.**

MATERIAŁ

Tabela 1. Skład recepturowy (%) badanych ciast

Table 1. Formula composition of the examined cakes (%)

Składniki	Rodzaje badanych ciast		
	Kontrolne – bez udziału warzyw	Z dodatkiem rozdrobnionych warzyw dyni (D), marchwi (M) lub słodkiego ziemniaka (Z)	
		bez dodatku cukru	z 50% dodatkiem cukru
Jaja	19	19	19
Cukier	20	0	10
Cukier wanilinowy	0,7	0,7	0,7
Proszek do pieczenia	0,5	0,5	0,5
Soda oczyszczona	0,2	0,2	0,2
Olej rzepakowy	18,5	18,5	18,5
Mąka pszenna (typ 550)	40	**25**	**20**
Przyprawa do piernika	0,4	0,4	0,4
Cynamon	0,4	0,4	0,4
Sól	0,3	0,3	0,3
Surowe warzywa rozdrobnione na drobnej tarce (dynia, marchew lub słodkie ziemniaki)	0	**35**	**30**
Suma (%)	100	100	100

Źródło: Badania własne

Surce: The own study

Materiałem do badań było ciasto ucierane wg składu podanego w tab. 1 (kontrolne) oraz ciasta o zmodyfikowanym składzie tj. z dodatkiem rozdrobnionych warzyw: trzy ciasta z dodatkiem marchwi, dyni lub słodkiego ziemniaka bez udziału cukru oraz trzy ciasta z dodatkiem marchwi, dyni lub słodkiego ziemniaka i ponadto także z 50% dodatkiem cukru przewidzianego w recepturze ciasta kontrolnego.

Wszystkie warzywa rozdrabniano na drobnej tarce i dodawano do ciasta w postaci surowej. Szczegółowy skład recepturowy poszczególnych prób ciast podano w tabeli 1.

Procentowy dodatek warzyw i mąki różnił się między próbami ciasta bez dodatku cukru i z połową cukru przewidzianego w recepturze podstawowej, zakładając, że w przypadku prób z warzywami do ciasta wprowadzony będzie cukier zawarty naturalnie w warzywach.

METODY BADAWCZE

Ocena sensoryczna – zastosowano metodę niestrukturowanej skali 10-cio punktowej. Oceniano:

a) jakość ogólną ciast (z określeniami brzegowymi: bardzo niska j. ogólna ® bardzo wysoka j. ogólna),
b) pożądalność smaku słodkiego (z określeniami brzegowymi: smak słodki niepożądany (mało słodki) ® bardzo pożądany smak słodki),
c) barwę na przekroju ciasta (z określeniami brzegowymi: niepożądana (nieatrakcyjna) ® wysoce pożądana (zachęcająca do spożycia),
d) barwę powierzchni ciasta (z określeniami brzegowymi: niepożądana (nieatrakcyjna) do wysoce pożądana (bardzo atrakcyjna),

W badaniu brał udział 10-cio osobowy zespół oceniający przeszkolony w zakresie stosowanej metody.

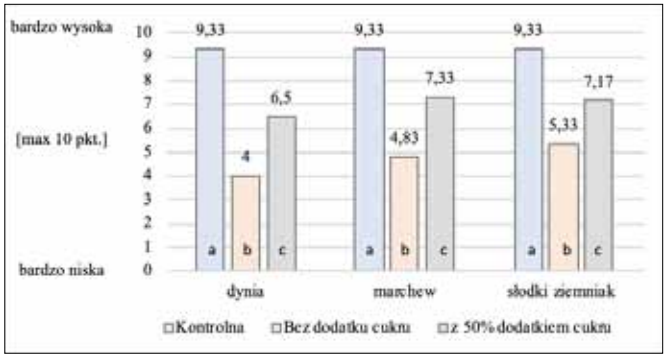
Instrumentalny pomiar barwy – badanie przeprowadzono fotokolorymetrem ColorFLEX EZ (HunterLab, Niemcy), w systemie pomiarowym L*, a*, b*, kalibrując przyrząd względem standardu czerni i bieli. Pomiar wykonywano w świetle odbitym D65. Materiał do badań stosowano w formie rozdrobnionej – poszczególne próbki miękiszu wraz ze skórką rozcierano w moździerzu laboratoryjnym, a następnie dokonywano pomiaru barwy w co najmniej trzech powtórzeniach.

Ekstrakt ogółem – badano refraktometrycznie (refraktometr NAR 1T, ATAGO CO., LTD., Japonia). Próbki do badań przygotowywano w następujący sposób: w wialkach wirówkowych o pojemności 50 cm^3 sporządzano naważki rozdrobionych próbek ciast o masie 5 g, dodawano po 20 cm^3 wody destylowanej, wytrząsano przez 1 godzinę (wytrząsarka HS 501 digital, IKA- Werke, Niemcy) z intensywnością ruchów 326 mot.•min^{-1}, następnie próbki wirowano (wirówka Rotina 420R, Hettich, Niemcy) z prędkością 5000 obr.•min^{-1} przez 5 minut. Uzyskany ekstrakt oznaczano odczytując wynik w stopniach Brixa [°Bx]. Każde oznaczenie wykonywano w co najmniej trzech powtórzeniach.

Analiza statystyczna – wykonano w programach statystycznych StatPlus, Statgraphic v. 12 oraz Statistica v. 10. Obliczano odchylenie standardowe oraz wykonano analizę wariancji, analizę regresji, analizę czynnikową oraz analizę składowych głównych PCA.

WYNIKI BADAŃ I ICH OMÓWIENIE

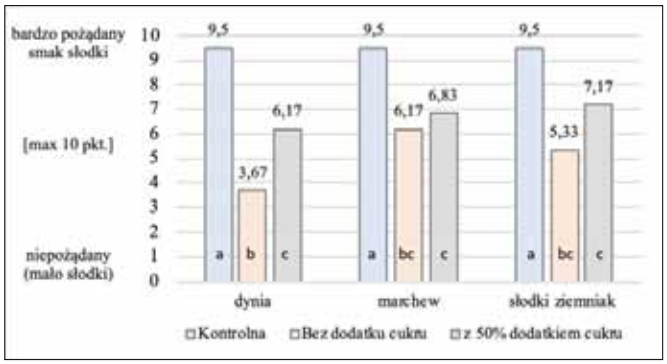
Jakość ogólna ciasta kontrolnego oceniana sensorycznie była istotnie lepsza od pozostałych wersji ciast (rys. 1). Jakość ogólna badanych ciast bez dodatku cukru nie różniła się istotnie, niezależnie od rodzaju zastosowanych warzyw. Analogiczną tendencję uzyskano w przypadku badanych ciast z 50% dodatkiem cukru. Wykazano także, że jakość ogólna ciast była ściśle związana ze smakiem słodkim. Po wyliczeniu współczynnika korelacji pomiędzy jakością ogólną a smakiem słodkim uzyskano wartość 0,9 (p=0,045).



**/ jednakowe oznaczenia literowe oznaczają brak istotnych różnic pomiędzy porównywanymi średnimi dla założonego poziomu istotności a-0,05.*

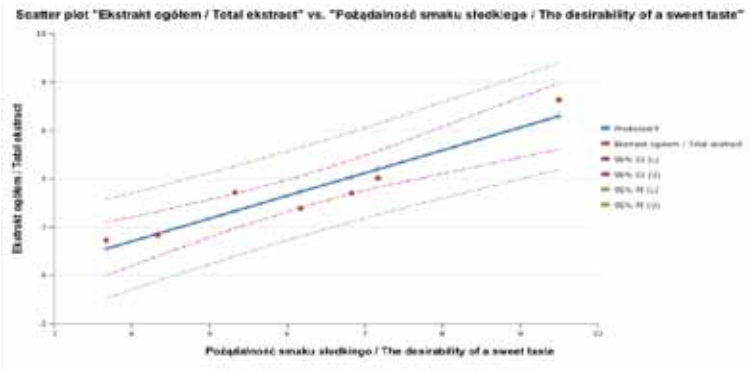
Rys. 1. Ocena sensoryczna jakości ogólnej ciast badana metodą 10-pkt.
Fig. 1. Sensory evaluation of total quality of the cakes, investigated by the 10-points method.
Źródło: Badania własne
Surce: The own study

Najbardziej pożądanym smakiem słodkim charakteryzowało się ciasto kontrolne (9,5 pkt. w skali 10-punktowej) – rys. 2. Ciasta z różnymi warzywami bez udziału cukru uzyskiwały od 3,67 do 6,17 pkt., natomiast z 50% dodatkiem cukru od 6,17 do 7,17 pkt. (rys. 2).



**/ jednakowe oznaczenia literowe oznaczają brak istotnych różnic pomiędzy porównywanymi średnimi dla założonego poziomu istotności a-0,05.*

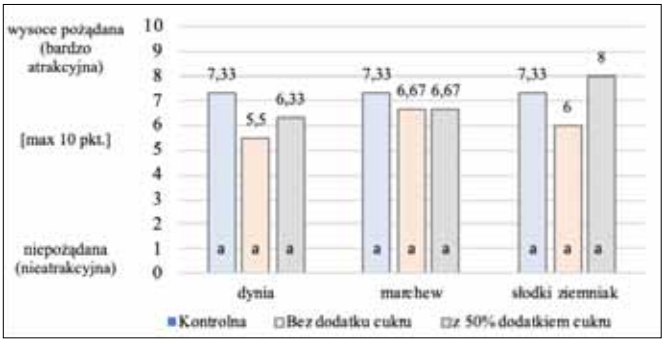
Rys. 2. Ocena sensoryczna pożądalności smaku słodkiego ciast badanych metodą 10-pkt.
Fig. 2. Sensory evaluation of desired of sweentess of the cakes, investigated by 10-points method.
Źródło: Badania własne
Surce: The own study



Rys. 3. Krzywa regresji wskazująca na związek intensywności smaku słodkiego ciast z zawartością w nich ekstraktu ogółem mierzonego refraktometrycznie.

Fig. 3. The curve of regression, indicating a relationship between the intensity of sweet taste of the cakes with amount of the total extract, measured in the refractometrical way.

Źródło: Badania własne
Surce: The own study

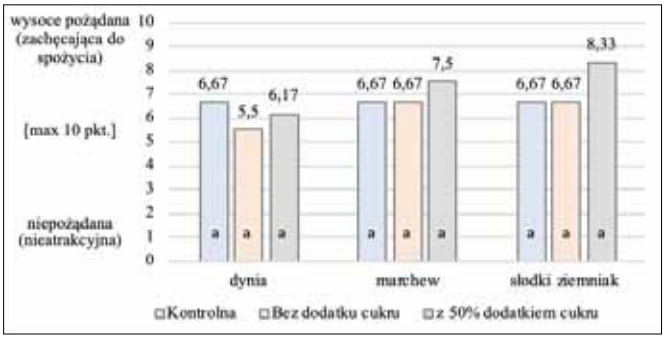


**/ jednakowe oznaczenia literowe oznaczają brak istotnych różnic pomiędzy porównywanymi średnimi dla założonego poziomu istotności a-0,05.*

Rys. 4. Ocena sensoryczna barwy na powierzchni ciast badanych metodą 10-pkt.

Fig. 4. Sensory evaluation of the surface's colour of the cakes, investigated by 10-points method.

Źródło: Badania własne
Surce: The own study



**/ jednakowe oznaczenia literowe oznaczają brak istotnych różnic pomiędzy porównywanymi średnimi dla założonego poziomu istotności a-0,05.*

Rys. 5. Ocena sensoryczna barwy na przekroju ciast badanych metodą 10-pkt.

Fig. 5. Sensory evaluation of cross-section's colour of the cakes, investigated by 10-points method.

Źródło: Badania własne
Surce: The own study

Podobnie jak w przypadku smakowitości, pożądalność smaku słodkiego ciast nie różniła się statystycznie w przypadku wszystkich badanych warzyw dodawanych do ciast. Dodatek cukru zwiększał pożądalność smaku słodkiego ciast przeciętnie o ok. 1–2 pkt. w skali 10-punktowej.

Stwierdzono bardzo wysoki współczynnik korelacji ($r = 0,95$, $R^2 = 0,91$) pomiędzy intensywnością smaku słodkiego ciast a zawartością ekstraktu ogółem mierzonego refraktometrycznie (rys. 3).

Oczekiwano przed przeprowadzeniem doświadczenia, że dodatek warzyw zawierających karotenoidy istotnie poprawi barwę ciasta, zwłaszcza udział barwy czerwonej. Karotenoidy bowiem są naturalnymi barwnikami, posiadającymi dodatkowo właściwości przeciwutleniające. Stąd na świecie wykorzystuje się je coraz częściej w procesach przemiałowych zamiast stosowania dodatków do żywności, w ramach trendu „claen label" [6].

Barwę badanych ciast oceniono metodą sensoryczną oraz instrumentalnie. W ocenie sensorycznej oceniano barwę ciast na powierzchni oraz na ich przekroju (rys. 4 i 5).

Z oceny sensorycznej wynika, że barwa wszystkich ciast (zarówno bez, jak i z dodatkiem cukru) była porównywalna i nie różniła się statystycznie od barwy ciasta kontrolnego (rys. 4 i 5). Natomiast analiza parametrów barwy mierzonej instrumentalnie wskazała, że wszystkie próby ciast z dodatkiem warzyw charakteryzowały się większym nasyceniem barwy czerwonej (a*) od ciasta kontrolnego (tabela 2), przy czym różnice te zależały od rodzaju warzyw. Wyróżniki L* i b* również zmieniały się w zależności od rodzaju ciast. Wszystkie ciasta z dodatkiem warzyw były ciemniejsze od ciasta kontrolnego (L*). Ciasto kontrolne charakteryzowało się prawie w każdym przypadku najmniejszym nasyceniem barwy żółtej (b*).

Tabela 2. Parametry barwy ciasta mierzone instrumentalnie

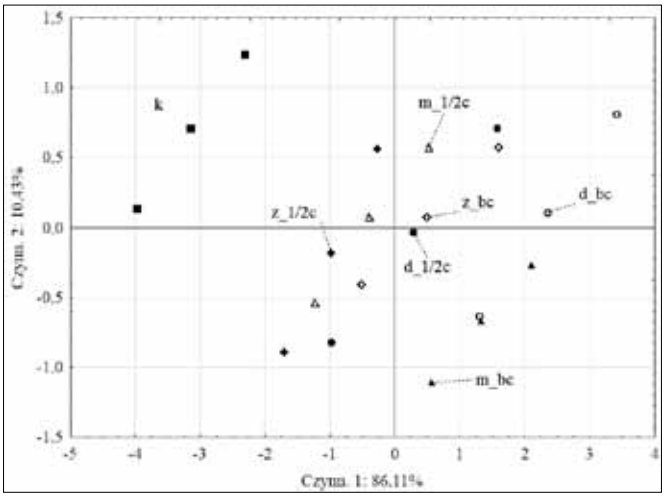
Table 2. Color parameters of cakes measured instrumentaily

Rodzaj ciasta		L*	a*	b*
Kontrolne – bez udziału warzyw		59,64 ± 0,57	6,87 ± 0,06	20,17 ± 0,15
Bez dodatku cukru	z dynią	49,20 ± 0,83	7,65 ± 0,13	22,58 ± 0,45
	z marchwią	41,97 ± 0,12	11,0 ± 0,29	26,99 ± 0,40
	z ziemniakiem	39,65 ± 0,67	11,64 ± 0,09	28,41 ± 0,22
Z 50% dodatkiem cukru	z dynią	42,27 ± 0,79	8,56 ± 0,16	20,86 ± 2,35
	z marchwią	40,60 ± 0,40	11,05 ± 0,58	23,94 ± 0,49
	z ziemniakiem	33,31 ± 1,65	12,59 ± 0,09	24,77 ± 0,63

Źródło: Badania własne
Surce: The own study

Zaobserwowano, że dodatek cukru do ciast z udziałem dyni i słodkiego ziemniaka, powodował wzrost nasycenia barwy czerwonej w stosunku do analogicznych prób bez udziału cukru, co tłumaczyć można powstawaniem związków barwnych podczas pieczenia. W przypadku ciasta z udziałem marchwi nie zaobserwowano takich istotnych różnic, co wynika prawdopodobnie z bardzo intensywnej barwy czerwonej samej marchwi.

Uzyskane wyniki charakteryzujące cechy jakościowe badanych ciast poddano analizie czynnikowej, a następnie analizie składowych głównych. Na podstawie analizy czynnikowej stwierdzono, że wszystkie zmienne były istotne do wyjaśnienia ogólnej wariancji. To znaczy różnice w jakości badanych rodzajów ciasta można było opisać mając zawartość ekstraktu, wartości smakowitości i pożądalności smaku słodkiego. Wyniki analizy czynnikowej zastosowano do grupowania przypadków w analizie składowych głównych (rys. 6 i 7).



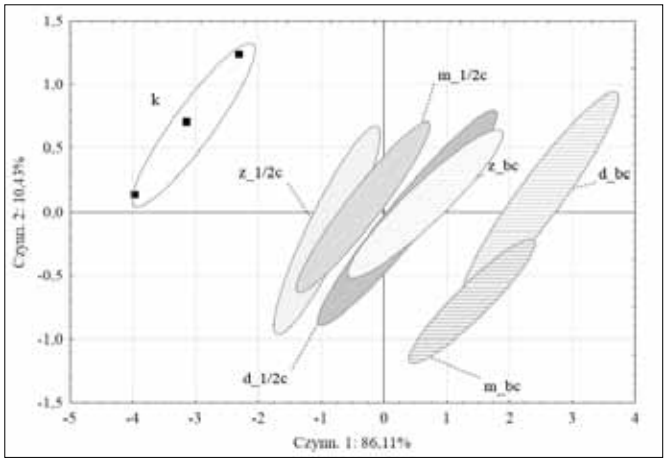
Rys. 6. Wyniki grupowania przypadków uzyskane w analizie składowych głównych. Oznaczenia ciast: k – kontrolne; m_bc, d_bc i z_bc odpowiednio z marchwią, dynią i ziemniakiem bez cukru; m_1/2c, d_1/2c i z_1/2c odpowiednio z marchwią, dynią i ziemniakiem z połową dodatku cukru.

Fig. 6. The Results of the grouping of the cases, achieved in the main components' analysis. Markers of the cakes: k – control; m_bc, d_bc i z_bc with carrot (m), pumpkin (d) and potatoes (z) respectively, without sugar; m_1/2c, d_1/2c i z_1/2c with carrot (m), pumpkin (d) and potatoes (z) respectively, with addition of half quantity of sugar.

Źródło: Badania własne

Surce: The own study

Dwa czynniki uzyskane w analizie czynnikowej a następnie w analizie składowych głównych wyjaśniały łącznie 96,54% ogólnej wariancji. Z rozrzutu przypadków (rys. 6) można było wyodrębnić dwa wyraźne skupiska punktów. Pierwsze – ciasta kontrolnego i drugie – ciast z dodatkiem warzyw. Ponieważ przypadki ciast z dodatkiem warzyw wydawały się być nieuporządkowane, to naniesiono na rysunek elipsy obejmujące punkty każdej z prób, tworząc oddzielne zbiory danych dla każdego rodzaju ciasta. Wyniki przedstawiono na rys. 7.



Rys. 7. Wynik grupowania przypadków – wyodrębnienie zbiorów danych dla każdego rodzaju ciasta. Oznaczenia analogiczne jak powyżej.

Fig. 7. The results of the grouping of the cases – extracting of datasets for each type of cake. Markers are the same as above.

Źródło: Badania własne

Surce: The own study

Po zakreśleniu danych dla każdego rodzaju ciasta, różnice w ich cechach jakościowych stały się wyraźne. Ciasto z pełną zawartością cukru (k) miało zupełnie inne wartości cech niż pozostałe rodzaje prób – tym samym potwierdzono wcześniejsze spostrzeżenia. Ciasto z dynią i marchwią bez cukru (próby d_bc i m_bc) były umiejscowione najdalej od próby kontrolnej. Oznaczało to, że ich cechy jakościowe były najbardziej „odległe" od ciasta kontrolnego. Znacznie bliżej w stosunku do próby k znajdowało się ciasto ze słodkimi ziemniakami bez cukru (próba z_bc). Ciasto to było też najlepiej ocenione sensorycznie i miało najwyższą zawartość ekstraktu spośród ciast niezawierających cukru. Spośród ciast z warzywami zawierającymi połowę zawartości cukru najmniej podobne do próby k było ciasto z dynią. Jego cechy mniej więcej były zbliżone do cech ciasta bez cukru ze słodkimi ziemniakami. Najbardziej zbliżone cechy do próby kontrolnej miało ciasto ze słodkimi ziemniakami i połową zawartości cukru. Ciasto to było jednocześnie najlepiej ocenione sensorycznie.

PODSUMOWANIE

Podsumowując należy stwierdzić, że badane ciasta z udziałem warzyw bez dodatku cukru, pomimo, że były gorzej oceniane niż analogiczne ciasta z 50% dodatkiem cukru oraz ciasto kontrolne, to nie były zdyskwalifikowane w ocenie sensorycznej. Na podstawie uzyskanych wyników można stwierdzić, że:

1. Istnieje możliwość ograniczenia zawartości cukru w ciastach poprzez wprowadzenie do ich składu warzyw o naturalnym smaku słodkim. Najbardziej zbliżone cechy do próby kontrolnej uzyskiwano po zastosowaniu słodkich ziemniaków i 50% dodatku cukru przewidzianego w podstawowej recepturze.
2. Najmniej przydatnym warzywem jako źródło smaku słodkiego w ciastach o ograniczonej zawartości cukru okazała się dynia, natomiast najbardziej przydatnym – słodki ziemniak.

3. Stwierdzono bardzo wysoki współczynnik korelacji pomiędzy intensywnością smaku słodkiego ciast a zawartością ekstraktu ogółem mierzonego refraktometrycznie. Refraktometryczny pomiar ekstraktu pozwala na szybkie przewidywanie pożądalności smaku słodkiego odczuwanej przez konsumenta, która w istotny sposób decyduje o jakości ogólnej ciast.

SUMMARY

It could be summerised that cakes with addition of vegetables and without sucrose, despite the fact that they were lower scored than the cakes with 50% of the total quantity of sucrose and than the control cake, weren't disqualified in the sensory evaluation. On the basis of the achieved results, it could be stated that:

1. It is possible to reduce the quantity of sucrose in the cakes by introcuction into their basic formula of vegetables that are naturally sweet. In the samples with addition of sweet potatoes and 50% of sucrose determined by the basic formula, were achieved the most similar values of features to the control cake.
2. The least useful vegetable as a source of sweetness in the cakes with the reduced sugar content was the punpkin, and the most useful– the sweet potato.
3. It was stated a very high level of correlation coefficient between the intensity of sweetness of the cakes and the amount of total extract that was measured refractometrically. The refractometric measurement of the extract allows us to quickly predict the level of the desired sweetness, perceived by the consumers, which significantly influences the total quality of the cakes.

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EVALUATION OF SELECTED PROPERTIES OF PRODUCTS (LEATHER FRUITS) BASED ON FRUIT PUREE®

Ocena wybranych właściwości produktów (leather fruits) otrzymanych na bazie puree owocowych®

The aim of the study was to evaluate the properties of leather fruit based on puree from own and industrial production. The scope of work included: developing the composition and method of obtained fruit structures with the use of puree: blackcurrant, plum, apple and apple with skin; developing a method of pouring properly prepared puree so as to obtain structures after drying.

Summarizing the results obtained, it was concluded that all presented types of puree can be used to develop healthy snacks. The research should be continued by modifying the parameters of the drying process and the constant dry matter content per cm² of the resulting surface, as well as the use of other types of puree in order to obtain more favorable results of the properties of snacks.

Key words: leather fruit, puree, snacks, mechanical properties.

Celem pracy była ocena właściwości skórki owocowej na bazie przecieru z produkcji własnej i przemysłowej. Zakres prac obejmował: opracowanie składu i metody otrzymywania struktur owocowych z wykorzystaniem przecierów: z czarnej porzeczki, śliwki, jabłka i jabłka ze skórką; opracowanie metody nalewania odpowiednio przygotowanego przecieru tak, aby po wysuszeniu uzyskać odpowiednie struktury. Podsumowując uzyskane wyniki, stwierdzono, że wszystkie przedstawione rodzaje przecierów można wykorzystać do opracowania zdrowych przekąsek. Badania należy kontynuować poprzez modyfikację parametrów procesu suszenia oraz stałą zawartość suchej masy na cm² uzyskanej powierzchni, a także stosowanie innych rodzajów przecieru w celu uzyskania korzystniejszych wyników właściwości przekąsek.

Słowa kluczowe: leather fruit, puree, przekąski owocowe, właściwości mechaniczne.

INTRODUCTION

In recent years, interest in clean-label health foods has increased and consumers are becoming more aware of the consequences of product choices and their impact on diet and positive health effects. The healthy eating and physical activity pyramid in the second place describes vegetables and fruit as essential and essential in our daily diet. Fruits and vegetables are rich in nutrients and are a natural source of antioxidants that help in the prevention of diet-related diseases such as diabetes, cardiovascular diseases and atherosclerosis.

Food producers must follow the changing trends in which the consumer needs not only healthy food with a variety of nutrients, but also ready for immediate consumption. Food technologists are constantly developing new technologies of healthy snacks for children and adults to replace the habits of snacking between meals of high-calorie snacks such as crisps, sweets or other fast-food meals. Healthy snacks include: freeze-dried fruit jellies, fruit chips, edible films and coatings as well as fruit leather (or pestil). According to well-known farm definitions and messages, it is an age-old natural sweet delicacy, to which you do not need to add anything else to make it delicious, perfectly smooth and visually attractive. Fruit leather is a flexible structure that results from hot air drying of fruit puree or juice concentrates with or without the addition of other ingredients. 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. However, technologists are constantly looking for new solutions to improve the functionality and properties of fruit leather, as well as the fillers and preservatives used, improving the structure and colour, in order to fit into the strategy of

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sustainable development and developing technologies for the production of innovative products with "clean label".

THE ROLE OF FRUIT IN HUMAN DIET

Nowadays, we are dealing with a global nutritional crisis, where society is experiencing a continuous increase in civilization diseases, which are influenced by diet and improperly selected diet. Global Burden of Disease research reports have identified unhealthy diets as one of the major factors contributing to the development of disease and death worldwide. This arouses more and more interest in the diet based on the principles of dietetics. Consumers introducing a diet into their lives must therefore pay attention to ensuring the appropriate quantity, quality and variety of products supplied to their bodies [18, 31].

Fruit-varied diets are rich in bioactive ingredients, minerals, vitamins, polyphenols, carotenoids and dietary fiber. A properly planned diet protects against deficiency and excess of basic food ingredients such as water, sugars, fats, proteins, vitamins, and mineral salts. In 2016, the Food and Nutrition Institute in Poland under the supervision of prof. dr hab. n. med. Mirosława Jarosza published dietary recommendations and a pyramid of healthy eating and physical activity, the second recommendation of which is: eat vegetables and fruit as often and as much as possible, at least half of what you eat. The World Health Organization (WHO) recommends consuming at least 400g of vegetables and fruit every day. Adults and children should provide the body with 5–7 servings a day of fruit and vegetables, keeping in mind the variety. One serving is defined as a medium apple or pear. You can replace one serving with a glass of 100% juice, which contains only naturally occurring sugar. Due to the potential health benefits, in many countries more and more people are choosing vegetarian and vegan diets rich in fruit, vegetables, legumes or soy products [17].

The fruit are used to obtain many products, like i.e. juices, jams, purees, canned food, but also as additives to cocktails, yoghurts, juices, ice cream, bakery products, confectionery and snacks. In the last few years, increased consumption of snacks, i.e. low-nutritional products, which were eaten between meals, has been noticed. The main snacks consumed by children and adults are desserts, sweetened drinks, crisps and salty snacks [16, 20, 25].

Producers respond to consumer interests in healthy and natural food and try to replace high-fat snacks with high-nutritional products such as: dried and freeze-dried fruit, fruit chips, fruit bars, "frushi" – sushi-like, fruit skins and fruit films [4, 19]. Kowalska et al. [15] developed a technology of apple chips without chemical preservation using osmotic dehydration in cherry concentrates or apple juices. The research showed that the apple chips were accepted in terms of taste and crispness, while the apple-cherry chips were distinguished by an attractive red colour, crispness, high acidity and polyphenol content. Fruit chips are snacks that combine modern trends: food with valuable nutritional value and processed, convenient ready-to-eat food. Fruit expeller, i.e. post-production waste from fruit juice processing, enrich bakery and confectionery products with dietary fiber, vitamins and phenolic compounds. Tańska et al. [26] investigated the effect of adding fruit pomace from rosehip, rowan, blackcurrant and elderberry on the properties of shortbread cookies. The cookies with the addition of bagasse were distinguished by a darker colour, greater hardness, more palpable flavor, aroma, and greater fiber content and antioxidant properties.

Fresh fruit are ideal full-value snacks, however, their seasonality determines fruit processing to develop new products and expand its range. The addition of processed fruit or post-production waste increases the nutritional and functional value of products and allows technologists to meet consumer expectations by preparing a rich offer of healthy snacks [19].

FRUIT SNACKS BASED ON PUREE – LEATHER FRUIT

Leather fruit (or pestil) is made from a wide variety of fruits such as apricot, banana, blackcurrant, cherry, peach, pear, pineapple, fig, apple, mango, strawberry, papaya and grapes. They are also produced from various combinations of fruit, e.g. rhubarb works very well in combination with strawberries, pears with apricots and bananas with strawberries [12, 30]. Fruit must be ripe without any blemishes, cores and seeds. Washed and peeled and cut into pieces that can be easily shredded. Mixing of the fruit should take place immediately after peeling to avoid excessive browning [22].

The preparation of the puree is a very important element for obtaining high-quality fruit leather. The method of puree has an impact on the nutritional value and physical properties of fruit skins (leather fruit) [3]. We can prepare fruit puree using the heat treatment method or the cold method without heat treatment. The cooked method is intended for hard fruit that need to be softened. The fruit can be rubbed hot by boiling it for 15 minutes and then blending it in a blender using the appropriate speed and blade. You can also first grind the fruit in a blender or grinder and then cook the puree for 10 minutes. Heat treatment causes enzyme inactivation, colour change and loss of nutrients. The cold method involves grinding the raw fruit in a blender using the correct speed and blade. The advantage of this method is the speed of execution and the higher content of bioactive compounds [22, 24]. Tontul and Topuz [27] compared pomegranate fruit leather made of heat-treated puree and cold-prepared puree without heat treatment. The authors showed that the skins without prior heat treatment of the purée were characterized by a higher content of bioactive compounds, less enzymatic browning and better textural properties. Chan and Marynenko [3] showed that modern hydrothermal treatment (HTD) resulted in inactivation of enzymes without high losses of bioactive compounds and anthocyanins. The purpose of the hydrothermal method is to perform blending, homogenization and heating in a closed system at the same time. This technique produces fruit purees with minimal deterioration in quality.

The aim of the study was to evaluate the properties of leather fruit based on puree from own and industrial production. The scope of work included: developing the composition and method of obtained fruit structures with the use of puree: blackcurrant, plum, apple and apple with skin; developing a method of pouring properly prepared puree so as to obtain structures after drying, the dry substance content

will be between 0.04 and 0.05 $g_{d.m.}/cm^2$ of the surface obtained by Fruit leather after the drying process; selected properties of leather fruit with particular emphasis on: dry substance content, solubility, opacity, testing mechanical properties are investigated.

MATERIALS AND METHOD

Technological methods

The research used: apple puree, apple puree with peel, blackcurrant puree, plum puree. Plum and blackcurrant puree were obtained from Doehler Sp. z o.o. Purees was produced in 2017 and stored in a freezer at -18°C, according to the manufacturer's instructions. Fresh apples of the Champion variety were stored in a temperature of +5 – + 8°C at an air humidity of 80-90%, before puree preparation.

Preparation of apple puree

The Champion variety apples were washed, peeled, removed the core and cut into pieces and puree in a Thermomixe multifunctional robot (TM6 from Vorwerk, Poland). Apple puree with the peel was prepared in the same way without removing the peel from the fruit. Pasteurized all kinds of puree were stored in jars.

Pouring the puree into the form with a non-stick coating

The puree was poured on sheets with a non-stick coating. The surface areas of the sheets, which are 455, 577 and 452 cm^2. Each type of puree was poured in two variants in such amounts that the dry matter content in the obtained product was constant and amounted to 0.04 and 0.05 g/cm^2 poured onto the surface of the fruit puree. Figure 1 shows a selected leather fruit obtained on the basis of blackcurrant puree.

Fig. 1. Leather fruit with black currant puree containing 0.05 gd.m./cm² of dry matter formed on the surface of the structure.

Rys. 1. Leather fruit otrzymane z puree z czarnej porzeczki o zawartości suchej masy 0.05 gs.s/cm² na powierzchni struktury.

Source: Own study

Źródło: Badania własne

The water content in the analyzed material was determined by the drying method under reduced pressure at the temperature of 70±1°C for 24h. The test was carried out in triplicate, in samples before and after the drying process.

Water solubility was determined and calculated using the method given by Basiak et al. [2]. Squares measuring 20 x 20 mm were cut from the prepared dried fruit leather. The squares were placed in glass dishes and weighed on an analytical balance with an accuracy of ± 0.0001 g and then dried in a drying chamber at 105°C for 24 hours. The samples were placed in a silica gel desiccator and then weighed to determine the initial dry weight (m_o). The dried squares were immersed in a flask containing 25 ml of distilled water and left at 25°C for 24 hours. The excess water was filtered off on filter paper and dried again at 105°C for 24 hours and then the samples were weighed to determine (m_{24}).

The solubility was calculated from the formula:

$$WS = \frac{m_0 - m_{24}}{m_0} \bullet 100\% \quad (1)$$

where: WS – solubility [%],
m_o – initial mass before drying [g],
m_{24} – mass of the sample after drying [g].

The opacity of fruit leather was measured according to the method described by Adilah et al. [1]. Rectangles measuring 1 x 4 cm were cut from the material. The opacity was measured with a UV/VIS spectrophotometer (Helios Gamma, Thermo Electron Corporation, Waltham, USA). Absorbance was measured at a visible light length of 600 nm. Measurements were made in 10 replications.

The opacity was calculated using the Hana and Flors formula [5]:

$$O = \frac{A_{600}}{l} \quad (2)$$

where: O – opacity [A/mm],
A_{600} – absorbance at a wavelength of 600 [nm],
l – thickness [mm].

The mechanical properties of fruit leather were tested with a texturometer (TA – XT2i from Stable Micro Systems, UK). The Texture Expert program was used to process the results. Fruit leather tensile test was performed. Fruit leather strips 100 mm long and 25 mm wide were used for the measurement. Thickness was determined using a Pro Gage thickness gauge (Thwing – Albert Instrument Company). The structures were placed 25 mm apart between the two measuring jaws, stretching at a speed of 1 mm/s. Measurement of the examined structures was performed in 10 replications. The tensile strength was calculated from the diagram (max tensile force/initial cross-sectional area).

RESULTS AND DISCUSSION

Dry matter and water content complement each other. The water content determines the quality, nutritional value and storage suitability of food products. With an increase in the percentage of water [%], the amount of proteins, fats, and carbohydrates important for the body, nutrients is reduced and the likelihood of microbial growth increases. As a consequence, the shelf life of products is reduced without appropriate thermal treatment [7].

Table 4 shows the average values of the dry substance content in the puree and in the produced fruit skins. The dry matter content of the puree was respectively: plum puree (12.94%) blackcurrant puree (14.07%), apple puree (17.30%) and apple puree with skin (18.60%). The dry matter content of apple puree with peel was within the range given by Kiczorowska et al. [13], who examined the chemical composition of peel and pulp of Jonica and Champion apples. They reported that the dry matter content in the flesh is much lower than in the peel of apples and is within in the range of 16.84-23.78%. The dry matter content in apple puree was similar to the results obtained by Wojdyło et al. [32], in which the dry matter content in the organic variety of apples of the Champion i variety was 17.40%. The dry matter content of plum puree significantly differs from the dry matter content of plum puree of 17.48% reported in the work of Ravanic et al. [23]. The dry matter content of black currant puree (14.07%) is similar to the dry matter content of black currant (15.03%) given by Jurgiel-Małęcka and Buchwal [10]. Skins made of apple puree were distinguished by the highest dry matter content of 90.77% and the lowest water content of 9.23%. It can be considered that apple skins will be the safest microbiologically and will have a longer shelf life than other fruit skins. Quintero Ruiz et al. [21] assessed the quality of apple skin during storage. The fruit skins were dried at 600°C by hot air drying to a water activity of 0.7. The moisture content of the apple skin after dehydration was 25%, (0.333 $kg_{water}/kg_{dry\ mater}$). Apple skins remained stable for 7 months at 20°C. According to the research by Kay and Maskan [11], the dry weight of plum skin was 80.5%, which is 9.5% lower than that of plum skin, 0.05 $g_{d.m.}/cm^2$ from this study. Drying techniques can reduce the water content. Hedayatizadech and Chaji [9] found that the use of pre-treatments before plum drying shortens the drying time and maintains high quality using less energy.

Table 1. Dry substance content in puree and obtained leather fruits having 0.04 g and 0.05 g d.m./cm² of the resulting leather fruits surface

Tabela 1. Zawartość suchej masy w puree i otrzymanych leather fruits o zawartości suchej substancji 0,04 i 0,05 gs.s./cm² na powierzchni tworzonej struktury

Fruit	Puree	Leather fruits 0.05gd.m./cm2	Leather fruits 0,04gd.m./cm2
Plum	12.94	89.46	89.99
Black currant	14.07	89.00	88.97
Apple	17.30	89.23	90.77
Apple with skin	18.60	89.90	89.37

Source: Own study

Źródło: Badania własne

Based on the results of statistical analysis, it was found that there were significant differences between blackcurrant skins and apple skins with peel compared to fruit puree, but significant differences were found in the aspect of different dry matter content per cm² surface. However, in the case of plum and apple skins, the statistical analysis shows significant differences for all of them. The analysis of the effect of the type of fruit puree used to produce fruit skins showed a significant statistical dependence of the type of fruit on the dry substance content of the examined structures, regardless of the dry substance content per cm² surface in the materials.

Solubility is the percentage of the dry weight of the film dissolved after 24 hours of immersion in distilled water. Water solubility is an important parameter for biodegradable packaging made of water-sensitive biopolymers. The potential use of the packaging is aimed at insolubility of edible films, however, solubility is indicated in the case of food encapsulation, food additives, or when food is eaten together with a film or fruit skin that needs to be dissolved quickly [2, 5].

The highest solubility of all the leathers was characterized by blackcurrant puree (Fig. 3). This may indicate the high content of pectin, which is a highly soluble compound in water and significantly contributes to the solubility [29]. The obtained results could result from different amounts of hydrophilic (such as polyphenols) and hydrophobic compounds present in fruit puree, in which the dominant compounds influenced the solubility of the membranes [8].

The statistical analysis of the solubility of the tested leather fruit did not show any significant differences between the tested materials in terms of the different content of dry substance remaining in their structure per cm² of surface area. However, for leather fruit obtained from apple and plum puree with a dry substance content of 0.04 $g_{d.m.}/cm^2$, lower solubility values were observed compared to the other leather fruits tested (Fig. 2). The study of the effect of the type of fruit puree used to produce leather fruit showed a significant statistical dependence of the type of fruit on the solubility of the examined structures, regardless of the dry substance content in the materials.

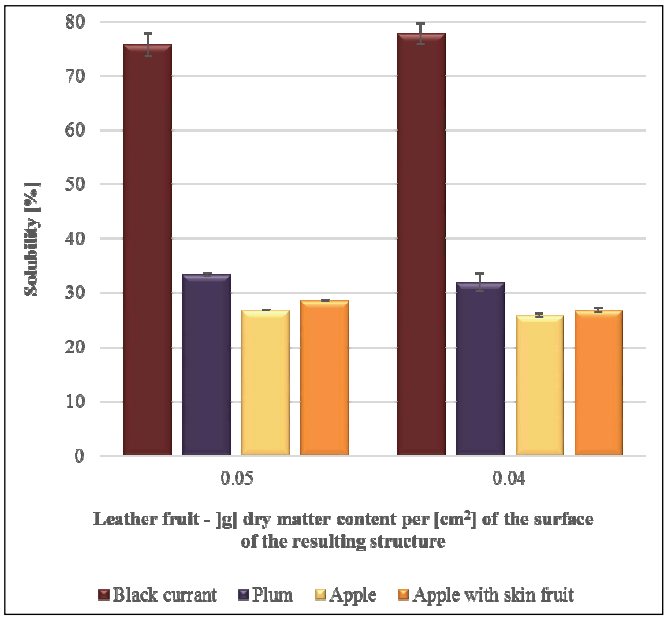

Fig. 2. Effect of the type of fruit puree and the dry substance content on the solubility of leather fruit.

Rys. 2. Wpływ rodzaju przecieru owocowego i zawartości suchej masy na rozpuszczalność leather fruit.

Source: Own study

Źródło: Badania własne

Edible films as food packaging materials are transparent and colour less, however the colour of the edible film prevents exposure to ultraviolet radiation and visible light, which deteriorate the quality of food products. Opacity is influenced by the density and thickness of leather fruit [1]. Leather fruit opacity values ranged from 2.12–6.17. Younis and Zhao [34] investigated the physicochemical properties of edible membranes from mixtures of high-methoxyl apple pectin and chitosan. **The opacity** of these films ranged from 1.76 to 10.82. Leather fruit $g_{d.m.}/cm^2$ had lower opacity in the case of plum, apple and apple skins with skin. However, in the case of black currant skins, 0.05 $g_{d.m.}/cm^2$ had higher opacity values compared to black currant skins 0.04 $g_{d.m.}/cm^2$ (Fig. 3). Leather fruit obtained from blackcurrant pruee 0.05 $g_{d.m.}/cm^2$, while the smallest was leather fruit with plum puree 0.04 $g_{d.m.}/cm^2$ (Fig. 3).

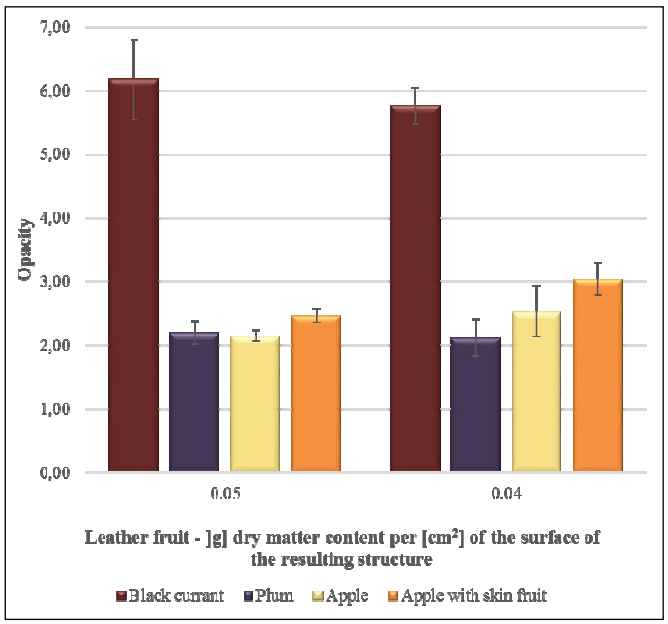

Fig. 3. Effect of the type of fruit puree and the dry substance content on the opacity of leather fruit.
Rys. 3. Wpływ rodzaju przecieru owocowego i zawartości suchej masy na nieprzeźroczystość leather fruit.
Source: Own study
Źródło: Badania własne

It can be assumed that the dry substance content has a direct impact on the opacity of leather fruit obtained from fruit puree, which can be assessed visually in figure 4. the dry matter content per cm^2 of the resulting structure area obtained from the puree. However, no significant differences were observed in blackcurrant skins and plum skins, regardless of the dry substance content. However, the static analysis did not confirm the thesis about the transparency dependence on the dry substance content in leather fruit obtained on the basis of the puree used. The research on the effect of the type of fruit puree used to produce leather fruit showed a statistically significant dependence of the effect of the type of fruit on the opacity of leather fruit, regardless of the dry substance content in the fruit skins.

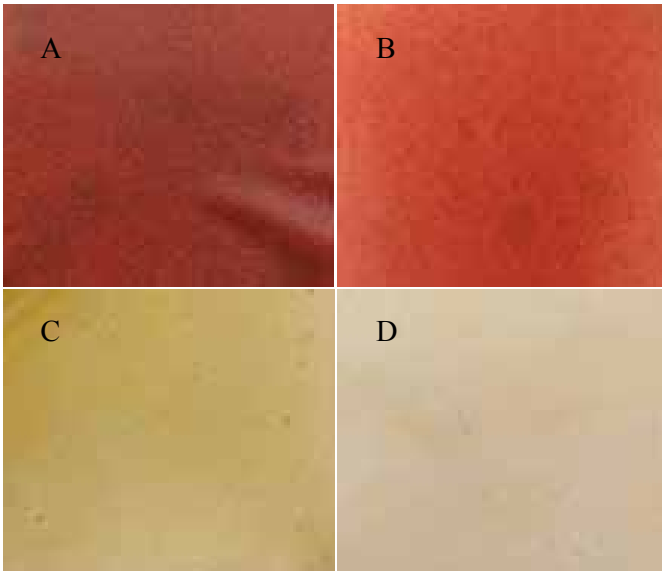

Fig. 4. Leather fruit with different dry matter content per cm^2 of the resulting structure area: A - plum 0.05 $g_{d.m.}/cm^2$; B - plum - 0.04 $g_{d.m.}/cm^2$; C – apple - 0.05 $g_{d.m.}/cm^2$; D - apple -0.04 $g_{d.m.}/cm^2$.
Rys. 4. Leather fruit o różnej zawartości suchej masy na cm^2 powstałej powierzchni struktury: A - śliwka 0.05 $g_{s.s.}/cm^2$; B - śliwka - 0.04 $g_{s.s.}/cm^2$; C – jabłko- 0.05 $g_{s.s.}/cm^2$; D - jabłko -0.04 $g_{s.s.}/cm^2$.
Source: Own study
Źródło: Badania własne

Tensile strength is the maximum force needed to break a structure. Figure 5 shows the tensile strength results of leather fruit obtained on the basis of the tested puree. The values of the index ranged from 0.3-2.38 MPa. Leather fruit with blackcurrant puree (0.04 $g_{d.m.}/cm^2$ of the resulting structure surface) was characterized by the highest tensile strength, while apple leather fruit was characterized by the lowest (0.04 $g_{d.m.}/cm^2$ of the resulting structure surface). These values were similar to those obtained by Galus et al. [6] in a study on the effect of the incorporation of modified starch or matlodextrin on the barrier and mechanical properties, moisture sensitivity and the appearance of edible membranes based on soy protein isolate. The tensile strength for the edible film based on soy protein isolate and acetate was 1.96 MPa. The results of this study significantly differed from those obtained by Wognphan et al. [33] who in their work presented the characteristics of edible membranes made of mixtures of starch, agar and matlodextrin, in which the tensile strength ranged from 2 to 20 MPa. They showed that stiffer polymer networks reduced flexibility and increased stiffness, and the use of the additive in this case 30% agar increased the tensile strength by 5 times. The addition of low molecular weight maltodextrin lowered the strength of the polymer networks and contributed to a reduction in mechanical properties. The increase in mechanical strength may result from the formation of intermolecular hydrogen bonds and compacts of the structure in blackcurrant leather fruit.

Statistical analysis showed a significant difference between leather fruit obtained from blackcurrant puree and apple puree due to the variable dry matter content per cm^2 of the resulting structure surface. On the other hand, no statistically

significant differences were found in plum and apple skins with skin. The analysis of the effect of the type of fruit puree used to produce leather fruit showed a significant statistical relationship between the types of fruit on the strength of the tested structures with different dry matter content in the materials. Analysis of mechanical properties is a fundamental pre-market research in food technology due to the wide variety of food products. Research into mechanical properties allows us to better understand the structure changes occurring during the drying process. Texture is a very good indicator of food quality and sometimes even decisive in consuming food choices. Mechanical properties make it possible to determine, inter alia, the strength and durability of fruit skins when used as coatings for edible films [14]. Leather fruit are products with low humidity and low durability. The composition of Leather fruit depends on the type of puree and the additives used. A common feature of all Leather fruits are large amounts of carbohydrates, which largely affect the texture properties [28]. The analysis of mechanical properties consists mainly of testing the tensile strength, sample elongation and the Young's Model.

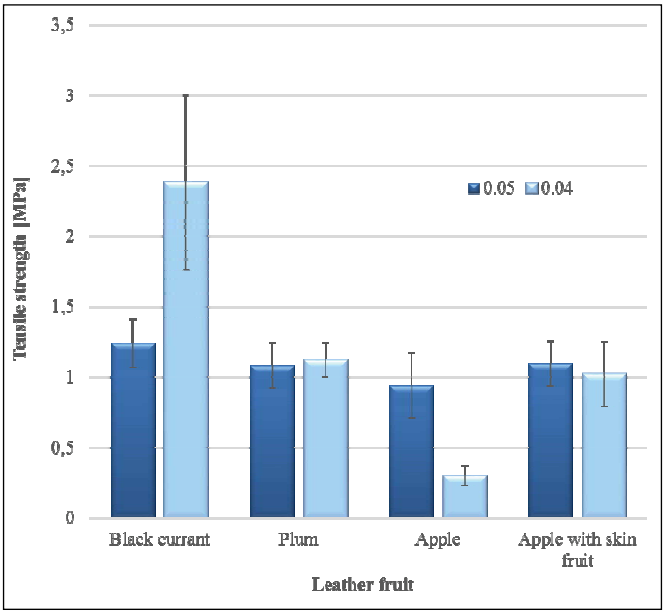

Fig. 5. Effect of the type of fruit puree and the dry substance content on the tensile strength of leather fruit.

Rys. 5. Wpływ rodzaju przecieru owocowego i zawartości suchej masy na wytrzymałość na rozciąganie leather fruit.

Source: Own study

Źródło: Badania własne

Figure 6 shows the values of the Young's Model for the tested leather fruit obtained on the basis of puree. Leather fruit obtained on the basis of blackcurrant puree 0.04 $g_{d.m.}/cm^2$ showed the highest values, while leather fruit obtained on the basis of apple puree 0.04 $g_{d.m.}/cm^2$ showed the lowest. The results of leather fruit obtained on the basis of puree black currant $g_{d.m.}/cm^2$ (43 MPa) were the closest to those obtained by Wongphan et al. [33] in edible films with a mixture of matlodextrin (20%) where Young's Modulus was also about (45 MPa). Probably the high adsorption of water caused an increase in plasticization in hydrophilic matrices and contributed to the reduction of the Young's Model in apple skins, which showed values of 2.58 and 8.37 MPa. On the basis of the statistical results of the Young Model, significant differences were observed in the leather fruit obtained on the basis of blackcurrant puree and in leather fruit obtained on the basis of apple puree without the peel of the fruit due to different dry matter contents per cm^2 in the materials. No significant differences were observed in leather fruit obtained on the basis of plum puree and apple puree with peel. Considering the aspect of the different types of fruit puree used to make the puree-based leather fruit, the type of fruit had a significant effect on the Young Model regardless of the dry matter content per cm^2 in the materials.

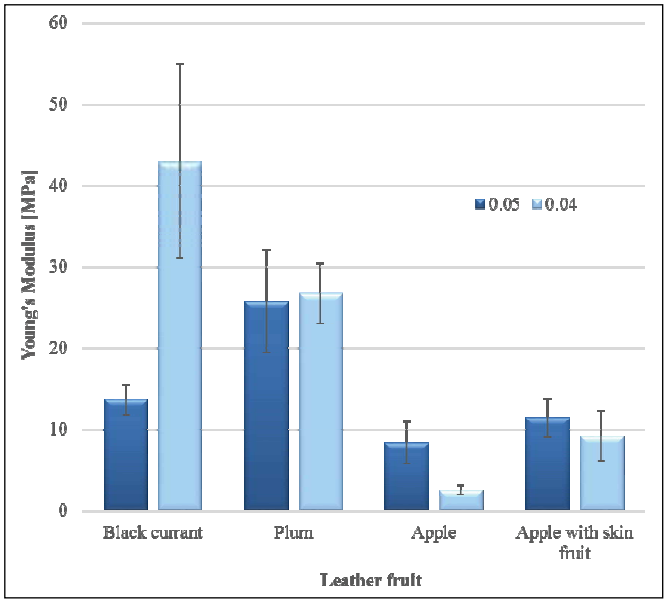

Fig. 6. Effect of the type of fruit puree and the dry substance content on the Young's Model of leather fruit.

Rys. 6. Wpływ rodzaju przecieru owocowego i zawartości suchej masy na Moduł Younga leather fruit.

Source: Own study

Źródło: Badania własne

SUMMARY AND CONCLUSION

Leather fruit obtained from blackcurrant puree was characterized by the lowest opacity, the highest tensile strength and the value of Young's Modulus, which may be an attractive feature for snack products commonly known as "chews" or "soluble gums."

Summarizing the results obtained, it was concluded that all presented types of puree can be used to develop healthy snacks. In summary, the research should be continued by modifying the parameters of the drying process and the constant dry matter content per cm^2 of the resulting surface, as well as the use of other types of puree in order to obtain more favourable properties of snacks.

Leather fruit obtained from apple puree were characterized by the highest dry matter content, which results in the lowest water content, which can significantly extend the shelf life compared to leather fruit obtained from other types of puree used. Leather fruit obtained from blackcurrant fruit puree was

characterized by the highest solubility, and different values of this parameter for leather fruit obtained from all puree may result from different amounts of hydrophilic and hydrophobic compounds present in the fruit puree, which is determined by the type and composition of the fruit. Leather fruit obtained from blackcurrant puree was characterized by the highest tensile strength, while the lowest was for apple puree. Leather fruit obtained from slug puree was characterized by the highest values of elongation at break, and the lowest values for apple puree. Mechanical parameters such as tensile strength and elongation may characterize the structure of the obtained leather fruit similar to the soluble fruit gum, which increases the attractiveness of the product in terms of consumption as a snack with specific features that can be shaped towards health-promoting foods with "clean label".

PODSUMOWANIE I WNIOSKI

Leather fruit otrzymane z puree z czarnej porzeczki charakteryzowały się najmniejszą nieprzezroczystością, najwyższą wytrzymałością na rozciąganie oraz wartością modułu Younga, co może być atrakcyjną cechą wyrobów przekąskowych zwanych potocznie „żelkami" lub „gumami rozpuszczalnymi".

Stwierdzono, że wszystkie przedstawione rodzaje puree można wykorzystać do opracowania zdrowych przekąsek. Podsumowując, badania należy kontynuować poprzez modyfikację parametrów procesu suszenia oraz stałą zawartość suchej masy na cm^2 uzyskanej powierzchni, a także stosowanie innych rodzajów przecieru w celu uzyskania korzystniejszych właściwości przekąsek.

Leather fruit otrzymane z przecieru jabłkowego charakteryzowały się najwyższą zawartością suchej masy, co skutkuje najniższą zawartością wody i może znacznie wydłużyć termin przydatności do spożycia w porównaniu z leather fruit uzyskanymi z innych zastosowanych przecierów. Leather fruit otrzymane z puree z czarnej porzeczki charakteryzowały się najwyższą rozpuszczalnością, a różne wartości tego parametru dla produktów uzyskanych z innych badanych puree mogą wynikać z różnej zawartości związków hydrofilowych i hydrofobowych w puree owocowym, co determinowane jest rodzajem i składem surowca owocowego. Największą wytrzymałością na rozciąganie charakteryzowały się leather fruit otrzymane z przecieru z czarnej porzeczki, a najmniejszą z puree jabłkowych. Leather fruit otrzymane z puree śliwkowego charakteryzowały się największymi wartościami wydłużenia na rozciąganie, a najmniejszymi dla produktów uzyskanych na bazie puree jabłkowego. Parametry mechaniczne, takie jak wytrzymałość na rozciąganie i wydłużenie, mogą charakteryzować strukturę otrzymanego produktu owocowego w postaci leather fruit strukturą zbliżoną do rozpuszczalnej gumy owocowej, co podnosi atrakcyjność produktu pod względem spożycia jako przekąski o określonych cechach, które można kształtować w stronę żywności o cechach prozdrowotnych z „czystą etykietą".

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THE INFLUENCE OF SELECTED TECHNOLOGICAL PARAMETERS OF THE BEER WORT FERMENTATION PROCESS PRODUCED ON AN INDUSTRIAL SCALE ON THE FILTRATION PROPERTIES OF BEER®

Wpływ wybranych parametrów technologicznych procesu fermentacji brzeczki piwnej produkowanej w technologii wielkozbiornikowej na właściwości filtracyjne piwa®

Celem artykułu jest przedstawienie wyników badań dotyczących wpływu głównych technologicznych parametrów fermentacji brzeczki piwnej produkowanej w technologii wielkozbiornikowej na właściwości filtracyjne piwa. Doświadczenia wykonano w warunkach przemysłowych – fermentacja i dojrzewanie w tankofermentorach o pojemności 3850 hl. Podczas doświadczeń badano wpływ następujących parametrów procesu fermentacji: temperatury fermentacji, początkowej dawki drożdży nastawnych, stopnia napowietrzania oraz czasu napełniania tankofermentorów. Wybrane parametry były poddawane oddzielnym seriom doświadczeń w trzech powtórzeniach. Procesy fermentacji głównej przebiegały w trzech badanych temperaturach: 8,5; 10 i 11,5°C. W przypadku dawki drożdży, do brzeczki dodawano drożdże zebrane po drugiej fermentacji (trzeci pasaż) w ilości 5, 7 i 9 mln komórek na 1 ml brzeczki. Brzeczkę napowietrzano sterylnym powietrzem w ilości 7, 10 i 12 mg na dm^3. Tankofermentory napełniano przez 4,5 oraz 9 i 13,5 godziny. Proces dojrzewania piwa w wymienionych tankofermentorach prowadzono w tych samych warunkach technologicznych. Doświadczenia wykazały, że zróżnicowana temperatura fermentacji, dawka drożdży oraz stopień napowietrzania brzeczki mają istotny wpływ na właściwości filtracyjne piwa. Wraz ze wzrostem temperatury fermentacji obniżała się filtrowalność piwa natomiast większa dawka drożdży przyczyniała się do jej poprawy.

Słowa kluczowe: brzeczka piwna, tankofermentor, temperatura fermentacji, dawka drożdży, napowietrzanie brzeczki, czas napełniania tankofermentora, filtrowalność piwa.

The aim of the article is to present the results of research on the influence of the main technological parameters of fermentation of beer wort produced in the multi-tank technology on the filtration properties of beer. The experiments were carried out in industrial conditions - fermentation and maturation in 3,850 hL tank fermentors. During the experiments, the influence of the following parameters of the fermentation process was investigated: fermentation temperature, initial dose of pitching yeast, degree of aeration and filling time of the fermentors. The selected parameters were subjected to separate series of experiments in triplicate. The main fermentation processes were carried out at the three tested temperatures: 8.5; 10 and 11.5°C. In the case of the yeast dose, the yeast harvested after the second fermentation (third passage) was added to the wort in the amount of 5, 7 and 9 million cells per 1 ml of wort. The wort was aerated with sterile air in the amount of 7, 10 and 12 mg oxygen per 1 L. The fermentors were filled for 4.5, 9 and 13.5 hours. The beer maturation process in the above-mentioned tankfermentors was carried out under the same technological conditions. Experiments have shown that different fermentation temperature, dose of yeast and aeration level have a significant impact on the filtration properties of beer. As the fermentation temperature increased, the beer filterability decreased, while the higher dose of yeast contributed to its improvement.

Key words: beer wort, tankfermentor, fermentation temperature, yeast pitching rate, wort aeration, filling time fermentor, beer filterability.

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INTRODUCTION

Beer nowadays is produced on four steps: malting, wort production, fermentation, and filtration step. After fermentation process beer contain various suspended particles yeast cells, preparations of protein, coagulation matter, resins hops etc., which ruin the taste and should be removed. Filtration is technological process, is separation of the solid phase of the suspension [7].

The filtration technology is used to remove particulate matter including yeast and sediments, which reduce the clarity and stability integrity of the product [1].

The conventional dead-end filtration with filter-aids (kieselguhr) has been the standard industrial practice for more than 100 years and will be increasingly scrutinized from economic, environmental and technical standpoints in the coming century. Kieselguhr is diatomaceous earth, which consists of skeletons of marine algae containing silicon dioxide. Kieselguhr powders for use in brewing are prepared by drying and milling on size of particles 5 – 20 µm [2].

The goal of beer filtration is to separate suspensions that cause turbidity or opalescence, and to give the appropriate clarity and gloss. As a result of filtration, the number of yeast should be reduced to 5 cells per 100 ml of beer, clarity below 0.5 EBC (at an angle of 90°) and the lowest possible oxygenation (below 0.02 mg / L). Beer filtration is most often done using diatomaceous earth, with the exception of membrane and cross-flow techniques. To obtain a clear beer, it is necessary to separate all solids larger than 0.5 µm. Thus, the process covers the area of fine filtration and microfiltration, and recently ultrafiltration techniques have also been applied. During filtration, especially ultrafiltration, the following groups of impurities are separated:

– microbial cells, mainly yeasts and bacteria, with dimensions from approx. 0.5 to 10 µm,
– proteins and protein-tannin compounds up to 5 µm,
– carbohydrate compounds, mainly starches, dextrins, pentosans and β-glucans, particles up to 5 µm in size. It should be noted that fine sediments are compressed during aging and block access to the filtration layer for subsequent beer batches [4].

During the process, beer flows through the filter and over the course of time higher pressure needs to be applied in order to maintain a continuous flow through the filter. Overall filter performance is dependent on the filter eficiency and beer volume through the filter between the recharge and the beer clarity. In the brewing industry, lager beer produced by industrial breweries is usually expected to not exceed 0.5° EBC haze, which is considered a 'brilliant' [6].

The aim of the article is to present the results of the impact of selected wort fermentation parameters carried out in industrial conditions on the filtration properties of beer.

MATERIALS AND METHODS

Experimental design

This study investigates the parallel process of beer production in three different cylindro-conical tanks (CCT), sampled during 18 days of the production cycle. Each cylindro-conical tank was filled with three brews (each batch taking 4.5 h) Total filling time for three fermenters was 13.5 h. High Gravity worts (15.5°P) were prepared from the same batch of malt under identical conditions.

Sample collection started after filling the CCT and continued during the following days at the same time every day. Sampling used a device equipped with an installed small pump working in a closed loop, enabling to be taken at vessel. The sampling point was located above the cone, 5 m from the bottom of the tank The CCT had a total capacity of 3850 hL with a 20% headspace. In order to obtain representative samples, the circulation pump was kept running during the process, but was switched off (approximately 24 hours) before yeast cropping.

In this work, a third generation bottom fermenting yeast was used and stored in the same yeast storage tank (YST).

The fermentation was performed at (Fig. 1): 8.5; 10 and 11.5°C. Yeast was pitched (5; 7 and 9 mln cells per 1 mL) using ABER system for rate control (Fig. 2). The wort was aerated (7, 10 and 12 mg/L) with sterile air (Fig. 3). The CCTs were filled by different time - 4,5; 9 and 13.5 hours (Fig. 4). The beer maturation was carried out in the same technological conditions.

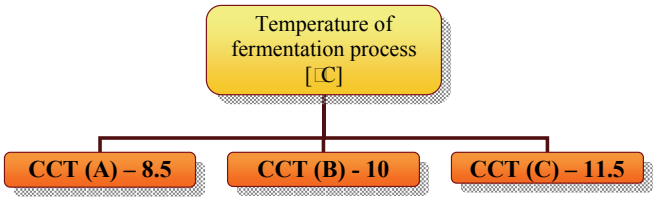

Fig. 1. Temperature of the wort fermentation.
Rys. 1. Temperatura fermentacji brzeczki.
Source: The own study
Źródło: Badania własne

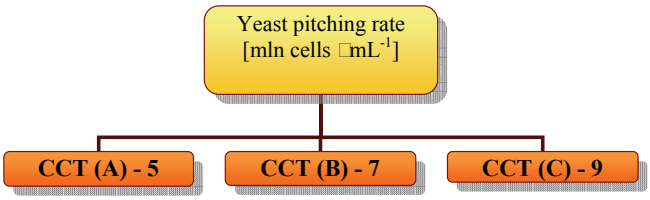

Fig. 2. Yeast pitching rate.
Rys. 2. Dawka drożdży nastawnych.
Source: The own study
Źródło: Badania własne

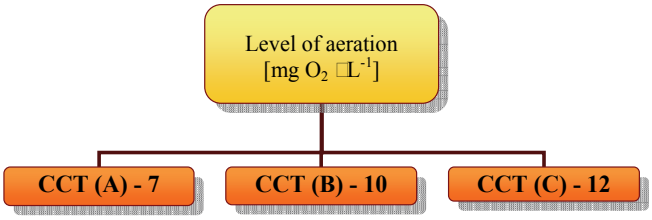

Fig. 3. Level of aeration.
Rys. 3. Stopień napowietrzania.
Source: The own study
Źródło: Badania własne

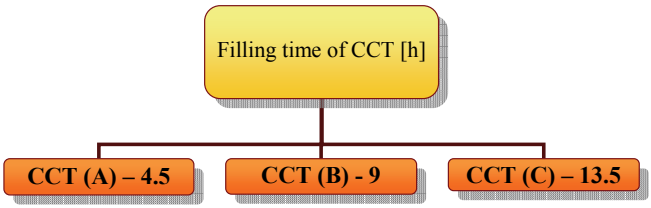

Fig. 4. Filling time of CCT.
Rys. 4. Czas napełniania tankofermentorów.
Source: The own study
Źródło: Badania własne

Measurement of filterability

During the filterability test, the tankfermenters with the selected tested parameters were subjected to the filtration process. The filterability of the beer was assessed on the basis of the pressure increase (dP) – pressure difference between input and output on the candle filter within one hour.

Statistical analysis

The results presented in this work were the average of three independent experiments with the bars representing the standard deviation. The data was analysed by one-way analysis of variance (ANOVA) to test the significance of the different fermentation temperatures on the fast of fermentation and beer losses produced on industrial scale. Significant differences between the means were verified by Duncan test ($P < 0.05$). Analyses of variance ANOVA were made with the use of Statistica v.10 (StatSoft Polska, Kraków, Poland).

RESULTS AND DISCUSSION

After the wort fermentation and maturation processes of the beer in the fermentation tank, the next stage of production is filtration, which is influenced by the parameters and technological conditions of previous post-process events.

For beer filtration, candle filters (Filtrox, Switzerland) were used, in which the filter material was diatomaceous earth, used in the amount of about 100 g · hL^{-1}. The filtering properties of beer are largely influenced by yeast flocculation as well as technological processes taking place in the brewhouse and during beer fermentation and maturation.

In this study, the filtration properties of beer were characterized only in relation to the method of filling the fermentor, wort aeration, dose of pitching yeast and fermentation temperature.

Figures 5-8 show the influence of the tested factors on the filtering properties of beer. The obtained results indicate that the fermentation temperature, dose of pitching yeast and aeration level have a significant impact on the filterability and filtration efficiency of beer.

The filterability of beer, determined by the increase in pressure per unit of time (1 h), indicates that the increase in fermentation temperature (Fig. 5) is related to the increasing filtration pressure. This means that the higher fermentation temperature lowers the filtering properties of the beer. In turn, increasing the dose of yeast contributes to their improvement (Fig. 6).

For the fermentation temperature of 8.5°C, the average pressure increase (Δp) during beer filtration was 0.13 bar·h^{-1}. On the other hand, fermentation of samples at 10 and 11.5°C increased the filtration pressure to 0.21 and 0.27 bar·h^{-1}, respectively.

It should be assumed that the reduced filterability of beer is the result of more intensive multiplication of yeast at higher fermentation temperature.

The increased concentration of especially young cells in the filtered beer causes a greater resistance of the filtration layer. The increased suspension of yeasts is due to their weakened flocculation. Young cells are characterized by a thinner and smoother cell wall and smaller dimensions, which makes it difficult for them to merge into larger conglomerates.

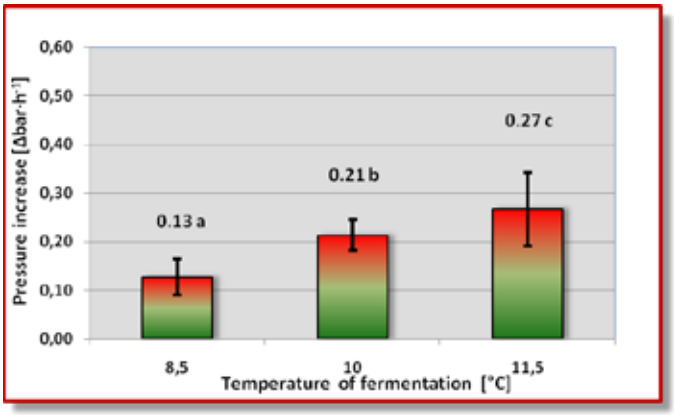

Fig. 5. Filtering properties of beer depending on the fermentation temperature.
Rys. 5. Właściwości filtracyjne piwa w zależności od temperatury fermentacji.
Source: The own study
Źródło: Badania własne

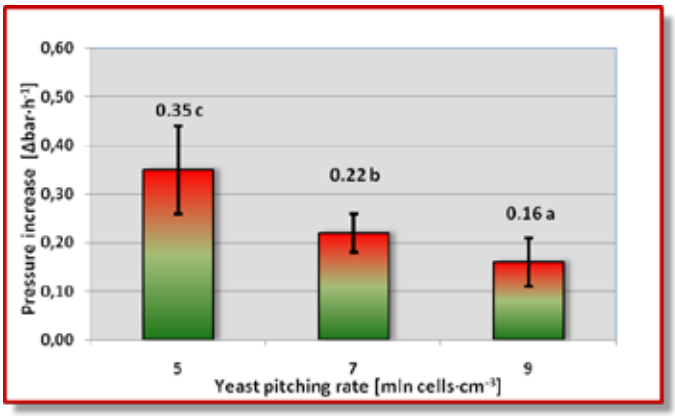

Fig. 6. Filtering properties of beer depending on the yeast pitching rate.
Rys. 6. Właściwości filtracyjne piwa w zależności od dawki drożdży nastawnych.
Source: The own study
Źródło: Badania własne

Fermentation settings with higher doses of yeast were characterized by their lower proliferation, and thus a smaller number of new cells in the beer, which resulted in a clearer drink in the aging process. In the case of the lowest dose of

pitching yeast (5 million cells·mL^{-1}), the resistance of the filtration layer increased by 0.35 bar·h^{-1} (Fig. 6). Increasing the initial amount of yeast in fermentation wort improved the filtration properties of beer. The commencement of fermentation with a concentration of yeast of 7 million cells·mL^{-1}, in the subsequent filtration process, contributed to the increase in pressure to 0.22 bar·h^{-1}. A further increase in the amount of inocculum (9 million cells·mL^{-1}) resulted in an extension of the filtration cycle due to the reduction of the pressure difference (0.16 bar·h^{-1}).

Figure 7 shows the effect of the method of filling fermentation tanks on the filterability of beer. Depending on the method of their refilling, the filtration pressure increased from 0.32 to 0.44 bar·h^{-1}.

The lowest pressure increase was observed for tanks filled for 9 hours. This time seems optimal to obtain a longer beer filtration process. In the case of filling the fermentor with successive brews without a break, the filtering properties of the beer are clearly deteriorated. A similarly unfavorable phenomenon occurs when the tanks are filled for too long.

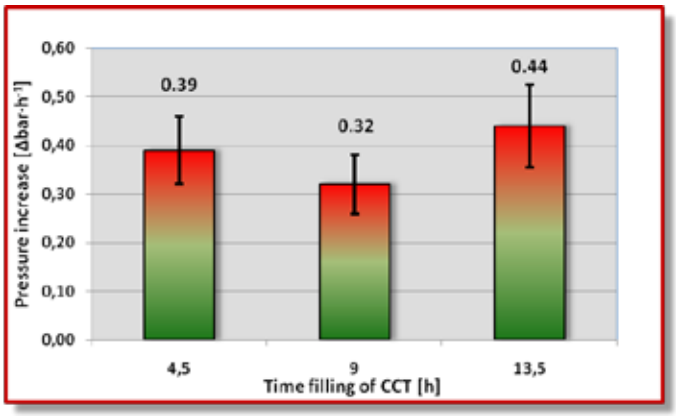

Fig. 7. Filtering properties of beer depending on the time filling CCT.
Rys. 7. Właściwości filtracyjne piwa w zależności od czasu napełniania CKT.

Source: The own study
Źródło: Badania własne

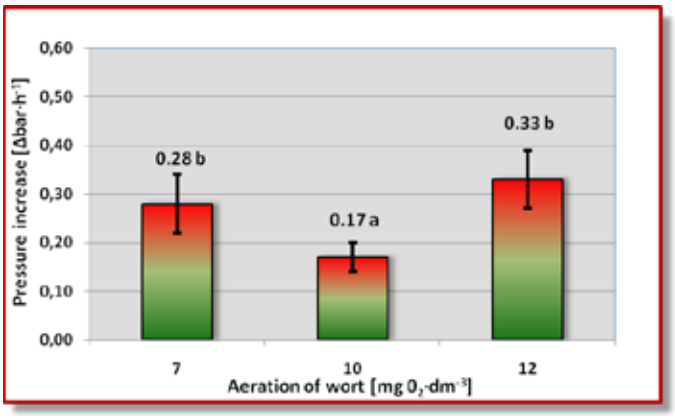

Fig. 8. Filtering properties of beer depending on the aeration of wort.
Rys. 8. Właściwości filtracyjne piwa w zależności od napowietrzania brzeczki.

Source: The own study
Źródło: Badania własne

The different degree of aeration caused the pressure increase from 0.17 to 0.33 bar·h^{-1} (Fig. 8). The research showed a significant influence of the aeration degree on the filtering properties of beer. Lower and higher initial doses of oxygen in relation to aeration at the level of 10 mg of oxygen per L have a negative impact on the efficiency of the filtration process. Experiments have shown that the degree of air entrainment may double or shorten the filtration batch.

Due to the unique approach to determining the impact of selected parameters of the fermentation process on the subsequent beer filtration process, the collected literature in this field is very little popular. One of the Authors who took up this topic is Pinguli et al. [3, 5]. Authors stated, that filtration process is controlled by yeast, proteins and carbohydrates. If yeast cell number is less than a million, filterability is dependent mainly from physico-chemical beer characteristics. Beer filterability is strongly depended by malt quality, especially β-glucans content that impact directly on beer viscosity. If beer or wort has a high viscosity it is strongly recommended to use enzymes to control carbohydrates that dominate filtration characteristics such as unmodified starch, dextrins, pentosans, and β-glucans.

Summarizing the filtering properties of beer, it should be stated that the selection of the parameters of the fermentation process affects the multiplication and sedimentation of yeast. Conditions affecting the deterioration of the yeast flocculation ability, such as an increased growth of fresh biomass or a greater share of young cells in the yeast population, reduce the permeability of the filtration layer and thus reduce the filtration efficiency.

WNIOSKI

1. Stwierdzono istotny wpływ temperatury fermentacji na właściwości filtracyjne piwa. Wyższe temperatury fermentacji powodują większe przyrosty ciśnienia podczas filtracji piwa.
2. Badania wykazały, że w doświadczeniach prowadzonych w warunkach przemysłowych, dawka drożdży nastawnych ma istotny wpływ na właściwości filtracyjne piwa. Wraz ze wzrostem dawki drożdży następowało wydłużenie szarży filtracyjnej.
3. Sposób napełniania i stopień napowietrzania brzeczki również wpływają na właściwości filtracyjne piwa. Czas napełniania tankofermentora przez 9 godzin jak również dawka tlenu w ilosci 10 mg/L zapewniają mniejsze przyrosty ciśnienia podczas filtracji piwa a tym samym zapewniają wydłużenie szarży filtracyjnej.

CONCLUSION

1. A significant influence of the fermentation temperature on the filtering properties of beer was found. Higher fermentation temperatures result in higher pressure increase during beer filtration.
2. Research has shown that in experiments carried out in industrial conditions, the dose of yeast has a significant impact on the filtering properties of beer. With the increase in the dose of yeast, the filtration cycle was extended.
3. The method of filling and the degree of aeration of the wort

also affect the filtration properties of the beer. The time of filling the fermentor for 9 hours as well as the dose of oxygen in the amount of 10 mg / L ensure lower pressure increase during beer filtration and thus extend the filtration batch.

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MODELING THE SHAPE OF MATERIALS AND FOOD PRODUCTS ON THE EXAMPLE OF PEANUT FRUIT (*ARACHIS HYPOGAEA* L.)®

Modelowanie kształtu surowców i produktów spożywczych na przykładzie owoców orzechy podziemnej (*Arachis Hypogaea* L.)®

The article presents two methods for acquiring information about the geometric parameters of peanut fruit. The first method involved direct measurements with the use of a caliper and geometric models (1D method). In the second method, peanuts were scanned to produce a 3D numerical model (3D method). The aim of the study was to compare the accuracy of both methods in determining the surface area and volume of peanut fruit. The comparison of two methods for determining the geometric parameters of peanuts revealed that the 3D method produced more reliable results. In the 1D method, the surface area of peanuts can be determined with the use of a sphere (M1), a model composed of a semi-spheroid and a cylinder (M6), or a model composed of a semi-ellipsoid and an elliptic cylinder (M7). A spheroid (M4) and an ellipsoid (M5) can be applied to determine the volume of peanuts in the 1D method. The relative error was below 5% when the above models were applied to measure the surface area and volume of peanuts.

Key words: modeling, peanut, measure, surface area, volume.

W artykule omówiono dwie metody pozyskiwania informacji o geometrycznych parametrach owoców orzechy podziemnej. Pierwsza to metoda pomiaru bezpośredniego, wykonana za pomocą suwmiarki i modeli geometrycznych (metoda 1D). Druga to metoda pomiaru przestrzennego modelu numerycznego otrzymanego za pomocą skanowania 3D (metoda 3D). Celem pracy była ocena wyżej wymienionych metod pomiarowych w zakresie dokładności wyznaczania pola powierzchni i objętości owoców orzechy podziemnej. Z przeprowadzonych badań na owocach orzechy podziemnej wynika, że spośród zastosowanych dwóch metod wyznaczenia parametrów geometrycznych owoców najlepsze efekty uzyskano przy metodzie 3D. Do wyznaczenia pola powierzchni owoców orzechy podziemnej metodą 1D można zastosować kulę (M1), model składający się z połowy elipsoidy obrotowej i walca (M6), model składający się z połowy elipsoidy i walca eliptycznego (M7). Wyznaczając objętość owoców orzechy podziemnej metodą 1D można wykorzystać elipsoidę obrotową (M4) i elipsoidę (M5). Wykorzystując wymienione modele do wyznaczania pola powierzchni i objętości owoców popełnia się błąd względny pomiaru mniejszy od 5%.

Słowa kluczowe: modelowanie, orzecha podziemna, pomiar, pole powierzchni, objętość.

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Symbols

A – total surface area (mm^2),
d_w – arithmetic mean diameter (mm),
d_z – equivalent diameter (mm),
L – length (mm),
N – sample size,
T – thickness (mm),
V – volume (mm^3),
W – width (mm),
1D – measurements involving the direct method,
3D – measurements involving the 3D numerical model.

Wykaz oznaczeń

A – pole powierzchni całkowitej (mm^2),
d_w – arytmetyczna średnica zastępcza (mm),
d_z – średnica zastępcza (mm),
L – długość (mm),
N – liczebność próby,
T – grubość (mm),
V – objętość (mm^3),
W – szerokość (mm),
1D – pomiar metodą bezpośrednią,
3D – pomiar metodą opartą o przestrzenny model numeryczny.

INTRODUCTION

Surface area and volume are used to plan dressing, coating, peeling, cleaning and packaging operations in food products and materials [8, 10, 12, 21, 22]. Basic geometric parameters are determined with measuring devices that enable direct linear measurements, including rulers and analog and digital calipers [6, 11, 14]. These devices are cheap and widely available, and they support rapid and direct measurements of the studied object's linear dimensions. In most cases, the analyzed samples do not require special treatment or preparation before the measurements. However, the obtained results have numerous limitations, and they apply only to selected points on the sample. Mathematical formulas from the literature can also be used to perform additional calculations [4, 5, 7, 9].

Measurements where the shape of a sample is rendered based on a cloud of points are a relatively new method. The points on the surface of a sample are registered with 3D scanners, and the results are used to develop a 3D model [16, 19]. Non-contact 3D scanners determine the distribution of points in the space of the analyzed object [16, 19]. A 3D numerical model supports metrological analyses, and the model's accuracy is determined by the scanner's resolution [17]. The generation of 3D numerical models is a laborious process, but the results can be stored in a computer. The numerical model represents the shape of the analyzed sample on the day of scanning, and it can be reproduced without the loss of data. This method can be applied to measure both small-sized and large-sized raw materials that are brittle and susceptible to damage [1, 2]. This article presents two methods for acquiring information about the physical parameters of food materials. The first method involves direct measurements with the use of a caliper (1D method). In the second method, the examined object is scanned to produce a 3D numerical model (3D method).

The aim of the study was to compare the accuracy of both methods in determining the basic geometric parameters of plant materials on the example of peanut fruit. The relative error in the surface area and volume of peanuts determined with the presented methods was compared.

MATERIALS AND METHODS

The experiment was conducted on peanut fruit (*Arachis hypogaea* L.) purchased in a grocery store of the PSS Społem retail chain in Olsztyn. Thirty peanuts without visible signs of damage were selected randomly for analysis. The peanuts were stored at a stable temperature of 20±1°C and relative humidity of around 65%. The linear dimensions of peanuts were measured with a caliper with a resolution of 0.05 mm. The measurements of peanut length are presented in Figure 1. Peanut width and thickness were measured at half-length.

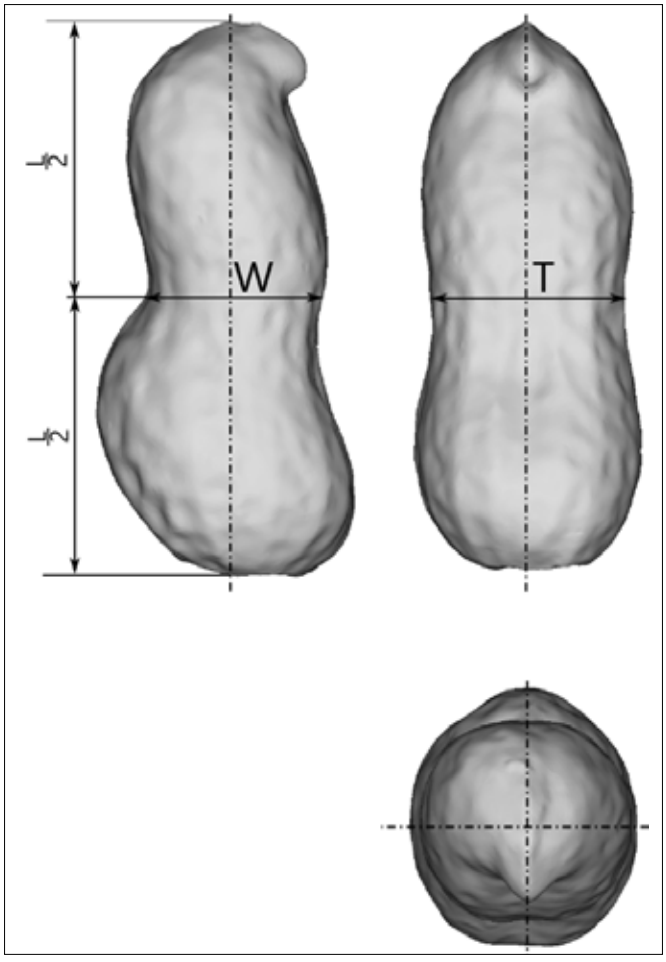

Fig. 1. A numerical model of peanut.
Rys. 1. Model numeryczny orzechy podziemnej.
Source: Own study
Źródło: Opracowanie własne

The surface area and volume of peanuts were determined with the use of 7 geometric models composed of selected geometric shapes (Fig. 2).

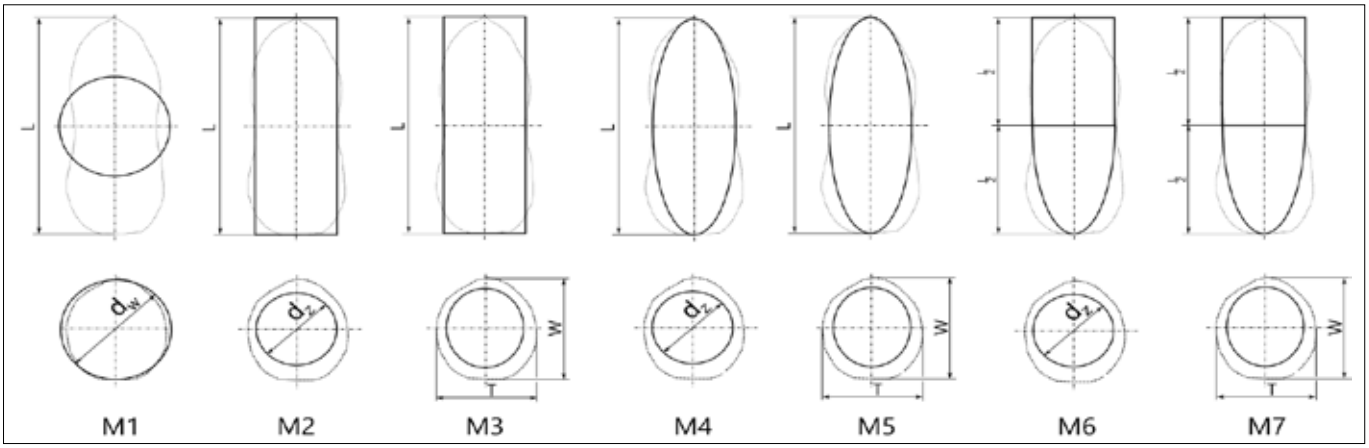

Fig. 2. Geometric models of peanuts: M1 – sphere, M2 – cylinder, M3 – elliptic cylinder, M4 – spheroid, M5 – ellipsoid, M6 – half of spheroid and half of cylinder, M7 – half of elipsoid and half of elliptic cylinder, d_w – arithmetic mean diameter, d_z – mean diameter, L – length, W – width, T – thickness.

Rys. 2. Modele geometryczne owoców orzechy podziemnej: M1 – kula, M2 – walec, M3 – walec eliptyczny, M4 – elipsoida obrotowa, M5 – elipsoida, M6 – połowa elipsoidy obrotowej i walec, M7 – połowa elipsoidy i walec eliptyczny; d_w – arytmetyczna średnica zastępcza, d_z – średnica zastępcza, L – długość, W – szerokość, T – grubość.

Source: Own study
Źródło: Opracowanie własne

Every geometric model was described with the following mathematical formulas:

– sphere (M1):

$$A_{M1} = \pi \cdot d_w^2 \tag{1}$$

$$V_{M1} = \frac{\pi \cdot d_w^3}{6} \tag{2}$$

– cylinder (M2):

$$A_{M2} = \pi \cdot d_z \cdot L + 2 \cdot \pi \cdot \left(\frac{d_z}{2}\right)^2 \tag{3}$$

$$V_{M2} = \frac{\pi \cdot d_z^2 \cdot L}{4} \tag{4}$$

– elliptic cylinder (M3):

$$A_{M3} \approx \pi \cdot L \cdot \left(\frac{3}{4} \cdot (W+T) - \sqrt{\frac{W \cdot T}{4}}\right) + 2 \cdot \pi \cdot \frac{W \cdot T}{4} \tag{5}$$

$$V_{M3} = \frac{\pi \cdot W \cdot T \cdot L}{4} \tag{6}$$

– spheroid (M4), when: $\frac{L}{2} > \frac{d_z}{2}$

then:

$$A_{M4} = 2 \cdot \pi \cdot \left(\frac{d_z}{2}\right)^2 \cdot \left(1 + \frac{\frac{L}{2}}{\frac{d_z}{2} \cdot e} \cdot \arcsin(e)\right) = \tag{7}$$

$$= \frac{4 \cdot \pi \cdot d_z^2 + \pi \cdot L \cdot d_z \cdot e \cdot \arcsin(e)}{8}$$

– where:

$$e = \sqrt{1 - \frac{d_z^2}{L^2}} \tag{8}$$

$$V_{M4} = \frac{\pi \cdot d_z^2 \cdot L}{6} \tag{9}$$

– ellipsoid (M5):

$$A_{M5} = 2 \cdot \pi \cdot \left(\left(\frac{L}{2}\right)^2 + \frac{\frac{T}{2} \cdot \left(\frac{L}{2}\right)^2}{\sqrt{\left(\frac{W}{2}\right)^2 - \left(\frac{L}{2}\right)^2}} \cdot \right. \tag{10}$$

$$\left. \cdot F(\Theta, m) + \frac{T}{2} \cdot \sqrt{\left(\frac{W}{2}\right)^2 - \left(\frac{L}{2}\right)^2} \cdot E(\Theta, m) \right)$$

– where:

$$m = \frac{\left(\frac{L}{2}\right)^2 \cdot \left(\left(\frac{T}{2}\right)^2 - \left(\frac{L}{2}\right)^2\right)}{\left(\frac{T}{2}\right)^2 \cdot \left(\left(\frac{W}{2}\right)^2 - \left(\frac{L}{2}\right)^2\right)} = \frac{L^2 \cdot T^2 - L^4}{T^2 \cdot W^2 - L^2 \cdot T^2} \tag{11}$$

$$\Theta = \arcsin\left(\sqrt{\frac{\sqrt{W^2 - L^2}}{|W|}}\right) \tag{12}$$

and $F(\Theta,m)$ and $E(\Theta,m)$ are incomplete elliptic integrals of the first and second kind [3].

$$V_{M5} = \frac{\pi \cdot T \cdot W \cdot L}{6} \quad (13)$$

– model composed of a cylinder and a semi-sphere (M6):

$$A_{M6} = \frac{\pi \cdot (W+T) \cdot (e \cdot (W+T+4 \cdot L) + 2 \cdot L \cdot \arcsin(e) + (W+T) \cdot e)}{16 \cdot e} \quad (14)$$

$$V_{M6} = \frac{5 \cdot \pi \cdot (W+T)^2 \cdot L}{96} \quad (15)$$

– model composed of an elliptic cylinder and a semi-ellipsoid (M7):

$$A_{M7} = \frac{A_{M3}}{2} + \frac{A_{M5}}{2} - \pi \cdot W \cdot T \quad (16)$$

$$V_{M7} = \frac{5 \cdot \pi \cdot T \cdot W \cdot L}{24} \quad (17)$$

In models M1, M2, M4 and M6, equivalent diameters were calculated with the following formulas:

$$d_w = \frac{L+W+T}{3} \quad (18)$$

$$d_z = \frac{W+T}{2} \quad (19)$$

Three-dimensional numerical models of peanuts were generated with the use of a NextEngine 3D laser scanner [15]. Peanuts were mounted on a rotary table with a grip (Fig. 3). Scanning resolution was 248 points per mm^2. The average scanning time to produce a complete numerical model was around 30 minutes.

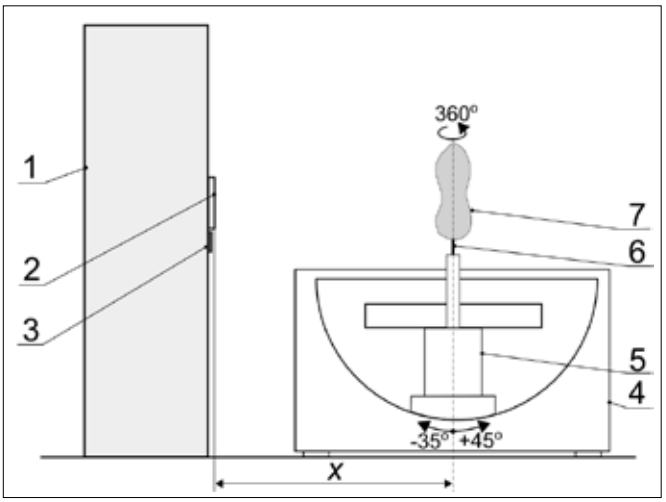

Fig. 3. Test stand for acquiring 3D scans of peanuts: 1– 3D scanner, 2 – camera, 3 – laser diodes, 4 – rotary table with a controlled inclination angle, 5 – motor, 6 – needle, 7 – sample, x – distance between the sample and the 3D scanner.

Rys. 3. Skanowanie 3D owoców orzechy podziemnej: 1– skaner 3D, 2 – kamera, 3 – diody laserowe, 4 – stolik obrotowy z regulowanym pochyleniem, 5 – silnik, 6 – igła, 7 – próbka, x – odległość próbki od 3D skanera.

Source: Own study
Źródło: Opracowanie własne

The acquired series of 3D scans were combined in the ScanStudio HD Pro program (http://www.nextengine.com) to generate 3D numerical models. The MeshLab program was used to measure surface area and volume in the generated models [13]. The significance of differences between the average values of total surface area and volume measured with the 1D method and the 3D method was compared by one-way ANOVA for multiple independent samples. Data were processed statistically in Statistica v. 13 PL, and the results were regarded as significant at $\alpha = 0.05$ [18, 20].

RESULTS AND DISCUSSION

The surface area and volume of peanuts were measured based on the acquired 3D numerical models. The total surface area of peanut samples determined with the 1D method and the 3D method is presented in Figure 4.

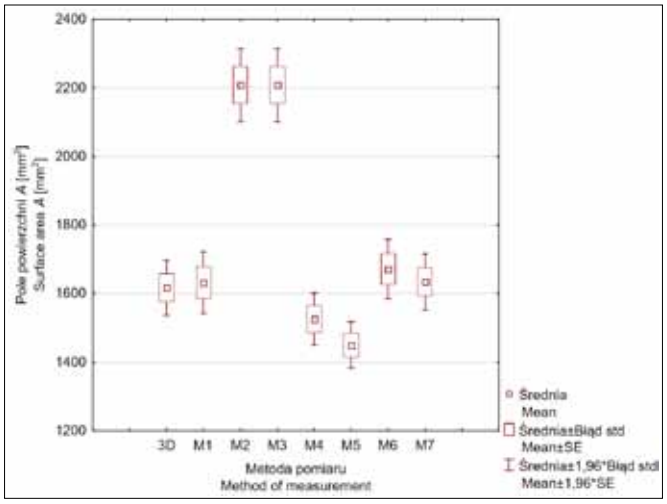

Fig. 4. Surface area of peanut fruit, determined by the 1D and 3D method.

Rys. 4. Pole powierzchni owoców orzechy podziemnej wyznaczone metodą 1D i 3D.

Source: Own study
Źródło: Opracowanie własne

The results revealed that the analyzed parameters had a normal distribution. The significance of differences between the parameters measured with the compared methods is presented in Table 1.

It was assumed that measurements of surface area in the 3D method were free of errors and that the calculated values could be used as a reference for the measurements performed with the 1D method. The relative error between the measurements conducted with the 1D method and the 3D method was referred to as the "error of the method". The relative error in surface area measurements conducted with the 1D method and geometric models M1, M6 and M7 was determined at 0.79%, 3.29% and 1.11%, respectively (Fig. 5). Relative error was higher than 5% in the remaining geometric models in the 1D method. In the 1D method, the actual surface area of peanuts was rendered as a continuous plane without indentations.

Table 1. Results of the calculations to verify the significance of differences between the mean values of the area

Tabela 1. Wyniki obliczeń weryfikacji istotności różnic między średnimi wartościami pola powierzchni

Pole powierzchni A (ANOVA test) / Area A (ANOVA test) F(7, N=232)=43.26; p=0.000 Prawdopodobieństwa porównań wielokrotnych / Probability of multiple comparisons				
Metoda pomiaru Measurement method	**Liczebność próby Number of observations N**	**Współczynnik zmienności Coefficient of variation**	**Odchylenie standardowe Standard deviation**	**Średnia Mean (mm^2)**
3D	30	13.98	226.09	1617.13^{ab}
M1	30	15.28	249.49	1632.52^{ab}
M2	30	13.52	298.74	2208.18^{d}
M3	30	13.53	298.87	2208.36^{d}
M4	30	13.98	213.26	1525.32^{ac}
M5	30	13.12	190.28	1450.07^{c}
M6	30	14.49	242.25	1671.30^{b}
M7	30	13.94	227.93	1634.22^{ab}

Wartości w kolumnach z takimi samymi literami nie różnią się istotnie; a, b, c, d ($P \leq 0,05$)
Values in columns marked with identical letters do not differ significantly: a, b, c, d ($P \leq 0.05$)

Source: Own study

Źródło: Opracowanie własne

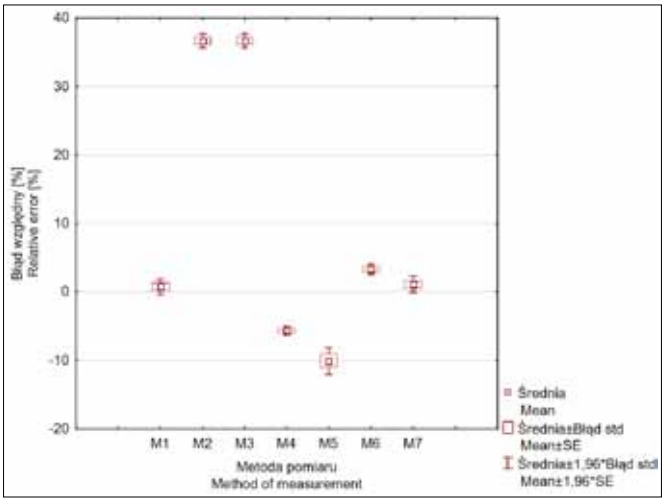

Fig. 5. Relative error in determining the surface area of peanuts by the 1D method with the use of geometric models and the 3D method.

Rys. 5. Błąd względny wyznaczania pola powierzchni owoców orzechy podziemnej metodą 1D z wykorzystaniem modeli geometrycznych i metodą 3D.

Source: Own study

Źródło: Opracowanie własne

The volume of peanuts calculated with the tested methods is presented in Figure 6.

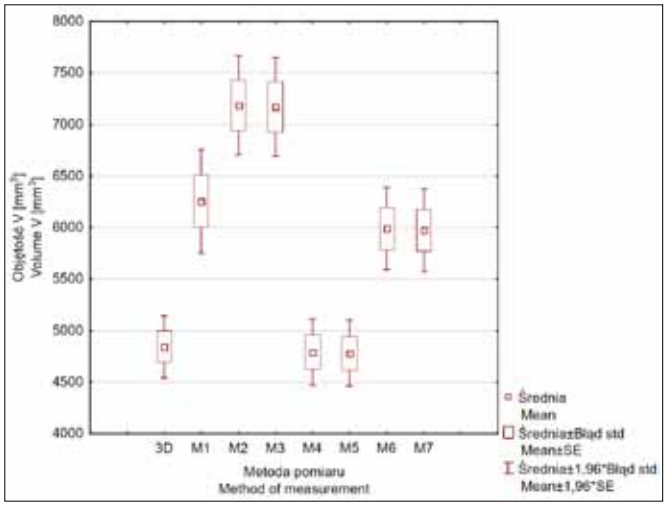

Fig. 6. Volume of peanut fruit, determined by the 1D and 3D method.

Rys. 6. Objętość owoców orzechy podziemnej wyznaczona metodą 1D i 3D.

Source: Own study

Źródło: Opracowanie własne

The significance of differences between the average values of peanut volume was determined by ANOVA. The results of detailed comparative analyses are presented in Table 2.

Table 2. Results of the calculations to verify the significance of differences between mean values of volume

Tabela 2. Wyniki obliczeń weryfikacji istotności różnic między średnimi wartościami objętości

Objętość V (ANOVA test) / Volume V (ANOVA test) F(7, N=232)=23.128; p=0.000 Prawdopodobieństwa porównań wielokrotnych / Probability of multiple comparisons				
Metoda pomiaru Measurement method	**Liczebność próby Number of observations N**	**Współczynnik zmienności Coefficient of variation**	**Odchylenie standardowe Standard deviation**	**Średnia Mean (mm^2)**
3D	30	17.41	843.60	4843.62a
M1	30	22.47	1405.78	6255.49b
M2	30	18.71	1345.09	7187.51c
M3	30	18.65	1337.42	7170.24c
M4	30	18.71	896.73	4791.67a
M5	30	18.65	891.61	4780.16a
M6	30	18.71	1120.91	5989.59b
M7	30	18.65	1114.51	5975.20b

Wartości w kolumnach z takimi samymi literami nie różnią się istotnie; a, b, c ($P \leq 0,05$)
Values in columns marked with identical letters do not differ significantly: a, b, c ($P \leq 0.05$)

Source: Own study

Źródło: Opracowanie własne

It was assumed that volume measurements in the 3D method were free of errors and that the calculated values could be used as a reference for the measurements performed with the 1D method. The error in volume measurements conducted with the 1D model and geometric models M4 and M5 ranged from 1.22% to 1.45% (Fig. 7).

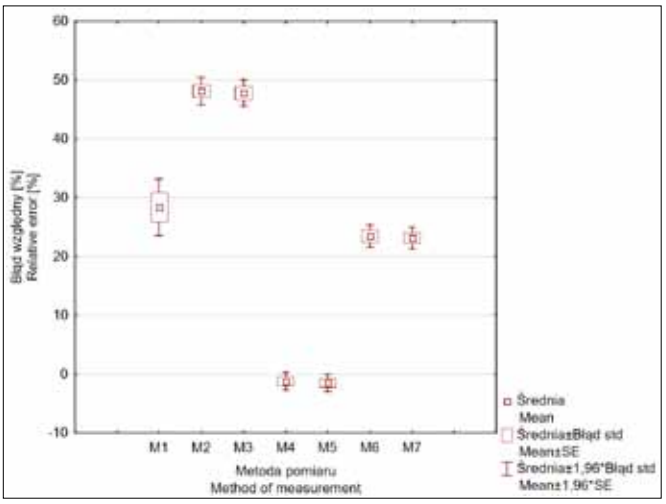

Fig. 7. Relative error in determining the volume of peanuts by the 1D method with the use of geometric models and the 3D method.

Rys. 7. Błąd względny wyznaczania objętości owoców orzechy podziemnej metodą 1D z wykorzystaniem modeli geometrycznych oraz metodą 3D.

Source: Own study

Źródło: Opracowanie własne

CONCLUSIONS

The comparison of two methods for determining the geometric parameters of peanuts revealed that the 3D method produced more reliable results. The geometric parameters (linear dimensions, surface area, volume) of entire samples and selected fragments of the examined samples can be determined based on 3D numerical models. The surface area of peanuts was more accurately rendered with the use of 3D numerical models than the direct method involving geometric models (1D method). In the 1D method, the surface area of peanuts can be determined with the use of geometric models M1 (sphere), M6 (semi-spheroid and a cylinder) and M7 (semi-ellipsoid and an elliptic cylinder). Geometric models M4 (spheroid) and M5 (ellipsoid) can be applied to determine the volume of peanuts in the 1D method. The relative error was below 5% when the above models were applied to measure the surface area and volume of peanuts. Reverse engineering of 3D numerical models (3D method) is a laborious process which requires adequate lighting, and the relevant conditions can be met only under laboratory conditions.

WNIOSKI

Z przeprowadzonych badań na owocach orzechy podziemnej, wynika, że spośród zastosowanych dwóch metod wyznaczenia parametrów geometrycznych owoców najlepsze efekty uzyskano przy metodzie 3D. Na podstawie przestrzennych modeli numerycznych można wyznaczyć parametry geometryczne (wymiary, powierzchnię, objętość) całych próbek jak i ich wybranych fragmentów. Pomiar pola powierzchni owoców z wykorzystaniem przestrzennych modeli numerycznych jest dokładniejszy niż pomiar pola powierzchni metodą bezpośrednią z wykorzystaniem modeli geometrycznych (metoda 1D). Do wyznaczenia pola powierzchni owoców orzechy podziemnej metodą 1D można zastosować modele geometryczne M1 (kula), M6 (połowa elipsoidy obrotowej i walec) i M7 (połowa elipsoidy i walec eliptyczny). Wyznaczając objętość owoców orzechy podziemnej metodą 1D można wykorzystać modele M4 (elipsoida obrotowa) i M5 (elipsoida). Wykorzystując wymienione modele do wyznaczania pola powierzchni i objętości owoców popełnia się błąd względny pomiaru mniejszy od 5%. Budowanie za pomocą inżynierii odwrotnej przestrzennego modelu numerycznego (metoda 3D) jest procesem długim, wymagającym zachowania określonych warunków oświetleniowych, które na chwilę obecną są łatwe do spełnienia tylko w warunkach laboratoryjnych.

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FOOD ADDITIVES IN CONFECTIONERY®

Dodatki do żywności w wyrobach cukierniczych®

The aim of the article is to present the results of the analysis of the use of various additives in the manufacture of confectionery. A total of 100 confectionery products were analysed. They were divided into 5 groups: chocolate candies, hard and soft candies, chocolate bars and chocolate tablets. In the first stage of the studies, we determined the type of additional substances used in each product. Subsequently, the average share of the declared additives in each sub-group of confectionery was calculated. It was found that of all additions declared in the composition, more than 63% included food additives, 19.4% were flavours and 17.1% included other additions, mainly affecting the nutritional value of products. Soft candies contained on average more than 7 additives, whereas hard candies - 5 different additives. On average, 5.6 different additives were declared in the composition of chocolate candies and bars, and in the composition of chocolate tablets - more than 6. The highest number of additives was found in soft candies (on average, there were 4.5 different additives in one piece), followed by chocolate tablets (4.3) and chocolate bars (3.8). In one piece of hard or chocolate candies one can expect an average of about 3 different food additives. Soft candies were dominated by the addition of glazing substances and dyes, hard candies by the addition of dyes and acidity regulators, chocolate candies and bars by the addition of emulsifiers and raising substances, whereas chocolate tablets, above all, by the addition of emulsifiers, dyes and acidity regulators.

Key words – confectionery, food ingredients, food additives, additional substances, flavours.

Celem artykułu jest prezentacja wyników dotycząca analizy stosowania różnych dodatków w produkcji wyrobów cukierniczych. Łącznie przeanalizowano skład 100 wyrobów cukierniczych, które podzielono na 5 grup: cukierki czekoladowe, cukierki twarde i miękkie oraz batony czekoladowe i czekolady. W pierwszym etapie badań, w każdym produkcie określano rodzaj stosowanych dodatków, w tym substancji dodatkowych. Następnie obliczano przeciętny udział deklarowanych dodatków w każdej podgrupie wyrobów cukierniczych. Stwierdzono, że spośród wszystkich deklarowanych w składzie dodatków do żywności, ponad 63% to substancje dodatkowe, 19,4% to aromaty oraz 17,1% pozostałe dodatki, w głównej mierze wpływające na kształtowanie wartości odżywczej wyrobów. Cukierki miękkie zawierały przeciętnie ponad 7, a twarde 5 różnych dodatków. W składzie cukierków czekoladowych i batonów deklarowano przeciętnie 5,6 różnych dodatków, a w składzie czekolad ponad 6. Największą liczbę substancji dodatkowych stwierdzono w cukierkach miękkich (przeciętnie w jednym cukierku znajdowało się 4,5 różnych substancji dodatkowych), następnie w czekoladach (4,3 szt.) i batonach czekoladowych (3,8 szt.). W jednym cukierku twardym lub czekoladowym można spodziewać się przeciętnie ok. 3 różnych substancji dodatkowych. W cukierkach miękkich dominował dodatek substancji glazurujących i barwników, w cukierkach twardych dodatek barwników oraz regulatorów kwasowości, w cukierkach czekoladowych oraz w batonach dodatek emulgatorów i substancji spulchniających, a w czekoladach przede wszystkim dodatek emulgatorów, barwników i regulatorów kwasowości.

Słowa kluczowe – wyroby cukiernicze, składniki żywności, dodatki do żywności, substancje dodatkowe, aromaty.

INTRODUCTION

In food production on an industrial scale, additives are considered as essential ingredients because they perform various technological functions, affecting, among others, the formation of the sensory characteristics of food (colour, taste, smell), physical properties (consistency), chemical parameters (e.g. acidity) or microbiological quality. They also often have an economic aspect – in many cases, a reduced-price effect of a food product can be achieved, the attractiveness of products as well as food safety [10, 19] can be increased. On the other hand, the use of additives is an element of concern for consumers, as there are known cases of adverse health effects [1, 3, 12].

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Food additives should be constantly monitored and reassessed on the basis of changing conditions of use and new scientific information. Legislation currently in force in the European Union states that food additives may be used if they benefit the consumer [11].

Therefore, there is a need for continuous monitoring of the consumption of various additions and, in particular, of additional substances, if only because, with an inadequately balanced diet, they could be over-consumed, going above the indicated safe level of consumption. It has been proven that the effects of consuming excessive amounts of certain additives may be manifested as late as after a few years [4]. The quality of products intended for children is particularly important [9].

POLBISKO research shows that more than 90% of Poles buy sweets, and for most of them they are a permanent part of the diet. These studies also indicate that almost 40% of the studied consumers eat something sweet at least 5 times a week, and 11% even several times a day. These studies also show that chocolate products are the largest segment of the Polish confectionery market [6]. This study has been inspired by the need to monitor the use of additives in this product group.

MATERIAL AND METHODS

The experimental material consisted of labels for food products included in the confectionery group. A total of 100 products were analysed and divided into 5 product groups: chocolate candies, hard and soft candies, chocolate bars and chocolate tablets. In each product group, 20 products from different manufacturers were analysed. The first stage of the studies focused on the type and number of different additives used for each product. Next, we calculated the average share of the analysed components in the products classified for each sub-group of those products. The results were compared in individual groups of selected confectionery products.

RESULTS AND DISCUSSION

In tab. 1, the values determining the total number of additives in each group of confectionery are presented, while tab. 2 presents the average number per single product. The content of 100 analysed products indicated the use of 593 different additives, of which 376 (63.5%) were food additives, 115 (19.4%) were flavours and 101 (17.1%) featured additions other than flavours and food additives (tab. 1).

On average, individual products in each group contained from 5 to 7.4 different additives, of which the following should be mentioned:

- food additives – used in the largest amount (on average approx. 3.1 to 4.5 different substances per single food product),
- flavours (approx. 0.7 – 1.5 in one product),
- and other additives (from 0.7 to 1.5 in one product) which mainly influenced the nutritional value of products. The highest number of such additives was found in soft candies (1.5 per single product), while the least (0.7–0.8 per single product) in chocolate tablets and hard candies (tab. 2).

All of the analysed products included the addition of flavours. The highest number of different flavours per product was declared in chocolate candies, soft candies and chocolates tablets (tab. 2). The most frequently used flavour was vanilla (ethylvanillin) and aromas declared as natural fruit aromas (lemon, apple, orange, raspberry), or other: mint, coffee, cola.

Table 3 shows a list of ingredients declared by manufacturers as additives. The additives affecting the nutritional value of products include: protein preparations, maltodextrins, natural flavouring-aroma and colouring ingredients, or vitamins. Concentrates of fruit juices and fruit and vegetable juices as well as plant extracts were used quite often – mainly in filled products. In the case of glazed candies, vegetable oils have been used, mainly in mixtures with the addition of glazing substances.

Table 1. Summary of the total number of additives in the groups of confectionery products

Tabela 1. Zestawienie łącznej liczby dodatków w grupach wyrobów cukierniczych

Groups of additives / products Grupy dodatków / wyrobów	Type of candy / Rodzaj cukierków			Chocolate bars / Batony czekoladowe	Chocolate tablets / Czekolady	Total / Razem
	Soft / Miękkie	Hard / (caramels) Twarde	Chocolate / Czekoladowe			
The total number of all declared additives Łączna liczba wszystkich deklarowanych dodatków	147	99	111	111	125	593
Flavourings / Aromaty	27	18	30	15	27	117
Additives / Substancje dodatkowe	90	65	61	75	85	376
Additives other than flavourings and additives Dodatki inne niż aromaty i substancje dodatkowe	30	16	20	21	13	100

Source: The own study

Źródło: Badania własne

Table 2. The number of additives in confectionery per one product

Tabela 2. Liczba dodatków w wyrobach cukierniczych w przeliczeniu na jeden produkt

Confectionery groups / Grupy wyrobów cukierniczych	Number of declared ingredients added to the confectionery / Liczba deklarowanych składników dodawanych do wyrobów cukierniczych			
	Total / Ogółem	including / w tym:		
		additives / substancje dodatkowe	flavourings / aromaty	others / pozostałe
Soft candies / Cukierki miękkie	7,4	4,5	1,4	1,5
Hard candies / Cukierki twarde	5	3,3	0,9	0,8
Chocolate candies / Cukierki czekoladowe	5,6	3,1	1,5	1,0
Chocolate bars / Batony czekoladowe	5,6	3,8	0,7	1,1
Chocolate tablets / Czekolady	6,3	4,3	1,4	0,7

Source: The own study

Źródło: Badania własne

Table 3. List of additives other than additives and flavorings used in confectionery

Tabela 3. Wykaz dodatków innych niż substancje dodatkowe i aromaty w wyrobach cukierniczych

Confectionery groups / Grupa wyrobów cukierniczych	Additives other than additives and flavourings / Dodatki inne niż substancje dodatkowe i aromaty
Soft candies / Cukierki miękkie	koncentraty soków owocowo-warzywnych, ekstrakty i wyciągi smakowo-barwiące z naturalnych składników (takich jak: kawa, szpinak, pokrzywa, kurkuma, papryka), witaminy (najczęściej wit. C, E oraz witaminy z grupy B), maltodekstryna
Hard candies / Cukierki twarde	oleje roślinne (głównie kokosowy w mieszaninach z substancją glazurującą), koncentraty owocowe oraz ekstrakty i wyciągi z roślin (najczęściej: krokosz, cytryna, rzodkiew, jabłka, czarna porzeczki, czarny bez), koncentraty i hydrolizaty białek (głównie mleka), naturalne koncentraty barwiące (z czarnej marchwi, papryki, kurkumy, spirulina) oraz witaminy (głównie C, E oraz z grupy B)
Chocolate candies / Cukierki czekoladowe	koncentraty białek serwatkowych i wszystkich białek mleka, ekstrakty roślinne (np. z papryki), wanilina, ekstrakt słodowy jęczmienny
Chocolate bars / Batony czekoladowe	maltodekstryny, wanilina, naturalne ekstrakty smakowo-barwiące oraz koncentraty białek (głównie mleka), składniki o charakterze zagęstników (głównie maltodekstryny)
Chocolate tablets / Czekoladady	ekstrakt i wyciągi smakowo-barwiące (np. z papryki chilli, wanilina), koncentraty soków owocowych (np. z dzikiej róży, czarnego bzu), ekstrakt słodowo-jęczmienny

Source: The own study

Źródło: Badania własne

Table 4. Groups of additives and their average number per one product

Tabela 4. Grupy substancji dodatkowych i ich przeciętna liczba w przeliczeniu na jeden produkt

Groups of additives / Grupy dodatków	Type of candy / Rodzaj cukierków			Chocolate bars / Batony czekoladowe	Chocolate tablets / Czekolady
	Soft (including stuffed) / Miękkie	Hard (caramels) / Twarde	Chocolate / Czekoladowe		
Colorants / Barwniki	1	1,4	0,1	0,1	0,5
Acidity regulators / Regulatory kwasowości	0,6	1	0,2	0,3	0,5
Acids / Kwasy/	0,6	0,2	0,1	0,1	0
Humectants / Utrzymujące wilgoć	0,2	0,2	0,4	0,5	0,3
Emulsifiers / Emulgatory	0,7	0,3	1,6	2,1	2,0
Loosening / Spulchniające	0	0	0,5	0,5	0,3
Glazing / Glazurujące	1,1	0,1	0,1	0	0,2

Source: The own study

Źródło: Badania własne

In this group of additives, the fairly frequent use of maltodextrins is indicated. According to the literature, maltodextrins are used in food production to bind water to products with reduced fat content, and to add stickiness. They ensure a delicate texture and a feeling of full taste. They are used primarily in meat preparations, cakes and bakery products, but also in confectionery as filling substances [17, 18].

Additional substances were declared in all products, and fulfilled a total of 14 different technological functions. Tab. 4 shows those groups of additives that were included in the list of ingredients of all the analysed products, while substances that were used individually included preservatives (candies, chocolate bars, and chocolate tabs), gelling substances (soft candies, chocolate tabs), antioxidants (hard and soft candies), stabilisers (bars, chocolates), anti-caking substances (hard candies), binders (bars) and thickening substances (soft candies, chocolate tablets).

Dyes were one of the most commonly used groups of additives in the manufacture of confectionery. It was found that dyes were most commonly used in the production of hard candies (1.4 pc in a single product) and in soft candies (an average of 1 dye per product). In the other product groups, significantly less than one dye was used per single product. In chocolate bars and chocolate candies, this was true for curcumin, and in chocolate tablets: chlorophylls and chlorophyllines, anthrocyanins, carotenes, titanium dioxide, beet brood, riboflavins, oxides and iron hydroxides, carmines, curcumin, paprika extract and cochineal (tab. 5).

The use of synthetic dyes in confectionery and other products, which are subjected to thermal processes, is justified since the properties of these colouring agents do not change under the influence of temperature [7]. It is also known that the colour stability of products often depends on the type of dye and the pH of the environment. It is higher in products with a pH of about 3.5 when L-ascorbic acid is added as an acidity regulator, instead of the popular citric acid [2].

Similar studies [5] found a large number of different types of colouring agents in different foods, with the most (an average of 3.33 pc in a single product) found in confectionery and bakery products. A fairly large group of additives declared on the labels included acidity regulators and acids, most commonly used in hard and soft candies. Citric and lactic acid were the most commonly used, but tartaric, fumaric or malic acids were also found (tab. 5).

On average, chocolate bars and candies contained about 2 different emulsifiers (from 1.7 to 2.2). On the other hand, less than 1 type of emulsifier (on average 0.3-0.7pc/1 product) could be found in a single hard or soft candies piece. Among a number of emulsifying substances used in these products are soya and sunflower lecithin, but also mono- and diglycerides of fatty acids, i.e. synthetic fats similar in composition to natural fat, gum arabic, polyglycerol polyricinoleate, i.e. semi-synthetic emulsifier and stabiliser obtained from polyglycerol and castor oil, used most often for quick and easy and more durable mixing and combining of various ingredients (tab. 6).

Humectants were most commonly used in the manufacture of chocolate bars and chocolate candies (from 0.2 to almost 0.5 substances per product). These were mostly sorbitols, but also glycerol (tab. 6).

According to literature data, sorbitol is very often used in the production of mint sweets, caramels, chocolate tablets, biscuits and as an addition to foods recommended for diabetics. It is also used in the concentrate, dairy and beverage industries [8].

A significant number of glazing substances was declared in soft candies (1.1 pc in a single product) (tab. 4). Only chocolate bars did not feature these substances. The most commonly used glazing substances are carnauba wax, beeswax, shellac and gum Arabic. Carnauba wax was found in hard and soft and chocolate candies, beeswax in soft candies and chocolate tabs (tab. 6). Hard and soft candies did not use raising substances. Their addition to sweets, chocolate bars, and chocolate tablets was found in the composition of chocolate candies, in bars and chocolate tabs (tab. 6).

Table 5. List of selected additives in confectionery products declared by different manufacturers

Tabela 5. Wykaz wybranych substancji dodatkowych w wyrobach cukierniczych deklarowanych przez różnych producentów

Confectionery groups / Grupy wyrobów cukierniczych	Colorants / Barwniki	Acidity regulators / Regulatory kwasowości	Acids / Kwasy
Soft candies Cukierki miękkie	dwutlenek tytanu, ekstrakt z papryki, kurkumina, kompleksy miedziowe chlorofili i chlorofil, karmele, czerwień buraczana, E153, E 120, E 132	kwas cytrynowy, kwas mlekowy, mleczan sodu, E 331	winowy, kwas cytrynowy, mlekowy
Hard candies Cukierki twarde	kurkumina, kapsantyna, koszenila, kompleksy miedziowe chlorofili i chlorofil, E162, antocyjany, indygotyna, karmelizowany syrop cukrowy	kwas cytrynowy i kwas mlekowy	mlekowy, fumarowy, cytrynowy, jabłkowy, winowy
Chocolate candies Cukierki czekoladowe	kurkumina	kwas cytrynowy	cytrynowy
Chocolate bars Batony czekoladowe	kurkumina	kwas cytrynowy, węglan sodu	cytrynowy
Chocolate tablets Czekoladady	chlorofile i chlorofil, antocyjany, karoteny, dwutlenek tytanu, czerwień buraczana, ryboflawiny, tlenki i wodorotlenki żelaza, karminy, kurkumina, ekstrakt z papryki, koszenila	kwas cytrynowy, węglany sodu, dwutlenek węgla, kwas winowy	cytrynowy

Source: The own study

Źródło: Badania własne

Table 6. List of selected additives in confectionery products declared by different manufacturers

Tabela 6. Wykaz wybranych substancji dodatkowych w wyrobach cukierniczych deklarowanych przez różnych producentów

Confectionery groups / Grupy wyrobów cukierniczych	Emulsifiers / Emulgatory	Humectants / Substancje utrzymujące wilgoć	Speeding agents / Substancje spulchniające	Glazing agents / Substancje glazurujące
Soft candies Cukierki miękkie	mono- i diglicerydy kwasów tłuszczowych, lecytyna z soi, guma arabska, E472c	sorbitole, syrop sorbitolowy	-	wosk pszczeli biały i żółty, wosk carnauba
Hard candies Cukierki twarde	lecytyny z soi,	sorbitol, syrop sorbitolowy	-	wosk carnauba
Chocolate candies Cukierki czekoladowe	lecytyny z soi, E476	inwertaza, glicerol, syrop sorbitolowy, sorbitole	wodorowęglan sodu, wodorowęglan amonu, pirosiarczyn sodu	guma arabska, szelak
Chocolate bars Batony czekoladowe	lecytyny, E 476, E 471, lecytyny z soi, lecytyna słonecznikowa	inwertaza, sorbitole, glicerol	wodorowęglan sodu, węglan sodu, węglan amonu	-
Chocolate tablets Czekolady	lecytyna sojowa, E476, lecytyna słonecznikowa	Syrop sorbitolowy, glicerol, inwertaza, sorbitole	węglany sodu, węglany amonu, pirosiarczyn sodu	guma arabska, wosk pszczeli, szelak, wosk carnauba

Source: The own study

Źródło: Badania własne

A study conducted in 2002 [13] showed that biscuit and confectionery products mainly used emulsifiers and aromas (19.4% of the total substances found) as well as raising agents and dyes (16.4%). Pastry and confectionery products from 2006, similarly to 2011, contained the most aromas (25.5% of the total pool), emulsifiers (22.6%) and dyes (19.5%) [14, 15, 16].

In the analysed confectionery products available in 2020, aromas accounted for 19.7% of all additives, and additional substances constituted 63.4%. Among the additional substances used in all groups of the analysed products, emulsifiers (35.8% of all declared additives) were the most commonly used, followed by dyes (16%) and acidity regulators (13.6%). However, when considering each group of confectionery separately, a significant differentiation in the use of additives is observed. Soft candies were dominated by the addition of glazing substances and dyes (24.4 and 22.2%), hard candies by the addition of dyes (41.5%) and acidity regulators (30.8%), in chocolate candies and bars the most frequently added substances were emulsifiers (52.5 and 56%) and loosening substances (16.4 and 13.3%), while in chocolate tablets – primarily emulsifiers (35.8%), dyes (11.8%) and acidity regulators (10.6%) (tab. 7).

Table 7. The frequency of declaring individual groups of additional substances in the composition of the analyzed confectionery products

Tabela 7. Częstotliwość deklarowania poszczególnych grup substancji dodatkowych w składzie analizowanych wyrobów cukierniczych

Groups of additives: / Grupa substancji dodatkowych:	Confectionery groups / Grupy wyrobów cukierniczych					
	CM	CT	CCz	BCz	Cz	Xśr.
– colorants / barwniki	22,2	**41,5**	3,3	1,3	**11,8**	**16,0**
– acidity regulators / regulatory kwasowości	13,3	**30,8**	6,6	6,7	**10,6**	**13,6**
– humectants / substancje utrzymujące wilgoć	4,4	1,5	9,8	**12,0**	7,1	7,0
– acids / kwasy	13,3	4,6	1,6	1,3	1,2	4,4
– thickeners / substancje zagęszczające	3,3	3,1	0,0	0,0	1,2	1,5
– glazing agents / substancje glazurujące	**24,4**	3,1	3,3	0,0	4,7	7,1
– emulsifiers / emulgatory	14,4	9,2	**52,5**	**56,0**	**47,1**	**35,8**
– stabilizers / stabilizatory	1,1	-	3,3	1,3	4,7	2,1
– bulkheads / substancje spulchniające	-	-	**16,4**	**13,3**	7,1	7,4
– preservatives / substancje konserwujące	-	-	1,6	2,7	1,2	1,1
– gelling agents / substancje żelujące	1,1	-	1,6	0,0	3,5	1,3

Groups of additives: / Grupa substancji dodatkowych:	Confectionery groups / Grupy wyrobów cukierniczych					
	CM	CT	CCz	BCz	Cz	Xśr.
– antioxidants / przeciwutleniacze	2,2	3,1	-	1,3	-	1,3
– anti-caking agents / substancje przeciwzbrylające	-	3,1	-	-	-	0,6
- binders / substancje wiążące	-	-	-	4,0	-	0,8

CM – soft candies / cukierki miękkie; CT – hard candies (caramels) / cukierki twarde (karmelki); CCz – chocolate candies / cukierki czekoladowe; BCz – chocolate bars / batony czekoladowe; Cz – chocolate tablets / czekolady

Source: The own study

Źródło: Badania własne

CONCLUSIONS

It was found that of all additions declared in the composition, more than 63% included food additives, 19.4% were flavours and 17.1% included other additions, mainly affecting the nutritional value of products.

Soft candies contained on average more than 7 additives, whereas hard candies – 5 different additives. On average, 5.6 different additives were declared in the composition of chocolate candies and bars, and in the composition of chocolate tablets – more than 6.

The highest number of additives was found in soft candies (on average, there were 4.5 different additives in one piece), followed by chocolate tablets (4.3) and chocolate bars (3.8). In one piece of hard or chocolate candies one can expect an average of about 3 different food additives.

Soft candies were dominated by the addition of glazing substances and dyes, hard candies by the addition of dyes and acidity regulators, chocolate candies and bars by the addition of emulsifiers and raising substances, whereas chocolate tablets, above all, by the addition of emulsifiers, dyes and acidity regulators.

PODSUMOWANIE

Stwierdzono, że spośród wszystkich deklarowanych w składzie dodatków do żywności, ponad 63% to substancje dodatkowe, 19,4% to aromaty oraz 17,1% pozostałe dodatki, w głównej mierze wpływające na kształtowanie wartości odżywczej wyrobów.

Cukierki miękkie zawierały przeciętnie ponad 7, a twarde 5 różnych dodatków. W składzie cukierków czekoladowych i batonów deklarowano przeciętnie 5,6 różnych dodatków, a w składzie czekolad ponad 6.

Największą liczbę substancji dodatkowych stwierdzono w cukierkach miękkich (przeciętnie w jednym cukierku znajdowało się 4,5 różnych substancji dodatkowych), następnie w czekoladach (4,3 szt.) i batonach czekoladowych (3,8 szt.). W jednym cukierku twardym lub czekoladowym można spodziewać się przeciętnie ok. 3 różnych substancji dodatkowych.

W cukierkach miękkich dominował dodatek substancji glazurujących i barwników, w cukierkach twardych dodatek barwników oraz regulatorów kwasowości, w cukierkach czekoladowych oraz w batonach dodatek emulgatorów i substancji spulchniających, a w czekoladach przede wszystkim dodatek emulgatorów, barwników i regulatorów kwasowości.

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THE USE OF THE ARDUINO MODULE IN CONTROLLING THE VEGETABLE INDUSTRY EQUIPMENT ON THE EXAMPLE OF A WEIGHING-PACKING MACHINE®

Zastosowanie modułu Arduino w sterowaniu urządzeniami przemysłu warzywniczego na przykładzie wagoworkownicy®

The article presents the concept and the completed prototype of a mechatronic, automated two-belt weighing-packing machine for vegetables. The solutions for the mechanical, electrical and electronic parts have been developed by the authors. The control concept was based on the Arduino programming platform and the Arduino 2560 board, while the control system itself was implemented in C++. The paper describes the structure of the machine as well as tests for checking the effectiveness of the machine for weighing potatoes in 2, 5 and 10 kg portions.

Key words: machine, weight, 3D models, system.

W artykule przedstawiono koncepcję oraz zrealizowany prototyp mechatronicznej, automatycznej dwutaśmowej wagoworkownicy do warzyw. Rozwiązania części mechanicznej, elektrycznej jak i elektronicznej zostały opracowane przez autorów. Koncepcję sterowania oparto o platformę programistyczną Arduino oraz płytkę Arduino 2560, zaś sam system sterowania zaimplementowano w języku C++. W pracy zawarto opis konstrukcji maszyny, jak i badania sprawdzające skuteczność działania maszyny dla ważenia ziemniaków w porcje 2, 5 i 10kg.

Słowa kluczowe: maszyna, waga, modele 3D, system.

INTRODUCTION

Agriculture is one of the most important parts of the world economy [8, 25, 26]. The level of mechanisation is a measure of the country's technological development [12, 16, 37]. Sustainable development of agriculture involves meeting the needs of current and future generations with particular attention to the need to harmoniously link economic, social and natural development aspects [14, 22, 28]. Operating with a full balance between socio-economic and environmental factors is a challenge that will be faced by farmers and food producers in the coming years [24, 33, 36]. Farmers and agricultural entrepreneurs more and more often invest financial resources in equipment based on solutions that enable rationalisation of the use of means of production, monitoring of crops, animals and machinery, and at the same time support production and business decisions [3, 23, 32].

The agri-food sector includes not only farmers but also entrepreneurs responsible for inputs and services, the food industry (processing) and trade [2, 6, 31]. Since Poland joined the structures of the European Union, the agri-food sector has become a key sector for the Polish economy and the agri-food sector has become a leader in Polish trade [21, 30, 34]. The development of agri-food processing was indicated as a priority action in the "Programme for Development of Main Agricultural Markets in Poland 2016–2020".

Modern agricultural production is referred to as Agriculture 4.0. It uses many innovative technologies [11, 15, 35]. These solutions include, among others autonomous vehicles, innovative agricultural machinery. The structures of modern agricultural tractors and machines are increasingly equipped with modern automation and electronics systems [9, 13, 20].

An example of a modern and very efficient device is an electronic weighing-packing machine [7, 10, 17]. It works by weighing a given amount of the product and pouring it into a substituted bag. It is possible to combine the scale with other automatic packaging machines. Tapes of this type of equipment used must have a food certificate and be suitable for contact with food. A novelty in this type of machine is the use of a touch panel to control the device. The scale is characterized by high performance and high accuracy during weighing.

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OVERVIEW OF SOLUTIONS AVAILABLE ON THE MARKET

In the vegetable industry, two types of weighing-packing machines are most often used: tape and drawer. The drawer weighing-packing machines are used when a high capacity of 10-15 tons per hour is required. This type of scales is also characterized by greater accuracy, which is obtained through a special algorithm that controls the weighing process. Typically, the goods transported by the conveyor go to the buffer chamber where they are spread over the entire width of the weighing area. Then, in each weighing cycle, the goods are transferred to the appropriate drawer chamber through vibrating chutes or, less frequently, belt conveyors. The amount of product reaching there is specified within a specific value range. The computer which controls the process and knows the value of each individual drawer chamber then selects the mass and the number of chambers with the sum of masses closest to the set mass. This is done on the basis of an algorithm based on a mathematical variance. After the selected chambers are opened, the product goes to the transverse collecting conveyor and is transported to a raschel bag or foil packing machine. After each cycle, the chambers are replenished, which is not limited to replenishing the empty ones, but also, if necessary, the product is poured into the chambers where the weight value is not within the specified range. This need arises because the cycle of filling the chambers designed to speed up the operation of the machine is limited to a specific time. The greater number of drawers translates into shorter filling time, at the expense of a greater selection of masses among all the chambers. It may even so happen that the algorithm selects the mass from 9 out of 10 chambers. The margin of error in weighing such goods is approx. 150 grams, and the minimum weighing value is approx. 250 grams [18], so it is possible to weigh small portions of goods (Fig. 1).

Fig. 1. Drawer weighing machine by Manter.
Rys. 1. Wagoworkownica szufladkowa firmy Manter.
Saurce: Own study based on [18]
Źródło: Opracowanie własne na podstawie [18]

Belt weighing machines, used more often in smaller production, are characterized by a less advanced design and are a great deal cheaper. They are used by agricultural producers who do not require higher capacity than 3 tons per hour and the overall production will be balanced by lower accuracy – about 300 grams and the minimum value of the weighed mass within 1-5 kg, depending on the solution [4, 19]. Belt scales are divided into single-belt or double-belt types.

Single-belt weighing-packing machines are used for vegetables whose shape hinders the free flow of the product, e.g. carrots or parsley. Another decisive factor that determines the choice of such a scale is its simplicity of construction, and thus also its price. Such a weighing-packing machine is built of a single conveyor with alternately set drivers. The weighing basket is filled by moving the belt, slowing it down appropriately, and then stopping it. An example of such scales is shown in Figure 2.

Fig. 2. Single-belt weighing-packing machine by Sorpac.
Rys. 2. Wagoworkownica jednotaśmowa firmy Sorpac.
Saurce: Own study based on [19]
Źródło: Opracowanie własne na podstawie [19]

Double-belt scales are more accurate and are used for e.g. oval-shaped vegetables. In addition to the main belt, they have an additional narrow weighing belt. The work cycle of such scales begins with the movement of both belts and a proportional slowing down, depending on the weight of the weighing basket being filled. In the final stage of filling, the main belt stops and the narrow weighing belt dispenses the remainder of the product [4]. A computer is responsible for controlling the work cycle, whose algorithm is responsible for the proper regulation of the movement of the belts (Fig. 3).

Fig. 3. Double-belt weighing-packing machine by Biljsma Hercules.
Rys. 3. Wagoworkownica dwutaśmowa firmy Biljsma Hercules.
Saurce: Own study based on [4]
Źródło: Opracowanie własne na podstawie [4]

Differences in the construction of such scales between manufacturers are small. They mainly differ in the way of hanging the weighing basket: the basket is suspended from the top on 2 strain gauge beams; the basket with a lower hook on one central beam; the basket is suspended from the top on a single beam attached to the basket handle.

Another significant difference in construction is the shape of the loading hopper – the baskets are connected together with the bulkhead side of the conveyor or are bolted separately to the conveyor structure.

Manufacturers currently focus mainly on improving the control of such devices. A simple solution is to use analogue logic gates based on contactors, but such a solution gives little opportunity to adapt the operation to real conditions. Better results are achieved with the use of PLC controllers, often connected with the HMI panel and a graphic menu interface [4, 19]. Although the producers provide ready-made operating modes for particular types of vegetables, the operator can additionally adjust the appropriate parameters at their own discretion.

THE AIM OF THE PAPER

The purpose of the design of the automated two-belt weighing-packing machine for vegetables is to show the possibilities of cheap microprocessor solutions from the Arduino family. They are much cheaper than the automation solutions based on PLC controllers which currently dominate the industry [27]. The standard PLC controllers, despite being adapted to work in industrial automation, are outdated solutions. The implementation of control systems based on the programming languages available in them, i.e. most frequently with the use of ladder logic, is strenuous with more advanced systems. The C++ language is a much more modern universal language. It offers the possibility of structured as well as object-oriented programming, thanks to which the program implementation with the use of appropriate design patterns is much easier, and the code is characterized by high transparency, even with complex systems [5]. Another advantage of Arduino is the fact that it is currently the most popular open-source microprocessor solution in the world, so there is a large number of libraries for facilitating the operation of peripheral systems (LCD displays, converters, stepper motor drivers), as well as a publicly available database of projects and courses and a user-friendly, free environment [1].

DESCRIPTION OF THE MECHANICAL PART

The main element of the automated double-belt weighing-packing machine (Fig. 4) is a double-belt conveyor (1) based on a welded frame (2) with adjustable legs in order that it can be levelled on any surface. The conveyor consists of two outer sides divided by a partition in the proportion of 400 mm to 120 mm. These dimensions are also the width of the belts made of PVC. There are 60 mm high drivers glued to the belts, so that the product can be transported upwards at an angle of 45 degrees. The product is poured into the double-belt conveyor through the loading hopper (3); it has been designed in such a way that the product can go both from the pallet box tipper and from all machines preceding the technological line whose final stage is the weighing. The belts are driven by angular geared motors (4 and 5) directly attached to the driving drums of the conveyor. The rotation of the motor around the shaft axis was blocked by a torque arm bolted to the gearbox and the side of the conveyor. The weighing basket (7) was suspended on two strain gauge packages (6). Each strain gauge package consists of two strain gauge beams with a maximum weighing range of 20 kg each. The beams were permanently bolted to the upper plate, while the lower closing plate was divided into two parts so that both beams could operate independently. The design assumption was that the compactly closed packages were resistant to working conditions and could constitute one uniform spare part, the replacement of which would be limited to switching the cable and screwing the new part. The weighing basket is covered with an adhesive anti-deflection sponge resistant to dirt and humid working conditions. The product is poured out by opening the rotating flap. The movement and closing state of the flap are forced by pneumatic actuators. After opening the flap, the product goes to the discharge channel (8), at the end of which a sheet metal is bent in a way that allows the operator to hook the bag. The channel was made in an open system so that the flowing product does not create blockages and the operator can control the quality of the product in real time.

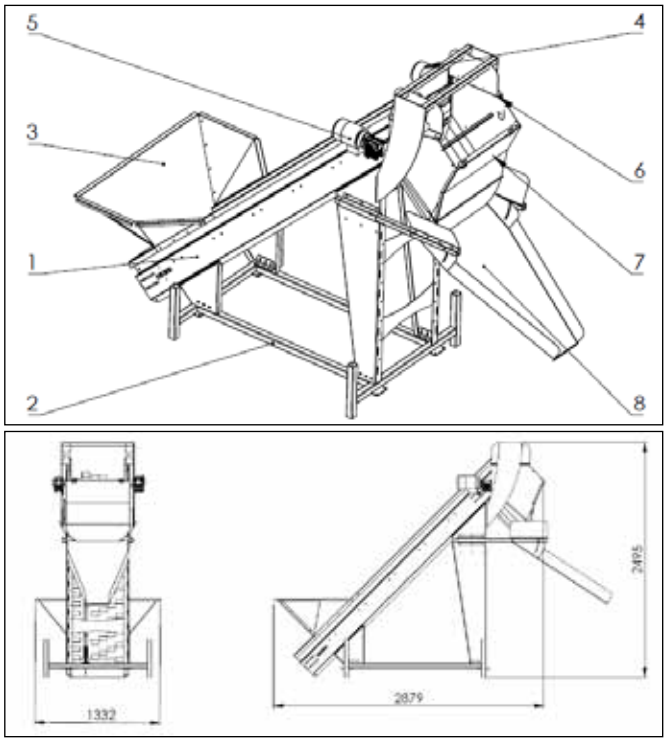


Fig. 4. Construction of the designed weighing-packing machine: 1 – double belt conveyor; 2 – welded frame; 3 – loading hopper; 4 – angle gear motor #1; 5 – angle gear motor #2; 6 – strain gauge packages; 7 – weighing basket; 8 – discharge channel.

Rys. 4. Konstrukcja zaprojektowanej wagoworkownicy: 1 – przenośnik dwutaśmowy; 2 – rama spawana; 3 – kosz zasypowy; 4 – motoreduktor kątowy 1; 5 – motoreduktor kątowy 2; 6 – pakiety tensometryczne; 7 – kosz ważący; 8 – kanał zrzutowy.

Saurce: Own study

Źródło: Opracowanie własne

DESCRIPTION OF THE CONTROL SYSTEM

The presented mechatronic weighing machine is based on the Arduino Mega 2560 R3 module with the AVR ATmega2560 microcontroller with 256 kB Flash memory, 8 kB RAM, 54 digital outputs/inputs (15 of them can transmit PWM signal), 16 analog inputs and popular communication interfaces [1]. Arduino works in the 5V standard and is sensitive to external interference from AC devices, especially the inverter, so it is important to isolate typically electronic circuits operating at 5V. After connecting to a 3-phase source, the power supply system is divided into 3 sections: 400V 3-phase AC; 24V DC generated with an industrial power supply; 5V DC generated with an industrial power supply.

The 400V 3-phase circuit is connected to the inverter only. 24V contactors (motor 1 contactor and motor 2 contactor) are connected in parallel to the output of the 3-phase inverter. Their task will be to start the motors: Motor 1 of the small belt with a power of 0.37kW and Motor 2 of the large belt with a power of 0.37kW.

The 24V DC circuit is used to control the actuating devices. The circuit is isolated from the 5V voltage. It supplies power to the pedal switch. The pedal switch is connected directly to the pneumatic solenoid valve which, when opened, supplies pressurized air to the pneumatic actuators responsible for opening the loading hopper flap. No voltage on the solenoid valve causes the loading hopper flap to close. Moreover, 24V is the voltage that is switched on by an opto-isolated relay module that activates the contactors of motors 1 and 2, starts the inverter with a 24V START signal and powers the PWM (Pulse-Width-Modulation) signal converter at between 0 and 10V.

The 5V DC circuit is responsible for powering the electronics (Arduino module, LCD display, strain gauge beam amplifier #1, strain gauge beam amplifier #2).

Arduino receives the following input signals: 5 bit signals from the set of buttons on the control panel; 1 bit signal from the flap opening sensor; 2 x digital signal from the strain gauge amplifiers, which take measurements on 2 parallel connected strain gauge beams and send out the measurement result in digital form [29].

Arduino sends the following signals: 4 x bit signal for opto-isolated relay module (inverter start signal, motor #1 contactor switch-on signal, motor #2 contactor switch-on signal, warning light switch-on signal); 1 x PWM signal to the PWM converter – 0 to 10V, used to control the rotational speed of the inverter; 1 x I^2C serial signal for the LCD display.

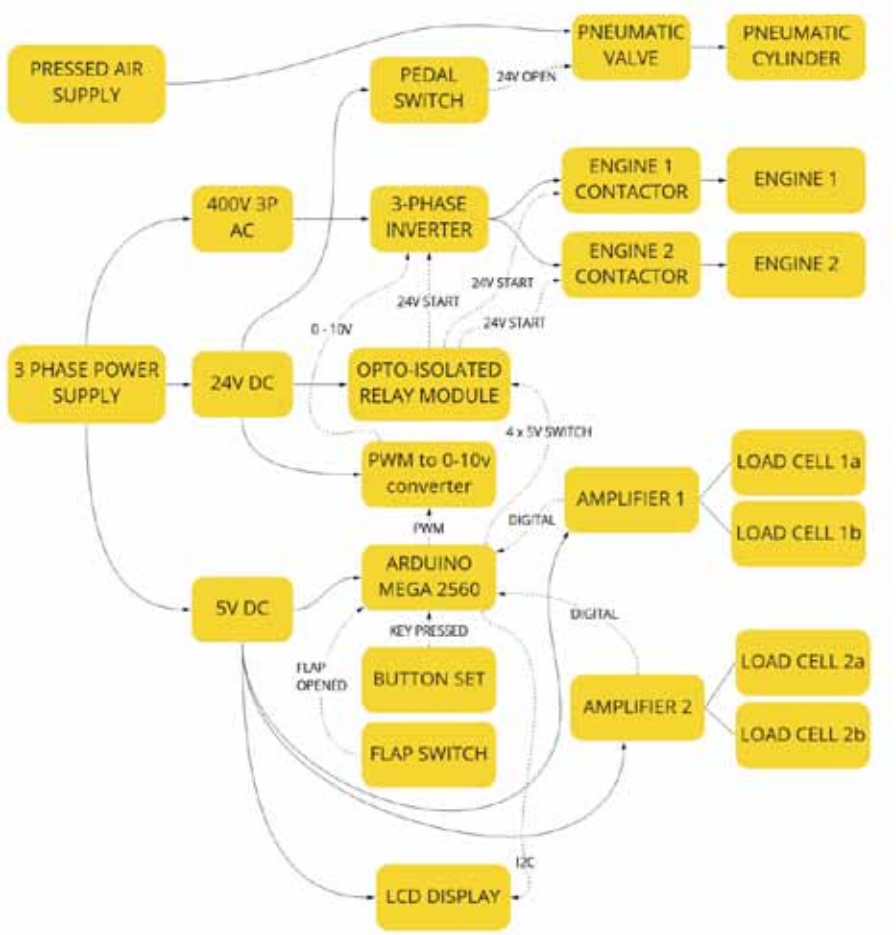


Fig. 5. Schematic model of the weighing machine control system.
Rys. 5. Model ideowy systemu sterowania wagoworkownicą.
Saurce: Own study
Źródło: Opracowanie własne

After proper connection, thus configured infrastructure permits the implementation of software controlling the machine operation (Fig. 5).

INSTALLATION OF ELECTRICAL AND ELECTRONIC COMPONENTS

In the prototype, it was decided to separate the electrical part working with 400V 3-phase AC and the electronic part powered by 5V DC. Two separate units were used for this purpose.

Transfer box #1 (Fig. 6A) includes a connection to a 400V 3-phase mains supply and: Main power switch; Residual current protection; Overcurrent protection; 24V and 5V DC power supplies; Inverter; Contactors for starting motors controlled with 24V voltage; 24V connection to the pedal of the pneumatic solenoid valve of the flap opening.

Transfer box #2 (Fig. 6B) contains all the control electronics and the user's panel. It includes respectively: The Arduino Mega 2560 R3 module embedded in the housing with connectors for easy cable connection; PWM signal converter

to 0-10V; Module of 4 relays controlling the 24V power supply for: inverter start, motor contactor #1, motor contactor #2, warning light; Set of switches for setting the machine; LCD display; Connection to strain gauges #1 and #2; Connection to the flap opening limit switch.

Transfer case #2 receives from case #1: 5V DC; 24V DC; Inverter start signal 24V; 24V signal to motor contactor # 1; 24V signal to motor contactor 2; 0-10V signal for controlling the frequency of the motor supply voltage, i.e. their rotational speed.

SOFTWARE IMPLEMENTATION

The full software for setting operating parameters and the weighing process itself takes approx. 500 lines of code. The program uses the following libraries:

- EEPROM – internal library used to write and read data from EEPROM semiconductor non-volatile memory, which is equipped with Arduino Mega 2560 R3;
- Wire – internal library used for communication via the I^2C serial bus;
- LiquidCrystal_I2C – external library used to operate the LCD screen with a converter based on the PCF8574 integrated circuit via I^2C;
- HX711 – a library that supports the 24-bit digital amplifier for strain gauge beams.

The program can be divided into 4 sections:

- Global declaration and definition of constants (including input and output pins, coefficients for weight calculation, start delay of engines and their maximum speed) and variables (initial machine settings, working variables determining the state of the weighing process). Thanks to this approach, the software is easily maintainable, it is adapted to a quick change of outputs, inputs and operating parameters, and the code is clearer;
- The setup() function – a function that is run at startup – the output and input pins are defined with predefined constants, and the LCD screen and weighing systems are initialized. Thanks to proper parameterization;
- The main loop() – the actual loop is continuously executed while the program is running. It is divided into 2 main blocks: the block of settings and menu operation by buttons and the block responsible for the weighing process;
- Auxiliary functions section – Most of the repetitive code has been wrapped in helper functions and used in the main loop (Fig. 7 and Fig. 8). On account of that, the code is shorter, the main loop contains only the proper logic, and the change of the implementation of individual methods is easily modifiable.

A B

Fig. 6. Transfer case: A – Transfer case no. 1; B – Transfer case no. 2.
Rys. 6. Skrzynia rozdzielcza: A – Skrzynia rozdzielcza nr 1; B – Skrzynia rozdzielcza nr 2.

Saurce: Own study

Źródło: Opracowanie własne

```
   double GetWeight() {
      double w1 = scale.get_units();
      double w2 = scale2.get_units();

      double weight = w1 + w2;
      if  (abs(weight  -  currentWeight)  <  5.0
failedWeightsCounter > 2) {

   currentWeight = weight;

   failedWeightsCounter = 0;
      }
      else {

   failedWeightsCounter++;
      }

      return currentWeight;
   }
```

Fig. 7. Reading of the weight, filtering the interference in the digital signal received from the amplifier, used in the loop.
Rys. 7. Odczyt wagi filtrujący zakłócenia w sygnale cyfrowym otrzymywanym ze wzmacniacza używany w pętli.

Saurce: Own study

Źródło: Opracowanie własne

The process control itself of the proper weighing has been developed empirically on the basis of time and accuracy tests for various weighing process runs (Table 1). The weighing process has been divided into 6 steps, in which the speed of the motors and the moment of disconnecting the large belt motor are selected on the basis of the missing mass. Empirically selected settings of the motor speed and the step switching thresholds ensure maximum efficiency without increasing the

```
   bool PressedButton1() {
      if (digitalRead(button1) == LOW) {

   if ((button1Timer++ % buttonsMultiplier == 0

   && button1Timer > buttonEdgeTime

   )

   || button1Timer == 1) {

   return true;

   }
      }
      else {

   button1Timer = 0;
      }
      return false;
   }

   bool PressedButton1Long() {
      if   (button1Timer   >   buttonEdgeTimeLong)
return true;
      return false;
   }
```

Fig. 8. Example of methods that support short and long-term button presses, adapted to loop operation.

Rys. 8. Przykład metod obsługujących krótkotrwałe i długotrwałe naciśnięcie przycisku przystosowane do działania w pętli.

Saurce: Own study

Źródło: Opracowanie własne

deviations from the set mass. For a mass difference of less than 1.2 kg, the motor of the larger belt is completely disengaged.

Table 1. Steps of the weighing process depending on the difference between the given mass and the actual mass

Tabela 1. Kroki procesu ważenia uzależnione od różnicy masy zadanej i aktualnej masy

Step number	Weight difference (kg)	% of maximum speed	Bigger tape engine	Smaller tape engine
1	>7	100	On	On
2	>4	75	On	On
3	>3	50	On	On
4	>2	25	On	On
5	>1.2	25	Off	On
6	> 0.2	10	Off	On

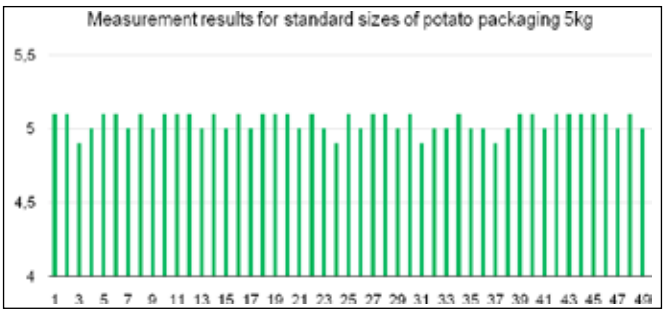
Saurce: Own study

Źródło: Opracowanie własne

MEASUREMENTS OF PERFORMANCE AND EFFICIENCY

In order to verify the effectiveness of the designed prototype, 3 series of measurements were performed for the process of weighing potatoes. A few weighing cycles were performed and then the mass of potatoes that was poured was recorded. Measurements were made for standard sizes of potato packaging: 2, 5 and 10 kg. The measurement results are as follows (Fig. 9), (Table 2).

A



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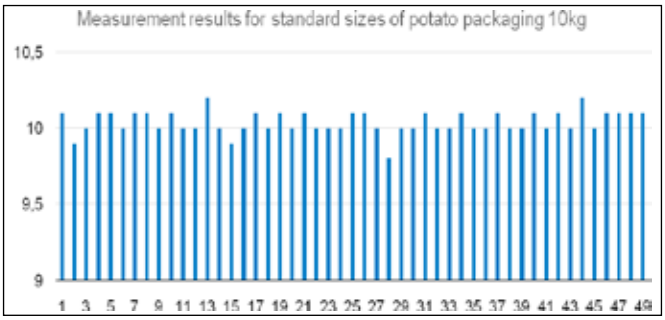

C

Fig. 9. Measurement results: A – Measurement results for standard sizes of potato packaging 2 kg; B – Measurement results for standard sizes of potato packaging 5 kg; C – Measurement results for standard sizes of potato packaging 10 kg.

Rys. 9. Wyniki pomiarów: A – Wyniki pomiarów dla standardowych rozmiarów opakowań do ziemniaków 2 kg; B – Wyniki pomiarów dla standardowych rozmiarów opakowań do ziemniaków 5 kg; C – Wyniki pomiarów dla standardowych rozmiarów opakowań do ziemniaków 10 kg.

Saurce: Own study

Źródło: Opracowanie własne

Table 2. Mean and standard deviation of the measurements

Tabela 2. Średnia i odchylenie standardowe pomiarów

Parameter	2 kg	5 kg	10 kg
Std. Deviation	0,079	0,065	0,073
Average	2,050	5,048	10,042

Saurce: Own study

Źródło: Opracowanie własne

SUMMARY

Three series for the given masses: 2 kg, 5 kg and 10 kg made it possible to verify the suitability of the prototype made. Slight deviations from the set mass were observed. The recorded standard deviation and the average deviation from the set weight did not exceed the weight of two potatoes. The highest standard deviation (0.08 kg) was observed at the value of 2 kg. Also, this series of measurements was characterized by the highest deviation of the mean from the set mass (0.05 kg). This is most likely due to a certain inertia of the engines observed at their start-up, as a result of which the deceleration of the engines in the last stage of weighing occurs with a certain delay. The most effective portioning took place when potatoes were weighed in 5 kg portions. The deviation from the mean was 0.048 kg and the standard deviation was 0.065 kg. This is probably due to the lower starting rotational speed of the engines, so the deceleration itself occured faster.

For all the three series of measurements, the results are fully validated, which confirms the effectiveness of the solution. The proposed design of an automated weighing and packing machine can be successively used as a weighing element of a potato line in production on an industrial scale. The machine's capacity for 5 kg bags is estimated at 2 tons per hour.

PODSUMOWANIE

Trzy serie dla zadanych mas: 2 kg, 5 kg oraz 10 kg pozwoliły zweryfikować przydatność wykonanego prototypu. Zaobserwowano niewielkie odchylenia od zadanej masy. Zarejestrowane odchylenie standardowe i odchyłka średniej od zadanej masy nie przekroczyły wagi dwóch ziemniaków. Największe odchylenie standardowe (0,08 kg) zaobserwowano przy wartości 2 kg. Również tę serię pomiarów cechowała najwyższa odchyłka średniej od zadanej masy (0,05 kg). Wynika to najprawdopodobniej z pewnej bezwładności silników zaobserwowanej przy ich starcie, w wyniku której samo zwalnianie silników w ostatnim etapie naważania następuje z pewnym opóźnieniem. Najskuteczniejsze porcjowanie miało miejsce dla przypadku ważenia ziemniaków w porcje 5kg.

Odchyłka od średniej wyniosła 0,048kg, a odchylenie standardowe 0,065 kg. Wynika to prawdopodobnie z niższej startowej prędkości obrotowej silników, a więc samo spowalnianie ich następowało szybciej.

Dla wszystkich trzech serii pomiarów wyniki są w pełni akceptowalne co potwierdza skuteczność rozwiązania. Proponowana konstrukcja automatycznej wagoworkownicy może być sukcesywnie używana jako element ważący linii do ziemniaków w produkcji na skalę przemysłową. Wydajność maszyny dla worków 5 kg szacuje się na poziomie 2 ton na godzinę.

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PRODUCTION TECHNOLOGY AND QUALITY ASSESSMENT OF FERMENTED DRINKS®

Technologia produkcji i ocena jakości napojów fermentowanych®

Fermented milk drinks MNF are becoming more and more popular among consumers. They owe their popularity to their health and dietary properties. They are known for their beneficial effects on our body. As the demand for fermented dairy products increases, so does the variety of these products on the market. Consumers more and more often know what to pay attention to in order to choose the most valuable for our body among so many products.

The article presents the production technology and characteristics of fermented milk beverages. Selected quality features of products available in the commercial circulation were examined (titratable acidity [° SH], dry matter content [%] and protein content [g]).

Key words: fermented drinks, kefir, buttermilk, yogurt, ocean of quality.

Mleczne napoje fermentowane MNF cieszą się coraz większym zainteresowaniem wśród konsumentów. Swoją popularność zawdzięczają posiadanym właściwościom zdrowotnym oraz dietetycznym. Znany jest ich dobroczynny wpływ na nasz organizm. Wraz ze wzrostem popytu na fermentowane artykuły mleczne zwiększa się różnorodność tych produktów dostępnych na rynku. Konsumenci coraz częściej wiedzą na co należy zwracać uwagę, aby wśród tak wielu produktów wybrać najbardziej wartościowe dla naszego organizmu.

W artykule przedstawiono technologię produkcji oraz charakterystykę mlecznych napojów fermentowanych. Zbadano wybrane cechy jakościowe produktów dostępnych w obiegu handlowym (kwasowość miareczkową [°SH], zawartość suchej masy [%] oraz zawartość białka [g]).

Słowa kluczowe: napoje fermentowane, kefir, maślanka, jogurt, ocean jakości.

INTRODUCTION

In Poland, dairy farming is the basic branch of agricultural production. Milk constitutes 15-17% of the commercial value of the production of the entire agricultural sector. Its production therefore not only affects the financial and development situation of the dairy sector, but also affects the entire agriculture.

Poland has been a member of the European Union since 2004, but restructuring and the adaptation of the dairy sector to its requirements has already started in 1998 [4]. In the modernization process, dairy plants carried out many investment activities to adapt to the requirements of the European Union, in particular in terms of sanitary and veterinary conditions and increasing technological standards. Activities such as modernization, adaptation and expansion of buildings, purchase of new machines, equipment and technological lines, improvement of water quality on farms or increasing the level of environmental protection in milk production and processing were undertaken.

Producers, adapting to the new regulations (and consumers' requirements), had to improve the quality of both the raw material - milk and its products. The quality of dairy products is significantly influenced by the quality of the milk used in the production process, therefore the quality of the dairy products increased along with the improvement of its quality. Of course, in addition to using milk with specific parameters, the producers also had to ensure appropriate production conditions.

The Polish dairy sector is among the largest in Europe both in terms of milk production as well as the production of dairy products. Moreover, the Polish dairy market is competitively priced compared to the market of other European countries. Poland is a significant exporter of dairy products, and foreign trade brings more and more profits.

The milk market, both in Poland and in other countries belonging to the European Community, is one of the most sensitive and is prone to large price fluctuations. Moreover, due to the level of farmers' income and consumer perception,

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the dairy sector is subject to many regulations by the EU. These regulations focus mainly on market support, limiting production volumes, compliance with sanitary and veterinary requirements (in the production, storage and marketing of dairy products) and compliance with sanitary and hygienic conditions in production (to ensure the best quality for consumers).

In recent years, the dairy processing sector has developed significantly in Poland. Among other things, the demand for dairy products. Among consumers, the interest in healthy food has increased, they are more likely to pay attention to what they eat and how it affects their body. The increase in interest can be easily seen by following production statistics. In the years 1990–1994 in Poland, a relatively small amount of processed milk products was produced in relation to the amount of milk produced. For example, the production of natural yoghurt was not involved at all (and the MNF itself produced 75 thousand tons per year), and already in 2012, its production was recorded at the level of 468 thousand. tonnes (MNF – 716 thousand tonnes) – importantly, with practically the same level of milk production.

On average, consumers spend about 15% of their expenses on food buying milk and milk products. The MNF market is currently the most profitable and dynamically developing segment of the dairy market in Poland. Consumers are interested in healthy eating and a proper diet. They pay attention to the nutritional value of products and their quality, and thus make more and more demands on producers. This is the driving force behind the development of the dairy processing sector. Currently used MNF production methods are modernized and modern, thanks to which products that are safe for health are created. They are free from microbiological, chemical and other contamination. Moreover, producers are obliged to carry out permanent internal control in dairy processing plants [5,7,8,10].

Milk and dairy products are of high nutritional value. They contain wholesome protein, vitamins and minerals [2]. Fermented milk drinks have a higher digestibility of proteins and fat than milk, but also a higher content of many vitamins. The bacteria present in them have a healing effect on the human body, including support the digestive and immune systems, inhibit the growth of pathogenic and putrefying bacteria, aid digestion, and reduce allergic reactions to milk (e.g. by partially breaking down lactose). Additionally, the peptides contained in them support the cardiovascular system. Fermented milk drinks also contribute to the degradation and decomposition of carcinogenic compounds [5].

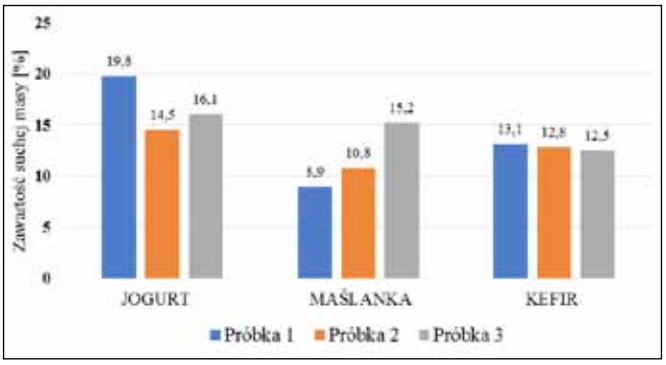
Fermented milk drinks are products obtained from milk (whole, partially or fully skimmed milk and from milk reconstituted from powder), which is fermented by microorganisms specific to the drink. In addition to the colonies specific to a given fermented beverage, other microorganisms may also be added. The microorganisms contained in these drinks must remain alive and active in an appropriate amount throughout the shelf life of the product. The exceptions are products that have undergone heat treatment after fermentation. In this case, the microflora is not required to remain alive [3].

The aim of this article is to assess selected quality parameters of fermented beverages. The parameters of three types of fermented beverages (yogurt, kefir, buttermilk) available on the Polish market were compared. Selected quality parameters, such as acidity, protein content and dry weight – in selected purchased products were examined in the study.

RESEARCH METHODOLOGY

The research material consisted of three types of fermented milk beverages – natural yoghurt, buttermilk and kefir. To test the quality parameters of MNF, samples from generally available products in the commercial circulation were used – three for each type of MNF. Determination of the acidity of prepared MNF samples available in commercial circulation made according to Soxhelt-Henkel methods. There are different methods for determining the dry matter (and water) content of a food. The work uses the thermal drying method. It occurs when the water vapor pressure in the product is greater than the atmospheric pressure in the dryer. Increasing the differential pressure, incl. can be obtained by increasing the temperature of the dried substance, removing moisture from the air in the dryer, or by reducing the pressure inside the dryer. The protein content of the samples was determined by the formol method.

ANALYSIS AND DISCUSSION OF THE RESULTS



Pic. 1. Dry weight in test samples.
Rys.1. Sucha masa w badanych próbkach.
Source: Own study
Źródło: Opracowanie własne

In the tested products, the dry matter content was normalized and ranged from 8.9% to 19.8%. The highest dry matter content in the tested products occurred in the case of natural yoghurts. The highest value is marked in sample no.1 – 19.8%, then there was sample no.3 – 16.1%, the lowest dry matter content in the case of natural yoghurts was determined in sample no.2 – 14.5%. In the case of buttermilk, there was quite a significant difference in the dry matter content – from 8.9% (sample 1) through 12.3% (sample 2) to 15.2% (sample 3). The dry weight of the kefir samples showed a very similar value from 12.5% (sample 3) through 12.8% (sample 2) to 13.1% (sample 1).

The obtained results of dry mass in the tested yoghurts are quite high and varied between products, but their level is acceptable and comparable to the results obtained in studies by other scientists (eg 14, 16% dry matter content in yoghurt [9]).

In the tested buttermilk, there was a significant difference in the dry matter content between individual samples. The water content in buttermilk is approx. 91%, therefore its dry mass should be approx. 9%. In the tested buttermilk, only sample 1 (8.9%) is close to the norm. The second sample (10.8%) is slightly higher, but still acceptable. The last result (15.2%) significantly differs from the adopted norm. This may be because this product is made with an increased dry matter content, but this information was not found on the product packaging.

Kefir with an increased dry matter content in a product is one that contains 14% of its composition [1]. Dry matter content test in kefir showed very similar results. All kefirs tested for this study showed a dry matter content below 14%, therefore it can be concluded that the tested products contain a dry matter content appropriate for them.

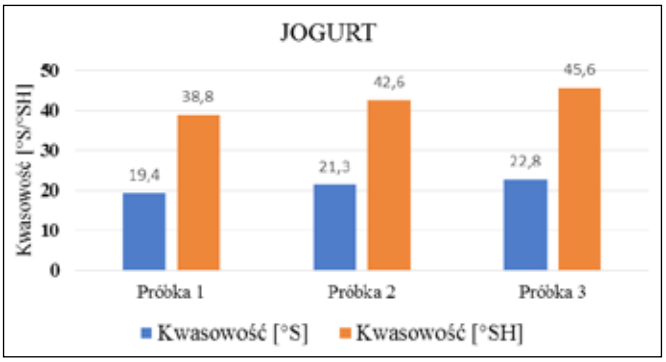


Fig.2. The acidity of the yogurt.
Rys.2. Kwasowość jogurtu.
Source: Own study.
Źródło: Opracowanie własne.

The study of the degree of acidity in individual analyzed yoghurts showed significant differences between the tested samples – from 38.8° SH through 42.6° SH to 45.6° SH. Observing the results of studies conducted by other scientists [9], who in their work checked the effect of storage time on the acidity of the product, it is possible to approximate the time that has elapsed since the production of the products tested for the purposes of the study. In their research, freshly produced products had an average acidity of 40.9° SH, after 7 days it was already 42.2° SH, and after 14 days – 44.1° SH. Comparing it to the results of own research, it was noticed that sample no. 1 has a low level of acidity (38.8° SH), which suggests a short time since its production and its freshness. Sample no. 2 and 3 already have a higher level of acidity, which may be caused by the passage of time (for sample no. 2, about a week, and for sample no. 3, even longer than two weeks) – from the date of production.

The level of acidity in all tested buttermilk is similar - from 36° SH to 40° SH. The obtained results were compared with the results obtained by a team of other scientists who investigated, inter alia, the level of titratable acidity in buttermilk available on the Polish market and the influence of the time on eggs [6]. The obtained results are within the limits set by the aforementioned scientists. As with yoghurts, the increase in acidity occurs as time passes from the moment the product is made. The data, however, are not as precise as in the previously described case, because the researchers did not use freshly manufactured products for their research, therefore it is impossible to determine how long the product was stored before the study. Taking into account the collected information and own observations, it can be concluded that sample no. 1 and 2 are fresher, and in the case of sample no. The storage time until testing was longer.

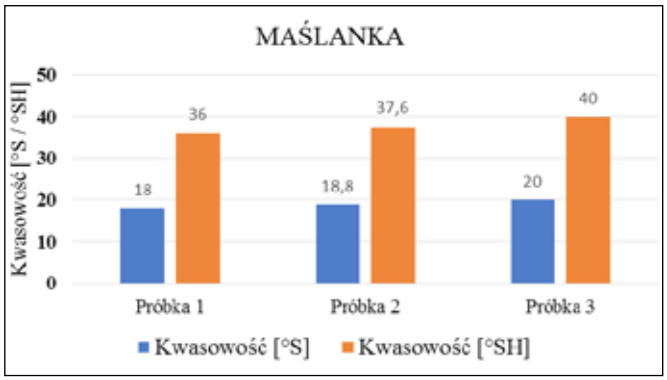


Fig. 3. The acidity of buttermilk.
Rys.3. Kwasowość maślanka.
Source: Own study
Źródło: Opracowanie własne

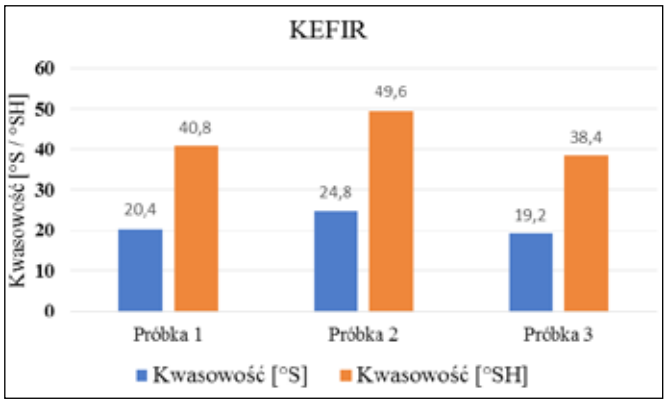


Fig4. The acidity of kefir.
Rys.4. Kwasowość kefir.
Source: Own study
Źródło: Opracowanie własne

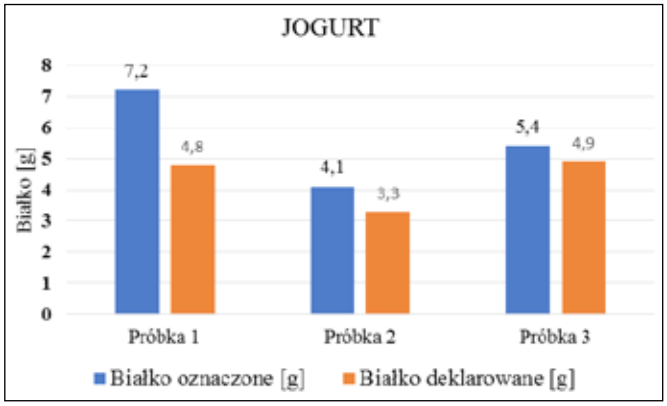


Fig.5. Protein content as declared by the manufacturer - natural yoghurt.
Rys.5. Zawartość białka oznaczonego z deklarowanym przez producenta – jogurt naturalny.
Source: Own study
Źródło: Opracowanie własne

The titratable acidity in the tested kefir samples is very diverse. Two of the tested samples showed the value of acidity at a similar level – 38.4° SH and 40.8° SH. In the third sample of kefir, a much higher level of acidity was found – 49.6° SH.

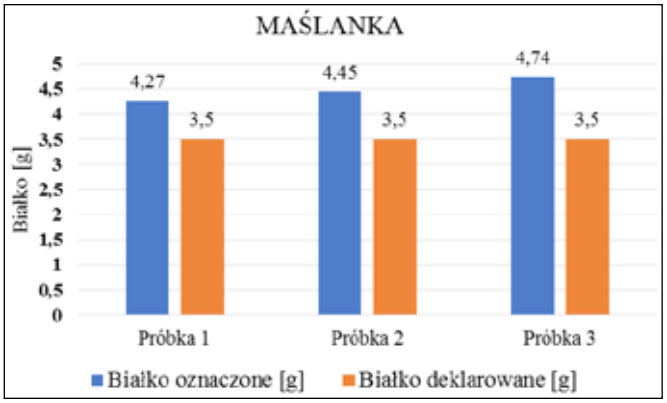


Fig. 6. Protein content determined with the declared by the producer – buttermilk.

Rys. 6. Zawartość białka oznaczonego z deklarowanym przez producenta – maślanka.

Source: Own study.

Źródło: opracowanie własne

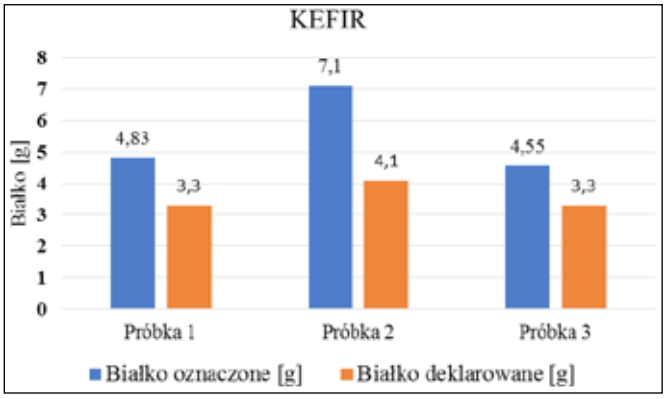


Fig.7. Protein content marked with the declared by the manufacturer – kefir.

Rys.7. Zawartość białka oznaczonego z deklarowanym przez producenta – kefir.

Source: Own study

Źródło: Opracowanie własne

All the tested samples of natural yoghurt showed a higher content of protein determined in the product than the content declared by the producer.

These differences ranged from 0.5 g (sample 3), through 0.8 g (sample 2) up to 2.4 g (sample 1) per 100 g of product. Producers declared different protein contents in their products.

The same can be observed in the measurement results – the obtained results are increased, but they increase proportionally to the declared values. The protein level declared by the producer is the minimum value that must be included in the product, therefore they all meet the quality requirements. Today, an increased amount of protein in dairy products is desired by many consumers.

As in the case of yoghurts, all tested buttermilk samples showed a higher content of protein in the product than declared by the manufacturer. The measurement of protein content in the samples was at a similar level – all producers declared the same protein content in their products.

The differences between the determined and the declaimed protein ranged from 0.77 g (sample 1), through 0.95 g (sample 2) to 1.27 g (sample 3) per 100 g of the product.

As in the above protein determinations, the same in the case of kefirs – the protein content in all samples is higher than the protein declared by the producer.

As in the case of natural yoghurts, also in kefirs, these differences are significant. They range from 1.25 g (sample 3), through 1.53 g (sample 1) up to 3.0 g (sample 2) per 100 g of product.

It can be seen that in the case of samples no. 1 and 3, the content of the declared protein is the same, and according to the results of the determinations, its value is increased by about 30% in both cases. The situation is different in the case of sample No. 2 where the marked value is almost twice as large as the declared value.

SUMMARY

Consumers' awareness of the choice of fermented milk beverages of good quality and valuable to our body is growing. Consumers more and more often read the labels of products available on the market and know which ingredients are the most valuable for our body. As shown by the research, in the case of dry matter content, the lowest value was achieved in buttermilk, while the highest dry matter content was achieved in yoghurt. In the case of yoghurts and kefirs, the acidity varied, while in the case of buttermilk, the values were similar. All the tested samples showed a protein level higher than the level declared by the manufacturer. These values were very diverse - the lowest was found in natural yoghurt (10% more protein than declared by the manufacturer), the highest was found in kefir (as much as 73% more protein).

PODSUMOWANIE

Świadomość konsumentów przy wyborze dobrych jakościowo i wartościowych dla naszego organizmu mlecznych napojów fermentowanych jest coraz większa. Konsumenci coraz częściej czytają etykiety dostępnych na rynku produktów i wiedzą które składniki są najbardziej wartościowe dla naszego organizmu. Jak pokazały przeprowadzone badania w przypadku zawartości suchej masy najniższą wartość osiągnięto w maślance, najwyższą zawartość suchej masy osiągnięto w jogurcie. W przypadku jogurtów i kefirów kwasowość była zróżnicowana, natomiast w przypadku maślanki wartości te były zbliżone do siebie. Wszystkie badane próbki wykazały poziom białka większy aniżeli poziom deklarowany przez producenta. Wartości te były bardzo zróżnicowane – najmniejszą wykazano w jogurcie naturalnym (10% więcej białka niż deklarował producent) najwyższą z kolei oznaczono w kefirze (aż 73% więcej białka).

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DETERMINATION OF AFLATOXIN M1 CONTAMINATION LEVELS IN MILK AND MILK PRODUCTS BY HPLC-FLD WITH POST – COLUMN DERIVATIZATION®

Oznaczanie poziomów zanieczyszczenia aflatoksyną M1 mleka i produktów mlecznych metodą HPLC-FLD z derywatyzacją pokolumnową®

This study was carried out as part of research project No. N N312 439837 co-financed by the Polish Ministry of Science and Higher Education in 2009–2011.

In the present study, 34 samples of pasteurised, ultra-high-temperature (UHT) treated milk and milk products (cheese, yoghurt and baby foods) in the city of Olsztyn, Poland, were analysed for aflatoxin M_1 (AFM_1). All samples were cleaned up using immunoaffinity column according to Romer Labs® procedure with minor modification. The Aflatoxin M_1 levels were investigated by high performance liquid chromatography with a fluorescence detection (LC-FLD) and post - column derivatization following sample clean-up using AflaStar™ M_1 immunoaffinity columns (Romer Labs®, Inc., America). The mean recovery of the method was 95 %. The standard curve was linear in the range of 0.01 – 0.25 µg/L with correlation coefficient of 0.9998. The limit of detection was 0.01 µg/L. Results showed 27 (79.4%) positive samples for AFM_1 at levels of 0.010-0.053 µg/L, which were below the tolerance limit of 0.500 µg/L as adopted for AFM_1 in this products by EU regulations. Mean levels of AFM_1 in pasteurized and UHT milk were 0.022±0,006 µg/L and 0.030±0,002 µg/L, respectively. However, only one sample among milk samples was contaminated at a level above the maximum permissible limit (0.050 µg/L) accepted by European Union and Poland for aflatoxin M_1 and six of seven samples of baby food were contaminated at a level above the maximum permissible limit (0.025 µg/L). It is concluded that the incidence of AFM_1 in milk traded in Olsztyn is high, but at levels that probably leads to a non-significant human exposure to AFM_1 by consumption of milk. Experimental results show that, in comparison to milk samples, AFM_1 contamination level was higher in samples of baby food. These data suggest that AFM_1 concentration in milk could be good predictor of its fate in milk products, especially for infants and babies. The results of this study imply that more emphasis should be given to the routine AFM_1 inspection of milk and milk products in Poland. Furthermore, both farmers and dairy companies should be informed on the

W niniejszej pracy analizie pod kątem zawartości aflatoksyny M_1 (AFM_1) poddano 34 próbki pasteryzowanego mleka po obróbce w ultra wysokiej temperaturze (UHT) i produktów mlecznych (ser, jogurt i żywność dla niemowląt) zakupionych w mieście Olsztyn, w Polsce. Wszystkie próbki oczyszczono przy użyciu kolumn immunoafinitywnych zgodnie z procedurą Romer Labs® z niewielkimi modyfikacjami. Poziomy aflatoksyny M_1 analizowano metodą wysokosprawnej chromatografii cieczowej z detekcją fluorescencyjną (LC-FLD) z derywatyzacją pokolumnową po oczyszczeniu próbki przy użyciu kolumn immunoafinitywnych AflaStar ™ M1 (Romer Labs®, Inc., Ameryka). Średni odzysk metody wyniósł 95%. Krzywa standardowa była liniowa w zakresie 0,01–0,25 µg/L ze współczynnikiem korelacji R^2 0,9998. Granica wykrywalności wynosiła 0,01 µg/L. Wyniki pokazały 27 (79,4%) pozytywnych próbek AFM_1 na poziomach 0,010-0,053 µg / l, które były poniżej granicy tolerancji 0,500 µg/L, przyjętej dla AFM_1 w tych produktach w przepisach UE. Średnie poziomy AFM_1 w mleku pasteryzowanym i UHT wynosiły odpowiednio 0,022 ± 0,006 µg/L i 0,030 ± 0,002 µg/L. Jednak tylko jedna próbka wśród próbek mleka była zanieczyszczona na poziomie powyżej maksymalnego dopuszczalnego limitu (0,050 µg/L) przyjętego przez Unię Europejską i Polskę dla aflatoksyny M_1, a sześć z siedmiu próbek żywności dla niemowląt było zanieczyszczonych na poziomie powyżej maksymalnego dopuszczalnego limitu (0,025 µg / l). Stwierdzono, że częstość występowania AFM_1 w mleku będącym przedmiotem obrotu w Olsztynie jest wysoka, ale na poziomach, które prawdopodobnie prowadzą do nieistotnego narażenia ludzi na AFM_1 w wyniku spożycia mleka. Wyniki eksperymentalne wskazują, że w porównaniu z próbkami mleka poziom zanieczyszczenia AFM_1 był wyższy w próbkach żywności dla niemowląt. Dane te sugerują, że stężenie AFM_1 w mleku może być dobrym wskaźnikiem jego losów w produktach mlecznych, zwłaszcza dla niemowląt

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importance of AFM_1, and the consequences of the presence of the aflatoxin in dairy products.

Key words: aflatoxin M_1, milk, milk products, solid phase extraction, high performance liquid chromatography (HPLC).

i małych dzieci. Wyniki tego badania sugerują, że należy położyć większy nacisk na rutynową kontrolę AFM_1 mleka i przetworów mlecznych w Polsce. Ponadto zarówno rolnicy, jak i firmy mleczarskie powinni być informowani o znaczeniu AFM_1 i konsekwencjach obecności aflatoksyny w produktach mlecznych.

Słowa kluczowe: aflatoksyna M_1, mleko, prdukty mleczne, ekstarkcja do fazy stałej, wysokosprawna chromatografia cieczowa (HPLC).

INTRODUCTION

Humans are exposed to different chemicals including carcinogenic substances during their life. One of them are mycotoxins that have aroused significant public concern worldwide. The occurrence of mycotoxins in human, animal and milk products is one of the most serious problems of food hygiene since milk is important food for adults, and the unique nutrient for infant [23]. Aflatoxins are secondary metabolites produced by some moulds (mainly *Aspergillus flavus* and *Aspergillus parasiticus*) and are contaminants of animal feeds particularly in critical temperature and humidity conditions before or during harvest [23]. Contamination of milk with aflatoxin M_1 is considered as a potential risk for human health. Aflatoxin B_1 (AFB_1) has the highest toxicity [15]. Epidemiological studies have shown that with prolonged exposure to AFB_1 liver cancer may develop, especially in persons with hepatitis B antigens [5, 22, 27] Consequently, the World Health Organization (WHO) classifies AFB_1 as a human carcinogen and proposes no safe dose [3]. The major metabolite of AFB_1 is aflatoxin M_1 (AFM_1), which is detectable in the urine, blood, milk, and internal organs of animals ingesting AFB_1-containing feed [1]. Aflatoxin M_1 could be detected in milk 12–24 h after the first aflatoxin B_1 ingestion, reaching a high level after a few days. Aflatoxin M_1 is relatively stable during pasteurization, sterilization, preparation, and storage of various dairy products. Although AFM_1 is less carcinogenic than AFB_1 (2-10% of potency), it is also a health danger. It has comparable liver toxicity, can reduce the immunity of infants, and is

considered to be a possible human carcinogen (2B) by the International Agency for Research on Cancer (IARC) [7, 8, 12,14, 15, 16, 27]. The molecular structures of AFB_1 and AFM_1 are presented in Figure 1 [5].

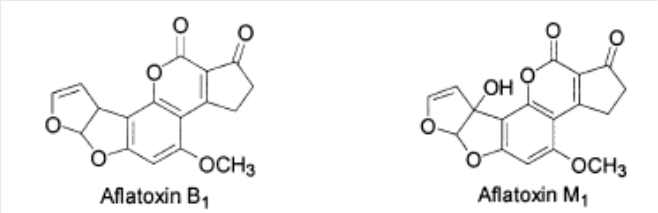

Fig 1. Molecular structures of aflatoxins B1 and M1 [5].
Rys. 1. Wzór strukturalny aflatoksyny B1 i M1 [5].

As milk is the main nutrient for infants and children who are considered to be more susceptible to adverse effects of mycotoxins, the presence of aflatoxin M_1 in milk is a concern [11, 13, 19, 20, 25, 26, 28]. But milk is not only consumed as liquid milk, but also utilized for the preparation of infant formulas, yogurt, cheese, and milk-based confectioneries. Therefore, it is important to determine aflatoxin M_1 levels in milk and dairy products in order to protect consumers in various age groups, from its potential hazards [1, 21, 24, 31].

The aim of this study was to determine of aflatoxin M_1 contamination levels in milk and milk products (milk, cheese, yoghurt and baby foods) by HPLC – FLD with post - column derivatization.

EXPERIMENTAL

1. Chemicals

Acetonitrile (HPLC grade) of J. T. Baker was used. Immunoaffinity columns (IAC) AflaStar M_1™ (stored at 4°C until use) were acquired from Romer Labs® (**Romer Labs® Diagnostic GmbH**, Tulln, Austria). The water used during analysis was double distilled with Millipore water purification system (Milli Q, Millipore). Water was purified in a Milli-Q system on 18.2 MΩ/cm.

2. Instrumantal

An Agilent 1100 Series (Agilent Technologies, Waldbronn, Germany) consisted of an LC system equipped with a membrane degasser, a quaternary pump, an autosampler, a 100 µL loop, a termostated column compartment and a fluorescence detector set at 360 nm (emission) and 440 nm (excitation) was used for the analyses. The LC column was a ZORBAX Eclipse XDB-C18, 150 mm×4.6 mm i.d., particle size 3 µm, purchased from Agilent. The mobile phase consisted of water (A) and acetonitrile (B) (25:75, v/v) flowed at 0.8 mL/min. A Pickering Laboratories PCX 5200 series was used to post-column derivatives.

3. Preparation of standard solutions

Standard solution of aflatoxin M_1 (0,993 μg/mL in acetonitrile) was purchased from Romer Labs® (BCR-423) and stored with care in freezer. Each stock solution was diluted step by step with the combined solution (acetonitrile/water, 75/25, v/v) to prepare a sequence of working solutions which were stored in vials below 4 ºC.

4. Materials

The pasteurized (n=11) and UHT (n=4) milk, yoghurt (n=10), cheese (n=2) and baby food (n=7) samples were obtained from the local supermarket. Dairy samples were stored in freezer compartment inside a refrigerator until these were analyzed for AFM_1.

5. Preparation of samples

After warming at about 37 ºC in water bath, the samples were centrifuged at 2000 g to separate fat layer and then

filtered. The prepared test portion of 50 mL was transferred into syringe barrel attached with AflaStar™ M_1 immunoaffinity columns (Romer Labs®, Inc., America) and passed at slow steady flow rate of 2–3 mL/min. The washing of column was done with 20 mL ultrapure water (Milli Q, Millipore) and then it was blown to dryness and afterwards aflatoxin M_1 was eluted with 4 mL pure acetonitrile by allowing it to be in contact with the column at least 60 s. The eluate was evaporated to dryness using gentle stream of nitrogen. The residue was solubilized in 500 µL of mobile phase and filtered by syrine driven filter unit Millex®-GN (0.2 µm, 13 mm, Millipore).

6. Peak identification

Identification and quantification of the AFM_1 residues was achieved by high performance liquid chromatography (HPLC). AFM_1 was identified on the base of retention time.

7. Statistical analysis

The experiment was comprised of three replications. The average value, standard deviation and the test of the significance were estimated using the Statistica 10.0 software. Results of the concentration of OTA in samples of beer and wine were analyzed by Tukey's test ($p \leq 0.05$).

RESULTS AND DISCUSSION

Milk and dairy products are highly nutritious foods containing many macro- andmicronutrients that are essential for the growth and maintenance of human health. The presence of aflatoxin M1 (AFM_1) in this products is an important issue, especially for developing countries [26]. Previous studies have shown that approximately 6.2% of AFB_1 ingested by livestock is metabolized into AFM_1 and excreted in milk. However, it mainly depends on the genetics of animals, milking process, seasonal variation and on the environmental conditions [17]. AFM_1 is very stable at high temperatures like other forms of AFs and the concentration of AFM_1 in milk is not affected significantly with the application of thermal processes i.e. pasteurization and ultra-high-temperature (UHT) treatments used in dairy industry [10, 17]. It was concluded that AFM_1 is 2–10% of less toxic than AFB_1 [2]. In our study, total 34 samples of milk and milk products were analyzed for the presence of aflatoxin M_1 (AFM_1) with the HPLC method equipped with fluorescence detector (Table 1).

Calibration curve was determined using a series of calibration solutions of AFM_1 in acetonitrile (range 0.01-0.25 µg/L, r^2 0.9998). The retention time for aflatoxin M_1 was 3.88 min. The obtained detection values (LOD – µg/L), quantification (LOQ – µg/L) and recovery (%) methods were respectively for aflatoxin M_1: 0.01/0.012/95. Recovery test were performed by spiking aflatoxin M_1-free milk, yoghurt, cheese and baby food samples with known amounts of AFM_1 and revealed mean recovery rates of 95% and mean relative standard deviations was < 8%.The obtained values of LOD, LOQ and recovery showed enough sensitivity for the detection of AFM_1 in all analyzed samples. The occurrence and levels of AFM_1 obtained are presented in Table 1. Analysis of 34 samples showed that 27 (79.4%) samples contaminated AFM_1 and in 6 (37.5%) baby food samples were found to be higher than the maximum acceptable limits for this type of milk products (above 0.025 µg/L) [6]. The levels of AFM_1 in UHT milk should be controlled and monitored continuously. Therefore, it is important to monitor the level of AFB_1 in feedstuffs of dairy animals, it is recommended that AFM_1 analysis and control must be taken seriously by the dairy industry in Poland to reduce AFM_1 contamination and improve the quality of milk and milk products. Among analyzed dairy

Table 1. The occurrence and mean concentration of AFM_1 in milk and milk products samples

Tabela 1. Występowanie i średnie stężenie AFM_1 w próbkach mleka i produktów mlecznych

Dairy samples	Production	Samples analyzed	Positive samples n (%)	Mean±SD* (µg/L or µg/kg)	Range (µg/L or µg/kg)
Pasteurized milk	Regional	3	0 (0)	< LOD	< LOD
Pasteurized milk	Ecological	2	0 (0)	< LOD	< LOD
Pasteurized milk	Commercial	6	6 (100)	0.022±0,006[a]	0.012-0.028
UHT milk	Commercial	4	4 (100)	0.030±0,002[b]	0.019-0.053
Cheese	Traditional	2	0 (0)	< LOD	< LOD
Yoghurt	Ecological	5	5 (100)	0.012±0,004[c]	0.010-0.015
Yoghurt	Commercial	5	5 (100)	0.022±0,008[a]	0.011-0.034
Baby food	Commercial	7	7 (100)	0.064±0,002[d]	0.013-0.097

The data in parenthesis represents the parentage of samples to total samples analyzed.

* EU limits (0.05 µg/L) for AFM_1 in pasteurized milk, UHT milk, yogurt, (0.02 µg/kg) for AFM_1 in cheese and (0.025 µg /L) for AFM_1 in baby food [26]

The English letter with different words represents the significant difference ($p \leq 0.05$).

< LOD – below limit of detection AFM_1 LOD= 0.01 µg/L

Dane w nawiasach przedstawiają udział procentowy próbek wobec wszystkich analizowanych próbek.

* Limity UE (0,05 µg/L) dla AFM_1 w mleku pasteryzowanym, UHT, jogurcie, (0,02 µg/kg) dla AFM_1 w serze i (0,025 µg/L) dla AFM_1 w żywności dla niemowląt [6]

Angielska litera z różnymi słowami przedstawia znaczącą różnicę ($p \leq 0,05$).

<LOD – poniżej granicy wykrywalności AFM_1 LOD = 0,01 µg/L

Source: The own study

Źródło: Badania własne

products, only in regional and ecological pasteurized milk not were detected of AFM_1 levels (< LOD).

The results of Iqbal et al. [17] orevealed that from winter season almost 45% samples of milk and milk products were found to be contaminated with AFM_1 (i.e. 51% of UHT milk, 40% of raw milk, 37% of yogurt, 60% of butter and 43% of ice cream samples and 24, 27, 25, 34 and 17% of samples were found above the recommended limit for AFM_1, respectively). However, from summer season 32% samples of milk and milk products were found to be contaminated (i.e. 36% of raw milk, 31% of UHT milk, 29% of yogurt, 40% of butter and 24% of ice cream and 23, 23, 18, 20 and 5% of samples were found above the permissible limit for AFM_1, respectively). The levels of contamination in winter milk and milk product samples were significantly higher ($p \leq 0.05$) than in summer season. In this study, the occurrence of AFM_1 in milk and milk products were higher, demanding to implement strict regulations and also urged the need for continuous monitoring of milk and milk products in order to minimize the health hazards [6]. In study de Oliveira et al. [4, 9] aflatoxin M_1 was determined in 75 samples of ultra-high-temperature (UHT)-treated fluid commercial milk from Brazil, in 2009. AFM_1 determinations were carried out by HPLC. Results showed that 23 positive samples for AFM_1 (30.7%) at levels of 1000-4100 ng/L, which were above the tolerance limit for AFM_1 in milk as adopted by Brazilian regulations [9].

The occurrence of AFM_1 in European milk and dairy products has been reported in Turkey, France, Italy, Spain, Croatia and from Greece [18, 30]. Ardic et al. (2009) found a mean AFM_1 level of 0.284 µg/kg in white brined cheese with the concentration ranging from 0.052 to 0.860 µg/kg. In another report, Tekinsen and Eked [29] analyzed 100 milk and 132 cheese samples and reported that 67 and 83% of these milk and cheese samples, respectively, were contaminated with AFM_1. The levels of AFM_1 in milk and cheese ranged from 0.010 to 0.630 µg/L and from 0.05 to 0.690 µg/kg, respectively. The range of AFM_1 levels from Turkey, followed by Croatia, is considerably higher compared to other countries. Generally, the levels and incidence of AFM_1 in milk and dairy products from Europe seems less than the South Asian countries, which may be the result of strict regulations on these mycotoxins in feed and milk products and from the adoption of good storage practices [18]. As descibed Iqbal et al. [28], in many parts of the world dairy livestock breeding has become increasingly difficult as the global temperature continues to rise. Elevated temperatures and extreme weather events, such as droughts and floods, may also indirectly influence milk production and its quality as a consequence of shifts in the availability and quality of feed and water [18]. Moreover, extremely high milk prices caused a decrease in the demand of milk by consumers, especially in countries where consumers could not pay the high prices. Aflatoxin M_1 in milk and dairy products could be a risk to human and animal health. High contamination in feed may result in a significant AFM_1 level in milk from animals which fed with highly contaminated foodstuffs. It is important the continuous aflatoxin level monitoring in animal feed and the implementation of strict regulations for mycotoxins in these countries [18].

CONCLUSION

The presence of AFM_1 in milk and milk products is a serious issue, since these products are regularly consumed by each age group in their daily diet [6]. This study is the continuous part of studies, to regularly monitor the contamination level of AFM_1 in milk and milk products. The results have revealed that 37.5% analyzed baby food samples were found to be above the EU limits for AFM_1. The recommendations includes that, there should be more studies on AFM_1 contamination in milk focusing on feeding practices in order to investigate the main factors that are responsible for high occurrence of AFM_1 contamination, especially in baby food. But contamination of milk and milk products (cheese, yoghurt) with aflatoxin M_1 does not appear to be a serious public health problem in the city of Olsztyn (Poland) at the moment. In short, adopting good harvesting practices, improving analytical facilities, and implementing strict regulations would avoid or reduce these natural contaminants in milk and ensure the safety of milk and milk products as human food.

PODSUMOWANIE

Obecność AFM_1 w mleku i produktach mlecznych jest poważnym problemem, ponieważ produkty te są regularnie spożywane przez każdą grupę wiekową w codziennej diecie [6]. Niniejsze badanie jest kontynuacją badań, mającą na celu regularne monitorowanie poziomu zanieczyszczenia AFM_1 w mleku i produktach mlecznych. Wyniki ujawniły, że 37,5% przeanalizowanych próbek żywności dla niemowląt przekraczało limity UE dla AFM_1. Zgodnie z zaleceniami należy przeprowadzić więcej badań dotyczących zanieczyszczenia AFM_1 w mleku, koncentrując się na praktykach żywieniowych w celu zbadania głównych czynników odpowiedzialnych za częste występowanie zanieczyszczenia AFM_1, zwłaszcza w żywności dla niemowląt. Jednak zanieczyszczenie mleka i produktów mlecznych (ser, jogurt) aflatoksyną M_1 nie wydaje się obecnie stanowić poważnego problemu zdrowotnego w Olsztynie (Polska). Krótko mówiąc, przyjęcie dobrych praktyk zbioru, ulepszenie zaplecza analitycznego i wdrożenie surowych przepisów pozwoliłoby uniknąć lub ograniczyć te naturalne zanieczyszczenie w mleku i zapewnić bezpieczeństwo mleka oraz produktów mlecznych jako żywności dla ludzi.

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COCOA POWDER AS SOURCE OF PHENOLIC COMPOUNDS, DETERMINING FACTORS – A REVIEW®

Proszek kakaowy jako źródło związków fenolowych, czynniki determinujące – przegląd®

In recent years, there has been increasing interest in the properties of cocoa powder as sources of valuable polyphenolic compounds. Cocoa powder is obtained in a multi-stage process of cocoa beans processing, during which many valuable bio-components are lost. The aim of this article is to characterize phenolic compounds present in cocoa powder in the context of their beneficial effects on human health.

Key words: cocoa beans, cocoa powder, chocolate, polyphenols content.

W ostatnich latach wzrosło zainteresowanie właściwościami proszku kakaowego jako źródła cennych związków polifenolowych. Proszek kakaowy otrzymywany jest w wieloetapowym procesie przetwarzania ziarna kakaowego, podczas którego traconych jest wiele cennych biokomponentów. Celem niniejszego artykułu jest charakterystyka związków fenolowych obecnych w proszku kakaowym w kontekście korzystnego wpływu na zdrowie człowieka.

Słowa kluczowe: ziarna kakaowe, proszek kakaowy, czekolada, zawartość polifenoli.

INTRODUCTION

Cocoa powder, commonly called cocoa, is obtained from refined, shelled and roasted cocoa beans. In accordance with the guidelines of the Directive [11], it must contain at least 20% cocoa butter calculated on a dry matter basis and no more than 9% water. This document also allows fat-reduced cocoa with a fat content below 20%. Such cocoa is most often used by food producers, as evidenced by the information on the labels of many products, e.g. chocolate. The market offers a wide range of cocoa powders. From light brown, honey–colored powders to dark brown powders resembling dark chocolate [28]. In addition, more and more bio–powders obtained from organic plantations are available. The customer / consumer is faced with the choice of which of the offered products is the most beneficial in terms of health and utility [32]. Modern customers are aware of their expectations regarding the food they buy. More and more often, consumers' purchasing decisions are focused on pro–health products, which, apart from satisfying their nutritional needs, also have a beneficial effect on their health. The answer to these expectations is cocoa powder, a source of valuable polyphenolic components that exhibit anti–atherosclerotic, anti–carcinogenic, anti–inflammatory, anti–aging and many others [4, 15, 10, 30]. In addition, the consumers expect products that are convenient, easy and quick to prepare or for direct consumption. The food industry is facing these expectations.

GENOTYPE OF COCOA BEANS

The raw material for the production of cocoa powder is cocoa beans. Cocoa beans are obtained from the fruit of Theobroma cocoa trees, which are grown in the equatorial belt. The main producers of cocoa beans are Ivory Coast, Ghana, Indonesia, Brazil, Ecuador, Venezuela, as well as the Dominican Republic, Peru, Sri Lanka and many other countries (Fig. 1) [29, 30].

Many varieties of cocoa beans are grown, but the most famous are two, *Criollo* and *Forastero* and their hybrid *Trinitario* (Fig. 2).

Criollo is considered to be the oldest cultivated cocoa species. The fruits ferment very easily and quickly, are characterized by an excellent, delicate taste, shaped, among others, by low theobromine content and low pH [22, 30]. The flavor of *Criollo* beans is described as little chocolate, but it is characterized by rich secondary notes shaped in the processing process. Unfortunately, trees are very susceptible to disease and pest damage. Therefore, their cultivation is difficult and only accounts for about 5% of all cocoa crops. Their

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Fig. 1. Cocoa growing regions.
Rys. 1. Regiony upraw kakaowca.
Source: Own study
Źródło: Opracowanie własne

fruits are green, through red to purple, which is determined, among others, by content of polyphenol compounds, mainly anthocyanins [6]. The grains obtained from them are used primarily for the production of so-called „premium".

Forastero is often referred to as the basic grain. Plantations are mainly found in West Africa and Brazil, but there are also many wild–growing trees of this species. The trees are resistant to climatic factors and pests. This variety is productive, on average about 40 seeds are obtained from one pod. Fruits differ from other varieties in shape and size. The beans are characterized by a bitter, tart taste, without any other aromas, but quickly losing their qualities, which means that these beans are often combined with other varieties in order to obtain appropriate sensory characteristics. The intense bitterness and tartness is also felt in the products obtained from the processing of these grains [24].

A variety that combines the properties of *Criollo* and *Forastero* is *Trynitario*, characterized by the resistance and efficiency of *Forastero* and the subtle flavor of *Criollo*. *Trinitario* is characterized by high variability resulting from the different characteristics of the basic varieties from which it was created. The cultivation of this cocoa tree occurs mainly in areas where *Criollo* was or is cultivated, among others in Mexico, Venezuela, Colombia and Southeast Asia.

Another variety of cocoa beans, "ruby", from which pink chocolate is produced, is also significant. This type of beans was discovered by Barry Callebaut. The company was the first to introduce pink chocolate to the market. This product is

a) **b)** **c)**

Fig. 2. Cocoa varieties: a) Criollo, b) Forastero, c) Trinitario.
Rys. 2. Odmiany kakaowca: a) Criollo, b) Forastero, c) Trinitario.
Source: [16]
Źródło: [16]

characterized by a fruity, berry taste and aroma; it is produced without the use of dyes and flavors. The secret of these cocoa fruits lies in the specific climatic conditions in which the trees grow. The company obtains these "berry" kernels beans from the regions of Brazil, Ecuador and the Ivory Coast [16]. Moreover, within the varieties, the cocoa fruit and beans are characterized by high variability and diversity. It is associated with the presence of many subspecies, differing in physico-chemical and sensory characteristics. Many attempts have been made to classify and group the fruit, considering the appearance and morphology of the pod as a significant and distinctive feature. Unfortunately, despite many attempts, the correlation between the shape of the pod and the characteristics of the fruit and grains has not been established [6]. Research is still being conducted to develop a model that allows the use of morphological features to predict the properties of grains and, consequently, the final products obtained from them.

The variety of characteristics within a given species depending on the cultivation region, climatic conditions and grain maturity are the basic factors influencing the sensory values as well as the physico-chemical properties of products obtained from cocoa bean processing. Ławrowski [20] described the variety of flavor notes of grains obtained from crops from different regions of the world. The author pointed out that the sour–fruity note is characteristic of the beans from Madagascar, while the beans from Java have a creaminess and caramel flavor, which are preferred by producers for milk chocolates. The beans from Ecuador are characterized by a licorice-fig aroma with a noticeable scent of wood; other beans from this region have a fruity note of blackcurrant or strawberry. On the other hand, the beans from Venezuela are characterized by an earthy note, with a noticeable aroma of wood, but also fruity and nutty. According to Kowalska et al. [19] the characteristics of cocoa bean processing products are shaped, among others, by volatile and non–volatile aromatics generated in the processing of cocoa beans. Therefore, apart from natural factors, an important role in shaping sensory features is played by technological processes that the grain is subjected to, especially fermentation and roasting [7]. It is in the technological process that the precursors of taste, smell and color are created. Three factors determine the "from grain to chocolate" process: ingredients, temperature and time. How is cocoa powder made?

THE SHAPING PROPERTIES OF COCOA POWDER

As mentioned, cocoa powder is obtained in the processing of cocoa beans. The main purpose of the entire cocoa beans processing is to obtain chocolate. The process of making chocolate can be divided into three stages: plantation processes (cultivation), obtaining pulp, fat and cocoa powder (from beans to pulp) and the chocolate production (from pulp to chocolate) [4, 30]. Cocoa powder is obtained in the second stage of cocoa beans processing. The fermented and dried grains are transported to processing plants all over the world. There, after initial sorting and cleaning, they are (or not) roasted, and then rolled to a liquor. Some of the liquor is intended for the production of chocolate, while the rest is pressed, resulting in cocoa butter (cocoa butter) and cocoa cake. After drying and grinding the cocoa cakes, cocoa powder is obtained. A consumer reaching for cocoa powder or chocolate from different manufacturers may feel the difference in taste, smell, color, in the case of powder – in its flowability, granulation and solubility, and in chocolate – in hardness, gloss or breakthrough (rheological properties). Where do these differences come from?

Manufacturers carefully hide the secrets of the technological process, and more precisely the parameters used (time and temperature). In addition, the secret of the production plant is also the mixing of cocoa beans with different properties, coming from different plantations or regions, to obtain the expected and unique taste and aroma characteristic for a given producer.

COCOA BEANS

The cocoa tree blooms and bears fruit all year round. However, of the thousands of flowers, only about 40 develop into fruit. Cocoa beans are made of the husks, kernels and sprouts. The husk and sprout are removed after the roasting process, while the kernel is used for further processing [31]. Cocoa beans are a valuable source of fat (approximately 50%), carbohydrates (approximately 25%) and protein (approximately 16%), as well as phenolic compounds. The grain also contains theobromine, niacin, minerals (calcium, iron, potassium, magnesium, sodium and phosphorus) and vitamins A, B1, B2 and B6 [12]. In the technological process, some of these components are lost. Manufacturers strive to preserve as many valuable components as possible, which is why low–temperature processes are increasingly used, as a result of which "raw" products are obtained [23]. Raw products are obtained from cocoa beans that have not been roasted, but dried and conched for many hours at a temperature not exceeding 50–55°C.

POLYPHENOL COMPOUNDS IN COCOA BEANS

Cocoa beans are a rich source of polyphenols that accumulate in the so-called polyphenolic cells [3]. It should be emphasized that polyphenols are present in the non–fat components of cocoa beans. They constitute about 15% of the dry weight of the grain. Polyphenols are responsible for the color, bitter and tart taste of the beans, as well as the sensory qualities of the products obtained from their processing. However, the most important action of polyphenols is their positive effect on human health. Polyphenols have a strong anti–cancer effect, neutralizing the participation of free radicals in the human body, they can have antiviral and anti–inflammatory properties, supporting the immune system in the fight against diseases. Three groups of polyphenols dominate cocoa beans: catechins (flavan–3–ols), anthocyanins and proanthocyanidins. Catechins constitute approximately 29–38% of all polyphenols, they are represented by (–) – epicatechin, (+) – catechin, gallocatechin (–) – epigallocatechin. Another group is anthocyanins (about 4% of all polyphenols), is formed by leucoanthocyanins – L1, L2, L3, and L4, cyanidin–3–α–L–arabinoside, and cyanidin–3–β–D–galactoside [3]. Proanthocyanins constitute approximately 58–65% of all polyphenols. This group includes dimers, trimers or oligomers of flavan–3,4–diols, the most important of which

are proanthocyanidins B1, B2, B3, B4, B5, C1 and D [2]. In addition to the main and predominant groups of polyphenols cocoa beans also contain apigenin, luteolin, kaempferol and polyphenolic acids – caffeic, chlorogenic and coumaric. The composition and content of polyphenols is different and depends on the genotype, region of cultivation, degree of maturity [30]. The content of flavanols also depends on the microflora [13]. According to Aprotosoaie et al. [3] yeast, lactic acid bacteria and acetic acid bacteria have a positive effect on the content of polyphenols, while the influence of aerobic spores and molds is negative.

SHAPING THE PRO–HEALTH PROPERTIES OF COCOA POWDER IN THE TECHNOLOGICAL PROCESS

The production of cocoa powder is multistage and complex. However, some processes play a special role in shaping the properties of the final product, including health–promoting properties.

There are beans in the cocoa fruit, from about 20 in *Criollo* to as much as 50–60 in Forasterro, dipped in the flesh. After slicing by the farmer, the fruit is left for several days during which the fermentation stage takes place [8, 9]. It is the first treatment that significantly shapes the value of the final products. Most often it is a spontaneous process taking place under natural conditions leading to obtaining grains of variable quality. During fermentation (aerobic and anaerobic), the pH and bitterness the grains decreased as a result of the decomposition of tannic compounds, the formation of taste and aroma precursors, and a color change. Lowering the pH increases the enzymatic activity, including polyphenol oxidase. In the fermentation process, proteins are broken down, which in turn leads to an increase in the content of peptides and free amino acids, including: tyrosine, phenylalanine, leucine, which are precursors of the cocoa / chocolate aroma [25, 32]. At this stage, the acidity also increases, associated with the formation of volatile (acetic) and non-volatile (citric and lactic) acids that penetrate into the kernel [29]. The content of soluble polyphenols is reduced, which, on the one hand, leads to a reduction in the bitter and sharp taste and aroma of the grains, and on the other hand, to the loss of valuable antioxidant compounds [5]. After fermentation, the beans are dried, most often in natural conditions – in the sun. During this process, first of all, the water content is reduced to about 6%, the changes that occurring during fermentation are preserved, acidity is reduced, and the precursors of the characteristic taste and smell as well as brown color are further developed [1, 3]. At the drying stage, phenolic compounds are also lost, which is related to humidity, high temperature, oxygen and polyphenol oxidase. Oxidases catalyze the conversion of polyphenols into quinones, which in turn undergo further condensation with free amino and sulfhydryl groups, resulting in the synthesis of brown polymers [1]. Most studies confirm significant losses of polyphenols in technological processes. However, there are also studies that have shown the preservation of polyphenols and even an increase in their content. Rusconi and Conti [27] explained this phenomenon as a consequence of the formation of proanthocyanidins as a result of polymerization.

Roasting is considered to be one of the most important, if not the most important, process in shaping the physico–chemical and sensory characteristics, as well as health–promoting products of cocoa bean processing. This is mainly due to the high temperatures (110–160°C) used at this stage [17]. The purpose of roasting is to loosen the grain structure, reduce the water content, and deactivate the microflora. During this process, due to high temperature, protein degradation, Maillard reactions or caramelization of sugars are also stimulated [30]. Volatile compounds, including acids, are also evaporated, which reduces the acidic aftertaste in the final products. As a result of these processes, new compounds are formed that shape the characteristic sensory features, mainly taste, smell and color. At the same time, exposure to high temperature reduces the content of polyphenolic compounds, which is attributed to the epimerization of (–) – epicatechin to (–) – catechin and (+) – catechins to (+) – epicatechin. Proanthocyanidin is also epimerized, the content of which decreases at the beginning of roasting and then increases. Oracz and Nebesny [21] indicated the influence of temperature on the content of polyphenolic compounds. They showed that the use of lower temperature and humid air preserves valuable antioxidants.

Some manufacturers take one more important step, especially with regard to cocoa powder. Alkalization, also known as refining, is the treatment of grains, pulp or powder with sodium or potassium bicarbonates [18]. The purpose of this process, also colled "Dutch", is to improve – darken the color, alleviate bitterness, as well as improve the dispersion of powder particles [3]. Unfortunately, as numerous studies show, alkalization, which also increases the pH, has a negative effect on the phenolic compounds contained in the raw material. According to Rodrigez et al. [26] and Garcia et al. [14] the color of alkalized cocoa is the result of the enzymatic activity of polyphenol oxidase, for which the optimal pH is around 8. As a result of this enzyme, polyphenolic compounds are oxidized to melanoidins (brown pigments), but at the same time the phenol content is degraded.

As reported by APROTOSOAIE et al. [3] a higher degree of alkalization leads to higher losses of polyphenols; epicatechin at the level of up to 98%, and of catechins by about 80%. As the pH increases, the color of the cocoa darkens, from reddish brown to almost black. Todorowic et al. [28] showed that the content of polyphenols in the alkalized powder was about 1.8 times lower than in the untreated powder. They also showed a similar relationship by determining the antioxidant activity, which was significantly higher in natural powders.

CONCLUSIONS

To summarize the beneficial effects of cocoa powder, the EFSA report [13], issued in 2012 on behalf of Barry Callebaut should be taken into account. The opinion confirms that cocoa flavanols help maintain proper vasodilation, which in turn contributes to normal blood flow. The report **recommended a daily intake of 200 mg of cocoa flavanols, which could be achieved by consuming 2.5 teaspoons of high flavanol cocoa powder or 10 g of dark chocolate**. The content of polyphenolic compounds in cocoa bean products depends on many factors. It is already shaped in the plantations, depending on the variety, region and growing conditions, degree of

maturity, as well as technological processes, and more precisely the parameters used during cocoa beans processing. Nevertheless, as numerous studies have shown, it is possible to preserve these valuable natural compounds by modifying the made from unroasted cocoa beans are offered. It has been shown to be one of the basic processes that degrade a significant amount of polyphenols. Similarly, the alkalization process that has a destructive effect on these valuable antioxidants can be dispensed with. Although non–alkaline powders are lighter in color and have a lower cocoa–chocolate flavor or smell, they contain much more of the desired polyphenols. Dark brown cocoa powders, also called "Dutch" cocoa, are alkalized which gives them color and intense aroma and taste. It should be mentioned **that cocoa powder is also a valuable source of minerals, as well as alkaloids (theobromine or caffeine), which have a stimulating effect, especially after exercise, and also improve concentration. In addition, serotonin, dopamine and tryptophan contained in cocoa beans and its processing products have a positive effect on the work of the brain. Cocoa powder contains more polyphenols than red wine or green tea**. It is important to consume cocoa or dark chocolate regularly, especially those with high cocoa content, in the recommended amounts. Consumers should note, however, that despite the benefits of consuming these products, they are high in calories.

WNIOSKI

Podsumowując korzystne działanie proszku kakaowego, należy wziąć pod uwagę raport EFSA [13], wydany w 2012 roku w imieniu firmy Barry Callebaut. Opinia ta dotyczy potwierdzenia działania flawanoli kakaowych, które pomagają w utrzymaniu prawidłowego rozszerzenia naczyń krwionośnych, co z kolei przyczynia się do prawidłowego ukrwienia. W raporcie **zalecono dzienne spożycie 200 mg flawanoli kakaowych, co można osiągnąć, spożywając 2,5 łyżeczki proszku kakaowego o wysokiej zawartości flawanoli lub 10 g gorzkiej czekolady**. Zawartość związków polifenolowych w produktach z ziarna kakaowego zależy od wielu czynników. Kształtuje się już na plantacjach w zależności od odmiany, regionu i warunków uprawy, stopnia dojrzałości, a także procesów technologicznych, a dokładniej parametrów stosowanych podczas obróbki ziarna kakaowego. Niemniej jednak, jak wykazały liczne badania, możliwe jest zachowanie tych cennych naturalnych związków poprzez modyfikację oferowanych z nieprażonych ziaren kakaowych. Wykazano, że jest to jeden z podstawowych procesów degradacji znacznych ilości polifenoli. Podobnie, można zrezygnować z procesu alkalizacji, który ma destrukcyjny wpływ na te cenne przeciwutleniacze. Chociaż niealkaliczne proszki są jaśniejsze i mają słabszy smak lub zapach kakao-czekolady, zawierają znacznie więcej pożądanych polifenoli. Ciemnobrązowe proszki kakaowe, zwane także „holenderskim" kakao, są alkalizowane, co nadaje im kolor oraz intensywny aromat i smak. Należy wspomnieć, **że proszek kakaowy jest również cennym źródłem związków mineralnych, a także alkaloidów (teobromina, kofeina), które działają pobudzająco, szczególnie po wysiłku, a także poprawiają koncentrację. Dodatkowo serotonina, dopamina i tryptofan zawarte w ziarnach kakao i produktach ich przetwarzania wpływają pozytywnie na pracę mózgu. Proszek kakaowy zawiera więcej polifenoli niż czerwone wino czy zielona herbata**. Ważne jest regularne spożywanie kakao lub gorzkiej czekolady, szczególnie tych z dużą zawartością kakao, ale w zalecanych ilościach. Konsumenci powinni jednak pamiętać, że pomimo korzyści płynących ze spożywania tych produktów są one wysoko kaloryczne.

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GAME MEAT IN A WELL-BALANCED DIET AS AN ATTRACTIVE ALTERNATIVE TO LIVESTOCK MEAT®

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The aim of this study presented in the article was an analysis of whether game meat could be a part of standardised and sustainable dietary pattern. Game meat is known to have a very small amount of fat but to be rich in polyunsaturated fatty acids, vitamins and minerals. Furthermore, the ratio of omega-3 to omega-6 fatty acids is also more beneficial in case of game meat instead of livestock. Consumption of game meat in Poland is significantly low, roughly 0.08 kg per person, therefore, it is crucial to indicate its health benefits which are adequate to the food pyramid suggestions to maintain a healthy diet.

Key words: game meat, balanced diet, dietary patterns.

Celem pracy zaprezentowanej w artykule jest analiza możliwości zastosowania dziczyzny zgodnie z zaleceniami żywieniowymi kształtującymi prawidłowe nawyki. Mięso zwierząt łownych cechuje niska zawartość tłuszczu, duża ilość wielonienasyconych kwasów tłuszczowych oraz witamin i składników mineralnych. Porównanie profilu kwasów tłuszczowych omega-3 do omega-6 dziczyzny i mięsa zwierząt rzeźnych również przemawia na korzyść dziczyzny. W związku z niskim spożyciem tego rodzaju mięsa w Polsce, które wynosi średnio 0,08 kg/osobę, zachodzi potrzeba wskazania możliwości wykorzystania jego walorów, adekwatnie do zaleceń określonych w piramidzie żywienia.

Słowa kluczowe: dziczyzna, zbilansowana dieta, zalecenia żywieniowe.

INTRODUCTION

Consumption of wild game meat in Poland had been present for many decades. However, the meat of deer, boar, pheasants was reserved for aristocracy. Hence, the confidence that this type of meat was of better quality than the livestock which was available to general public. Nowadays, the availability of game meat is significantly higher.

Game meat have a very small amount of fat and is rich in polyunsaturated fatty acids, vitamins and minerals [3]. It can be a great nutritionally dense alternative to the industrially farmed livestock meat as it meets the dietary guidelines in terms of lean meat consumption. Taking this into account, the implementation of game meat into the well-balanced every-day diet could be suggested. **Considering the scarce knowledge of advantages of the game meat consumption, the aims of this short review were to compare the nutritional value of the meat of selected wild game with their corresponding farmed animals, as well as to present the ways in what it can be prepared and processed, taking into account the health and safety measures in terms of acquisition of such produce.**

GAME MEAT IN DIETARY GUIDELINES

The dietary patterns are one of the crucial aspects of maintaining good health. Improper nutrition habits can lead to a higher risk of obesity, diabetes, hypertension or some type of cancers [19]. Abnormalities in dietary habits usually consist of a diet rich in saturated fatty acids and simple carbohydrates, which leads to obesity due to excessive energy intake. Obesity is associated with the consumption of highly processed foods like sweets, savoury snacks, and fast foods. Furthermore, a lack of nutritional diversity and incorrect proportions of the amount of foods from different food groups are also factors that lead to a higher body mass. Namely, the unbalanced ratio between fruit and vegetables and consumption of meat products. To minimise the risk of obesity and associated with obesity lifestyle diseases it is crucial to follow the principles of balanced nutrition patterns. One of the principles is to consume the right amounts of lean meat [12, 18]. Therefore, the reduction of the livestock meat consumption by exchanging a part of it with the game meat seems to be the choice in the right direction.

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Generally, the knowledge of advantages of the game meat consumption among the Polish consumers is scarce. Meanwhile, it is characterized by a low fat content but it is rich in polyunsaturated fatty acids. This type of meat is also a great source of vitamins and minerals [3]. The public that has acquired substantial nutritional knowledge shows that the food choices they make are driven by obtaining food produce, which is more nutritious, for instance, the products are nutrient-denser and more satisfactory. By nutritionally educating the public it is possible for them to swap highly processed foods for the more nutritious ones. What is also important in nutritional awareness is an environmental factor, where the consumer chooses food groups that are less harmful to the environment but are still sustainable in terms of supply. It has been observed that the number of consumers who are likely to choose better quality produces have been on a rise for some time. There is also quite a high interest in sustainable diets and unprocessed foods. Less processed foods and more variety lead to a higher quality of meals. Meat is often considered as a less sustainable food choice, although, could game meat be the answer to a healthy and sustainable source of necessary nutrients?

Nowadays, the game meat is more readily available in supermarkets, yet, its price is often the reason why consumers choose not to buy it. Also, the foodborne zoonotic diseases might be off-putting potential customers (for instance trichinellosis) [14, 15]. However, the foodborne zoonotic diseases are not found in wild game meat available in shops, so those fears are unfounded. The hunter is obliged to give caught wild boar (or any other species for that matter) for extensive veterinary tests to check the presence of trichinella larvae [14, 15]. It is surprising that the percentage of Polish consumers choosing a wild game is relatively low, while Poland is one of the main producers and exporters of wild game meat in Europe [10, 15]. The majority of game meat is exported to Western Europe, among others Germany, France, Italy, Benelux countries. Poland has excellent natural and environmental conditions where a quarry can be obtained in significant amounts. Due to the current state of hunting economy, the country is able to maintain the current level of a ground game [14]. Polish statistical data [11] showed that 266 thousand of wild boar, 95.4 thousand of deer and 102.9 thousand pheasants have been sourced in the hunting season 2018/2019 meanwhile, the annual consumption of wild game is negligible and amounts to only 0.08 kg per person [14]. The pork meat, followed by poultry meat and beef are the most popular meat products consumed in Poland. In 2018, the consumption of pork has reached 40 kg per person, of poultry 27.8 kg per person, and in 2019 the consumption of beef reached 3.4 kg per person [1, 2, 16] that makes an extremely large difference in comparison with game meat consumption. Pork, poultry and beef are main Polish meat staples, they could easily be substituted with their wild game 'analogues' which are more nutritionally beneficial and have a better amino acid profile.

NUTRITIONAL VALUE OF WILD GAME MEAT

Wild game is of a very high nutritional quality. Its profile of fatty acids, minerals and the amount of fat it consists of is much better in comparison with widely consumed types of meat. But it is worth to note, that the profile of nutrients can differ in relation to a season in which the animal has been sourced.

Pheasant meat is higher in protein than the majority of poultry (Tab. 1). It is also characterised by a lower amount of fat and cholesterol, and a lower content of saturated and monounsaturated fatty acids (Tab. 1).

Table 1. Comparison of nutritional values between poultry and pheasant meat

Tabela 1. Porównanie wartości odżywczych mięsa z drobiu i bażanta

Nutrient	Poultry	Pheasant meat
Energy Value [kcal]	98-125	140
Protein [g]*	17.8-21.5	23.7
Fat [g]	1.3-6.0	1.30-3.46
Cholesterol [mg]	58-84	36.8-49.1
SFA [%]	22.31-24.67	34.2-44.9
MUFA [%]	23.08-30.0	29.7-43.1
PUFA [%]	23.08-28.67	10.4-29.5
CLA [%]	18.46-24.83	-
N-3 [%]	3-3.85	0.33-2.86
N-6 [%]	19.23-25.67	10.1-26.7
DHA [%]	0.77-1	0.214-1.98
EPA [%]	0.33-0.77	0.0451-0.104
N-6/n-3	4.99-8.56	9.84-32.3

* Nutrients provided are per 100g of product. The % of fatty acids in general fat content. Based on: [3, 13, 21]

* Składniki odżywcze w 100g produktu. Podano % udział kwasów tłuszczowych w ogólnej zawartości tłuszczu. Na podstawie [3, 13, 21].

In comparison with poultry, pheasant meat is richer in polyunsaturated fatty acids as well as in omega-6 (for instance arachidonic acid) and omega-3 (docosahexaenoic acid, DHA) fatty acids. Whereas eicosapentaenoic (EPA) acid content is slightly higher in poultry. Furthermore, pheasant meat has higher contents of minerals, in particular of potassium, sodium, calcium, magnesium, iron, zinc as well as vitamins, especially of vitamin E [3, 13, 17, 21].

The wild boar is proven to have lower energetic value than pork meat [3] mainly resulting of lower fat content (Tab. 2). Contrary, pork meat is slightly richer in proteins (Table 2). On the other hand, wild boar meat is higher in polyunsaturated fatty acids, omega-3 and omega-6 fatty acids. It also has an advantageous ratio of n-6 to n-3 fatty acids, comparing to the pork meat (Tab. 2). Comparing with pork meat, the wild boar meat contains more vitamins (D, E, B2, B12) and folates [23, 24] and mineral compounds, in particular in potassium, iron, zinc, manganese and iodine [13].

Table 2. Comparison of nutritional values between pork meat and wild boar

Tabela 2. Porównanie wartości odżywczych mięsa wieprzowego i dzika

Nutrient	Pork	Wild Boar
Energy Value [kcal]	128-129	103
Protein [g]*	21.4-22.9	20.88
Fat [g]	4.2-4.7	3.45
Cholesterol [mg]	42-56	98.11
SFA [%]	40.71-43.19	42.98
MUFA [%]	40.71-41.06	35.18
PUFA [%]	9.15-10.71	17
CLA [%]	7.86-7.87	-
N-3 [%]	0.85-1.19	3.05
N-6 [%]	8.30-9.52	13.63
EPA [%]	0.24	-
N-6/n-3	8-9.76	6.13

* Nutrients provided are per 100g of product. The % of fatty acids in general fat content. Based on: [3, 13, 21].

* Składniki odżywcze w 100g produktu. Podano % udział kwasów tłuszczowych w ogólnej zawartości tłuszczu. Na podstawie [3, 13, 21].

Table 3. Comparison of nutritional values between beef and deer (venison)

Tabela 3. Porównanie wartości odżywczych mięsa wołowego i jelenia

Nutrient	Beef	Deer (venison)
Energy Value [kcal]	152	98.8
Protein [g]*	21.5	22.36
Fat [g]	7.3	1.90
Cholesterol [mg]	70	70.57
SFA [%]	47.81	42.13
MUFA [%]	42.60	26.57
PUFA [%]	3.29	23.47
CLA [%]	2.46	1.44
N-3 [%]	0.82	6.20
N-6 [%]	2.47	17.05
DHA [%]	-	0.84
EPA [%]	-	0.30
N-6/n-3	3.01	2.75

* Nutrients provided are per 100g of product. The % of fatty acids in general fat content. Based on [3, 13, 21].

* Składniki odżywcze w 100g produktu. Podano % udział kwasów tłuszczowych w ogólnej zawartości tłuszczu. Na podstawie [3, 13, 21].

When comparing the deer meat (venison) with beef it is evident that beef had a higher fat content, thus, the higher energy value (Tab. 3). Both types of meat had a similar level of cholesterol. Wild game meat overall has less saturated and monounsaturated fatty acids than beef. It also consists of higher amounts of polyunsaturated fatty acids overall and significantly higher amounts of fatty acids from the omega-3 and omega-6 group, as shown in Table 3. The ratio between mentioned fatty acids in deer is therefore beneficial for health. Also, deer meat (venison) is proven to have a higher level of vitamin E and iron compared to beef [4, 6, 9, 13, 20, 25].

GAME MEAT: FROM SOURCING TO CULINARY PRACTICE

It is interesting to describe how wild game meat lands on the consumer's table. An animal that is sourced by a hunter (who has obtained the necessary permission to perform cull) is gutted on the hunting grounds. Every hunter is obliged to protect a carcass against infusing in case it is not immediately packaged for transport. Refrigeration of the carcass consists of placing it indirectly on the ground by placing wooden struts in cuts [5]. Afterwards, caught venery is transported to the wholesale point where it is stored in refrigerators or cold storage chambers where possible before it gets transported to the processing. Wild game meat that ends on the market is subjected to a mandatory quality testing specified in national regulation (Art. 11, 11a: Act of 16 December 2005 on products of animal origin) (Dz. U. z 2019 poz. 824) [26]. Therefore, concerns about zoonotic diseases are without merit.

Currently, the wholesale price of wild game in Poland is relatively low and amounts about 4 PLN for one kilogram of wild boar, 8 PLN for one kilogram of deer (venison) premium class. Contrary, the prices of game meat in shops is significantly higher, for instance, 1kg of wild boar gammon is about 60 PLN, similarly for venison. Such unfavourable prices are mainly a result of a relatively low number of shops which sell wild game meat. There are only about 1500 of those shops available in the country [22]. In addition, the demand for the wild game meat is low [8, 22, 27]. The use of wild game meat in the gastronomy vary significantly and depend on the known Polish cuisine practices. There is plenty of smoked product, wild game sausages, kinds of bacon, and even pate. The variety of ways how that kind of meat can be prepared is also far from limited. The most popular cuts are scrag, ham, shoulder, loin, and joints.

The culinary processing of wild game, similarly to other types of meat, influences the contents of the nutrients. For instance, some nutrients can be diminished during the cooking process. Thus, the conditions of thermal processing of the wild game meat should be carefully selected in order to minimise the nutrient loses. To decide which cooking process is appropriate it is crucial to identify the cuts first. For instance, lean wild boar cuts or cuts obtained from large adult animals is ideal for boiling, and meat obtained from younger animals (due to the high content of muscle tissue to connective tissue) should be steamed or roasted. Fine meat is ideal for frying due to its sensitive and tender structure. During the steaming and roasting process, the liquid is released which softens the membranes and fascia. Combined with spices, it

makes a sauce which aids the aromatic and taste compounds. Wild game meat consists of a high number of membranes and tendons and muscle fibres are very dense, thus, the heat treatment is relatively long comparing to the widely consumed meats. There is a possibility to shorten the heating up process but still with keeping necessary organoleptic properties. Namely, it is the process of maturing meat. Game meat is ideally matured in feathers (birds) or leather. The meat should be placed in an airy and cool room, ideally hanged out. The time of maturing depends on the temperature and a season in which the maturing process is taking place. For example, maturing time in summer/winter for partridge is 2/6 days, for roe deer 4/8 days and for wild boar 5/10 days [7]. After the required time, meat is ready for the cooking process or further processing.

SUMMARY

Summarising the research presented in this article, it can be stated that:

- game meat is an excellent alternative to farmed animals' meat in terms of dietary guidelines and it could be a part of a well-balanced and diverse diet;
- compared with livestock meat, a wild game is definitely in favour for health due to its nutritional composition, in particular the high contents of vitamins and minerals as well as its advantageous fatty acid profile;
- the current availability of game meat is better than before, but still it is far from being a staple food;
- commercial distribution is of low capacity but the high game meat's price is also an obstacle to its greater popularity.

PODSUMOWANIE

Podsumowując badania przedstawione w niniejszym artykule, należy stwierdzić, że:

- Dziczyzna jest doskonałą alternatywą dla mięsa zwierząt hodowlanych pod względem żywieniowym i może stanowić element dobrze zbilansowanej i zróżnicowanej diety.
- W porównaniu z mięsem zwierząt hodowlanych zwierzyna łowna jest zdecydowanie bardziej wskazana dla zdrowia ze względu na swój skład odżywczy, w szczególności wysoką zawartość witamin i składników mineralnych oraz korzystny profil kwasów tłuszczowych.
- Dostępność dziczyzny poprawiła się na przestrzeni lat, ale w dalszym ciągu nie jest ona brana pod uwagę podczas codziennego spożycia.
- Mała ilość detalicznych sklepów oferujących dziczyznę oraz jej wysoka cena stanowią dużą przeszkodę w dostępności i popularności tego rodzaju mięsa.

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HEALTH-PROMOTING PROPERTIES OF BIOACTIVE COMPOUNDS OF TEA AND THE INFLUENCE OF METHOD OF INFUSION PREPARATION AND TIME ON THEIR CONTENT®

Właściwości prozdrowotne związków bioaktywnych występujących w herbacie oraz wpływ sposobu i czasu parzenia na ich zawartość®

Tea is one of the most consumed non-alcoholic beverages in the world, not only because of its unique taste and aroma, but also health-promoting properties resulting from the presence of bioactive compounds. The main ingredients of tea which are attributed to have beneficial health effects are polyphenols. The content of bioactive compounds in tea depends on the particular type of tea, way of leaves processing, as well as method and time of infusion preparation. The aim of the article is to characterize the health-promoting properties of bioactive compounds found in tea, as well as to determine the influence of the method and time of infusion preparation on their content in tea infusion.

Key words: tea, bioactive compounds, antioxidant activities.

Herbata jest jednym z najczęściej spożywanych napojów bezalkoholowych na świecie, nie tylko ze względu na swój unikatowy smak i zapach, lecz także właściwości prozdrowotne wynikające z obecności związków bioaktywnych. Głównymi składnikami herbaty, którym przypisuje się korzystne działanie zdrowotne są polifenole. Zawartość związków bioaktywnych w herbacie jest zależna od konkretnego rodzaju herbaty, sposobu jej produkcji oraz metody i czasu parzenia. Celem artykułu jest scharakteryzowanie właściwości prozdrowotnych związków bioaktywnych występujących w herbacie, jak również określenie wpływu sposobu i czasu parzenia na ich zawartość w naparze herbaty.

Słowa kluczowe: herbata, związki bioaktywne, działanie antyoksydacyjne.

INTRODUCTION

Tea is one of the most frequently consumed nonalcoholic beverages worldwide [36]. Due to its unique taste and aroma, as well as health-promoting properties tea is currently gaining more interest and popularity [13,32]. According to the report of Food and Agriculture Organization of the United Nations (FAO) world tea consumption increased annually by 4.5 percent over the decade to 2016 and the consumption of black tea is supposed to grow at 2.5 percent annually to 2027 [25]. The global consumption of different tea types vary depending on the region, as black tea is predominantly consumed in Western countries [7], green tea is favoured in Asian countries [18] and oolong tea is typically consumed in China [29].

Tea is prepared from the processed leaves of *Camellia sinensis* and based on the complex production processes, flavor and aroma six different tea types may be distinguished – green, white, yellow, oolong, black and dark [63]. According to the different degrees of fermentation, teas may be categorized as non-fermented (green and white teas) [59], slightly fermented (yellow and oolong teas) [77] and fermented (black and dark teas) [31]. Among these types of tea, dark tea is unique, as it undergoes a microbial fermentation [79]. The manufacturing process of green tea aims to prevent the polyphenols oxidization by polyphenol oxidase, which naturally occurs in tea leaves. Therefore, polyphenol oxidase is inactivated during firing or steaming [47]. As a result, green tea retains the highest level of polyphenols due to its minimal oxidation, comparing to teas in which partial or full oxidation take place [42]. Although yellow tea is similar to green tea, it is characterized by higher total soluble sugar content, as a result of an additional fermentation step, which removes grassy smell being typical for green tea [35,70]. In black tea, during the chemical process of fermentation polyphenols are oxidized

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to water-soluble oxidation products, such as theaflavins and thearubigins, which provides the aroma, taste and black color of this type of tea [45]. Green tea and black tea are the two most consumed types of tea worldwide [25].

The aim of the article is to characterize the health-promoting properties of bioactive compounds found in tea, as well as to determine the influence of the method and time of infusion preparation on their content in tea infusion.

BIOACTIVE COMPOUNDS IN TEA

Tea contains approximately 30% of soluble ingredients which may vary, depending on different factors, such as harvesting time and harvesting conditions, climate, cultivation practices and technological processes during tea production [24,67,68,74]. Tea contains nearly 4 000 bioactive compounds, including polyphenols, alkaloids, polysaccharides, pigments, saponins and free amino acids [4,63], however, the share of specific bioactive compounds may differ between various types of tea [63].

The main components of tea are polyphenols which constitutes up to 20–35% of tea's dry weight [75]. Polyphenols are plant metabolites which are categorized into following subclasses – flavonoids, flavanols, flavonols, flavones, isoflavones, flavanones and anthocyanidins [20], however their content may be dependent on the particular type of tea. Green tea is reported to contain higher level of phenolic compounds, comparing to black tea [5] and is also best studied in terms of its beneficial health effects [33]. The major flavonoids which are present in green tea are epicatechin, epicatechin gallate, epigallocatechin and epigallocatechin gallate [51]. In black tea, these flavonoids are present in lower amounts, as they are partially converted during fermentation process to condensation products, such as theaflavins and theaflagallins [62]. A number of studies indicate that polyphenols are mainly responsible for the vast range of its beneficial health effects, including antioxidative [2, 76], anti-inflammatory [14, 56], anticancer [26, 44], antibacterial [46] and hepatoprotective [60] actions. Some studies indicate that green tea catechins modulate epigenetic processes, as they reverse DNA methylation of tumor suppressor genes [74]. Flavonoids, such as catechin, epicatechin and epigallocatechin-3-gallate are found to be effective in cardiovascular diseases prevention due to lowering cholesterol level, improving endothelial function and alleviating oxidative stress [30, 78]. The antioxidant effects of tea infusions are attributed mainly to the polyphenols. It was shown that tea polyphenols are effective scavengers of reactive oxygen species which are generated due to oxidative stress [12]. It was also indicated that tea extract prevents damage of cellular DNA *in vitro* which was caused by arsenic-mediated oxidative stress [1]. However, it must be emphasized that due to the differences in bioavailability of polyphenols, in vivo antioxidant activities cannot be simply extrapolated from their in vitro antioxidant properties [27].

Tea contains substantial amounts of alkaloids, mainly purine alkaloids, such as caffeine, theobromine and theophylline which are responsible for tea's stimulating effect on the body and nervous system [16, 43]. A cup of tea may contain up to 100 mg of caffeine, however, on average, green tea contains 35 mg of caffeine and black tea – 70 mg [10]. Caffeine, called theine due to its origin and its metabolites increase the secretion of neurotransmitters which reduce fatigue and drowsiness and improve concentration. As a result, tea consumption increases the ability to perform mental and physical work, while reducing the feeling of mental and physical exhaustion [43].

Polysaccharides are another bioactive component found in tea which are a nonstarch protein-bound acidic polysaccharides [15]. There is evidence that tea polysaccharides may prevent obesity development [68, 71]. In the study of Wu et al. [69] oolong tea polysaccharides combined with polyphenols were administrated to rats fed with high-fat diet. It was indicated that tea polysaccharides combined with polyphenols showed the highest anti-obesity effect in terms of body weight gain. Therefore, these two bioactive compounds may be beneficial regarding obesity prevention. Moreover, tea polysaccharides attenuate oxidative stress through scavenging of free radicals and enhancing antioxidase enzymes activities [23]. Another health benefit which may be attributed to tea polysaccharides is antidiabetic activity, as in the study of Ren et al. [55] it was revealed that tea polysaccharides ameliorated insulin resistance and hepatic oxidative injury in mice.

Pigments, such as theaflavins, thearubigins, and theabrownins, which are the products of catechins oxidation during fermentation process, are typical for black, oolong and dark teas [63, 64]. Tea pigments have been recognized as one of the bioactive compounds which are responsible for health-promoting properties of tea, such as anticancer [49], hepatoprotective [66] and anti-inflammatory, however, the antioxidant activity of pigments may be lower than catechins [53].

THE INFLUENCE OF BREWING TEMPERATURE ON THE CONTENT OF BIOACTIVE COMPOUNDS IN TEA

Despite differences in tea processing, the method of tea drinking is similar and it implies steeping tea leaves for a few minutes in hot water, at a temperature 70–100°C, depending on tea type [3, 38]. Typically, green tea is prepared by steeping tea leaves in hot water at 80–90°C for about 3-4 minutes, while white tea is usually brewed at 60°C for 5 minutes [50]. However, the way of drinking tea may vary by specific countries. In Japan green tea is usually steeped in hot water for about 2 minutes and the infusion is used two to three times, while in China tea is typically steeped in hot water and the same tea leaves are reused up to seven times [40, 65]. In the United Kingdom, Canada and Ireland black tea is prepared using boiling water and it is often consumed with milk and sugar [65]. Despite typical methods of infusion preparation, in recent times, alternative methods, such as steeping tea with cold water (4°C or room temperature) or steeping tea leaves using hot water followed by addition of ice are also attracting interest [19, 38].

It is emphasized that the method of infusion preparation, including temperature of water, infusion time and number of extractions influence polyphenol content and antioxidant capacity of the tea infusion [34, 52, 61], as well as it may affect sensory properties [39]. In the study of Komes et al.

[34] it was stated that maximum extraction efficiency of phenolic compounds was obtained while brewing green tea at 80°C. The study of Saklar et al. [58] analyzed the influence of different steeping conditions (temperature ranging from 75 to 95°C and time ranging from 1 minute to 45 minutes) on catechins content in green tea. It was found that brewing tea at 85°C for 3 minutes was optimal in terms of epigallocatechin gallate content in green tea infusion (50.69 mg/100 ml), which is in accordance with commonly recommended steeping conditions of this type of tea. Safdar et al. [57] studied 10 different methods of preparing green tea, including brewing infusion at 25, 52, 75 and 80°C. The method of preparing tea affected the chemical composition of infusions. Infusions brewed using water at room temperature contained less tannins and more saponins, comparing to those obtained by traditional brewing. In infusions which were brewed over 20 minutes, the presence of proteins was detected, which were not present in infusions obtained as a result of brewing for up to 3 minutes [57]. In order to maximize optimal extraction of bioactive compounds from green tea it is advised to brew it at moderate temperatures, as at high temperatures exceeding 90°C polyphenols are destroyed [6, 58].

Steeping tea leaves using cold water may maximize health effects and sensory appeal of tea infusion [11, 19, 28, 41, 54, 72]. Castiglioni et al. [11] studied the effect of steeping conditions on antioxidant activities of green and white teas. It was indicated that the maximum extraction efficiency of the phenolic compounds from tea samples was obtained while teas were brewed with cold water for 120 minutes and with hot water for 90 minutes, however, the extraction was higher in cold than in hot infusions only in the case of teas from large leaves. In the study of Damiani et al. [19] it was shown that white teas brewed at room temperature for 120 minutes were characterized up to 70% more phenols, flavonoids and catechins content and antioxidant capacity, comparing to those which were brewed at 70°C for 7 minutes. Overall, this beneficial effect of brewing tea with cold water may be dependent on the certain type of tea, as in the study of Hajiaghaalipour et al. [28] it was indicated that the highest antioxidant activity for white tea was observed in prolonged hot and in some assays prolonged hot and cold extracts, while for green tea the highest activity was in prolonged cold brewing. Tea infusions prepared with cold water are also stated to contain lower amounts of caffeine and reduced bitterness than tea infusions made using hot water [72]. Additionally, in the study of Lin et al. [41] it was stated that cold brewing provides lighter color of tea infusion and higher sensory-rated infusions.

Although brewing tea using cold water seems to be a promising method in order to maintain high content of bioactive compounds in tea infusions, it requires longer infusion time, comparing to brewing tea using hot water [38]. Therefore, a novel modification has been proposed in order to overcome it. Lantano et al. [38] introduced an additional step after steeping tea with hot water, including ice addition, which enables to avoid slow cooling process causing changes in the bioactive compound content. Even if the antioxidant activity of hot-iced tea was lower than in the cold one, the amount of catechins was higher in hot-iced tea.

THE INFLUENCE OF BREWING TIME ON THE CONTENT OF BIOACTIVE COMPOUNDS IN TEA

It is well known that not only the temperature, but also the time of tea infusion influence the extraction of bioactive compounds, as well as antioxidant capacity [11, 37, 48, 50, 52, 54]. Therefore, monitoring these parameters should be a matter of great importance in order to obtain all health benefits of tea [52]. Most of the available studies show that longer brewing time has a beneficial effect on the polyphenol content and antioxidant capacity of tea infusions [8, 17, 21, 22, 52]. Research of Pérez-Burillo [52] revealed that antioxidant capacity of white tea gradually increased in the linear manner with infusion time and temperature. In the study of Dmowski et al. [22] it was stated that the average polyphenols content in the tea samples ranged from 67,70 mg gallic acid equivalent (GAE)/100 ml (3-minute infusions) to 239,57 mg GAE/100 ml (15-minute infusions), so the infusion time was relevant factor polyphenol content. Similar results were obtained by Błaszak et al. [8], as the higher amount of polyphenolic compounds was contained in infusion of black tea leaves brewed at 80°C for 5 minutes, comparing to infusion of black tea which was brewed at 80°C for 3 minutes (24,6 mg GAE/100 ml; 23,5 mg GAE/100 ml, respectively). The research of Dmowski et al. [21] determined the total polyphenol content in black teas, taking into consideration the brewing time and origin of tea [5]. It was indicated that the highest phenolic content was stated in the black tea from Sri Lanka. Interestingly, the longer time of tea brewing was, the higher the polyphenol content was recorded. Braud et al. [9] demonstrated that a 5 minute infusion time is sufficient to reach maximal bioavailability of phenolic compounds and caffeine in tea. Further increase of the brewing duration (15 or 30 min) cause no change, or even a decrease, of their concentrations. These results are at variance with those obtained by Cleverdon et al. [17], as in case of green tea, 10-minute infusion was characterized by significantly higher total polyphenol content than 5-minute infusion.

THE INFLUENCE OF NUMBER OF EXTRACTIONS ON THE CONTENT OF BIOACTIVE COMPOUNDS IN TEA

Tea brewing may be performed by reusing the same tea leaves, as a number of bioactive compounds is retained, which have not been exhausted [34, 61]. In the study of Komes et al. [34] it was revealed that during a second and third brewing of green tea, which were performed at the temperature of 80°C for 3 min, the antioxidant activity increased by 25%, comparing to the first infusion. The research of Yang & Liu [73] investigated the influence of numbers of extractions on phenolic and flavonoid contents in different types of teas. It was observed that in general green tea contained the highest level of phenolics and flavonoids, comparing to oolong and black teas. Moreover, the first brewing was characterized by the highest content of bioactive compounds and the fourth brewing by the lowest content. Another study performed by Sharpe et al. [61] aimed at assessing the effect of six successive green tea infusions at 60°C for a period of 5 minutes on

antioxidant capacity. It was observed that certain types of teas did not release significant levels of bioactive compounds apart from the first infusion. However, some teas continued to release catechins within six brews or more. Therefore, it seems that another factors, such as harvest season or form of tea (bagged vs. loose-leaf) may play role in the ability of tea to be reused.

CONCLUSION

Tea is currently gaining great interest, not only because of its sensory properties, but also its health-promoting properties. The beneficial health effects of tea are related to the presence of many bioactive substances, including polyphenols, alkaloids, polysaccharides, pigments and saponins. These compounds have antioxidant, anti-inflammatory, anti-cancer, antibacterial and hepatoprotective properties, and can also be used in the prevention of obesity and cardiovascular diseases. Caffeine found in tea stimulates the nervous system, reducing fatigue and increasing concentration. The content of the bioactive compounds in tea depends on the temperature and time of tea brewing, as well as the number of extractions of the tea leaves. Most of the available studies show that longer brewing time has a beneficial effect on the polyphenol content and antioxidant capacity of tea infusions. It is indicated that the temperature of 85°C is optimal to obtain the maximum amount of polyphenolic compounds in the infusion of green tea, however, there are indications that using of cold water in the tea preparation may also have a positive effect on the content of bioactive compounds in the infusion. Preparing tea several times using the same leaves may result in further extraction of bioactive compounds, however, research results in this field are inconclusive and it is assumed that other factors such as the harvest season and the form of the tea (bagged or loose-leaf) may determine the possibility of further extracting bioactive compounds from the infusion.

PODSUMOWANIE

Herbata cieszy się obecnie dużym zainteresowaniem, nie tylko ze względu na jej właściwości sensoryczne, lecz również właściwości prozdrowotne. Korzystne działanie zdrowotne herbaty związane jest z obecnością wielu substancji bioaktywnych, w tym polifenoli, alkaloidów, polisacharydów, pigmentów i saponin. Związki te wykazują działanie antyoksydacyjne, przeciwzapalne, przeciwnowotworowe, antybakteryjne, hepatoprotekcyjne, jak również mogą być wykorzystywane w prewencji otyłości i chorób sercowo-naczyniowych. Kofeina znajdująca się w herbacie działa stymulująco na układ nerwowy, redukując uczucie zmęczenia i zwiększając koncentrację. Zawartość związków bioaktywnych w herbacie jest zależna od temperatury i czasu przygotowania naparu, jak również liczby ekstrakcji liści herbaty. Większość dostępnych badań wskazuje, że dłuższy czas parzenia wpływa korzystnie na zawartość polifenoli i zdolności antyoksydacyjne naparów herbaty. Wskazuje się, że temperatura wynosząca 85°C jest optymalna do uzyskania maksymalnej ilości związków polifenolowych w naparze zielonej herbaty, jednakże istnieją przesłanki, że używanie zimnej wody do przygotowywania herbaty może również korzystnie wpływać na zawartość związków bioaktywnych w naparze. Kilkukrotne przygotowywanie herbaty przy użyciu tych samych liści może powodować dalszą ekstrakcję związków bioaktywnych, jednakże wyniki badań z tego zakresu są niejednoznaczne i przypuszcza się, że inne czynniki, takie jak pora zbioru liści herbaty oraz forma herbaty (w torebkach lub liściasta) mogą determinować możliwość dalszej ekstrakcji związków bioaktywnych z naparu.

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CHARACTERISTIC OF PHENOLIC COMPOUNDS OF WINE AND THE INFLUENCE OF RAW MATERIAL AND PRODUCTION PROCESS ON THEIR CONTENT®

Charakterystyka związków fenolowych występujących w winie oraz wpływ zastosowanego surowca i procesu produkcji na ich zawartość®

The tradition of wine production and consumption has been known since ancient times. Consumption of wine is particularly widespread in the Mediterranean countries. Wine is composed mainly of water, ethanol, carbohydrates, organic acids, minerals and phenols that shape the taste, aroma and colour of the final product. Phenolic compounds contained in wine also determine its beneficial effect on health. The aim of this article is to characterize the phenolic compounds of wine, as well as presenting the impact of the raw material and wine production process on phenolic content, as well as its healthy properties.

Key words: wine, phenolic compounds, antioxidant properties, production process.

Tradycja produkcji i konsumpcji wina sięga czasów starożytnych. Spożycie wina jest szczególnie rozpowszechnione w krajach basenu Morza Śródziemnego. Wino składa się głównie z wody, etanolu, węglowodanów, kwasów organicznych, składników mineralnych oraz związków fenolowych, które kształtują smak, aromat i barwę produktu finalnego. Obecność związków fenolowych w winie decyduje także o jego korzystnym wpływie na zdrowie. Celem artykułu jest charakterystyka zawartych w winie związków fenolowych, a także przedstawienie wpływu zastosowanego do produkcji wina surowca oraz procesów produkcji wina na zawartość fenoli, jak również ich prozdrowotne właściwości.

Słowa kluczowe: wino, związki fenolowe, właściwości antyoksydacyjne, proces produkcji.

INTRODUCTION

The tradition of wine production and consumption has been known since ancient times. Consumption of moderate amounts of wine is particularly widespread in the countries of the Mediterranean basin, thus making wine one of the basic elements of the traditional Mediterranean diet recommended in the prevention and prophylaxis of cardiovascular diseases [18]. The health-promoting effect of wine is related to the phenolic compounds present in it, which have a wide spectrum of biological activity, potentially beneficial for health [71]. The interest of profile and action of phenolic compounds present in wine started the 1990s, with an attempt to explain the incidence of cardiovascular diseases in the French lower than in other countries. Especially that the diet of the French, like most Europeans, was characterized by an excessive amount of fat [48]. Scientists found a correlation between the consumption of moderate amounts of red wine and the reduction of the risk of cardiovascular diseases [86] and the observed effects were related to the beneficial impact of phenolic compounds present in red wine on lipid parameters and strengthening the body's defense against free radicals [15]. The high content of phenols in wine is desirable not only for their beneficial health effects, but also for technological reasons, as phenols protect the wine against oxidation [6].

The phenolic content of wine depends on many factors, namely the grapevine variety, the location of the vineyard, the cultivation system, climate, soil type, grapevine, harvest time, production and storage process [20]. Wine is produced from grapes, but in recent years there has been growing interest and demand, and consequently the production of fruit wines [92], depending on the region produced from apples, blueberries, cherries, apricots, pears, plums, peaches, strawberries, currants, kiwi, bananas, figs, pineapples, pomegranates, lemons, mandarins or oranges [35]. Taking into account that fruits are a valuable source of not only vitamins and minerals, but also phenolic compounds [29], wine produced from them can be an alternative to traditional wine made from grapes. Fruit wines, as well as grape wines, contain phenolic

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compounds, but, they are characteristic for the fruits from which they were produced [47].

The aim of this article is to characterize the phenolic compounds of wine, as well as presenting the impact of the raw material and wine production process on phenolic content.

ENERGY AND NUTRITIONAL VALUE OF WINE

The composition of wine is varied, determined by many factors, including the climatic and soil conditions specific to the wine-growing area, the type of vines used, the degree of fruit maturity and the method of production. Wine contains on average about 60–90% of water, 9–18% volume of ethyl alcohol, carbohydrates (e.g. glucose, fructose, sucrose), organic acids (e.g. tartaric, malic, amber), higher alcohols (including e.g. propanol, hexanol, glycerol), esters (e.g. ethyl acetate, ethyl formate, ethyl tartrate), aldehydes (e.g. acetaldehyde), vitamins (e.g. B_1, B_2, niacin), minerals (e.g. potassium, sodium, magnesium, calcium) [53], whereby the sweet wine has the highest energy value, which is related to the higher carbohydrate content, while the content of minerals and vitamins, regardless of the type of wine, is similar (Table 1).

Table 1. Energy and nutritional value of red and white wine [42]

Tabela 1. Wartość energetyczna i odżywcza czerwonego i białego wina [42]

Parameters	Red wine	White dry wine	White semi-dry wine	White sweet wine
100 ml				
Energy (kcal)	68	66	81	95
Water (g)	89,9	90,2	86,6	83,5
Carbohydrates (g)	0,2	0,6	3,7	5,9
Potassium (mg)	110	61	70	110
Phosphorus (mg)	13	6	7	13
Magnesium (mg)	11	8	4	11
Calcium (mg)	7	9	10	14
Sodium (mg)	7	4	3	13
Iron (mg)	0,9	0,5	1,8	0,6
Niacin (mg)	0,01	0,01	0,05	0,01
Vitamin B6 (mg)	0,02	0,02	0,02	0,01
Vitamin B2 (mg)	0,01	0,01	0,005	0,01

Classic wine is made from grapes, while fruit wines are made from fruits such as peaches, plums, apricots, bananas, elderberry and blackcurrant, which means that they contain most of the ingredients present in fruit juice. During fermentation, amino acids and other ingredients are released from yeast, which increases the nutritional value of fruit wine. The energy value of fruit wines ranges from 70 to 90 kcal per 100 ml, the carbohydrate content is about 2–3%, and the ethyl alcohol content is usually about 8–11% [78]. When alcohol level of wine is considered, fruit wines can be classified as table wines or fortified wines. Table wines usually contain 11–16% ethanol, but can be also only 7%. Ethanol content in fortified wines ranges from 16% to 23% and the ethanol content is higher if brandy is added [41].

CHARACTERISTICS OF PHENOLIC COMPOUNDS IN GRAPE WINE AND ITS PROPERTIES

There are phenolic compounds in wine, which constitute a large group of secondary metabolites with a very complex structure that shape the organoleptic properties of wine, in particular its colour, taste and aroma [9]. In grapes, these compounds are mainly in the skin and seeds [72], and they protect the plant against fungi and UV radiation [74]. In the literature, several classifications of phenols are distinguished [102, 58], according to one of them [102], phenolic compounds can be divided into four categories: containing one phenolic ring (benzoic and cinnamic acids), containing two phenolic rings (stilbenes), containing three phenolic rings (anthocyanins, flavanols and flavan- 3-ole) and more complex structures (ellagic acids). According to another classification [58], phenolic compounds can be divided into two groups: flavonoids and non-flavonoids. There are mainly flavonoids in wine, namely flavanols, anthocyanins, flavan-3-oils and oligomeric or polymeric condensed tannins called anthocyanidins (delphinidin and pelargonidine).

Flavonoids are low molecular weight compounds composed of a tricyclic structure with various substituents, which gives them a variety of structures. They are found in the skins of both red and white grapes [22]. Flavanols, which mainly protect plants from UV radiation, are found in the skins and pulp of grapes [39], but are also produced in the vinification process (quercetin, kaempferol, myricetin) [58]. Flavanols form oligomers and polymers (condensed tannins) that shape the tartness and bitterness of the wine [58], additionally interact with saliva proteins, enhancing the feelings of tartness and bitterness of wine [8]. The colour of red wines is given by anthocyans which are water-soluble flavonoid pigments, and depending on the pH, they can give different colours such as red, purple and blue [52]. Typically, anthocyans are found mainly in the grape skins, with some grape varieties also containing anthocyans in the grape pulp [76].

The group of non-flavonoids includes three groups of compounds: hydroxycinnamic acids, stilbenes (including resveratrol) and phenolic acids (including gallic, coumaric, caffeic and ferulic acid) [11, 68]. Phenolic acids are found in the skins of red grapes and in the cell vacuoles of the grape flesh, they have no colour but can oxidize giving them a yellow colour. Phenolic acids do not affect the sensory properties of wine, but are of technological importance as they are precursors of some volatile phenolic compounds produced by microorganisms during the wine-making process [87]. Phenolic acids can be classified into two main groups, benzoic acids and cinnamic acids. Among benzoic acids, gallic acid is the most abundant in wine, and cinnamic acids are present in greater amounts in the skin than in the grape pulp [58].

The beneficial properties of red wine, in particular, are determined by the polyphenols present in it, which are a group of natural compounds with a different structure and exhibiting a broad spectrum of biological activity, potentially beneficial to health [71]. Numerous studies have shown that the beneficial effect of phenols on health is related to their antioxidant properties [17], anti-inflammatory [83], anticancer [98], antidiabetic [7], neuroprotective [31] and cardioprotective [12]. Given that oxidative stress plays a significant role in the pathogenesis of various diseases, investigating the antioxidant capacity of phenols has become the subject of special interest to scientists [44]. As it has been shown, these abilities are conditioned by the presence of numerous hydroxyl groups, and the contribution of polyphenolic compounds in the body's defense against reactive oxygen species consists in the removal of free radicals and chelation of free metal atoms, such as copper or iron, which prevents biochemical reactions generating reactive oxygen species, for example lipid peroxidation [89].

Phenolic compounds, especially flavonoids, have a protective effect on the cardiovascular system, thanks to their anticoagulant, antioxidant, antiproliferative, anti-ischemic and vasodilating properties, and also have antitumor, antiviral and antiallergic properties [100]. A special class of phenolic compounds are stilbens, and the main representative of this group is resveratrol, which is formed in the grapevine in response to fungal infections [22]. The greatest amounts of resveratrol are found in the skins of red grapes, which is why red wine also contains the highest amount of it (2,8–4,3 mg/kg resveratrol in red wines vs 0,1–0,5 mg/kg resveratrol in white wines) [66, 69]. In addition, it has been identified as the substance responsible for the health-promoting benefits of regular moderate consumption of red wine [23]. Resveratrol is characterized by antioxidant [88], anti-inflammatory [45], anti-aggregation [28] and anticancer actions [51]. However, not only resveratrol has antioxidant activity, because phenolic compounds form the so-called antioxidant potential, which is a measure of the body's ability to both defend the body against free radicals and prevent diseases resulting from the so-called oxidative stress [20], that is, a disturbed balance between the production of free radicals and their neutralization.

Due to the production technology, the total phenolic compounds content in white wines is ten times lower in comparison with red wines (~4600 mg/L gallic acid equivalent in red wines *vs* ~360 mg/L gallic acid equivalent in white wines) [66]. The main phenolic compounds in white wine are hydroxycinnamic acids and their derivatives, which are responsible for the antioxidant properties of wine, and by conjugation with tartaric acid, they form tartaric acid esters of hydroxycinnamic acid, constituting 80% of all polyphenols of white grape juice [59].

It is worth adding that the production of wine produces waste, namely bagasse, wine sediment and yeast sediment [36], which are a major problem for the wine industry, because using them as compost turned out to have an adverse effect on the soil [56]. The waste produced during the fermentation of white and red wine contains significant amounts of phenolic compounds and is characterized by high antioxidant activity. The wine waste contains mainly proanthocyanidins, namely catechins and epicatechins, with epicatechin dominating in white wine sediments, and epicatechin in red wine sediment [101]. Considering that these compounds are characterized by a broad pro-health effect, including antioxidant, antihypertensive, anti-inflammatory, antiproliferative, anticoagulant and anti-hyperlipidemic effects [99], as well as antidiabetic and anticancer [1], wine waste may be valuable raw material for their re-use, e.g. in dietary supplements intended for humans. Interestingly, one of the few ways to reuse wine sediment is to try to use it as an additive in ice cream production, which significantly improved rheological and antioxidant properties, while antioxidants from wine sediment were quite stable in the ice cream production process [32]. Grape pomace, which is a by-product of wine production, can be a valuable material for use in the pharmaceutical, cosmetic and food industries, because it contains bioactive compounds [36]. Grape seeds are also a valuable raw material, which can be used to produce oil that is a rich source of tocopherol, carotenoids, linolenic acid, but also resveratrol, quercetin, procyanidins and phytosterols with the possibility of application in the pharmaceutical, cosmetic and food industries [26].

CHARACTERISTICS OF PHENOLIC COMPOUNDS IN FRUIT WINE AND ITS PROPERTIES

Of the fruit wines, the most widespread is apple wine produced mainly in Great Britain, France and the United States, pear wine in France [16], raspberry and plum wine in South Korea [13, 43], while wines from other, less known fruits are produced by small, local producers [78]. Fruit wines, just as grape wines, contain phenolic compounds, but characteristic of the raw material from which they were produced. However, the profile of phenolic compounds in fruit wines and their potential health benefits have not been investigated as thoroughly as in grape wines [47]. Fruit wines are a source of various ingredients, including minerals, carotenoids (carotene and lutein) or phenolic compounds (anthocyanins, flavonols, flavan-3-ol, proanthocyanidins, ellagitanins and phenolic acids) [91]. In the study Ljevar et al. [47] the analysis of phenolic compounds in fruit wines showed that blackberry (1936 mg/L gallic acid equivalent), cherry (2074 mg/L gallic acid equivalent) and blackcurrant (2013 mg/L gallic acid equivalent) wines contained the higher total phenols than strawberry (752 mg/L gallic acid equivalent) and apple (449 mg/L gallic acid equivalent) wines, in addition, cherry (244 mg/L) and blackcurrant (250 mg/L gallic acid equivalent) wines had also the higher total anthocyanin content compared to blackberry (90 mg/L gallic acid equivalent) or strawberry (4 mg/L gallic acid equivalent) wines. Different phenolic composition was also noted for each type of fruit wine, especially for anthocyanins. In the study Čakar et al. [16] the highest amounts, especially of procyanidins, were found in cherry (111,7–134,4 µg/ mL epicatechin, 22,3–29,7 µg/ mL catechin) and blueberry (27,8–24,7 µg/mL epicatechin, 1,7–4,5 µg/mL catechin) wine, while the content of these compounds in other wines was much lower (5,9-7,2 µg/mL epicatechin in black chokeberry wine or 1,3-3,7 µg/mL epicatechin in apple wine). On the other hand, blackberry, cherry, raspberry and currant wines analyzed by

Ljevar et al. [47] also had a significantly higher antioxidant capacity than strawberry and apple wines. Also in the study Stępniowska et al. [84] blackcurrant wine was shown to have the highest concentration of phenolic compounds, tannins and anthocyanins, and the highest free radical scavenging capacity than redcurrant, strawberry, raspberry or grape wine. The reason is that black currant contains the most phenolic compounds and vitamin C, which translates into high antioxidant activity, because the higher the content of phenolic compounds, the higher the antioxidant activity [84]. Čakar et al. [16] noted that the highest total phenolics content was for black chokeberry wine (2414 mg/L gallic acid equivalent), and the lowest for apple wine (584 mg/L gallic acid equivalent). In the study Pantelić et al. [61] it was shown that the profile of phenolic compounds found in cherry wine was more diverse compared to grape wines, and the main phenolic acids found in cherry wine were: caffeic acid, chlorogenic acid, protocatechuic acid, and p-coumaric acid and their content it was much higher in cherry wine than in grape wines. In addition, characteristic only for cherry wine were naringenin and apigenin, and seven anthocyanins, namely delphinidin-3-rutinoside, cyanidin-3-sophoroside, cyanidin-3-pentosylrutinoside, pelargonidin-3-glucosylrutinoside, cyanidin-3-rutinoside, peonidin-3-rutinoside, and pelargonidin-3-glucoside, whereas plum wines are mainly characterized by presence peonidin-3-glucoside, cyanidin-3-rutinoside, peonidin-3-rutinoside, chlorogenic and caffeic acids and rutin [55].

Phenolic compounds present in fruit wines, similarly to those found in grape wines, show health-promoting effects, mainly antioxidant [16], although there is scientific evidence of their possible anti-cancer effects. Fruit wines inhibited the growth of human cancer cells *in vitro* in a dose dependent manner, with blackberry, cherry, raspberry and currant wines being the most effective [47]. In contrast, phenolic acids such as caffeic acid, p-coumaric acid and chlorogenic acid present in fruit wines inhibit the oxidation of LDL lipoproteins *in vitro* [54].

THE IMPACT OF VARIETY, CLIMATIC AND SOIL CONDITIONS ON PHENOLIC CONTENT IN WINE

Phenolic compounds are stable during storage of the raw material, however, in the course of processing comes to significant changes in the content of these compounds and their content in the final product [84]. In the case of grape wine, the content of phenolic compounds depends on the grapevine variety, location of the vineyard, cultivation system, climate, soil type, grape cultivation method, harvest time, production and storage process [20].

In the production of grape wine, mainly French grape varieties are used, which are widely used in wineries around the world, leading in a sense to the globalization of the taste of wine produced from specific grape varieties. Some wine producers re-use local grape varieties, analyzing their suitability for the wine industry [50]. In the study Kallithraka et al. [37] the content of phenolic compounds was analyzed in rare native varieties of Greek grapevines that are not used for wine production. It was noted that some of the rare varieties, e.g. *Karvouniaris*, *Thrapsa*, *Nerostafilo*, *Bakouri*, *Vertzami* contained significant amounts of phenols, which means that they are a very good raw material for the production of quality wines.

Grapes are a source of phenolic compounds, but the great variety of grape varieties means that the grapes differ in phenol content and profile, and thus also in colour and taste. Thus, wines produced from different grape varieties may also have a different taste and colour, and according to some authors, the grape genotype may have a significant impact on the profile of phenolic compounds and antioxidant properties of the wine [90]. The content of phenolic compounds in wine depends, among others, on their concentration in the skins, flesh and seeds of the grapes [4] and the total phenolics content of the grapes varies between grape varieties. In the study Van Leeuw [90] showed a significantly lower antioxidant capacity of wine produced from the French *Pinot Noir* grape variety (948 mg/L gallic acid equivalent) compared to wines produced from other grape varieties, for example antioxidant capacity of wine produced from the *Syrah* grape variety is 3476 mg/L gallic acid equivalent), which was associated with differences in the content of individual phenols, especially with significantly lower levels of anthocyanidins and flavonols. On the other hand, wine made from the Italian grape variety *Ancellotta* (3926–4202 mg/L gallic acid equivalent) was characterized by a significantly higher concentration of phenols, especially flavanols, flavonols and anthocyanins 3-O-glycosides (flavanols, flavonols and anthocyanins 3-O-glycosides) than the wines *Rebo* (2262–2409 mg/L gallic acid equivalent), *Nebbiolo* (1756–2323 mg/L gallic acid equivalent), *Barbera* (1319–2360 mg/L gallic acid equivalent) i *Teroldego* (3209-3356 mg/L gallic acid equivalent) varieties [79]. Gomez Gallego et al. [27] analyzed, inter alia, the composition of phenols and the antioxidant properties of two vintages of Spanish red wines produced from the grape varieties *Moravia Dulce*, *Rojal* i *Tortosí*. It was shown that the phenol content was influenced by both the grapevine variety and the vintage year, while the phenol profile was mainly influenced by the grape variety. Among the anthocyanins in wines produced with *Moravia Dulce* and *Tortosí,* malvidin 3-glucoside dominated, and peonidin 3-glucoside dominated in the wine of the *Rojal* variety. Among the flavonols (flavonol), quercetin dominated in *Rojal* and *Tortosí* wines, and myricetin dominated in *Moravia Dulce* wines, while all wines contained large amounts of resveratrol. Chlorogenic, coffee and syringic acids dominated in the composition of phenolic compounds in Brazilian red wines produced from grapes of the *Vitis labrusca* variety [19]. Thus, depending on the grape variety used, wines can also be differentiated in terms of the content of phenolic compounds.

The climatic and soil conditions of the wine-growing area also have a significant influence on the chemical composition of the wine and the phenolic content. Grapes grown in orphan soil have the highest total phenolic and tannins, which influenced the composition of the wine, while grapes grown in aeolian soil have the highest anthocyanin content [95]. The Mediterranean region, where summers are warm and dry and winters cool and wet, are optimal, and therefore the most favourable for wine production, in contrast to the tropical climate, which is characterized by high temperature, rainfall and high humidity. However, climate change is

leading to vineyards being planted in upland areas changing the ecosystem, as seen in areas such as western North America [30]. In the study of Brighenti et al. [9] the phenolic content of wines produced in the high mountain regions of southern Brazil at an altitude of 1,400 meters was analyzed as this area has a high accumulation of global solar radiation promoting phenol synthesis in grapes. In the case of white wines, the highest content of polyphenols was found in wine produced from the *Greco di Tufo*, variety, and in the case of red wines - in wine produced from the *Ancellotta* variety [9]. According to other authors, the Italian grape varieties *Ancellotta*, *Rebo*, *Nebbiolo*, *Barbera* and *Teroldego* can be successfully grown in southern Brazil, where the subtropical climate prevails [79].

In the samples of wines from Apulia in southeastern Italy, the amount of phenolic compounds depended largely on their colour, with red wines containing the highest amounts of phenols (23,7–28,0 mg/kg gallic acid) compared to white (2,7–12,5 mg/kg gallic acid) and rosé (5,5–7,4 mg/kg gallic acid) wines. The dominant phenolic compounds in wines were gallic acid, syringic acid and luteolin, as well as hydroxytyrosol, quercetin and resveratrol [69]. In red wines produced in the Canary Islands, quercetin was the dominant phenolic compound, which may be a characteristic element of these wines [72]. Interestingly, Gambelli & Santaroni [24] analyzed the possibility of correlating the concentrations of phenolic compounds with the geographical origin of wine and using the properties of these compounds for wine classification. Wines from the two Italian regions of Apulia and Molise, which differ in environmental conditions, were analyzed. The results showed differences in the concentration levels of individual compounds in the group of flavonols, anthocyanins and phenolic acids, however, the observed differences were not related to the geographical origin of the wines, so it is not possible to identify the geographical origin of the grape wine on the basis of the concentration of phenolic compounds. In the case of fruit wines, an experiment by Klarić et al. [38] showed that blackberry wines from three different Croatian sub-regions can be classified according to the content and composition of phenolic compounds according to their geographical origin.

It is worth adding that the composition of phenolic compounds in wine also depends on the method of grapevine cultivation or fruit ripeness during harvest [63]. Due to the premature harvest of the grapes, the phenolic maturity of the grapes may be lagged behind their technological maturity. Wines made from these grapes may have a lower phenolic content or an unbalanced phenolic composition, which may reduce the overall quality of the wine [2].

THE IMPACT OF WINE PRODUCTION PROCESSES ON PHENOLIC CONTENT

The profile of phenolic compounds in wine depends not only on the concentration of phenolic compounds in grape skins, flesh and seeds, but also depends on the techniques of wine production [4]. Grapes contain significant amounts of water and sugar, which makes them very susceptible to spoilage during storage, even when refrigerated [96]. One of the techniques used to eliminate microorganisms in grapes stored at low temperatures is the use of high hydrostatic pressure or ozone treatment, which prevents spoilage and significantly extends the shelf life of grapes [57]. Fresh grapes can be used for the production of wine, but the grapes have also been previously subjected to dehydration, an example is Tokaj wine, which is made from dried grapes. It is worth noting that depending on the time and drying temperature it can lead to degradation of phenolic compounds in the raw material [94].

In the case of wine made from grapes, the first stage of production is the mechanical separation of the stems from the fruit and the mechanical crushing of the grapes, releasing the juice and pre-fermentation [85]. Then must is heated and it is maceration, in which not only the temperature is important, but also the activity of hydrolytic enzymes, ethanol content, and then the must is mixed [34]. To increase the extraction of anthocyanins, tannins and other phenolic compounds from the grape skins, various techniques can be used, e.g. ultrasound, pulsed electric fields or high hydrostatic pressure, which facilitate the degradation of the grape cell walls and the increased release of these compounds accelerates the maceration process [57]. Pulsed electric fields or high hydrostatic pressure can also be particularly useful in extracting grapes poor in phenolic compounds, so there is no need to mix these grapes with grape varieties richer in phenolic compounds or use enzymes pectolytic [21]. The enzymes added to the must at the maceration stage are mainly pectinases, cellulases and hemicellulases, the so-called pectolytic enzymes degrade pectins into shorter and more soluble molecules in the process of hydrolysis, which facilitates pressing of grapes and extraction of coloured and aromatic compounds [80]. In winemaking, enzymes are used at different stages: pre-fermentation, alcoholic fermentation, post-fermentation and wine maturation, using both natural enzymes that are present in grapes and commercial enzymes, most often produced by the *Aspergillus* species [14].

Maceration is an important process, especially in the production of rosé and red wines, because in this process, mainly tannins and anthocyanins and aromatic substances from grape skins, seeds and pulp are extracted into wines. The different maceration techniques used in red wine production affect the amount and chemical composition of phenols in the wine [10]. Higher maceration temperature increases the extraction of phenolic compounds and enhances the color of red wine, while maceration at lower temperatures before fermentation has a positive effect on the composition of wines, including lower oxidation of anthocyanins and aromatics, and inhibition of the action of undesirable enzymes. Maceration carried out in the temperature range from 10 to 15°C produces red wines with the highest total phenolic and anthocyanin content, as well as with a more intense color and richer aroma [81]. In the study Bayram et al. [5] the effect of the type of maceration on the content of phenolic compounds in red wines was compared, while in classic maceration the must and pomace were macerated and fermented at 24°C for 10 days, in cold maceration at 4–6°C for 96 hours before the process fermentation. It turned out that cold maceration did not increase the content of phenolic compounds in wine, and the content of individual phenolic compounds in wines subjected to classic maceration was higher than in wines subjected to cold maceration [5]. The maceration time affects

the extraction efficiency of phenolic compounds from grapes into wine. In the experiment of Ivanova et al. [33] the highest content of phenolic compounds was found in wines produced with 6 days of maceration, with the exception of flavan-3-ols, belonging to the tannins, the highest amounts of which were recorded in wines macerated for 10 days. Casassa et al. [10] reports that anthocyanins, responsible for the colour of red wines, reach their peak of extraction after 4 or 5 days of maceration, and then their level decreases with increasing maceration time. In turn, Sener [81] reports that prolonged maceration also leads to a wine with a stable red colour and a more tart taste.

Rosé wines are also macerated, the method of production of which is similar to the production of red wine, but in rosé wines the grape skins are removed before fermentation, unlike red wines, which ferment with the skins. Maceration of rosé wine moderately reduces the phenolic content of the wine [67]. In the production of white wines, maceration is not used or the process is short (24 hours at a temperature below 20°C), often carried out before fermentation, and the goal is to obtain a more complex taste thanks to the extraction of grape aromas into the must [49]. According to Ružič et al. [75] the use of this process in the production of white wine allows to obtain the content of polyphenols and antioxidant properties similar to red wine. On the other hand, white wines, produced without maceration, contain lower amounts of total phenols compared to red wines, and they are mainly non-flavonoid compounds, concentrated in the pulp, namely hydroxycinnamic acids and their derivatives [59]. In the study Korenika et al. [40] it was observed that the phenolic profile of white wine depends on the maceration time, with the most optimal maceration time being 6 months, because the polyphenol content was the highest and the antioxidant properties were the best, moreover, it was found that the higher the total phenolic content, the higher the antioxidant capacity of white wine. Also Lukić et al. [49] showed that the extended maceration time of white wine increased phenol concentration, color intensity, antioxidant activity. Contradictory results were obtained by Preserova et al. [67], who observed that the maceration of white wine caused a significant reduction in the total phenolics content. Fruit wines are also macerated with commercial enzymes at the early stage of fruit extraction, and then during pressing and clarification [92].

In red wine production, the grape pulp, skins and seeds are kept together after crushing and during all or part of the fermentation process, with the skins not being separated from the juice, unlike in white wine production, where the juice is separated from the peel and then clarified by sedimentation or centrifugation, then yeast is added to the clarified juice to initiate fermentation [85]. Due to the fact that white wine is produced from grape-free must, it contains less polyphenolic compounds compared to red wine made from whole fruit [65]. Piljac et al. [66] observed that white wines contained about 10 times less phenolic compounds than red wines, which is due to the lack of anthocyanins and other pigments present in red wine. The significantly higher content of phenolic compounds in red wines (2082–3184 mg/L gallic acid) also causes their antioxidant activity to be much greater than that of white wines which contains less phenolic compounds (213–277 mg/L gallic acid) [73].

In general, the method of producing fruit wines is similar to the technique of grape wine production, although the extraction of sugars and other compounds from the flesh of some fruit is most problematic, therefore specialized equipment is used for fine grinding the fruit, and then pressing it to squeeze the juice from the finely ground pulp [85]. Interestingly, although the lowest content of phenolic compounds is in raspberries (121 mg phenolics/g fresh weight) compared to bilberry (525 mg phenolics/g fresh weight), lingonberry (652 mg phenolics/g fresh weight) or redcurrant (1400 mg phenolics/g fresh weight), the extraction of phenols into wine from these fruits is the highest due to the thin skin [62]. On the other hand, in currants, which have a thick skin, the percentage of extraction of bioactive compounds from fruit is the lowest [84].

The next stage of wine production is fermentation, during which yeast, most often *Saccharomyces cerevisiae*, transforms the sugars contained in the juice into ethyl alcohol and carbon dioxide [85] and produces various by-products, e.g. carbonyl compounds, alcohols, esters, acids and acetals that influence the quality of the finished wine [82]. Often, sulphur dioxide is added to the must before fermentation, which has an antibacterial and antioxidant effect, and also increases the transfer of phenolic compounds to the must [33, 57]. However, due to the negative effects of sulphur dioxide on health (diarrhea, urticaria and abdominal pain), modern techniques are currently being used, such as pulsed electric fields, high hydrostatic pressure, but also UV irradiation or e-beam irradiation that make it possible to produce wine without the addition of sulphur dioxide [57]. It is also possible to produce red wine in an organic system, so without the addition of sulphur dioxide, and in terms of the total content of polyphenols and flavonoids, phenol profile and antioxidant activity, such wine does not differ from conventionally produced wine [25].

Fermentation at a lower temperature of 10-15°C has an unfavourable effect on yeast growth, leading to an extended fermentation time and the risk of its inhibition, while a higher temperature allows faster growth of yeast and its use of sugar, which promotes the formation of ethyl alcohol [97]. Liu et al. [46] showed that high fermentation temperature (25–30°C) not only accelerated sugar utilization and alcohol formation, but also increased the content of phenols, tannins and flavonoids in red wine. Similarly, in the production of rosé wines, fermentation with the use of yeast caused a rapid increase in the content of phenolic compounds, while in the production of white wine it did not change the content of phenols [30, 67]. White wine fermentation is carried out using exogenous yeast in stainless steel tanks at relatively low temperature between 12 and 18°C [49].

Fruit wines are made from a mash or fruit juice that is fermented, and may need to add sugar to stimulate the fermentation process when the fruit does not contain enough natural sugar to ferment by itself in the presence of yeast. Some fruits, such as cherries, raspberries, strawberries, and pineapples, contain significant amounts of acids, which may require the addition of sucrose to counteract the acidity of the fruit, and water to dilute the excess acid [77]. The higher the sugar content, the higher the amount of alcohol produced, which additionally facilitates the transfer of phenols to fruit

wine [16]. One of the most widespread non-grape fruit wines is apple wine, which is made from fermented apples. As in the production of grape wines, apple must is fermented, with the optimal temperature ranging from 15 to 18°C, after prior addition of sulfur dioxide [85]. Alcoholic fermentation of apples does not affect the overall content of phenolic compounds in the resulting apple wine, which means that the level of phenolic compounds of the original clarified apple juice is maintained, while the content of some phenols: caffeic acid and catechin increases [60]. After fermentation, the apple wine is filtered, clarified and then pasteurized at 60°C for about 20-30 minutes [85]. In the case of raspberry, blackberry, blueberry, cherry and black chokeberry wines, fermentation is carried out at a temperature of about 20°C for 7–10 days [16]. Due to the differences in the composition of the fruit used in the production of fruit wines, the yeast strain used for fermentation must be adapted to different environments, e.g. sugar concentration, the presence of organic acids, etc. However, most often the same strain is used as in wine production grape, namely strains of *Saccharomyces cerevisiae* [92].

The next stage is wine clarification using special clarifying agents, eg enzymes, gelatin, bentonite, etc., while the wine clarification techniques do not significantly affect the profile of phenolic compounds or the antioxidant activity of wines [93]. Although it is indicated that the addition of bentonite to the clarification of white and rosé wine significantly reduces the total phenol content [67]. The clarification of fruit wine is the same as that of grape wine, and pasteurization is carried out before bottling the wine, with or without preservatives [92].

The next process is filtration to obtain clear wine without organoleptic changes, e.g. using membrane filtration, which allows simultaneous clarification, filtration and sterilization of the wine, and in addition does not change the antioxidant activity of the wine [93].

Then the grape wine is stored in stainless steel vessels or in oak barrels [85], while maturing and aging in oak wood wine barrels, polyphenolic compounds (tannins) from oak wood, especially ellagitanin C-glucoside, which take part in oxidation reactions, affecting the organoleptic properties of wine, including for its tartness [70]. The wines mature for at least 12 months in oak barrels and another 12 months in a bottle [3]. During maturation in a barrel or in a bottle, polymerization and condensation reactions take place, which modify the composition of the wine and its quality features [33]. Arnous et al. [3] observed that ripening red wines are characterized by a different polyphenolic composition compared to young wines, mainly due to the fact that phenolic compounds, especially anthocyanins, undergo polymerization reactions, but also oxidation, hydrolysis and other changes that may take place during aging. Bimpilas et al. [6] noted that when wine is stored for 12 months, the content of anthocyanins tenfold decrease as they participate in polymerization reactions, and there is also a slight decrease in the total amount of flavonols (from 161 to ~140 mg/L quercetin equivalent for Merlot wine and from 193 to ~150 mg/L quercetin equivalent for Syrah wine). Additionally, the amount of glycosylated flavonols, which are subject to enzymatic hydrolysis, is reduced. However, these reactions do not significantly affect the total polyphenol content of the wine. Similarly, Ivanova et al. [33] showed that during wine storage, anthocyanin content decreases rapidly, especially in wines that have been macerated briefly (from 54 to 84%) and those that have been stored at higher temperatures (300-850 mg/L total anthocyanin) compared to those that have been stored at lower temperatures (50-400 mg/L total anthocyanin). Peri et al. [64] found no significant changes in total phenolic content, total flavonoid content and total antioxidant capacity in the red wine maturation period, however, a significant decrease in anthocyanin content was noted.

Fruit wines also undergo a maturing process, during which the aroma changes are observed, the process takes standardly 6 months, but may be extended to 2-3 years in order to obtain a clear wine with a mild taste [41].

CONCLUSION

The content and profile of phenolic compounds in grape wine depends on many factors: grape variety, location of the vineyard, cultivation system, climate, soil type, grapevine cultivation method, harvest time, as well as the production and storage process of the finished product. The production of grape wine involves several technological processes that can be modified depending on the type of wine produced. Based on the literature data, it can be concluded that pressing, maceration and fermentation of the must increase the total content of phenolic compounds in wines, clarification and filtration generally do not significantly affect the phenolic content of wine, while wine maturation and storage mainly significantly reduces the anthocyanin content, but also favourably shapes the taste and aroma thanks to the processes of polymerization and condensation. The production of fruit wines is similar to the method of producing grape wine, therefore the technological processes will similarly affect the content and profile of phenols in these wines, although it depends mainly on the raw material used. The amount of research on the influence of various factors on the level of phenols in fruit wines is insufficient in contrast to numerous studies on viticulture and the characteristics of grape wines. Phenolic compounds present in both grape and fruit wines are characterized by a wide spectrum of biological activity, demonstrating antioxidant, anti-inflammatory, anticancer and cardioprotective properties, therefore it seems that fruit wines can be an alternative to grape wine.

PODSUMOWANIE

Zawartość i profil związków fenolowych w winie gronowym zależy od wielu czynników: odmiany winorośli, lokalizacji winnicy, systemu uprawy, klimatu, typu gleby, sposobu uprawy winorośli, terminu zbioru, a także od procesu produkcji i przechowywania gotowego produktu. Produkcja wina gronowego obejmuje kilka procesów technologicznych, które mogą być modyfikowane w zależności od rodzaju produkowanego wina. Na podstawie danych literaturowych można stwierdzić, że tłoczenie, maceracja i fermentacja moszczu zwiększają ogólną zawartość związków fenolowych w winach, klarowanie i filtracja generalnie nie wpływają w sposób istotny na zawartość fenoli w winie, natomiast dojrzewanie i przechowywanie wina wpływa przede wszystkim na

znaczące zmniejszenie zawartości antocyjanów, ale także korzystnie kształtuje smak i aromat dzięki zachodzącym procesom polimeryzacji i kondensacji. Produkcja win owocowych jest zbliżona do sposobu wytwarzania wina gronowego, zatem procesy technologiczne w podobny sposób będą wpływały na zawartość i profil fenoli w tych winach, choć jest on zależny głównie od zastosowanego surowca. Liczba badań dotyczących wpływu różnych czynników na poziom fenoli w winach owocowych jest niedostateczna w przeciwieństwie do licznych badań dotyczących uprawy winorośli i charakterystyki win gronowych. Związki fenolowe obecne zarówno w winach gronowych, jak i owocowych charakteryzują się szerokim spektrum działania biologicznego, wykazując właściwości przeciwutleniające, przeciwzapalne, przeciwnowotworowe czy kardioprotekcyjne, zatem wydaje się, że wina owocowe mogą być alternatywą dla wina gronowego.

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PROCESS, SYSTEMIC AND DIALECTICAL ASPECTS INVENTIVENESS IN THE FOOD PRODUCTION INDUSTRY®

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Invention is one of the most eminent manifestations of the creative process. The article analyzes this issue in an integrated approach: system-process-dialectical. This approach is logically justified by the nature of the process. The inventive process is not and cannot be unequivocally predictable because there is a special interaction of causal and consciousness processes in it. Invention, by its very nature, is also a dialectical process in which there is a constant confrontation of various opposing thoughts. For the inventive process itself, especially in the area of food production, two determinants related to a potential invention in the most direct way are important: the specificity of agricultural raw material and a set of creative rules. The article proposes an algorithmic method of inventive procedure that captures these determinants.

Key words: inventiveness, system approach, algorithmization of the invention, food industry.

Wynalazczość należy do jednego z najznakomitszych przejawów procesu twórczego. W artykule przeanalizowano to zagadnienie w zintegrowanym ujęciu: systemowo-procesowo -dialektycznym. Takie ujęcie jest logicznie uzasadnione charakterem procesu. Proces wynalazczy nie jest i nie może być jednoznacznie przewidywalny, ponieważ dochodzi w nim do szczególnego współdziałania procesów przyczynowych i świadomościowych. Wynalazczość ze swej natury jest także procesem dialektycznym, w którym dochodzi do nieustannej konfrontacji różnych przeciwstawnych myśli. Dla samego procesu wynalazczego, szczególnie w obszarze produkcji spożywczej, ważne są dwie determinanty związane z potencjalnym wynalazkiem w sposób najbardziej bezpośredni: specyfika surowca rolniczego i zespół zasad twórczych reguł, W artykule zaproponowano algorytmiczny sposób postępowania wynalazczego ujmujący te determinanty.

Słowa kluczowe: wynalazczość, ujęcie systemowe, algorytmizacja wynalazku, przemysł spożywczy.

INTRODUCTION

After nearly 2.5 thousand years, since the Greek philosopher Socrates uttered the sentence: *I know that I know nothing*, despite the experience from the practice of creating countless inventions and writing thousands of books on this subject, its validity is not questioned in relation to the act itself creativity of inventive and innovative nature. There is never too much knowledge about inventiveness and innovation. In Poland, the inventiveness indicators are highly unsatisfactory (according to the latest WIPO report on global intellectual property indicators, in 2018 Poland was 27th in the ranking of countries in terms of inventive activity; out of a total of 3,326. ml patents granted in the world, Poland was granted only 2906 of them). According to many authors, technical progress and globalization forces an increase in inventive activities and innovations also in the food production industry.

Dekker and Linnemann [4] presented their major directions in four broad areas of knowledge, giving them the meaning of generation:

- 1st generation – progress in food preservation and production of microbiologically safe food with a long shelf life,
- 2nd generation – a combination of nutritional value and taste requirements,
- 3rd generation – convenience in using the product and preparing food – development of the convenience food market,
- 4th generation – protection or improvement of consumer health – development of the functional food market.

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The Polish food industry is strongly associated with the international market and capital, which recognized that in Poland it is an industry with a future and that it is worth investing in their development [24]. The dynamics of socio-economic changes, contrary to what is commonly believed, is relatively slow, not up to the expectations [20]. Innovative culture is shaped by the education process, prevailing habits, patterns and the presence of innovative organizations operating in the neighborhood of traditional companies [1]. In the system, no part will work properly without proper cooperation. The above argument gives us a partial answer, why the same technologies and organizational and social solutions, tested in other countries, eg in Germany or the USA, allow to achieve high macroeconomic efficiency and are not effective in others [19].

Introducing the necessity to popularize innovation processes is connected with the need to introduce into their structure at least general knowledge about the first phase of this process, i.e. creating an invention. Such an approach may facilitate the construction of the organizational structure of innovative activities in the enterprise and the growth of inventiveness. The issue of knowledge in this field, adapted to the specificity of food production, is not adequately reflected in the manuals and publications in question.

In the development of new devices for food processing, the main role is played by the causal relationships between the properties of the raw material and the natural phenomena used in their creation (energy transfer, heat and mass exchange, and others). This industry, unlike other industries, processes a specific raw material or treats it to meet specific consumer needs (by eliminating some of its properties and enriching others) [21]. Hence, the role of the properties of this raw material is so important in the development of the construction of machines and apparatus used in this industry – as the authors indicated in the article [8], which started the presented cycle on inventiveness in 2013. Continuing these considerations in this article, in a way summarizing the presented issue, an integrated process, system and dialectical approach was used, which facilitates the understanding of the interdependence of processes occurring in the creation of the invention and provides the basis for its algorithmization.

THE ESSENCE OF INVENTION

The term "inventiveness" is derived from the term "invention", which is used to describe a new technical solution not obviously arising from the state of the art, for which (according to the regulations in force in a given country) a patent may be granted. Without inventiveness, there will be no innovation that is its derivative. Nowadays, in social perception, the key word is the concept of "innovation", which in terms of frequency of use has long dominated "inventiveness" and is treated as its synonym. However, it covers a much wider range of "novelties".

Inventiveness is the creative ability to use thought tools in a targeted support of the process of creating new solutions in all areas of the economy and social life, especially in the area of technology and technology [9, 17]. In solving inventive problems, creative thinking formulates needs (goals, functions) as well as ways of their implementation that relate to abstract beings, as well as structures for their application in the form of machines and apparatuses or their hybrid connections. The problem of understanding inventiveness results from the complexity of the problem. In the most general terms, all activities of the mind of an inventive nature constitute the process of creation in which the so-called "Creative element" – a concept introduced over 100 years ago by J. Schumpeter [16]. It is he who is inherent in all beings created by man, both abstract and material [23].

The authors analyzed the creative element as a determinant of the technical and civilization development of mankind in the article [7], published in the previous issue of this journal. The basis of this analysis was the finding by Przybysławski [15] that the two basic concepts of world development are:

a) development – as decreasing and increasing (cyclicality and repetition),
b) development – as the duality of what is one, into mutually exclusive opposites and their mutual relation (dialectical unity of opposites).

In fact, the image of the changes taking place depends mainly on the context of the analysis (in popular terms it is described by the saying: *the point of view depends on the point of sitting*). In terms of the first concept, it was made in the mentioned article [7], while here it will be presented in terms of the second concept. It is a synthesis of the topics included in the series of considerations and analyzes concerning thinking and inventive practice, resulting from the literature and author's experience in the field of food production. Among others, it is distinguished by the properties of the processed raw materials of plant and animal origin and the energy phenomena of nature used as the main factors determining its specificity in terms of universal knowledge about inventiveness.

Invention is a property belonging to a human being. No "thing" causes or creates another "thing." It is the result of a human idea and deed. Invention is the product of human thinking, the problem-solving process, and the eternal striving to improve the material world.

There is no mathematical formula for the invention that would ensure success for everyone, under any circumstances. In inventiveness, there is a special "interaction" of causal processes (relationship between events) and consciousness processes (relationship between thoughts), related to a large extent to the resources of knowledge. Scientific knowledge along with the ability to use it is the most common source of inventiveness [6, 13]. It is also worth emphasizing that inventions are usually not the result of knowledge from only one field, but several, and not all of them are of a strict or technical nature.

The process of inventive activity is associated with the need to solve specific problems occurring in the mental and material sphere. Invention, which is discussed here, is a correlate in the opposition: the sphere of the mind and the sphere of empiricism, goals and means, values and their material conditions. The determining factor, and thus limiting the course of the inventive process and, more broadly, the innovative process, can be each of the components of the initial situation shown in Fig. 1.

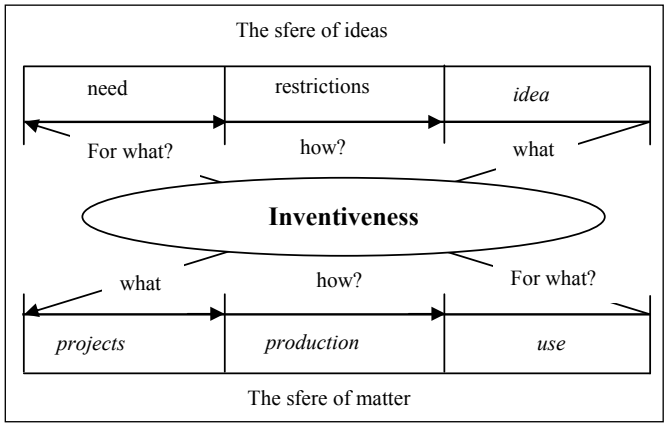

Fig. 1. Diagram of a systemic connection of the problems of inventiveness.

Rys. 1. Schemat systemowego powiązania problemów wynalazczości.

Source: Own study

Źródło: Opracowanie własne

You cannot free yourself from the action of both „external" and „internal" nature – that is, the subjective limitations of the creator, not you can also take a complete break with the environment in which you live [2]. It is a strategy of a higher level of human invention (the mere fact of asking a specific question is an expression of this level). It is a state in which a person acquires greater skills than the average of others, and in his imagination works that were not there before. It is she who, as if dozing in a human being, at least as a leaven of invention, demands implementation, disturbs, captivates, delights. The joy of creating, however, is not the joy of play, but the joy born of the difficulty of unveiling the new [5]. Achieving something essentially new requires an effort of the imagination, a willingness to take risks and overcome resistance to established routine and beliefs, which few can do [10]. This is possible when one can see in material reality something that is missing or something that can be obtained in a better way [17].

Thinking about inventiveness is therefore difficult, and it is even more difficult to follow the meanders of someone's creativity. It is easy to deviate, because many unspoken statements become dead ends. We don't really know how the brain works. As one of the most respected physicists of our times, Michio Kaku writes: *the two greatest mysteries of nature are the mind and the universe* [12].

THE PROCESS AND SYSTEM APPROACH OF INVENTION

Invention needs systemic support. For in order to find certain regularities in the process of creating an invention, we need the "macro-causal", ie systemic, level. Each system is a collection of properly arranged elements. The systems are different, but the approach to researching them and their properties is the same.

The themes of systemic thinking run through history and cultures in various ways, from the Chinese Book of Changes to the Mayan Calendar and from Buddhism to Kabbalah. Originally, however, this knowledge was not practical, but rather met intellectual requirements. In the mid-twentieth century, however, this knowledge began to take on a thoroughly practical aspect. Today, the "systemic approach" is treated as a cognitive, scientific and cultural phenomenon [22].

This approach allows for a significant simplification of the analysis of the socio-economic systems that interact with each other and with the environment. It is also a widely recognized methodology in social sciences, enabling both the use of the black box approximation, and then its gradual "whitening", until obtaining satisfactory descriptions of internal relations and structure [10]. The main feature of the systemic approach is universalism, i.e. the possibility of applying this approach to a wide range of issues. Thinking about the parts of the system produces quite different results if we see these parts as components of a whole, if we look at them holistically [2].

The applicability and the possibility of algorithmization increases as the domain area is specified [22]. For the inventive process itself, especially in the area of food production, two determinants related to a potential invention in the most direct way are important: the material and the set of rules of creative rules. They cannot be treated solely as passive, passive factors. Each material has its own properties and offers its own resistance, each creative rule is more or less obliging. The role of the material was discussed by the authors in the article [8], now a synthesis of thoughts concerning the "set of principles of creative rules" will be presented.

Narrowing (limiting) the concept of "inventiveness" only to the domain area, which is food processing and the range of generic transformations in the properties of agricultural raw materials and dynamic processes occurring in it, made it possible to use the systemic approach to present the algorithmic procedure for creating inventions. Analyzes in the field of food production engineering, using a system approach, are too varied and complex to be presented in such a short article; they were more widely presented by the authors in earlier studies published in this journal. Some of the ideas presented in more detail in the previous ones will therefore be synthesized below.

Inventive efficiency is not determined by a simple gathering of information concerning a specific problem, but by a thought process in which the brain "prepares" from this information the way for a creative idea [5]. In this approach, the algorithmization of creating inventive solutions in the food production industry can be interpreted as: setting out a path of inventive thinking determined by a system approach, and not the creation process itself, based on the use of knowledge about inventiveness and its other areas, adapted to the specificity of agricultural raw materials and the resulting specificity of processes their processing. For, as cognitive sciences claim, "the meaning of words cannot be included in definitions alone." Interpretation gives meaning.

Being creative is not just about looking for something new – anyone can do it, as novelty can be found in any random juxtaposition of things – but about making the novelty pop out of some well-established system [5].

Different people come up with ideas for new solutions at different times and in different places. However, there is no simple recipe: to whom? when? and where? it will happen. It is a derivative of: knowledge, skills and a relatively rare event (accident). While the third aspect is a "gift of fate", the

first two are human-dependent and can be shaped in some way. We start with function (*what is* "it" and *what does it do*?) because function is at the heart of all difficult inventive problems. The diagram presented in Fig. 2 is illustrated the contextual connection of: information, knowledge and skills in the thought system ***Sm***, which leads to the integration of: a function, method and device into the system of implementation (cause-effect) ***Sr***, which is the basis for the algorithmization of the inventiveness triad.

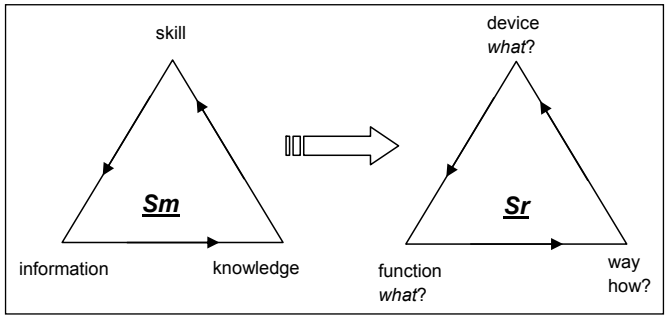

Fig. 2. Contextual integration of the *Sm* thought system and the *Sr* task execution system.
Rys. 2. Kontekstowa integracja systemu myślowego *Sm* i systemu realizacji zadania *Sr*.
Source: Own study
Źródło: Opracowanie własne

The triad of the *Sr* system, ordering inventive thinking, leads to answers to problem questions:

1) what? – resulting from the definition of the function,
2) how? – resulting from the adoption of the procedure. The way defines the essence any technology; includes: specific selection of elements and sequence of actions,
3) what? – resulting from a compelling question (invention) material structure of the working organ or reaction chamber.

Asking the wrong questions may result in setting the wrong course of action at the very beginning [5]. The most common question is how? in place of what? To get the right picture of what to do, you need to prioritize some things and ignore others temporarily. This is the essence of the algorithm procedure. The algorithm for this triad is shown in Fig. 3. These are some fixed points that will help to see the general outline of the procedure. This triad has a hierarchical organization. It maps the distribution of subsystems with specific properties and the ways of connecting these subsystems. Unlike other algorithmization procedures, this procedure is not linear and assumes the possibility of multiple iterations at each of its stages, resulting from the system feedback. Invention is the interaction of ideas with the possibilities of their application through multiple comparisons and improvements to successive versions of a product [11, 14]. This creates a multiple improvement cycle. The use of the "mechanism" of this cycle is one of the secrets of the inventive successes. The essence of this "mechanism" is described by essentialism (following the principle of "less, but better"). This principle can be established in the mind of the inventor or introduced in an artificial intelligence computer program. The starting point for the search for these interactions is the question: *why does not what can (or should) be*? It is the main problem. This question is fully answered by obtaining answers to all sub-questions of the inventive triad.

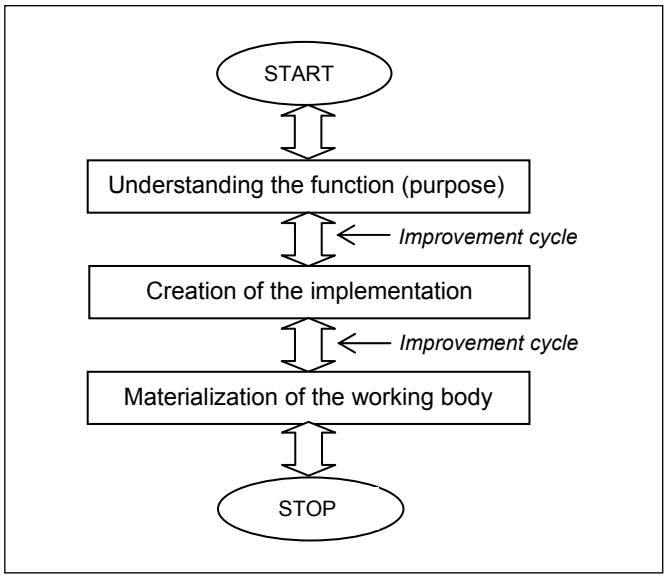

Fig. 3. Design work algorithm for an inventive task.
Rys. 3. Algorytm pracy projektowej dla zadania wynalazczego.
Source: Own study
Źródło: Opracowanie własne

The sub-questions describe the specific problems that are the basis for solving the main problem. The main problem is a kind of problem that cannot be solved with the knowledge available to the inventor. It is right to believe that „a well-formulated problem is half the solution." The description of this task, which is a problematic situation, must therefore include inefficiencies, imperfections and shortcomings in the analyzed area of technology. A problematic situation is an objectively existing (regardless of awareness of it) discrepancy between the existing state (what is it?) And the desired state (what should it be like?). Such a description should not be long and complicated, but should nevertheless go to the heart of the issues that need to be changed. From this description, a first-order constraint can be prepared, i.e. a problem that requires an inventive solution. When setting up an inventive problem one should be aware of (and also describe):

- what do we already know about it and what has already been written about it?
- what are the conclusions and what are the problems for further research?
- in which issues are there controversies, understatements, polemics?

In order to achieve the goal of a technological device fulfilling a given function, it is necessary to find answers (solutions) to the above-mentioned three steps of the inventive algorithm. To specify these steps, it requires (in total) the determination of nine of their constituent elements of systemic structures (located in two-way cause-effect relationships), using the processes of analysis, optimization, synthesis and inference. These subsystems (conceptually treated as autonomous systems) require the indication of

their constituent elements, selected so that cause and effect relationships exist between them. Following the pattern of the procedural triad system (Fig. 2), they can be presented in the form of material and formal system structures, treated as its subsystems, created to find a solution to the problem contained in each of the questions that define them. The models of these subsystems are shown in Fig. 4.

A set of related actions resulting from the action function analysis (Fig. 4a). creates a subsystem of the goal. Invention is most often efficiently oriented (better, faster, more efficient...). After all, we find something for a specific purpose, in particular – to satisfy some or other needs existing at a given time and in a given society. Hence, the inherent (inseparable) property of this subsystem is pragmatism.

From this first set of interdependent elements, information is obtained that determines the function (what?), Which is an input element to the second subsystem (Fig. 4b), which gives the answer to the question how? It is a virtual or mental subsystem, where activities take place in human memory (*vir - Latin human*). These are the three basic thought operations: analysis, comparison and synthesis [14]. In search of an answer to the question of how? three settings should be integrated:

1) *physical*, every thing (as a rule) behaves according to the laws of physics,
2) *design*, the relationship between things results from reflection (design),
3) *intentional*, aimed at achieving the goal better (more efficiently).

Synthesis as a summarizing thought operation concerning the question of how? Creates an input, and at the same time a problem to be solved, in the material (executive) subsystem shown in Fig. 4c, for the question what?, in which the idea for the working organ of the machine or the reaction chamber of the apparatus appears. It is important to know the material, as well as the ability to use specific techniques that will enable its transformation. The scale of possible transformations is very extensive. In food production, they are referred to as "unit processes": from mechanical to thermal and biochemical processes. As a result of the integration of the answers obtained (to each of the sub-questions), a new device appears (a machine or apparatus, sometimes with the features of an invention). The answer to each of the functional questions is thus obtained in a systemic approach in an identical procedure, creating a kind of (verbal) algorithm of conduct, starting from the definition of the function, through the way of work, to the material structure of the working organs.

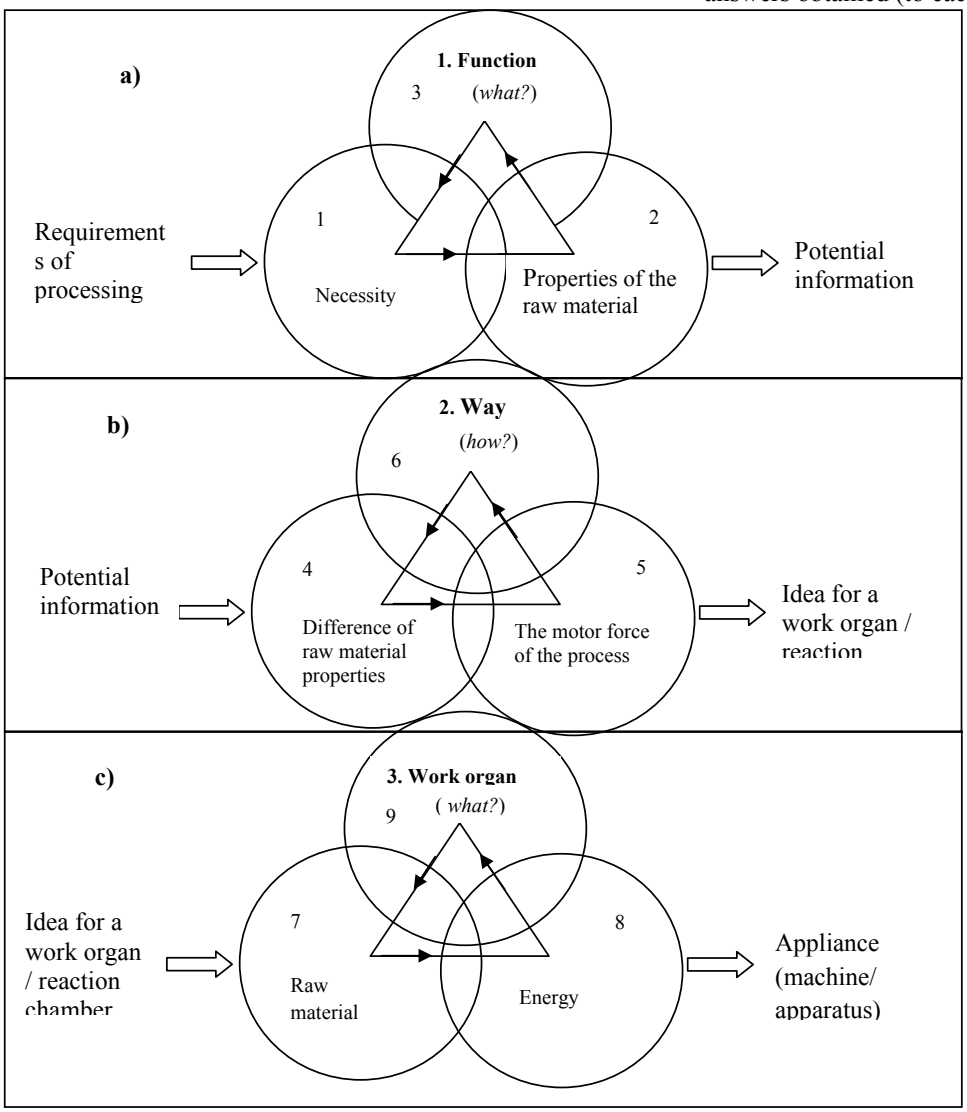

Fig. 4. Implementation subsystems of the inventive triad algorithm.
Rys. 4. Podsystemy realizacyjne algorytmu triady wynalazczości.
Source: Own study
Źródło: Opracowanie własne

The simpler the working organ is and the less it needs powering energy, the better. It is impossible (yet) to know what materials it will be made of, what physical principles will determine it, but it is known to what limit it is going. Their development begins with changes at the macro (part) level and then progresses to the micro (atoms) level. Descent to this level is one of the most important trends in the development of technology.

In every creative activity there can be not only a work-product, but also a work-process (eg the process of interpreting a musical work) [21]. The diagrams of the three component subsystems of the triad of inventiveness presented in Fig. 4 are just such a work-process. It is only against the background of the activities described by these schemes that the multifactoriality and complexity of creative thinking in the area of inventions becomes visible. It should also be emphasized here that even with

rigorous observance of the presented "set of creative rules", it cannot be said that the invention is fully algorithmized. It is neither guaranteed by the raw material nor by these rules, but results from the discovery of a special necessity, a discovery that cannot be foreseen. But, as W. Stróżewski writes, "a happy discovery is a simple consequence of correct reasoning, in which the intermediate terms are sometimes skipped" [21]. This fact is a classic case of the dialectic of inventiveness.

INVENTION DIALECTIC

In the light of knowledge about mental processes, inventiveness has not two, but three faces. In addition to the synthesizing (systemic) and dynamic (process), there is also a third – dialectical. They must be taken into account because the creative process is essentially a dialectical process. During its duration, there is a constant confrontation of various dialectically opposing thoughts [21]. Creative thinking is characterized by "the ability to change the track, combine various threads, the ability to modify the starting material, break patterns and thought blocks, and the ability to act in a situation when we deal with insufficient funds" [14]. That is why the creative process is so exhausting. An illustration of such a triple approach can be seen in Fig. 5.

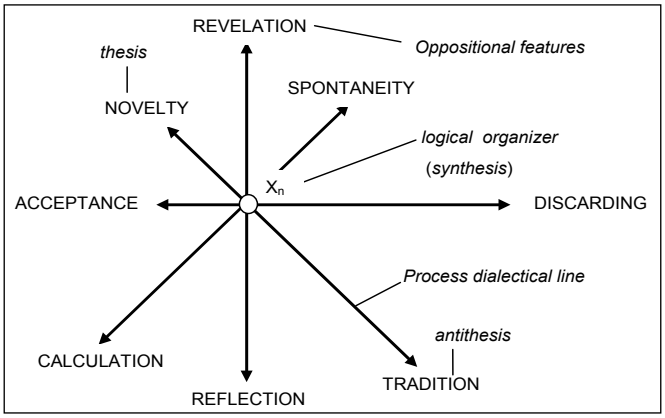

Fig. 5. System-process-dialectical model of creative thinking.

Rys. 5. Systemowo-procesowo-dialektyczny model twórczego myślenia wynalazcy.

Source: Own study

Źródło: Opracowanie własne

This drawing is a graphic illustration of the method of reasoning, which consists in moving from a given concept (thesis) to its opposite (antithesis) and combining them into a higher quality (synthesis). The Hegelian triad: thesis, antithesis and synthesis form a systemic structure that defines the pattern of thought processes. This type of structure is very beneficial for the processes that stimulate creative thinking.

Each activity related to the search for novelty depends on the cognitive processes running along various lines of dialectical opposition (the process nature is described by the arrows on these lines). They create a „tension" in the mind of the inventor from passing thoughts from one opposition to another. The mental life of an inventor is a constant change of narrative: from acceptance to rejection, from calculation to spontaneity, etc. It is a continuous process. The consensus between a thesis and an antithesis results from the creative synthesis of thought and can be described by some *logical organizer* $x_n\{X\}$, which abolishes the contradiction between dialectical oppositions. The unique organizer is functionally reflected in the form of an equally unique path of activity in the brain's neural network. As a result of this reflection, there may be novelty having the features of the invention.

Anyone who is inventive knows, however, that behind what is realized in an invention, there remains an ideal, non-exhaustible "rest", an insight into which this novelty opens and closes at the same time (dialectical unity). Each invention is therefore "a bit like" [5]. Therefore, completing one task somehow necessitates undertaking the next one (the dialectical law of improvement). When changes are introduced, the creator's dialectical coupling with his work continues. The creative process ends – when the contemplation of the work begins. The term "dialectic" in ancient Greece meant the art (skill) of proper reasoning when speaking or talking. In modern times, however, the term is used much more often in the philosophical sense prevailed by Heraclitus. Through this concept, he recognized "the variability of reality and the unity of opposites as the principle of the existence of the world" [3].

Why the authors support the analysis of the inventive process in dialectical terms, can be best explained by the encyclopaedic statement that: "dialectical reasoning concerns statements that arouse controversy and are also based on unverified hypotheses. Dialectics does not deal with problems that can be solved with logical inference peculiar to deductive sciences. Its principles are applied to argumentation in those areas that are devoid of formalization – when the rules of formal logic are not obvious or binding. The arguments analyzed by dialectics are not based on the inevitable cause-effect relationship, but on probability. This is the case with the inventive process.

With regard to creativity, this concept was thoroughly analyzed by W. Stróżewski in his book Dialektyka creative [21]. In this work, however, the author clearly stipulates that the subject of his deliberations is artistic creation, and thus other types of creativity, such as scientific or technical, are excluded from the sphere of direct interests. Hence, the authors made the effort to analyze this issue in relation to technical creativity, in which inventiveness plays a dominant role.

Dialectics is a process that permeates all reality. This means that reality is in its essence dynamic, changeable, transformations of one state into another take place in it. Therefore, when examining the inventive reality, this feature cannot be omitted from the description. The dialecticality of the creative process consists in the fact (as W. Stróżewski writes) in the fact that in each of its aspects that appear to the researcher, there are opposing moments or forces which only in their tensions show the essential features of this process. These tensions are different each time, have a different "intensity", a different "drama", but they always lead to something different, and at the same time new in its essential form [21]. Since it is difficult to analyze the course of human thinking or to consider the various stages of the formation of ideas, creativity is usually judged on the basis of its effect, i.e. output. Creative is considered not only an artistic product, but also any product that is new and valuable [14].

In assimilating inventive thinking, the basic question that an inventor asks himself is: how to do it differently to get a better effect? Hence, a dialectical indication for inventive activity may be the saying of Voltaire *better is the enemy of good*. The aim of this activity is to bring closer or reveal the *better*. One thing is to be sure that nothing that is not explained physically can play the "better" in any invention - there is no miracle *perpetual motion machine*.

The creator answers the question addressed to him by value. The choice of values adopted by him determines the choice of one of the possible ones, contained in the starting point, and thus the rejection and, in this sense, the negation of others. Each invention has its own (but not exhaustive) "value selection". The adopted values determine its originality. In the field of inventions, the value is primarily utility, resulting from pragmatism. An innovation (in a broader sense) can be a novelty that has value in other areas, e.g. aesthetics or organization.

According to Stróżewski, the necessity to assign a creative process to one of the values does not determine the fact that "a necessity related to a certain value may be rejected in favor of a necessity related to another value", for example the usefulness of, for example, a nuclear weapon may be rejected in favor of environmental protection.

In the dialectics of creativity, apart from the methodological perspective, we also have an axiological and sense-creating perspective. The point is "to know what it is, to know that it can be changed, and to know that there is something that can happen as a result of this change, and is now waiting to be realized. And then that something, even if it is good, can become better, and the better is in the field of view " [21].

It is also worth mentioning that if an inventor sees a specific value in the invention he shapes, it does not mean that the society and specialist knowledge will discover the same value, hence not all "novelties" reported to the patent office obtain their legal protection, e.g. in the form of a patent or utility model. The value of "novelty" therefore comes from the outside and is not subject to dialectical dynamics.

The dialectic of inventiveness can in fact be reduced to two main processes: separating anything and combining anything. An example, in relation to food production, can be the original invention of mechanization of separating fish from ice, using the difference in the density of these materials. The scientific thesis (there is a difference in density) and its dialectical antithesis gave an answer to the questions: what? and what?, and this (as a result of creative synthesis) led to the implications of the invention. The idea of the method of implementation arose in the human mind through a systemic approach: the properties of the raw material, the more precisely mentioned differences in density, buoyancy force (Archimedes' law) and needs (more efficient work), which are also a kind of elements of inventive thought. If this relationship had not resulted in the materialization of this thought (cause and effect process) regarding the method (question: how?) And the device (question: what?), Then the process of separating fish from ice would still be done by hand.

For the purposes specified in the subject of the article, the dialectic used is related to the procedure, so it can be defined as "techne dialectics" (art, skill). Systemically, two opposing methods can be distinguished:

a) inventive, intentional (planned) dialectic.

b) non-intentional (unplanned) inventive dialectic.

The authors provided in-depth descriptions of these methods in relation to the food production industry in their article from 2015 [18]. In the first case, it is used to describe rationally planned activities in the field of creating novelties with an inventive aspect. The flagship example of this type of behavior was the activity of the greatest inventor in human history, Thomas Alva Edison (1841-1931). The world's first "invention factory" organized by him, in Menlo Park, New Jersey, planned to create a small invention every 3 months, and a large one every 6 months (the output of this "factory" is over 1000 patents).

The inventive procedure used by T. Edison was based on the "trial and error" method. Nowadays, in such cases, the inventive algorithmization method is used, mainly based on the TRIZ theory, developed by H.S Altszuller [2]. This acronym, derived from the Russian words "Теория решения изобретательских задач", means „Innovative Problem Solving Theory". It is designed to overcome the mental inertia resulting from habit, education and existing paradigms of TRIZ to solve the problem with a creative solution, ie understanding the problem as a system and reaching its ideal solution (IFR) by resolving internal contradictions. Consequently, inventing inventions can be done analytically. The first TRIZ indication is „model the system and the problem and don't try to jump straight to the solution" [2]. The inventive procedure presented earlier (Fig. 4) illustrates this recommendation.

Non-intentional dialectics most often results from an unexpected event (the phenomenon of serendipity) and the mental enlightenment of people who are generally not inventive. This moment of illumination, a glimpse of intuition, appears in many statements by the inventors. Glare, or a sudden impulse of thought allowing one to become aware of something important, is called the „Eureka effect". It is a phenomenon related to the experience of the opening of a new reality, of a sudden understanding of the true (deeper) meaning of many issues. It alludes to the historical cry (heureka Greek – I found) uttered by Archimedes when he discovered the law of buoyancy during his experiments in the bathtub. The *serendipity* itself is not an invention, but an opportunity for its creation. Before it arises, however, there must be people who can understand practically. There are only two ways for them to arise: they must either evolve their own understanding, or be designed to be properly understood by those who have previously evolved [5].

An outstanding (for humanity) example of an invention derived from the phenomenon of serendipity (luck) may be the discovery of penicillin in 1928 by the Scottish physician A. Fleming. The phenomenon of serendipity was also the reason for the discovery of kevlar, one of the strongest materials in the world, by an American chemist of Polish origin - Stephanie Kwolek in the laboratories of DuPon in 1965, a microwave oven, X-ray radiation, Teflon, and thousands of other novelties, often (as shown above) features of the invention even on a global scale.

SUMMARY

The *sequence of concepts relating to inventiveness adopted in the title of the article* is logically justified. For anything to arise, including the rare abstract event of solving an inventive problem, a mental and material process is needed. The process of physical metabolism (processed agricultural raw materials) takes place under the influence of motor force, which is a manifestation of the flow of one or more of the 16 known types of energy.

When analyzing various methods of supporting inventiveness, it can be noticed that the inventiveness process has two faces: heuristic and algorithmic. However, we cannot divide into heuristic inventiveness and algorithmic inventiveness, because both of these aspects constantly interpenetrate and both are equally important.

Among the many concepts and procedures presented for supporting the ability to solve inventive problems, two aspects deserve special mention:

a) noticing the process and multi-stage nature of inventions as well as the source meaning and role of information (more broadly, knowledge from many fields), describing information about the material and energy properties of dynamic inventive processes,
b) acquiring the skills of systemic approach to these processes in their formal and material system structures, in which there are cause-and-effect relationships leading to the algorithmization of the invention.

Algorithmization, apart from general assumptions, defines the steps of individual design processes, which makes design work predictable at the level of the assumed partial effects. Moreover, thanks to clearly defined methodological frameworks, the possibility of creative chaos, i.e. the occurrence of an unstructured conceptual phase, is reduced. Considering the ability to algorithmize the procedure from the perspective of inventiveness makes it possible to sensitize to many aspects of the process itself, which, in another form, may be poorly emphasized. The undoubted feature of the algorithm is the ability to use the same mental creation to solve similar or synonymous tasks.

Ideas fully developed for new solutions to the ways of transforming matter and devices for their technical implementation appear relatively rarely. Complex intellectual structures of this type usually undergo a gradual and delayed process of improvement. The above statement applies to all areas, including the food production industry that is important for the development of the world. There is a view that the inventor's failure is a lack of answers to questions that he has not yet asked, which gives rise to great hopes of using the possibilities of artificial intelligence to support the processes of creating inventive solutions, already applicable in practice. Third-generation systems that combine machine learning with knowledge-based reasoning will be able to search millions of data and make conclusions in a specific context (a new, more advantageous solution). In the current state of technology development, the phenomenon of artificial intelligence creativity is more and more common.

Many pharmaceutical and IT companies already support the processes of creating new inventions and technologies with artificial intelligence. Soon computers will be inventions routinely, and it is only a matter of time before they are behind most innovations. Already in 2019, for the first time in the world, applications for patents were filed, the owner of which is to be the DABUS multi-neural network system created by Stephan Thaler from the University of Surrey (United Kingdom). The system can generate ideas and create inventions without human intervention. This example shows the practical possibility of algorithmizing the invention. If the future of technology really belongs to the inventions created by artificial intelligence (which is highly probable), then one must agree with the position that obtaining an appropriate patent by such a system will open a wide range of questions to which there are no clear answers.

PODSUMOWANIE

Przyjęta w tytule artykułu sekwencja pojęć odnoszących się do wynalazczości jest logicznie uzasadniona. Aby cokolwiek powstało, w tym rzadkie wydarzenie o charakterze abstrakcyjnym, jakim jest rozwiązanie problemu wynalazczego, potrzebny jest proces umysłowy i materialny. Proces fizycznych przemian materii (przetwarzanych surowców rolniczych) przebiega pod wpływem siły motorycznej, stanowiącej przejaw przepływu jednego lub więcej spośród 16-tu poznanych rodzajów energii.

Analizując różne metody wspomagania wynalazczości można zauważyć, że proces wynalazczości ma dwa oblicza: heurystyczne i algorytmiczne. Nie możemy jednak dokonać podziału na wynalazczość heurystyczną i wynalazczość algorytmiczną, gdyż oba te aspekty stale się przenikają i oba są jednakowo ważne.

Spośród wielu przedstawianych pojęć i procedur wspomagania umiejętności rozwiązywania problemów wynalazczych na szczególne wyróżnienie zasługują dwa aspekty:

a) dostrzeganie procesowego i wieloetapowego charakteru powstawania wynalazków oraz źródłowego znaczenia i roli informacji (szerzej wiedzy z wielu jej dziedzin), opisujących informacje o właściwościach materialnych i energetycznych składowych dynamicznych procesów wynalazczych,
b) nabycie umiejętności systemowego ujęcia tych procesów w ich formalnych i materialnych systemowych strukturach, w których występują związki przyczynowo-skutkowe prowadzące do algorytmizacji wynalazku.

Algorytmizacja, poza ogólnymi założeniami definiuje bowiem kroki postępowania poszczególnych procesów projektowych, przez co praca projektowa staje się przewidywalna na poziomie zakładanych efektów cząstkowych. Ponadto, dzięki jasno określonym ramom metodologicznym zredukowana jest możliwość twórczego chaosu, czyli występowania nieustrukturyzowanej fazy konceptualnej. Rozpatrywanie umiejętności algorytmizowania postępowania z perspektywy wynalazczości stwarza możliwość uwrażliwienia na wiele aspektów samego procesu, które w innej postaci mogą zostać słabo uwypuklone. Niewątpliwą cechą algorytmu jest możliwość wykorzystania tegoż samego tworu myślowego do rozwiązywania podobnych, względnie bliskoznacznych zadań.

Pomysły w pełni ukształtowane na nowe rozwiązania sposobów przekształcania materii i urządzeń do ich technicznych realizacji pojawiają się stosunkowo rzadko. Tego typu złożone konstrukcje intelektualne zwykle podlegają procesowi stopniowego i rozłożonego w czasie ulepszania. Powyższe twierdzenie dotyczy wszystkich dziedzin w tym, ważnego dla rozwoju świata, przemysłu produkcji żywności. Istnieje pogląd, według którego *porażka wynalazcy to brak odpowiedzi na pytania, których jeszcze nie zadał*, z którego wynikają wielkie nadzieje wykorzystywania możliwości sztucznej inteligencji, do wspomagania procesów tworzenia rozwiązań wynalazczych, znajdującej już zastosowanie w praktyce. Systemy trzeciej generacji łączące uczenie maszynowe z wnioskowaniem opartym o wiedzę, będą mogły przeszukiwać miliony danych i wnioskować w określonym kontekście (nowego, korzystniejszego rozwiązania). W aktualnym stanie rozwoju techniki zjawisko kreatywności sztucznej inteligencji jest coraz bardziej powszechne. Już obecnie wiele firm farmaceutycznych i informatycznych, wspomaga procesy tworzenia nowych wynalazków i technologii sztuczną inteligencją. Wkrótce komputery będą tworzyły wynalazki rutynowo i jest tylko kwestią czasu, zanim będą stały za większością innowacji. Ten czas już nadszedł. W 2019 r. po raz pierwszy na świecie złożono bowiem wnioski na patenty, których właścicielem ma być, stworzony przez Stephana Thalera z Uniwersytetu Surrey (Wielka Brytania), system wielu sieci neuronowych imieniem DABUS. **System może generować pomysły i tworzyć wynalazki bez ingerencji człowieka**. Przykład ten wskazuje na praktyczną możliwość algorytmizacji wynalazku. Jeżeli rzeczywiście przyszłość technologii należy do wynalazków wytworzonych przez sztuczną inteligencję (co jest wysoce prawdopodobne), to trzeba się zgodzić jednak ze stanowiskiem, że uzyskanie odpowiedniego patentu przez taki system otworzy szeroki wachlarz pytań, na które nie ma jednoznacznych odpowiedzi.

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Cardiovascular diseases (CVDs) have been the main cause of death in Europe for years. The development and the course of the CVDs depends on a variety of factors, among other things, nutritional ones. Legume seed products contain high levels of nutrients and phytochemicals linked with the cardiovascular health benefits. The paper provides up-to-date knowledge on the nutritional value and processing and utilization of legume seeds as well as effects exerted by nutrients and bioactive compounds contained in legumes on the cardiometabolic risk factors intermediating in development of cardiovascular diseases. Familiarity with these issues is necessary for a proper planning of nutrition in patients with CVDs risk.

Key words: legume seeds pulses, soybean, cardiovascular risk, cardiometabolic factors.

Choroby sercowo-naczyniowe (CVDs) są od lat główną przyczyną zgonów w Europie. Rozwój i przebieg CVDs zależy od wielu czynników, w tym żywieniowych. Przetwory z nasion roślin strączkowych są bogatym źródłem składników odżywczych i fitozwiązków, które wpływają korzystnie na układ sercowo-naczyniowy. W artykule scharakteryzowano aktualną wiedzę na temat wartości odżywczej, procesów przetwórczych i wykorzystania nasion roślin strączkowych oraz wpływu składników w nich zawartych na kardiometaboliczne czynniki ryzyka pośredniczące w rozwoju chorób sercowo-naczyniowych. Ich znajomość jest niezbędna do prawidłowego planowania żywienia dla osób z ryzykiem CVDs.

Słowa kluczowe: nasiona roślin strączkowych, soja, ryzyko sercowo-naczyniowe, czynniki kardiometaboliczne.

INTRODUCTION

Despite decreasing trends in mortality from cardiovascular diseases (CVDs) [13], CVDs remain the main cause of death in Europe, including Poland. They are responsible for 46% of the total deaths (more than 4 million deaths yearly) in the continent. The number of CVDs death is higher in women than men [62]. In 2016 there were approximately 167 thousand deaths (48,8% of women and 38,2% of men) in Poland resulting from diseases of the circulatory system [15].

High fat diet rich in saturated and trans fatty acids or high carbohydrate or high sodium diets are major contributors to the risk of cardiovascular diseases. On the other hand, adequate vegetable consumption is the cornerstone of dietary approaches for CVDs and the other chronic diseases primary prevention. Current dietary guidelines promote an increase in intake of all vegetables, but legumes (comparing to all vegetables, but also to other food products) are completely unique. Soy legumes, but also non-soy legumes have high nutrition value as a result of high content of protein, unsaturated fatty acids, complex carbohydrates, fiber, vitamins, minerals and bioactive compounds beneficial for cardiovascular health. Legume seed products, especially soy products, can be used as ready to eat or cook products, functional technological

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ingredients, nutrition value enhancers and meat analogues. Replacing energy-dense food with legumes has been shown to have beneficial effects on the prevention of cardiovascular diseases [38, 60].

Given that the soy (soybean) and non-soy (pulses) legumes have a different nutritional profile [8], the aim of the present review is to summarize the existing evidence regarding legume intake and cardiometabolic factors intermediating in development of CVDs, differentiating between soy and non-soy legume seeds. We did not include studies considering fresh legumes and peanuts that have nutritional similarity with nuts [8].

CVDs RISK AND PREVENTION

Cardiovascular diseases cover a broad group of medical problems that affect the heart and blood vessels (the circulatory system), often resulting from atherosclerosis involving large and medium sized arteries. Coronary heart disease (CHD), cerebrovascular disease and peripheral artery disease (PAD), are main groups of CVDs. Clinical manifestations of these diseases include angina, myocardial infarction, transient cerebral ischaemic attacks, strokes and intermittent claudication [35].

Cardiovascular diseases etiopathogenesis is complex and multifactorial. Among factors inducing or enhancing the pathogenic processes in the heart and blood vessels the first place is mentioned to be taken by lifestyle factors such as tobacco use, an unhealthy diet and physical inactivity. These modifiable risk factors result in obesity and progression of atherosclerosis which lead to CVDs [35, 54].

Obesity is independent risk factor for developing CVDs and one of the main causes of the increased risk of other cardiometabolic factors such as dyslipidaemia, insulin resistance, hyperglycaemia, type 2 diabetes (T2D) and hypertension. Under these pathological conditions oxidative stress, inflammatory signals, macrophage accumulation in the wall of vessel, coronary calcification and thrombosis as well as overstimulation of renin-angiotensin and sympathetic nervous systems dysregulate endothelial activation and functions, and influence the pathogenesis of atherosclerosis. Atherosclerosis is a chronic immune-inflammatory disease characterized by atherosclerotic plaques formed in the wall of vessels, consisting of necrotic core, calcified regions, accumulated modified lipids (mainly oxidised low density lipoproteins – oxLDL), and endothelial cells, leukocytes, inflamed intimal smooth muscle cells, and foam cells [5, 10, 11, 26, 29, 35, 49, 51, 57, 69, 71]. The relationships between lifestyle and cardiometabolic risk factors for developing CVDs are presented in Figure 1.

Type 2 diabetes increases CVDs risk and cardiovascular incidences. Pathological vascular processes predispose to cardiovascular diseases worsen when T2D and hypertension coexist. Endothelial dysfunction in obesity, insulin resistance, diabetes and atherosclerosis diminishes production and/or availability of nitric oxide (NO) which is relaxing factor, and disrupt balance between vasoconstriction and vasodilation, growth promoting and inhibitory factors, proatherogenic and antiatherogenic factors, and procoagulant and anticoagulant factors. These functional changes in the vessel wall are accompanied by proliferation, hypertrophy, remodeling and apoptosis of vascular smooth muscle and degradation of endothelial cells [49, 53, 57, 69].

Continuing exposure to cardiometabolic risk factors leads to further progression of atherosclerosis, resulting in vascular stiffening, destabilization of the atherosclerotic plaques, formation of thrombus, narrowing of blood vessels or total occlusion and obstruction of blood flow to vital organs, such as heart and brain. It constitutes a crucial step regarding the risk of acute cardiovascular events [26, 49].

In addition to lifestyle and cardiometabolic risk factors which can be prevented, changed, or controlled, non-modifiable risk factors, as genetic factors, ageing and gender enhance the risk for CVDs. Psychosocial factors, such as chronic emotional stress, symptoms of depression, and low socioeconomic status are also of importance [35, 71].

Important modifiable factor for CVDs is the diet. High fat diet rich in saturated and trans fatty acids or high carbohydrate diet rich in simple sugars or high sodium diet and diets low in mono- and polyunsaturated fatty acids and fiber are the crucial players in the development of the cardiovascular diseases. Lifestyle changes including consuming a diet full of vegetables, fruits, and whole grains, low fat dairy products, poultry, fish, legumes, non-tropical vegetable oils, and nuts and limiting intake of saturated and trans fats, cholesterol, sweets, added sugars, salt and sugar sweetened beverages as well as red and processed meats, may provide the cardiovascular health benefits. Other lifestyle changes including increasing physical activity, avoiding cigarette smoking and alcohol intake, and maintaining a healthy body weight will optimize health benefits. Effective actions will reduce not only mortality, but also morbidity, disability of CVDs and improve quality of life [6, 9, 22, 34, 38, 50, 60].

Diets recommended by international cardiovascular clinical practice guidelines, as Dietary Approaches to Stop Hypertension (DASH), Mediterranean, Portfolio, Nordic and vegetarian dietary patterns have been shown to have a decreasing effects on cardiometabolic risk factors and reduce cardiovascular incidence and mortality [7, 12, 25, 60]. Legumes, whose relevance is characterized below, are considered as a part of these healthy dietary patterns.

LEGUME SEEDS CHARACTERISTIC

Legumes are the pod or fruits of plants that belong to *Leguminosae* (also known as *Favaceae*) family. *Leguminosae* is one of the three largest families of flowering plants and includes the soybeans, chickpeas, lentils, beans, peas, and broad beans among others. Grain (food) legumes can be divided into two groups, the pulses and the oilseeds. The pulses group includes dry seeds of cultivated legumes which are traditional food. The oilseeds group consisting of soybean and peanut is used primarily for their oil content [3, 33, 37].

Legumes are widely grown and used for food purposes because of their unique nutritional value, appropriate functional attributes and low production cost. Chemical composition of legume seeds depends on variety, species and region. Compared to other vegetables, pulses and soybeans are characterized by a higher energy value and protein content (20-45% dry weight). Although soybeans are the richest

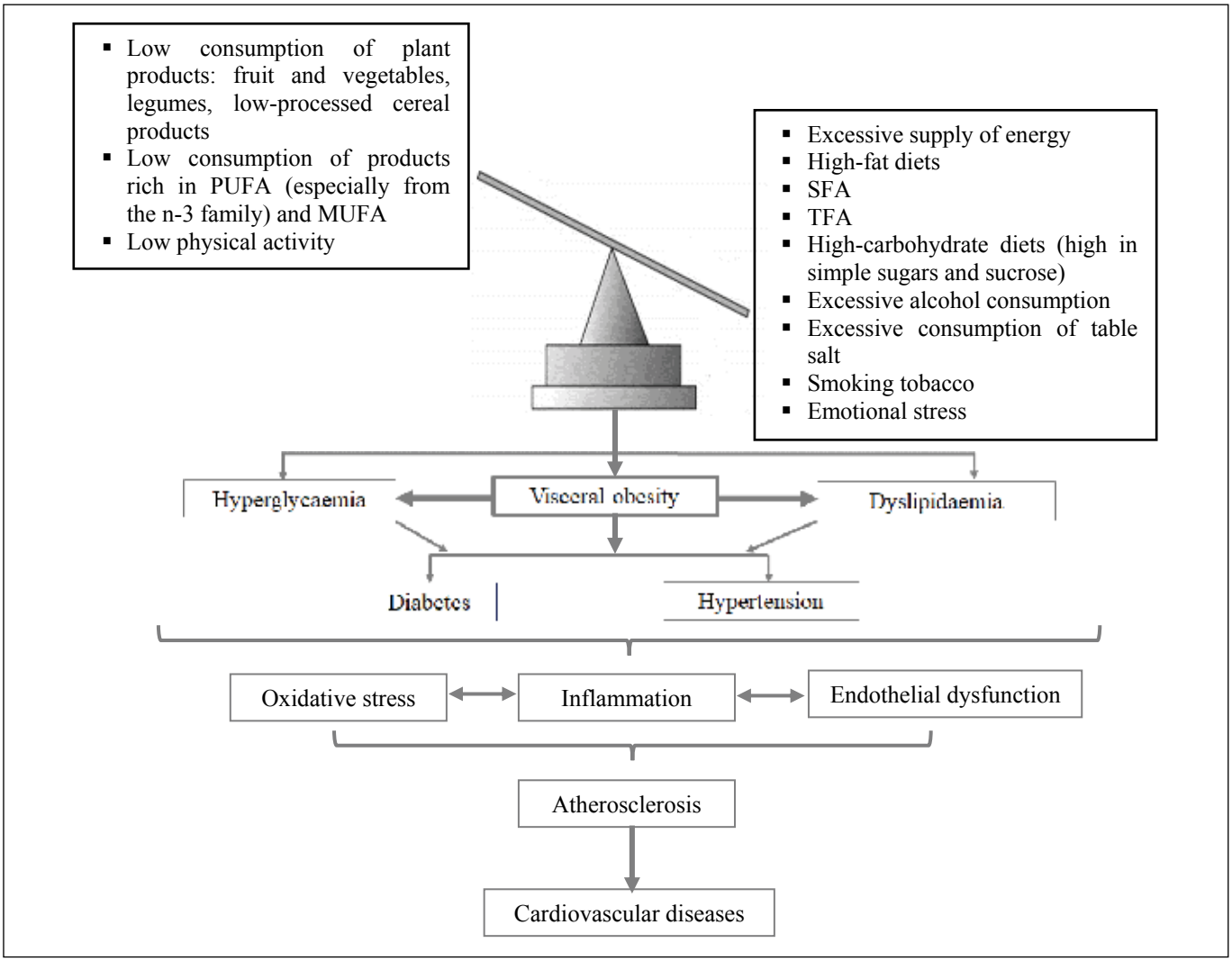

Fig. 1. Relationships between lifestyle and cardiometabolic risk factors for developing cardiovascular diseases (PUFA – polyunsaturated fatty acids; MUFA – monounsaturated fatty acids; SFA – saturated fatty acids; TFA - trans fatty acid isomers).

Rys. 1. Zależności między stylem życia a kardiometabolicznymi czynnikami ryzyka rozwoju chorób sercowo-naczyniowych (PUFA – wielonienasycone kwasy tłuszczowe; MUFA – jednonienasycone kwasy tłuszczowe; SFA – nasycone kwasy tłuszczowe; TFA – izomery trans kwasów tłuszczowych).

Source: Own study

Źródło: Opracowanie własne

source of protein, other legumes are also good source of cheap and widely available proteins with essential amino acids. Legume seeds have an average of twice or triple as much protein as cereals and the nutritive value of the proteins is usually high, though the bioavailability of animal proteins is still proven to be higher. The protein digestibility is affected by other legume compounds like carbohydrates, lipids, and especially anti-nutritional factors. Legume proteins can be divided into four fractions – albumins, globulins, prolamins and glutelins. The majority of pulse and soybean proteins are globulins (approximately 70% of the total legume protein) which can be divided into two groups, namely vialin and legumin. Legumes are gluten free, what makes them suitable for celiac disease patients or individuals sensitive to gliadin or glutenin. Legume (with the exception of soybean) proteins are low in sulphur-containing amino acids (methionine, cysteine and cysteine) and tryptophan, but they have greater amounts of lysine than cereal grains. Improved nutritional quality can therefore be achieved by combining legumes with cereals [37, 45, 52, 59, 61, 66].

Legume seeds are a good source of complex, energy providing carbohydrates (60% dry weight), mainly amylose starch (30–40%), soluble and insoluble fibre (5–37%), and resistant starch. Legumes typically contain more insoluble than soluble fibre. The total fibre content of legumes ranges from 8% to 27,5%, with soluble fibre in range 3,3–13,8% dry weight. Legumes contain also oligosaccharides (consisting mainly of raffinose and stachyose), sucrose and monomers such as glucose, galactose, arabinose, rhamnose, xylose and mannose. The high content of carbohydrates and dietary fibre makes the seeds of legumes have a low glycemic index (GI) [37, 52, 64].

Most legume seeds are very low in fat (<5% energy from fat), with the exception of chickpeas and soybeans (15% and 47%, respectively). Legumes are low in saturated fatty acids and cholesterol-free. An important component of legumes are mono- and polyunsaturated fatty acids (MUFA and PUFA), i.e. oleic acid, omega-6 linoleic acid and omega-3 α-linolenic acid, and phytosterols [37, 45].

Legumes contain water soluble B-group vitamins, namely thiamine, riboflavin, niacin, pyridoxine, folic acid and the vitamin A precursor β-carotene, and minerals, such as iron, calcium, zinc, potassium, phosphorus, copper, selenium, manganese, magnesium and chromium [9, 37, 52]. Beans are good source of folate, and two or more servings of some legumes can provide approximately 400 mg, which represents close to 100% of the daily requirement [52]. Legumes are a poor source of fat soluble vitamins, vitamin C (except broad bean) and are low in sodium [37].

The energy, macronutrient, fibre and micronutrient content of some commonly consumed legumes are presented in table 1.

Legumes contain non-nutrient bioactive compounds with antioxidant properties including polyphenols and their derivatives such as flavanols, flavan-3-ols, anthocyanins/ anthocyanidins, condensed tannins/proanthocyanidins and tocopherols as well as saponins and glycosides. Soy isoflavones (genistein and daidzein and their respective β-glycosides, genistin and dadzin) constitute a special group among phytochemicals [1, 37, 39].

Nutritional value of legumes is limited by the presence of proteinaceous and anti-proteinaceous anti-nutritional factors such as some enzyme inhibitors (trypsin and chymotrypsin proteinase inhibitors), phytic acid, flatulence factors (rafinose family oligosaccharides), lectins (hemagglutinins or phytohemagglutinins), tannins, cyanogens, non-protein amino acids and saponins. Many legumes contain a few of these anti-nutritional factors, only a few legumes may contain all of them. Tannins and cyanogens are the two anti-nutritional factors that are present almost in all legumes. Proteinase inhibitors and tannins decrease protein digestibility if they are not properly inactivated during processing. Phytic acid forms a complex

Table 1. Energy and nutritional value of some commonly consumed legumes in Poland [30]

Tabela 1. Energetyczność i wartość odżywcza najczęściej spożywanych w Polsce roślin strączkowych [30]

Parameters \ Legumes	Soybean*	White beans*	Pea*	Broad bean	Red lentil*
	in 100g				
Energy (kcal)	382	288	293	66	327
Proteins (g)	34.3	21.4	23.8	7.1	25.4
Carbohydrates (g)	32.7	61.6	60.2	14.0	57.5
Starch (g)	4.8	40.8	44.0	5.4	44.5
Dietary fibre (g)	15.7	15.7	15.0	5.8	8.9
Fats (g)	19.6	1.6	1.4	0.4	3.0
Saturated fatty acids (g)	2.82	0.19	0.22	0.06	0.45
Oleic acid (g)	4.07	0.12	0.22	0.08	0.51
Linoleic acid (g)	9.80	0.33	0.52	0.17	1.14
α-linolenic acid (g)	1.49	0.58	0.10	0.01	0.27
Thiamine (mg)	0.690	0.670	0.770	0.090	1.072
Riboflavin (mg)	0.189	0.230	0.280	0.060	0.446
Niacin (mg)	1.18	2.20	3.10	2.40	3.20
Pyridoxine (mg)	0.81	0.53	0.30	0.06	0.60
Folate (μg)	280	187	151	145	36
Vitamin C (mg)	0	2	2	32	3
β-carotene (μg)	12	0	117	170	60
Iron (mg)	8.9	6.9	4.7	1.9	5.8
Calcium (mg)	240	163	57	60	46
Phosphorus (mg)	743	437	388	57	301
Magnesium (mg)	216	169	124	24	71
Potassium (mg)	2132	1188	937	261	874
Zinc (mg)	3.46	3.77	4.20	1.62	3.34
Copper (mg)	1.5	0.48	0.50	0.10	0.85
Manganese (mg)	2.49	2.00	2.03	0.39	1.35

* - in dry seeds

* - w nasionach suchych

with trace elements and macroelements such as zinc, calcium, magnesium and iron, in the gastrointestinal tract and makes them unavailable for absorption and utilization by the body. It can also inactivate digestive enzymes such as proteases and amylases of the intestinal tract, thus inhibiting proteolysis. Lectins, cyanogens and non-protein amino acids are major anti-nutritional toxic factors limiting the use of legumes. Raffinose, verbascose, stachyose and ajugose are not digested and absorbed in human small intestine due to lack of the enzyme α-galactosidase to cleave the α-galactosyl linkage. These oligosaccharides accumulate in the large intestine where the α-galactosidase containing intestinal bacteria degrade them and subsequent anaerobic fermentation results in production of hydrogen, carbon dioxide and methane. These gases result in abdominal discomfort due to a flatulence and sometimes cause diarrhea. Fortunately, most of the anti-nutritional factors are inactivated or reduced by traditional prolonged cooking and food processing, which increases the bioavailability of nutrients as well as improves flavour and palatability. Moreover, recent research has shown potential health benefits of some of anti-nutritional legume compounds such as polyphenols and saponins [1, 28, 37, 40, 47, 52]. Cotyledons and seed coats of some legumes contain a variety of pigments (for example chlorophyll, carotenoids, lutein and β-carotene) resulting in specific colour of legume seeds [63].

LEGUME SEEDS PROCESSING AND UTILIZATION

Legumes may be consumed by humans in several forms. Most of the crops from both legume groups are harvested as dried grains, but several legumes may be eaten raw as cooked or green vegetables if are picked before the pods are fully ripened and dry out. Dried legume seeds cannot be consume raw and therefore there are processed into semi-finished or finished products through several processing steps (primary and secondary unit operations). Food can be processed at different levels, home-based or industrial, that could be at the cottage or on a large scale [61].

Primary unit operations in the processing of legumes include sundrying, husking (hulling), winnowing, separation and storage. During secondary unit operations before use legumes are sorted and cleaned by dry or wet methods to remove dirts, stones, chaff, broken and spoilt seeds and other foreign materials [61]. Next legume seeds are prepared for consumption by soaking, blanching (soaking in hot water or boiled in water for few minutes), boiling/cooking (traditionally, microwave or under pressure), extrusion, autoclaving, roasting, fermenting, germinating, milling, ultrafiltration, sieving, frying, canning, confectioning, and enzyme processing. Beans can also be used as spices or condiments or processed into vegetable oil that may be extracted by pressing or by solvent extraction. These physical or biochemical processes increase the digestibility of plant proteins and carbohydrates and bioavailability macronutrient and micronutrients in legumes as well as inactivate enzyme inhibitors, and also reduce or eliminate the other anti-nutritional factors such as tannins, phytic acid, hemagglutinins etc. Some of these processes e.g. fermentation and germination, activate endogenous enzymes (α-amylase, phytase, and other glucosidases) which degrade anti-nutritional factors as well as improve the appeal and eating quality of legumes. Chicken peas and broad beans are usually germinated before being eaten, cooked, or used in salad dressings. Canning cooked beans in brine, sugar or tomato purees allows for all year round availability of the product and for food preservation. However, beans processed in this form are expensive [1, 14, 43, 59, 61].

Wet-milling of seeds results in a paste production while dry-milling will produce flour. Wet milled legume may be mixed with other ingredients and steamed in leaves to obtain pudding (moinmoin) or fried in hot oil to produce bean cake (akara). The rehydrated flour may be used to obtain these products. Dry or wet sieving removes unwanted materials from ground legume seeds. Example of wet sieving is in the filtration of ground soybean paste in the production of soymilk. This process removes the okara, an unwanted residue from soybeans. Sieving dry-milled legume flour, in turn, helps to achieve different ranges of particle sizes [61]. Different legume flours may be used as a natural colouring component in the production of durum wheat semolina pasta. Addition of legume flours is also a good way to increase the nutritional value of wheat pasta [63].

A variety of processed soybean products are classified into two groups, non-fermented and fermented (by microorganisms and their enzymes). The former products include soybean milk, tofu (soybean curd), soy cheese, yuba (a sheet-like coagulant formed on the surface of warm soy milk as it cools), soy flour and soybean sprouts. Fermented products, on the other hand, include soy sauce, soy paste, fermented tofu (sufu/furu) and fermented whole bean. These traditional products have a specific aroma, flavor and taste, and have their own local names in each country [19, 20, 36].

In Thailand, most fermented soy products are similar to Chinese soy fermented products mentioned above. Tempeh, originated from Indonesia, is made from whole soybeans which are fermented with spores of *Rhizopus oligoporus*. Tempeh has also been produced from other legumes or mixture with whole grains. The major traditional soybean foods in Japan are soy paste (miso and natto), soy sauce, tofu and its derivatives. Soybean sauces such as shoyu and tamari traditionally used in Asian cooking are processed by fermenting soybeans, usually with the addition of grains [36, 44, 61].

Soy is a plant whose seeds are widely used in the food industry. The basis for the use of soybeans in the food industry is primarily its high protein and fat content. Soya is used to make pastes, to produce substitutes for cereal products (bread, noodles, flour) dairy products (soy milk, cheese), and meat substitutes. Soy milk is the basis for the production of various types of cheese, yoghurts and powdered soy milk, while full-fat flour is used for the production of bakery and confectionery products, sauces, soups, as well as meat extenders and animal protein substitute so-called "Soy meat" and the so-called "Soybean fish". The following modern technologies are expected to create new products from soybean and create a new market for them: extrusion cooking, high pressure cooking, ohmic heating and others [37, 44, 45, 66]. Possible utilization of non-fermented and fermented soy products is summarized in table 2.

Table 2. Soy-based products utilization [19, 20]
Tabela 2. Wykorzystanie produktów sojowych [19, 20]

Soy product		Utilization
Soy milk		powdered soy milk, soy crude, soy cheese, yoghurts, soy-corn milk
Okara		vegetarian dishes, tofu, yuba
Tofu	silk	a replacement for mayonnaise and cream in dressings and dips as well as puddings and fillings
	soft	replaces ricotta in lasagne, an ingredient in fruit smoothies
	hard	for the production of hamburgers, pates, dishes imitating roast and goulash meat as well as seasoning mixtures
Yuba		meat analogues, for wrapping stuffing, addition to soups and desserts; when fried, it creates a layer that imitates roasted chicken skin
Soy flour and grits		a flour filler or improver in the production of bread and certain meat and delicatessen products; ingredients of vegetarian, gluten-free, textured products and protein hydrolysates
Soy protein concentrate		addition to meat substitutes in the meat and delicatessen industry; used for the production of sausage, luncheon meat, pate and burger; enrichment substance for bread and confectionery products
Soy protein isolate		production of nutrition for infants and children, athletes, people on slimming, health foods, powdered soy drinks, milk replacers, soups, sauces, mayonnaise, bakery and confectionery products; ingredients for edible coatings, mainly in the meat industry; enrichment substance for the production of meatless sausages and meat analogues
Textured soy proteins		production of vegetarian products, dinner concentrates, cereals, vegetable and meat preserves, burgers, meatballs, bread and bakery products, pizza additives; meat extender and substitute in meat and delicatessen products; imitation of ham, bacon, poultry fillet
Tempeh		production of spaghetti sauces, soups, salads, hot spices, casseroles and veggie burgers, meatballs and bacon; addition to other dishes in the form of stewed, deep-fried, marinated and dried
Sufu		use such as ripening cheese
Miso		base for soups, sauces and meat marinades; relish
Natto		addition to rice or vegetables; in dried form as a snack or addition to yoghurts and salads
Soy sauces		flavouring food

The industrial products obtained from legumes, in addition to flour and grits, paste, sauce and vegetable oil, also include texturized vegetable protein, protein concentrates and isolates as well as starch isolates and dietary fiber fractions. The protein extraction methods which are used in the preparation of protein-rich materials are classified into dry and wet processing. Dry method involves the separation of flours and their fractionating into starch and protein rich concentrates at protein level from 40% to 75%. Wet extraction methods including acid/alkaline extraction-isoelectric precipitation, ultrafiltration and salt extraction can be exploited for preparing both protein concentrates an isolates with protein content of 70% and 90% (or higher), respectively. Protein flours, grips, concentrates and isolates from soybeans and pulses can be useful in producing various food products to increase their nutritional value and/or to provide functional attributes such as solubility, gelation, emulsification, oil and water absorption capacity, and foaming. These functional properties of legume proteins impact the texture and organoleptic characteristics of a food [37, 59]. Soy protein concentrates and isolates are a common concentrate and isolate, but they are also made from a variety of legumes such as chickpea, faba been, lentil, mung bean, smooth pea, pea, winged bean, white bean and lupin as well as pinto and navy beans [59, 61]. Pulse protein concentrates and isolates can be incorporated into many food products such as beverages, imitation milk, baby foods, bakery products, meat analogs, cereals, snack food, bars, and nutrition supplements. Legume starch isolates, in turn, are employed as thickeners in soups and gravies in the food industry. Dietary fiber fractions from legume are used in the bakery, meat, extruded products and beverage industries as stabilizers, texturing agents, fortifiers, bulking agents, fat replacers and emulsion stabilizers [37, 59].

In summary legume seed products are attractive not only to vegans or vegetarians, but also to health conscious consumers, athletes, overweight/obese, diabetic and celiac patients. Due to the recommendations to limit the consumption of meat, especially red meat and processed meats, and the high content of vegetable protein, legume seeds are one of the best alternatives to meat in the traditional and plant-based diets.

LEGUME SEED PRODUCTS VS. CVDs

A positive effect of legume consumption on cardiovascular health has been confirmed in many clinical trials, epidemiological and experimental studies. The consumption of legumes, especially pulses was found to significantly reduce total CVDs risk and/or mortality [8, 9, 17, 18, 31, 38, 41, 52, 55, 65], CHD [2, 8, 9, 17, 38, 52, 65] and vascular impairment in PAD [72] as well as myocardial infarction [24, 41], transient cerebral ischaemic attacks [9], stroke [9, 41] and diabetes [8], and all-cause mortality [31].

The mechanism of CVDs protection may depend on the fact that increased consumption of legumes lowers cardiometabolic risk factors: obesity, hyperglycaemia, insulin resistance, dyslipidaemia, hypertension, oxidative stress and inflammation. Thus, legume intake could provide an effective tool in the prevention and management of these CVDs risk factors [4, 16, 46, 67]. A summary of the relationship between pulses and soybeans and CVDs risk factors has been illustrated in table 3.

Table 3. Soy and non-soy legumes and CVDs risk factors

Tabela 3. Sojowe i niesojowe rośliny strączkowe a ryzyko sercowo-naczyniowe

Cardiometabolic factors	Parameters	Legumes	
		pulses	soybeans
Adiposity	Body weight	↓↔	↔
	Body mass index (BMI)	↓↔	–
	Fat mass	↔↓	↔
	Waist circumference	↔	↔
	Waist–hip ratio (WHR)	↓	–
Glucose metabolism	Fasting blood glucose level	$\downarrow^{1,2,3} \leftrightarrow^{2}$	↔
	Fasting blood insulin level	$\downarrow^{1,2} \leftrightarrow^{2}$	$\downarrow^{4} \leftrightarrow^{5}$
	Postprandial blood glucose level	↓	–
	Glycosylated blood proteins	$\downarrow^{1,2,3}$	↔
	Homeostatic Model Assessment – Insulin Resistance (HOMA-IR)	$\downarrow \leftrightarrow^{2,3}$	↔
Lipid profile	Total cholesterol level (TC)	↓	↓
	Low-density lipoprotein cholesterol level (LDL-cholesterol)	↓	↓
	High-density lipoprotein cholesterol level (HDL-cholesterol)	↔	
	non-HDL-cholesterol level	↔↓	↓
	Lipoptotein (a) level	↓	–
	Apolipoprotein B level (apo-B)	↔	–
	Triglyceride level (TG)	↓	↓
Blood pressure	Systolic blood pressure (SBP)	↓↔	$\leftrightarrow^{4} \downarrow^{5}$
	Diastolic blood pressure (DBP)	↔↓	$\leftrightarrow^{4} \downarrow^{5}$
	Mean arterial blood pressure	↓	–
Inflammation	C reactive protein level (CRP)	↓↔	↓↔
	Interleukin 6 level (IL-6)	↓↔	↓↔
	Tumour necrosis factor α level (TNF-α)	↓↔	↓↔
Oxidative stress	Markers of oxidation	↓	↓
	Total antioxidant capacity		–

↓ – decrease, ↑ – increase, ↔ – no effect, – – no data, 1 – alone, 2 – as a part of low-glycemic index diets, 3 – as a part of high fiber diets, 4 - whole soy diets, 5 – purified isoflavones or isolated soy protein

↓ – spadek, ↑ – wzrost, ↔ – brak wpływu, – – brak danych, 1 – samodzielnie, 2 – w ramach diet o niskim indeksie glikemicznym, 3 – w ramach diet bogatych w błonnik pokarmowy, 4 – w ramach pełnowartościowych diet sojowych, 5 – oczyszczone izoflawony lub izolaty białka sojowego

Source: Own study

Źródło: Opracowanie własne

Dietary pulses may be favourable for weight loss and may reduce body fat under both neutral and negative energy balance diets. Diets that included dietary pulses diminished body mass index (BMI) and waist–hip ratio (WHR), but did not significantly reduce waist circumference, while a trend was seen in trials that favoured a reduction in body fat [8, 16, 29, 55, 72]. Soybeans, in turn, did not influence of aforementioned measures of adiposity [8].

Dietary pulses may contribute to the weight loss effect because of being high in fibre and protein and low in the GI. The satiating properties of pulses are one of the mechanisms that could explain their anti-obesigenic effect. The high-fibre content of dietary pulses contribute to the feeling of fullness because it increases the chewing time, thereby decreasing intake rates and stimulating an interaction of neural and hormonal signals that mediate satiety. Moreover, the soluble

fibres are able to delay gastric empting and the absorption of macronutrients as they form viscous gels, thereby slowing their passage through the gastrointestinal tract. Last, high-protein food such as pulses stimulates the secretion of the intestinal hormones that regulate appetite and causes the sensation of fullness. These effects of pulse fibre and proteins may help prevent overeating and promote weight control. Another mechanism may have been the reduced amount of energy from fat and starch that can be metabolized, because fibre and cell walls of pulses lower the access of digestive enzymes to the starch granules and decrease physical contact of the nutrients with intestinal villi [29, 32, 48, 52]. Additionally, it has been suggested that indigestible carbohydrates intake and amino acids composition of pulses may play a role in their effects on energy expenditure. Short-chain fatty acids (SCFAs) formed during colonic fermentation of soluble fibre and resistant starch of legumes, increase glycogen storage, decrease glycolysis, thereby stimulate hepatic fat oxidation and energy expenditure. Furthermore SCFAs, particularly propionate, may induce satiety. Glutamine has been shown to increase postprandial energy expenditure, whereas arginine, a major amino acid in pulses, has been shown to have thermogenic properties that enhance carbohydrate and fat oxidation [52].

Legume consumption, while focusing on pulses, lowers glycaemic responses after meal and improves glucose tolerance and medium- and long-term markers of glycaemic control. Pulses were found to decrease fasting and postprandial glucose and insulin levels, glycosylated blood proteins (glycosylated haemoglobin and fructosamine) and peripheral insulin resistance. Normalization of glycaemia, insulinaemia and glycosylated proteins reduces cardiovascular events [8, 16, 52, 58, 64]. Non-soy legumes used alone or in low GI or high-fibre diets improve glycaemic control in individuals with and without diabetes. Glycaemic benefits appeared to be modified by pulse type. The strongest evidence for benefits was for chickpeas, but potential benefit was also seen for beans: black, white, pinto, red and white kidney and fava beans [58]. In contrast, soy food consumption did not influence on most measures of glycaemic control and insulin resistance. Whole soy diets, but not purified isoflavones or isolated soy proteins, reduce fasting blood glucose and insulin levels. A reduction in fasting blood glucose levels was observed after consumption of soy nuts in adults who were at cardiometabolic risk. Diet containing soy nuts did not reduce fasting blood glucose concentrations in postmenopausal women with or without metabolic syndrome. Moreover, fasting blood glucose, insulin or Homeostatic Model Assessment – Insulin Resistance (HOMA, a marker of insulin resistance) did not reduce after the consumption of soy nuggets, desserts, and soy-based drinks [8].

Starch composition and digestibility is the main mechanism that contributes to the regulation of the glycaemic response to pulse and whole soy food intake. Amylose starch digestion and intestinal absorption of its products are significantly lower compered to amylopectin starch. Therefore plasma glucose levels and insulin requirement are reduced after high amylose meal. Moreover, protein-starch interactions and the high fibre content in pulses may further hinder starch digestibility [52]. Additionally, slowly digested starch and high content of fibre make legumes have low GI that reduces blood glucose concentration and insulin release [29, 58, 64]. The discrepancy in results between whole soy food and isolates of soy protein or isoflavones suggests that other (than protein and isoflavones) soybeans components or their interactions might explain the effect of whole soy intake on the improvement of glucose control [58].

Legumes in the diet are related to cardometabolic risk reduction because they improve not only carbohydrate metabolism, but also lipid profile [18, 55, 64]. Non-soy legume consumption, such as beans, peas, chickpeas, lentils and mix pulses (flour and whole food) was found to reduce total, low density lipoprotein cholesterol (LDL-cholesterol), triglycerides and lipoprotein (a) levels. Effects of pulse products were observed in predominately middle aged, normolipidemic or hiperlipidemic adults at moderate risk of CHD. Elevated LDL-cholesterol concentration is a major risk factor of atherosclerosis and cardiovascular incidences and its decreasing is a main goal of dyslipidaemia's therapy. A 5% reduction in LDL-cholesterol concentrations after pulse diet suggest that pulses consumption might reduce the risk of major cardiovascular events by 5-6%. No effect of dietary pulses was reported on apolipoprotein B (apoB), as well as high-density lipoprotein cholesterol (HDL-cholesterol) and non-high-density lipoprotein cholesterol (non-HDL-cholesterol) levels [8, 18, 31, 70]. Moreover, in patients with diabetes, pinto beans and lentils consumption did not have a beneficial effect on lipid profile [8].

It has been shown that soybean-enriched diet, soy protein and isoflavones also improve lipid profile [4, 8, 67, 68]. Soy products (including soy nuggets, burgers, desserts and drinks) significantly reduce LDL-cholesterol, triglycerides, non-HDL-cholesterol and total cholesterol concentrations. Additionally, levels of HDL-cholesterol is increasing. High-density lipoprotein (HDL) has a variety of functions that contribute to anti-atherogenesis [7, 8, 67, 70]. It is worth emphasizing that whole soy products, such as soy milk, soybeans and soy nuts reduced LDL-cholesterol to greater extent than soy extracts or supplement. The hypolipdemic effects of soy products were more pronounced in hypercholesterolemic than in healthy subjects [8].

There are several mechanisms that could explain the hipolipidemic effects of legume-based products. Dietary pulses may contribute to the hypocholesterolemic effects because of being high in soluble fibre. Viscus fibre has the ability to bind to bile acids within the intestine and prevents their reabsorption, thereby the liver increases bile acids production and excretion, resulting in a reduction in the hepatic pool of cholesterol. As a consequence, cholesterol uptake from the blood increases, leading to a reduction of circulating concentrations of cholesterol. Additionally, SCFAs generated during bacterial fermentation of soluble fibre in large intestine might inhibit expression of hepatic enzyme limiting for cholesterol synthesis. Furthermore, other pulse components, such as polyphenols and saponins, might be responsible for the reduction of in serum total cholesterol, triglycerides, LDL-cholesterol, and a significant increase in HDL-cholesterol [8, 34, 38, 52, 55, 64].

The hypolipidemic action of soy-based products might be attributed to soy protein that might decrease the expression of transcriptional factor and genes of lipogenic enzymes, which

in turn reduce the biosynthesis of fatty acids, triglycerides and very low-density lipoprotein (VLDL) – the main blood transporter of triglycerides. Moreover, a globulin fraction of soy protein might regulate the synthesis and estrification of cholesterol. On the other hand, isoflavones and amino acids from soy protein might increase hepatic and extrahepatic uptake and degradation of cholesterol through the simulation of the expression of the low-density lipoprotein (LDL) receptor [4, 8, 42, 70]. Additionally, isoflavones as a agonists of estrogens might cause a reduction in blood cholesterol concentrations by binding to estrogen receptors [8]. Also, other constituents of soy, such as soluble fibre, lectin or saponins might act independently or synergistically with soy proteins and exert the lipid-lowering effect [8, 52].

Non-soy legumes have blood pressure-lowering effects [8, 29, 52, 65]. Pulses reduce systolic (SBP) and mean arterial blood, but diastolic blood pressure (DBP) changes are often no greater in comparison with diets containing animal foods. Soy isoflavones and proteins, but not whole soy products, have shown a potential beneficial effect. Soy-based products, such as nuggets, burgers, drink, desserts, and soy nuts or soy flour did not reduce SBP, DBP and 24-h ambulatory blood pressure. In contrast, soy nuts significantly diminished SBP and DBP in hypertensive women and postmenopausal women without metabolic syndrome and DBP in those with metabolic syndrome and SBP in normotensive women. Isolated soy protein supplements and soy milk had also anti-hypertensive effects in hypertensive subjects [4, 8, 23, 42].

Dietary pulses may contribute to the hypotensive effects because of being high in protein and fibre. Increase in protein and/or fibre consumption has been associated with reduced SBP and DBP. Furthermore, these two pulse components may have an additive effect on blood pressure reduction. Additionally, different minerals occurring in non-soy legumes, such as potassium and magnesium have been associated with a blood pressure lowering effect [8, 27, 52]. Anti-hypertensive effects of soy protein, in turn, is mediated by its production of angiotensin converting enzyme inhibitor [4, 42].

Among the potential mechanisms of cardiovascular protection, the antioxidant and anti-inflammatory action of legume compounds may mediate their effects [4, 38]. Legumes are rich in polyphenols, which have been demonstrated to be associated with a significant reduction of oxidative stress markers and stimulation of antioxidant defence systems. Non-soy legume-enriched diets reduced lipid peroxidation, especially concertation of plasma-oxidized LDL and enzyme that generates superoxide anions in arterial cells. On the other hand, they increased nitric oxide and antioxidant enzymes, such as catalase and superoxide dismutase expression and activity [8, 52]. Polyphenols reduce oxidative stress-induce degradation of nitric oxide and vasoconstriction, as well as endothelial dysfunction and increase total antioxidant capacity [1, 41, 52, 55]. Soybeans are also dietary sources of isoflavones, α-linolenic acid and vitamin E, which have CVDs protection probably by their antioxidant effects [4, 38]. Soy consumption reduced advanced oxidation protein products in women, but not in men. The low GI, high fibre content of soy and non-soy legumes and SCFA production and action are another properties that may also improve oxidative stress [8].

Analyses that evaluated the effect of non-soy legume consumption on inflammatory markers are poor and contradictory. In overweight and diabetic adults diets with lentils, chickpeas, peas and beans reduced levels of inflammatory markers, such as interleukin 6 (IL-6) and tumour necrosis factor α (TNF-α). Non-soy legumes lowered also peripheral level of C-reactive protein (CRP) a marker of general inflammation, which is elevated in the presence of CVDs and its cardiometabolic risk factors. Moreover, an evening meal consisting of brown beans decreased IL-6 and interleukin 18 (IL-18) levels. In contrast, in another studies, no effects in CRP, IL-6 and TNF-α were observed after diets enriched pulses [8, 21, 55, 56]. Soy isoflavones, whole soy foods, soy beverages or soy bread did not lower concentrations of CRP. Similarly, soy nuts did not reduce CRP, TNF-α an interleukins, such as IL-6, IL-18 or IL-10. However a significant reduction in circulating CRP was observed in postmenopausal women with and without metabolic syndrome after soy nuts consumption [8]. Dietary fibre (soluble and insoluble) and resistant starch content in pulses can explain the potential effects showed on CRP and other inflammatory markers, because this constituent was inversely associated with different inflammatory markers concentrations. SCFAs, PUFA, L-arginine, magnesium, and phenolic compounds (phenolic acids, flavonoids and anthocyanins) also have well documented anti-inflammatory potentials. Polyphenols have been shown to inhibit cellular enzymes that produce pro-inflammatory metabolites of fatty acids, such as arachidonic acid, prostaglandins and leukotrienes, thus exerting an important anti-inflammatory action, as well as downregulate the expression of pro-inflammatory markers. Additionally, non-soy legume's ability to reduce body weight and hyperglycaemia, and its low GI may also mediate in anti-inflammatory effects by the inhibition of production of advanced glycation end products, thereby decreasing the production of acute-phase reactants [8, 21, 52, 56].

Intakes of legume nutrients and bioactive compounds may also protect against atherosclerosis. Dietary fibre is supposed to ameliorate not only body metabolism and reduce chronic inflammation by affecting body weight, serum lipid profile, blood pressure and insulin sensitivity, but also reduce fibrinolysis and coagulation that may be important in the prevention of atherosclerotic plaque development and progression. Moreover, legume proteins hydrolysed in the digestive tract are a source of bioactive peptides (e.g. lunasin) which have been demonstrated to exert cholesterol-lowering effects, blood pressure-lowering ability as well as antithrombotic and antioxidant activities. Legumes have also folic acid that reduces homocysteine levels and therefore, reduces the risk of atherosclerosis and stroke. It has also been shown a strong association between polyphenols intake and reduction of atherosclerosis. Polyphenols have not only multiple antioxidant and anti-inflammatory effects, but also inhibit platelet activation thereby preventing activation of a prothrombotic state, lower expression of adhesion molecules and inhibit of smooth muscle cells proliferation [34, 38, 42, 52, 66].

Besides the aforementioned potential effects of pulse and soybeans on cardiometabolic risk factors, another potential mechanism of protection is due to the fact that increased intake

of legumes reduces the intake of animal sources of protein that are high in saturated fatty acids and total fat which are one of the strongest atherosclerosis and CVDs incidences risk factor [38].

In summary, neither soy legumes nor non-soy legumes affect all cardiometabolic risk factors to the same extent. It may depend on many factors, such as interactions between components of legumes and other food products in the diet or daily amount of soybeans and/or pulses consumed, as well as inter-study heterogeneity, which was high in some analyses. Regardless of this, particularly strong cardiovascular health benefits have been observed with consumption of pulse, such as beans, peas, lentils and chickpeas.

CONCLUSION

Soybean and pulse seeds have an unique nutritional, functional and health attributes. Before use they are subjected to many traditional and modern thermal, mechanical and biochemical processes that allow to achieve the different forms of legume products: ready to eat (e.g. soy milk, tofu, sufu, tempeh, paste, sauce, soy oil) or cook (soy texture proteins) or semi-finished products used by food producers (flours and grits of different fat content, and concentrates and isolates). Processing techniques of soybeans and non-soy legumes reduce or eliminate anti-nutritional factors and enhance digestibility and bioavailability of nutrients as well as improve organoleptic properties of final products.

Systemic revives and meta-analyses of prospective cohort studies and randomized and non-randomized controlled trials have shown that legumes have a beneficial and complex effect on the cardiometabolic factors for the CVDs, including obesity, hypertension, hyperglycaemia and dyslipidaemia. Components contained in legumes and processed legume seed products such as vegetable protein, complex slowly digested carbohydrates, fiber and polyunsaturated fatty acids, as well as B-group vitamins, minerals and numerous bioactive compounds exert a multidirectional effect on satiety, energy expenditure, glucose and lipid homeostasis, and endothelium function, as well as have antithrombotic, antioxidant and anti-inflammatory properties in the endothelial and vascular smooth muscles cells. These variety of mechanisms determine the anti-obesity, antidiabetic, hypoglycemic, hypolipidemic, hypotensive and antiatherosclerotic effects of pulses and soybeans. Therefore, consumption of soy and nonsoy legumes may reduce the risk of morbidity and mortality from cardiovascular diseases.

Consuming legumes as a vegetables and processed legume seed products should be more common in Poland and should be recommended as a means of optimising cardiometabolic factors of CVDs risk in the primary prevention of cardiovascular diseases and their acute or chronic incidents.

PODSUMOWANIE

Nasiona roślin strączkowych charakteryzują się wyjątkowymi właściwości odżywczymi, funkcjonalnymi i zdrowotnymi. Przed spożyciem poddawane są wielu tradycyjnym i nowoczesnym procesom termicznym, mechanicznym i biochemicznym, które pozwalają na uzyskanie produktów o zróżnicowanym stopniu przetworzenia: gotowych do spożycia (np. mleko sojowe, tofu, sufu, tempeh, pasty, sosy, olej sojowy) lub gotowania (teksturaty białkowe) oraz półfabrykatów wykorzystywanych przez przemysł spożywczy (mąki i grysy o różnej zawartości tłuszczu oraz koncentraty i izolaty). Techniki przetwarzania soi i innych roślin strączkowych przyczyniają się do redukcji lub eliminacji składników antyodżywczych oraz zwiększają strawność i biodostępność składników odżywczych, a także poprawiają właściwości organoleptyczne gotowych produktów.

Przeglądy systematyczne i metaanalizy prospektywnych randomizowanych i nierandomizowanych kohortowych badań z grupą kontrolną wykazały, że rośliny strączkowe mają korzystny i złożony wpływ na kardiometaboliczne czynniki ryzyka chorób układu sercowo-naczyniowego, w tym na otyłość, nadciśnienie tętnicze, hiperglikemię i dyslipidemię. Składniki zawarte w roślinach strączkowych i przetworzonych produktach z nasion roślin strączkowych, takie jak białko roślinne, wolno trawione węglowodany złożone, błonnik pokarmowy i wielonienasycone kwasy tłuszczowe, a także witaminy z grupy B, składniki mineralne i liczne związki bioaktywne, wywierają wielokierunkowy wpływ na sytość, wydatek energetyczny, homeostazę glukozy i lipidów oraz funkcje śródbłonka, a także mają właściwości przeciwzakrzepowe, przeciwutleniające i przeciwzapalne w komórkach śródbłonka i mięśni gładkich naczyń. Te różnorodne mechanizmy działania wymienionych składników sprzyjają redukcji masy ciała i decydują o właściwościach przeciwcukrzycowych, hipoglikemizujących, hipolipemizujących, hipotensyjnych i przeciwmiażdżycowych nasion roślin strączkowych. W związku z tym spożywanie soi i roślin strączkowych innych niż soja może zmniejszyć ryzyko zachorowalności i śmiertelności z powodu chorób układu krążenia.

Spożywanie roślin strączkowych jako warzyw i przetworów z nasion roślin strączkowych powinno być w Polsce bardziej powszechne i powinno być zalecane jako sposób optymalizacji kardiometabolicznych czynników ryzyka chorób sercowo-naczyniowych w profilaktyce pierwotnej chorób układu krążenia oraz ich incydentów o ostrym lub przewlekłym przebiegu.

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PHYTOESTROGENS FROM LEGUME SEEDS AND THEIR ROLE IN THE PREVENTION OF OSTEOPOROSIS IN POSTMENOPAUSAL WOMEN®

Fitoestrogeny z nasion roślin strączkowych i ich rola w zapobieganiu osteoporozie u kobiet w wieku postmenopauzalnym®

Research financed by Polish Ministry of Science and Higher Education within founds of Institute of Human Nutrition Sciences, Warsaw University of Life Sciences (WULS), for scientific research

Praca finansowana przez Ministerstwo Nauki i Szkolnictwa Wyższego w ramach utrzymania potencjału badawczego Instytutu Nauk o Żywieniu Człowieka, SGGW w Warszawie

Menopause is associated with numerous changes and disturbances in a woman's body that reduce her quality of life. They include, among others, disturbances in bone metabolism and with the consequence developing osteopenia and osteoporosis as a result of estrogen deficiency in the body. Legume seeds and their products are a rich source of phytochemicals which, due to their chemical structure similar to estrogens, are estrogenic indicators. The article presents the current state of knowledge on their impact on bone metabolism. Its knowledge is important in planning the nutrition of perimenopausal women due to the knowledge of the risk of developing osteoporosis in this population group.

Key words: phytoestrogens, legume seeds, soybean, menopause, osteoporosis, isoflavones.

Menopauza wiąże się z licznymi zmianami i zaburzeniami w organizmie kobiety, które obniżają jakość jej życia. Należą do nich m.in. zaburzenia metabolizmu kostnego i w konsekwencji rozwijająca się osteopenia i osteoporoza będące skutkiem niedoboru estrogenów w organizmie. Nasiona roślin strączkowych i produkty z nich otrzymywane są bogatym źródłem fitozwiązków, w tym o budowie chemicznej podobnej do estrogenów, wykazujących właściwości estrogenne. W artykule przedstawiono aktualny stan wiedzy na temat ich wpływu na metabolizm kostny. Jego znajomość jest istotna w planowaniu żywienia kobiet w wieku okołomenopauzalnym ze względu na możliwość zmniejszenia ryzyka rozwoju osteoporozy w tej grupie populacyjnej.

Słowa kluczowe: fitoestrogeny, nasiona roślin strączkowych, soja, menopauza, osteoporoza, izoflawony.

INTRODUCTION

Menopause is the term for the last menstrual bleeding, after which menstruation doesn't occur during the next 12 months and no pathological reasons are found to cause this condition. Menopausal period induces significant changes in female organism which trigger many ailments and disorders, including climacteric symptoms, connective tissue lesions, cardiovascular diseases, postmenopausal osteopenia and osteoporosis. All of them lower women's quality of life. Therefore, women in the perimenopausal period should be given a special care by medical professionals, which aims to provide them with access to education about the physiology of the changes occurring in their bodies, the effects of these changes and ways to prevent them and/or minimize their severity. [31].

Osteoporosis is a skeletal disease characterized by an increased risk of bone fractures as a result of an imbalance in bone metabolism with a predominance of resorption over bone formation. In Poland, the problem of osteoporotic fracture applies to nearly 2 million patients over 50 years

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of age. Osteoporotic fracture is associated with huge pain and suffering, it can lead to disability and even death – this is especially true for proximal femur fractures. In order to increase the effectiveness of the fight against osteoporosis, not only efficient diagnosis and treatment are necessary, but above all – effective prevention. [9].

The risk factors for osteoporosis involve: low bone mineral mass, reduction in estrogens production (menopause, including premature and artificial), other concomitant diseases which impair bone metabolism (for example hyperthyroidism, hypogonadism, primary and secondary hyperparathyroidism, anorexia), and applied drugs (for example corticosteroids, proton pump inhibitors, oral anticoagulants, thyroid hormones in suppressive doses). Among them, the primary risk factor for osteoporosis is low bone mineral mass. It depends on both non-modifiable factors (ethnicity, sex, age, genetic factors and familial predisposition) as well as modifiable – nutritional and related to physical activity. Nutritional factors can be divided into two groups – increasing bone mass: 1. protein, calcium, magnesium, zinc, vitamin D, K and C intake in accordance with the demand for these nutrients; 2. appropriate proportions between calcium and phosphorus and 3. presence of phytoestrogens and omega-3 fatty acids in the diet; and reducing bone mass: 1. high calorie diet, excess of sodium in the diet, caffeine, alcohol; 2. smoking tobacco and 3. underweight (defined as body mass index, BMI <18.5). [9, 13, 19].

Nutritional factors, specifically the significance of phytoestrogens contained in processed legume seed products, as modifiable factors, constitute an essential field of the preventive measures and therefore will be discussed in detail in the following article.

ESTROGEN REGULATION OF BONE FUNCTION

Bones as an active metabolic tissue, undergo two opposing processes of the permanent internal reconstruction: formation of the bone marrow through osteoblasts action and resorption of the bone marrow through osteoclasts action. Osteoclasts remove (resorb) bone by acidification and proteolytic digestion, while osteoblasts secrete osteoid (organic matrix of bone) into the resorption cavity. The amount of resorbed bone should be balanced by equal amount of formed bone. The dynamics of this bone remodelling process subjects to hormones regulation, including parathyroid hormone, growth hormone, estrogens, androgens, thyroid hormones, glucocorticoids, and is aiming to maintain a permanent mass on the adequate level of resistance and quality [22].

Estrogens have an important impact on bone physiology. They promote the acquisition of bone mass during puberty and are required for the growth and maintenance of the adult skeleton by slowing the rate of bone remodelling and maintaining a balance between resorption and formation. They primarily are inhibitors of bone resorption that decreases both osteoclast numbers and activity, rather than the enhancers of bone formation. As in other tissues, the effects of estrogens on bone are exerted upon binding with high affinity to the estrogen receptor (ER) alpha and beta. Both ERs have been detected in bone cells, including osteoblasts and osteoclast progenitors and their descendants, as well as B lymphocytes. Estrogens inhibit osteoclast activity and increase osteoclast apoptosis through three different mechanisms. First – through direct signalling, and second – *via* osteoblast secretion of OPG and RANK ligand. Bone resorption and formation are coupled by local factors, and one of the key regulators is the RANK/RANK-ligand/osteoprotegerin (RANK/RANKL/OPG) system. RANK is a receptor expressed on the cell membrane of osteoclast precursors and mature osteoclasts, and its activation stimulates osteoclast differentiation and activity. RANK ligand is secreted by stromal cells or osteoblasts and is the major paracrine factor in activating the bone remodelling unit. OPG is also secreted by osteoblasts and is a soluble decoy receptor that binds to the RANK-ligand and blocks the RANK-ligand/RANK interaction. Therefore OPG is very potent inhibitor of osteoclastogenesis and bone resorption *in vitro* and *in vivo*. The secretion of RANK ligand and OPG is regulated by hormones, including estrogens. These hormones up-regulate OPG expression in osteoblasts mainly through the ERs [17, 39]. Third – indirect – mechanism includes decreased secretion of proresorptive cytokines such as interleukin-1 (IL-1) and 6 (IL-6) and tumour necrosis factor-alpha (TNF-alpha) by bone marrow cells. These cytokines were found to be extremely potent stimulators of bone resorption. Binding of different cytokines to their receptors in osteoblasts causes release of soluble factors that act directly on osteoclasts to modulate their recruitment or activity. Estrogens can inhibit the release of osteoclast stimulatory factors or enhance the release of osteoclast inhibitory factors. They also increase osteoblast differentiation and bone formation, at least partly through inhibition of sclerostin secretion by osteocytes. Sclerostin binding to its receptors on the cell surface of osteoblasts induce a downstream cascade of intracellular signalling with the ultimate effect of inhibiting osteoblastic bone formation. [2, 17].

In premenopausal women 95% of circulating estrogens is secreted by the ovaries, and the remainder is synthesised by extra-gonadal conversion of other sex steroids. In postmenopausal women hormonal activity of the ovaries is minimal and therefore nearly all the circulating estrogens are derived from extra-gonadal conversion of adrenal steroids (by aromatase in fat and other tissues). A decline of estrogens levels in females at menopause is the primary cause of perimenopausal symptoms which significantly lower women's quality of life, among others loss of bone mass and strength and contributes to the development of osteoporosis, one of the most common metabolic disorders of old age. In postmenopausal women, the rate of bone turnover increases dramatically and remains elevated for up to 40 years after cessation of ovarian function, leading to continuous, progressive bone loss. The basis for the increased bone turnover is thought to be due in part to a shortening of the lifespan of osteoblasts and a prolongation of the lifespan of osteoclasts. Moreover, estrogens deficiency may contribute to the development of osteoporosis by decreasing the sensitivity of bone to mechanical loading [2, 22, 39].

PHYTOESTROGENS

Phytoestrogens are non-steroidal compounds of plant origin, which, due to their similarity in structure to natural and synthetic estrogens have a number of estrogen-like effects.

Phytoestrogens have affinity for ERs, therefore they can act as agonists or antagonists of these receptors, competing with estrogens for a binding sites. Phytoestrogens affinity for ERs, compared to estradiol (endogenous estrogen), indicates their less biological activity. However, their effect may be compensated by their amount provided in the diet [16, 18].

Phytoestrogens are divided into various classes of compounds, including flavonoids and non-flavonoids. Among flavonoids two groups are distinguished: isoflavones and coumestans, whereas among non-flavonoids lignans and resorcinol derivatives are distinguished. The most significant group of phytoestrogens and the best studied in terms of their beneficial effects on the human body, including their modulating effect on the ERs, are isoflavonoids. All of the phytoestrogens occur in plants usually in the form of inactive beta-D-glycosides or in a precursor form. Their active forms with a chemical structure similar to estrogens are formed in the digestive tract as a result of complex enzymatic and metabolic transformations. Hydrolysis of glycosides in the human digestive tract occurs under the influence of gastric hydrochloric, intestinal and bacterial beta-glucosidases and beta-glucosidases contained in food. As a result of this process, bioactive forms aglycones are formed which are absorbed in the small intestine. Their further metabolism leads to the formation of active metabolites which have been found in blood, urine, bile, feces, semen, saliva and milk, suggesting the possibility of their effects on the functioning of many cells and organs. The size and range of phytoestrogens metabolism is individual, variable and depends primarily on the amount of absorption of individual phytoestrogens and their metabolites, the qualitative and quantitative composition of the bacterial flora of the gastrointestinal tract and the type of applied diet [7, 11, 18, 29].

Phytoestrogens are found in many plants and their processing products. The richest source of phytoestrogens are soybeans, its processing products and, to a lesser extent, seeds of other legumes (lentils, beans, broad beans, peas, chickpeas), but also their content was detected in fruits and vegetables, and in nuts. Phytoestrogens contained in food products are compounds that are moderately sensitive to the culinary processing techniques used. Soaking the seeds has been shown to reduce the content of polyphenols, including flavonoids, in legume seeds: lentils are the most sensitive and chickpeas the least. Traditional cooking of lentils causes a significant loss of polyphenols (even by more than 50%) and they are comparable to steaming. However, in the case of other legume steaming, it causes significantly lower (even several times) polyphenol losses. Both soaking and cooking are basic and the most popular techniques for culinary processing of legume seeds, it is worth paying attention to the fact that these processes are carried out correctly. No significant changes were shown in soybeans total daidzein/genistein and their glycosides daidzin/genistin content during soaking, while free daidzein and genistein content increased significantly during this process. This can be due to their release from glucosides and/or ester glucosides. In this study the only procedure resulting in the decrease of total phytoestrogens content was boiling [3, 24, 33].

Legume seeds are valued worldwide as an inexpensive meat alternative and are considered the second most important food source after cereals. In addition to their nutritional superiority, legumes have also been ascribed economical, cultural, physiological and medicinal roles owing to their possession of beneficial bioactive compounds. The consumption of legumes has also been reported to be associated with numerous beneficial health attributes. The nutritional demand of legumes is increasing worldwide because of increased consumer awareness of their nutritional and health benefits. Furthermore, recent years have seen more people substituting animal protein with vegetable protein; thus, further increasing the demand for legumes as they are the major source of plant proteins. To meet this demand, there is a need to educate consumers on the nutritional value of legumes. As it was mentioned, soy phytoestrogens are receiving increasing attention for their health benefits related to their consumption. They are also considered natural estrogens with a high safety profile. Soy phytoestrogens with the strongest estrogenic activity because of structural similarity to 17 beta-estradiol are genistein, daidzein and glycitein, which belong to isoflavones [27].

Over the years, there has been a significant decrease in the consumption of dry legume seeds in Polish households. The likely cause of the limited consumption of legumes is probably the necessity of long-term culinary processing of seeds, lack of skills in preparing dishes with their use and the content of anti-nutritional substances. Anti-nutritional substances include: protease and amylase inhibitors, haemagglutinins, phytates, saponins, phenolic compounds, goitrogens, cyanogenic glycosides, allergens, and others. Moreover, legume seed oligosaccharides of the raffinose family do not undergo hydrolysis in the human digestive tract (due to the lack of the α-galactosidase enzyme). High consumption of these sugars with food often leads to an excess of gas production in the gut causing flatulence, abdominal pain and diarrhea. However, although the oligosaccharides in legumes are viewed negatively, their beneficial attributes outweigh their negative properties. Oligosaccharides are prebiotic in nature and therefore, promote the growth of the probiotics, which play a major role in the maintenance of a healthy colon. Therefore, it is worth knowing and using appropriate culinary techniques to reduce their content and avoid or minimize side effects. The process of soaking in hot water (called as “hot soaking”) and traditional cooking cause the greatest changes in the content of these sugars. Most of anti-nutrients mentioned above are heat labile and since legumes are consumed after cooking, they do not pose a health hazard. Legumes can also be ‘detoxified’ by dehulling, soaking, boiling, steaming, sprouting, roasting and fermentation prior to processing. Research has shown that most of these non-nutrients are phytochemicals with antioxidant properties which play a role in the prevention of some cancers, heart diseases, osteoporosis and other chronic degenerative diseases [12, 14, 27, 40].

EFFECTS OF PHYTOESTROGENS ON MENOPAUSE DISORDERS AND ON BONES

Many of perimenopausal women, as recommended, decide to use hormone replacement therapy (HRT) to minimize symptoms of menopause, such as bleeding disorders, vasomotor symptoms, vaginal atrophy, cardiovascular and osteoporosis prevention. According to the statistical data, a number of women receiving hormone replacement therapy

is still relatively small. Moreover, most women discontinue therapy after the first year of application because of irregular vaginal bleeding, mastalgia, nausea, migraine headaches, weight gain, water retention and carcinophobia. All this reasons mean that some women approach HRT with caution and do not use it or look for natural forms of therapy. In addition, there are number of women for whom HRT is relatively or absolutely contraindicated regardless of personal preferences. For this reason, search and development of the alternative forms of therapy that may have benefits as with HRT without side effects, and without contraindications is of wide interest. An alternative treatment route, using plant extracts containing polyphenolic compounds with estrogenic activity – phytoestrogens is becoming more and more popular. Due to its hormone-like properties, however, there is a concern that phytoestrogens will cause undesirable side effects related to their affinity for ERs. Many studies have been carried out to assess the efficacy and safety of compounds, mainly based on an extract of soy-derived phytoestrogens. On their basis, it was found that during the use of phytoestrogens, only the incidence of gastrointestinal side effects, i.e. abdominal pain, as well as subtle muscle pain and slight sleepiness, was higher than in the control group. There was also no relationship between the duration of phytoestrogens treatment and the frequency of side effects. On the contrary, side effects were seen less frequently in women taking phytoestrogens for long periods. These observations indicate that there is no phenomenon of phytoestrogen doses accumulation. The research carried out so far also do not indicate serious undesirable side effects of phytoestrogen treatment, such as in women using HRT (e.g. thrombosis, heart attack, stroke and breast cancer). Therefore phytoestrogens should be proposed to women looking for a safe treatment alternative to the HRT [28, 42].

In recent years, many studies have been conducted on the importance of phytoestrogens in the prevention and treatment of osteoporosis. It was documented, that isoflavones – the main class of the phytoestrogens – have the potential to maintain bone health and delay or prevent osteoporosis but they can provide health benefits only when consumed at sufficient levels, conversely, they have been categorized as endocrine disruptors that cause environmental problems and deleterious effects on reproductive systems. It is important to say that phytoestrogens content in their dietary sources and hence their intake can reach the amount which enables them to achieve effective concentrations in bodily fluids. Isoflavones exert biphasic dose-dependent effects on osteoblasts and osteoprogenitor cells: stimulating osteogenesis at low concentrations and inhibiting osteogenesis at high concentrations [6]. Based on the study of Lousuebsakul-Matthews et al. the frequency of consumption of legumes should be once daily or more to significantly influence bone metabolism (to reduce the risk of hip fracture just in this study) [25].

The greatest interest and the best and widest known phytoestrogens are isoflavones, and among them glycosides: genistin and daidzin and their aglycone forms: genistein and daidzein, respectively. Isoflavones are primarily found in the fabaceae family, and among them the richest source in human diet is soy and its derivatives. Hence most of the animal and human in vitro, in vivo and intervention research are based on the effects of soybeans and their products.

Mechanism of action

Phytoestrogens influence the bone metabolism and functioning but the exact and full mechanism of action is still not completely understood. Phytoestrogens may affect cellular function because of their low molecular weight so they can pass through cell membranes and interact with receptors and enzymes. They are best known for their ability to mimic the activity of estrogens. However, they have a number of other biological effects, independent of those of estrogens. The most widely studied in terms of their mechanism of action are isoflavones, a class of phytoestrogens involving daidzein and its metabolite S-equol, and genistein.

Phytoestrogens bind to estrogen receptors (ERs) and have estrogen-like activity. Whether the induced response will be anti-estrogenic or estrogenic depends, among others on the type of ER (alpha or beta) and its distribution in tissues, as well as the method of phytoestrogens administering, its concentration and to a lesser extent, time of exposure of cells to phytoestrogens. It is important to mention that ER-mediated action has focused on the preferential binding of phytoestrogens to ER beta than ER alpha, which acts as a dominant-negative regulator of estrogens signalling. ER beta expression is increased during bone mineralization and the high affinity of isoflavone genistein towards ER beta could make its action efficient at physiological levels. Phytoestrogens may also stimulate transcription of ER alpha and beta in many different tissues, including bone tissue [6].

It was also shown that phytoestrogens may act *via* mechanisms unrelated to ERs. These non-ERs molecular mechanisms are based on enzyme-inhibiting effects: some phytoestrogens, like genistein, inhibit tyrosine kinase, thus phytoestrogens act as intracellular signal transfer modulators and are able to modulate activity of other substances affecting bone tissue, including hormones insulin, or insulin-like growth factor 1 (IGF-1). Other enzymes inhibited by phytoestrogens are topoisomerases I and II, protein histidine kinase, and mitogen-activated protein kinases (MAPKs), which are crucial for bone cellular signal transduction and functions, especially for bone resorption. It was also shown that peroxisome proliferator-activated receptors (PPARs) are additional molecular targets of phytoestrogens. PPARs are ligand-activated transcription factors, suggesting that PPARs are crucial transcriptional targets of phytoestrogens. PPARs are present in bone tissue - they have been found in bone marrow mesenchymal cells, osteoprogenitor cells and osteoblastic cells, and they are involved in the regulation of bone formation and bone resorption. It was shown that phytoestrogens can dose dependently activate PPARs and induce differential effects on bone. As a result, the balance between concurrently activated transcriptional factors like ERs and PPARs determines the dose-dependent biological effects of phytoestrogens in the target tissues, including bone tissue. It also suggests that phytoestrogens can act as selective nuclear receptor modulators [8, 32].

Phytoestrogens stimulate the synthesis of sex hormone binding globulin and are the inhibitors of several enzymes involved in sex hormones metabolism, including 5 alpha reductase, 17 beta hydroxysteroid dehydrogenase and human P450 aromatase system. In this way phytoestrogens modulate the amount of biologically active hormones circulating in the blood which could affect many tissues, including bone [15, 23].

Phytoestrogens may also influence bone function and structure through indirect mechanisms. Namely, *in vitro* studies showed that isoflavones like genistein and daidzein may modulate intestinal and colonic calcium transport. Moreover, they can increase production of an active form of vitamin D – $1,25(OH)_2D$ – through stimulation of 1 alpha OHase transcription (an enzyme activating vitamin D on the last stage of this activation). In these ways phytoestrogens modulate calcium balance and bone structure and function [30].

A considerable number of studies have been published that have sought to investigate the effect of phytoestrogens on bone metabolism and bone loss in both postmenopausal women and in animal models of postmenopausal bone loss.

Epidemiological studies generally suggest a positive association between soy consumption and bone mineral density (BMD). There is strong epidemiological evidence that Asian women have a much lower incidence of the above diseases compared with western women. Interestingly, emigrant Asian women who adopt a western diet lose their protection. Epidemiological studies have demonstrated that Asian populations with a particularly soy-rich diet have a low incidence of postmenopausal fractures and high BMD. The Study of Women's Health Across the Nation (SWAN) – a multi-site longitudinal, epidemiologic study demonstrated that BMD was positively correlated with genistein intake in premenopausal Japanese women who had a higher intake of genistein compared with African-American, Caucasian and even Chinese women, confirming the importance of the amount ingested in yielding better BMD values at the spinal and femoral neck level. These epidemiological observations have given rise to the theory that phytoestrogen-rich diet could contribute to protect women against postmenopausal osteoporosis [4, 6, 32].

Numerous *in vitro* studies with human and animal osteoblasts or osteoblast-like cell lines, and with osteoclasts, have been carried out, with consistent observations of direct effects of phytoestrogens and related compounds on both cell types. In vitro studies indicate that phytoestrogens could be the ideal candidates for treatment of osteoporosis because they are able to stimulate osteoblastic activity and inhibit osteoclast formation.

Both genistein and daidzein stimulate osteoblast proliferation, differentiation, and activation by an ER-dependent mechanism. In osteoblasts isolated from trabecular bone from young piglets, daidzein increased secretion of both OPG and soluble RANKL and increased concentration of membrane-bound RANKL by an ER-mediated mechanism. Phytoestrogens are able to stimulate osteoblasts to produce protein synthesis and alkaline phosphatase release; in culture, ethanol extracted soy stimulated osteoblast-like cell proliferation, collagen synthesis and alkaline phosphatase activity. In vitro, genistein and daidzein inhibit synthesis of the pro-inflammatory cytokine IL-6 by MC3T3-E1/4 osteoblast-like cells [32, 35, 37, 41].

Genistein and daidzein both suppress osteoclast activity by a number of possible mechanisms. Daidzein has been shown to promote apoptosis of osteoclast progenitors by an ER-mediated mechanism. Low-dose genistein (10^{-8} M) decreased osteoclast numbers in bone marrow culture by decreasing osteoclast viability. Higher concentrations of genistein (10^{-5} M) attenuated osteoclast formation. In a cell line capable of differentiating into osteoclasts (RAW264.7 cells) genistein and daidzein stimulate ER alpha expression and promote proliferation but inhibit multinucleation (and therefore differentiation into the mature osteoclast phenotype). Both genistein and daidzein have been found to inhibit inward rectifier K^+ channels in osteoclasts, leading to membrane depolarization, intracellular influx of Ca^{2+} and inhibition of osteoclast-mediated bone resorption. In postmenopausal women supplemented with genistein for 12 months, the ratio of sRANKL:OPG in serum was significantly lower than in non-supplemented controls. This may indicate that genistein inhibits RANKL-induced osteoclastogenesis in postmenopausal women [32, 35, 37, 41].

These *in vitro* studies are highly important because most of the *in vitro* results have been confirmed in *in vivo* studies where it is possible to evaluate more complex effects on bone such as the variation of bone mineral density. While the mechanism of action for isoflavones remains complex and still elusive, it is evident from the many lines of evidence that there are multiple pathways, genomic and nongenomic, that conserve the integrity and activity of osteoblast and osteoclast cells to maintain stable bone mass in adults. Certainly the presence of estrogen receptors in bone and the wide-ranging biological properties of these nonsteroidal dietary estrogens provide good rationale for thinking that dietary phytoestrogens should play a role in bone remodelling.

Animal and human observational and interventional studies with short or long duration had examined the effects of phytoestrogens, especially soy isoflavones on bone mineral density (BMD) or other indices of bone turnover and they confirm the general findings from the *in vitro* effects of phytoestrogens on bone cells in culture. Markers indicative of osteoblast and osteoclast activity and thus bone turnover that have been measured include among others osteoprotegerin, pyridinoline, C-telopeptides, urinary calcium, magnesium and phosphorous, hydroxyproline, bone-specific alkaline phosphatase, tartarate-resistant acid phosphatase, osteocalcin, insulin-like growth factor 1, and interleukin 6. These studies provided promising but mixed and inconclusive results. This is perhaps not surprising due to the large array of variables known to influence the bioavailability, metabolism and, ultimately, physiological effects of phytoestrogens. Explanations for the inconsistencies included differences in menopausal status, age, inadequate doses of isoflavones and relatively short duration of isoflavone treatment. Moreover, The European Food Safety Authority (EFSA) [10] evaluated the health claims related to the reduction of vasomotor symptoms and the maintenance of bone mineral density by soy isoflavones during menopause. It was concluded that the available evidence was not sufficient to establish a relationship between the maintenance of bone mineral density and the consumption of soy isoflavones. Currently, when the recent data is pooled and scrutinized via meta-analyses, the benefits of isoflavones on bone mass are more clear. For the effects of isoflavones to be seen, long-term use of at least six months and sufficiently high dose seem to be required. Specific skeletal areas seem to be important too. Generally, phytoestrogens isoflavone interventions prevent osteoporosis-related bone loss and thus have beneficial effects

on BMD outcomes and are safe in postmenopausal women. They may be considered as a complementary or alternative option in the prevention and treatment of menopause-related osteoporosis.probably independently from weight status, treatment duration or subjects' ethnicity [1, 4, 5, 20, 21, 26, 32, 34].

It is important to notice that very few studies have assessed the bioavailability of isoflavones; however, isoflavone bioavailability may differ considerably among their source and in different study populations. There is considerable inter-individual variation in isoflavone metabolizing ability. For example, in Western societies only approximately 33% of the population is capable of producing equol. The composition of the gut microflora is a major factor governing daidzein metabolism. There is some indication that individuals who consume high amounts of isoflavones develop higher amounts of flavonoid-metabolizing bacteria in the colon and, therefore, may produce relatively more active forms of phytoestrogens than those with a lower isoflavone intake. Age, race, and dietary components such as the carbohydrate content, presence of probiotics, total amount of fat in the diet, and its type also influence phytoestrogen metabolism. Then, differences among study populations in terms of isoflavone-metabolizing ability may also considerably impact trial outcome [15, 32].

It must also be said that both therapies repeatedly tested, the hormone replacement therapy and phytoestrogens, have beneficial effects on the bone metabolism, causing a significant decrease in bone resorption process. Comparative assessment showed no significant differences between the effectiveness of the hormone therapy and the phytoestrogens used in the study, in terms of effects on BMD and bone resorption, when administered to groups of women with the same sociodemographic and clinical characteristics. Therefore when there is a choice or when there are contraindications to use HRT phytoestrogen "therapy" can be safely and successfully used in prevention and/or support postmenopausal osteoporosis [38].

Menopause is not a disease, but a normal phase in the women life; postmenopausal osteoporosis is a process lasting 15–20 years which primarily affects the trabecular bone only of women at risk. Physicians should maybe restrict their pharmacological approach in favour of advising women in the premenopausal period to abandon dangerous habits, such as smoking, and adopt good levels of physical activity and correct dietary habits. There is a strong possibility that dietary phytoestrogens can counteract the effects of the increased bone turnover in perimenopause avoiding perimenopausal bone loss, as recent studies have suggested.

Functional food based on products of plant origin is assigned a supporting role the body in maintaining good physical condition, mental and helping to prevent, and even treatment of certain diseases. Legumes are widely used in functional food production because their seeds contain a group natural anti-nutritional compounds which constitute the so-called synergists (enhancing effectiveness antioxidant activity). They are also an advantage indifferent organoleptic properties, that allow to obtain products devoid of a specific taste and smell. Oligosaccharides of the raffinose family contained in legume seeds considered in the past as anti-nutritional substances, and for many years have been incorporated into health-promoting functional foods [36].

SUMMARY

In conclusion, up to now phytoestrogens have been seen as alternatives to HRT, but phytoestrogens have different potentialities, being first of all powerful active components of human diet. It appears that the optimal diet for postmenopausal women should contain legumes because food phytoestrogens promise to be pivotal non-nutrient for estrogen-lacking diseases such as postmenopausal osteoporosis. Phytoestrogen-rich foods, being able to improve bone density and metabolism, and being for the most part safe from unexpected long term risks, are emerging as the ideal candidates for the role of functional foods able to reduce the risk of osteoporosis.

PODSUMOWANIE

Fitoestrogeny zawarte w nasionach roślin strączkowych są związkami aktywnymi bardzo szeroko badanymi pod względem ich wpływu na zdrowie człowieka, w tym na zapobieganie i/lub minimalizowanie skutków menopauzy u kobiet. Przedstawione w artykule wyniki potwierdzają, że są one zdolne do poprawy gęstości kości i ich metabolizmu w okresie okołomenopauzalnym. Dodatkowo z ich stosowaniem nie wiążą się żadne długoterminowe zagrożenia. Optymalna codzienna dieta dla kobiet w okresie okołomenopauzalnym powinna zawierać rośliny strączkowe, jednocześnie mogą one stanowić idealny składnik żywności funkcjonalnej, która zmniejszy ryzyko osteoporozy w tej grupie populacyjnej.

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THE IMPACT OF THE HIGH-PRESSURE HOMOGENIZATION ON SOME MICROORGANISMS AND ENZYMES – A REVIEW®

Wpływ homogenizacji wysokociśnieniowej na wybrane mikroorganizmy i enzymy – przegląd publikacji®

The article presents the effect of high-pressure homogenization (HPH) on the reduction of microbial growth and changes in the activity of enzymes in food. The publications on the impact of HPH on the bacteria of the Alicyclobacillus, Escherichia and Lactobacillus genies, yeasts of the Zygosaccharomyces genus, as well as changes in the activity of the enzymes: alpha-amylase, amyloglucosidase, pectin methylesterase, glucose oxidase and neutral protease were reviewed.

Key words: High pressure homogenization, food, microorganisms, enzymes.

W artykule przedstawiono wpływ homogenizacji wysokociśnieniowej (HPH) na redukcję wzrostu drobnoustrojów oraz zmiany aktywności enzymów w żywności. Dokonano przeglądu publikacji dotyczących wpływu HPH na bakterie z rodzaju Alicyclobacillus, Escherichia oraz Lactobacillus, drożdży z rodzaju Zygosaccharomyces, a także zmiany aktywności enzymów: alfa-amylazy, amyloglukozydazy, metyloesterazy pektynowej, oksydazy glukozowej i neutralnej proteazy.

Słowa kluczowe: Homogenizacja wysokociśnieniowa, żywność, drobnoustroje, enzymy.

INTRODUCTION

High pressure homogenization (HPH) Emerged as a non-thermal technology to guarantee food safety, stability with a reduced sensory and nutritional damage [15], consists of pressurizing a fluid to flow quickly through a narrow gap valve, which greatly increases its velocity, resulting in depressurization with consequent cavitation and high shear stress. Thus particles, cells and macromolecules suspended in the fluid are subjected to high mechanical stress, becoming twisted and deformed [1]. In the pharmaceutical, cosmetic, chemical and food industries, HPH processing is used for the preparation and stabilization of emulsions and suspensions or for creating physical changes in products [4].

Moreover, a highly efficient technology for the preparation of drug nanosuspensions is high pressure homogenization (HPH), which achieves size reduction by the cavitation forces generated when drug dispersion is forced through a very narrow gap under extremely high pressure. The particle size of a nanosuspension manufactured by HPH is controlled by the homogenization pressure, the number of cycles, and the hardness of the drug particles [12].

A significant increase in the surface area accelerates the dissolution rates of the drugs, leading to improved bioavailability and rapid onset of action [12].

Several studies have evaluated the use of HPH for microbial inactivation in fruit products. The use of HPH as a partial or total substitute for the thermal processing of foods has been studied.

The aim of this reviewing study is presenting a microbial inactivation and enzymes activity changing effects, caused by the introduction into the manufacturing process the high-pressure homogenization operation.

THE HPH EFFECTS ON MICROBIAL GROWTH

A topic of great interest in food microbiology is the use of nonthermal methodologies for food preservation, i.e. approaches able to prolong food shelf life and inactivate foodborne pathogens and / or spoiling microorganisms without any significant increase in the temperature, in order to maintain the sensorial quality at acceptable levels. Some of these technologies are based on the use of high-pressure, ultrasound, pulsed electric fields or on the addition of natural antimicrobials [3].

High-pressure homogenization has been used to disrupt cells containing larger biospecies such as proteins, antibodies, vaccine particles, and DNA plasmids. In using disruptive fluid forces to break open cells containing such shear-sensitive entities, the potential exists for the product to be destroyed as it is released from the cells. In such a situation, it is likely that the concentration of intact and extracellular product in the homogenizer effluent could be maximized by exposing the cell-containing solution to the optimum combination of fluid dynamic forces inside the homogenizing valve [10]. This impact has been the most accurately documented for Alicyclobacillus, Escherichia and probiotical Lactobacilli bacterias and yeast of Zygosaccharomyces genus.

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The impact of HPH on Alicyclobacillus acidoterrestris was shown in work [2]. This study focused on three different strains of A. acidoterrestris: DSMZ 2498, G4 and c8, isolated from a spoiled pear juice and soil, respectively. The strains were maintained at 4C on malt extract agar slants, acidified to pH 4Æ5 through a sterile solution of citric acid (acidified MEA) [2].

The results confirmed, that high pressure caused a low reduction of inoculated cell number for c8 strain at 1700 bar. G4 population, however, was reduced less at 500 and 1700 bar. The HPH processing caused a strong reduction of inoculated cells of DSMZ 2498 strain. The reduction of inoculated spores was low or low-to-moderate. The reduction of cells and spore number in function of homogenization pressure, is shown in fig. 1.

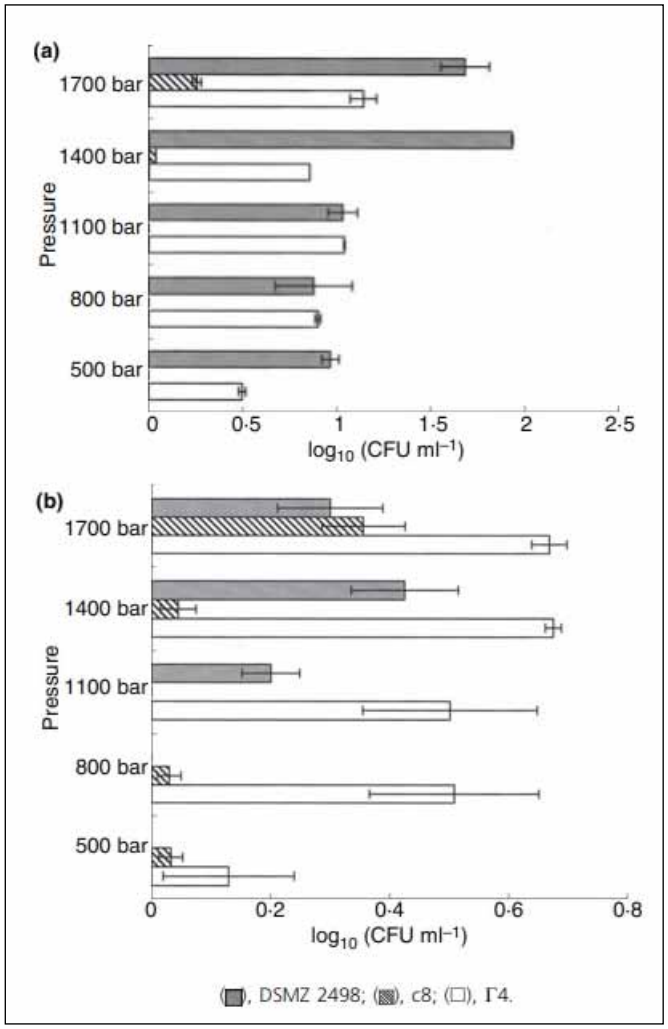

Fig. 1. Reduction of cell (a) and spore number (b) (log10 CFU ml-1) of Alicyclobacillus acidoterrestris in acidified malt extract broth (pH 4Æ5), processed through high-pressure homogenization.

Rys. 1. Zmniejszenie liczebności komórek (a) I przetrwalników (b) (log10 CFU ml-1) Alicyclobacillus acidoterrestris w zakwaszonym bulionie z ekstraktu słodowego (pH 4,5), poddane operacji homogenizacji wysokociśnieniowej.

Source: [2]

Źródło: [2]

Presented work provided useful information on the susceptibility of an emerging spoiling micro-organism, like A. acidoterrestris, to HPH and showed that this technique could be used in the food industry to reduce the thermal damage of fruit juices. Further investigations are in progress in order to clarify the way of action of HPH against A. acidoterrestris and the different mechanisms involved in the susceptibility /resistance of cells and spores. Moreover, the application of several successive rounds of HPH could have an additive effect on the reduction of viability and increase of susceptibility of A. acidoterrestris spores [2].

The next spoiling and very dangerous for food consumer is Escherichia coli bacteria.

In paper [6] was described the inactivation of E. coli MG1655 by high-pressure homogenization at different pressures (100-300 MPa) and temperatures (5–50°C). It can be seen that at constant temperature inactivation increases with increasing pressure, and at constant pressure inactivation increases with increasing temperature. In addition, the influence of temperature increases at higher pressures. For example, at 100, 150, 200, 250, and 300 MPa the difference in inactivation between a treatment at 5 and 45°C was, respectively, 0.8, 1.2, 2.0, 2.2, and 2.7 log units [6] – showed on fig. 2.

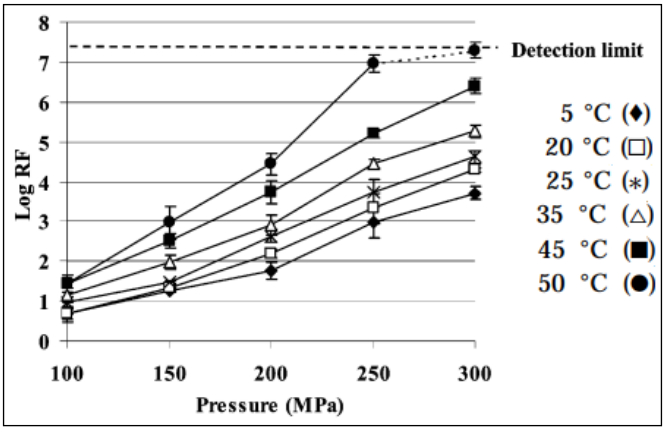

Fig. 2. Inactivation (log RF) of E. coli MG1655 by high pressure homogenization in function of pressure (MPa) at different process temperatures.

Rys. 2. Inaktywacja (logRG) E. coli MG1655 poprzez działanie HPH w funkcji ciśnienia (MPa) w odmiennych temperaturach prowadzenia operacji.

Source: [6]

Źródło: [6]

From these results it can be also concluded that temperature in the range where it does not by itself cause microbial inactivation (approximately 0–45°C) plays an important role in the inactivation of E. coli by highpressure homogenization. Although the exact cause of inactivation by high-pressure homogenization is not yet completely understood, it is clear that temperature has an influence on some of the proposed inactivation mechanisms, such as cavitation and turbulence. Fluid temperature has a dual effect on cell breakage due to hydrodynamic cavitation, which is defined as the dynamic process of gas cavity growth and collapse in a liquid. Cavities arise when the pressure in a liquid is lower than the vapor pressure of the liquid. At low temperature, liquids have a lower

vapor pressure and thus cavity formation will be reduced. On the other hand, the severity of cavitation increases at low temperature as a result of a more violent collapse when the vapor pressure is low [6].

The later experiments, described in [9] confirmed, that high-pressure homogenization is a promising technology, which may be an alternative to thermal Escherichia coli inactivation (by pasteurization) for apple juice and apple cider. Whereas homogenization pressures of 100 to 200 MPa cause microbial inactivation due to high pressure homogenization, homogenization pressures >250 MPa resulted in significant thermal inactivation. Homogenization pressures of >250 MPa resulted in greater than 7 log CFU/mL of E. coli K-12 inactivation in apple juice and apple cider mainly due to the thermal component of the high-pressure homogenization process. There were no significant ($P < 0.05$) 3-way interactions observed. However, significant ($P < 0.05$) 2-way interactions (pressure ∗ type of substrate and pressure ∗ chitosan concentration) were found during the study. The homogenization pressure was a critical factor in causing the inactivation and the incremental quantity of chitosan (2 types) acted synergistically with the pressure to give higher inactivation. Addition of chitosan (2 types) at 0.1% concentration resulted in enhancing E. coli K-12 inactivation in apple juice and apple cider up to 200 MPa. There was no significant ($P < 0.05$) effect of type of chitosan on the bacterial inactivation. Also, there was significantly ($P < 0.05$) higher inactivation in apple juice than apple cider using same homogenizing pressure. Future study will be carried out to evaluate the sensory and shelf-life studies to assess the impact of high-pressure homogenization on the apple juice [9].

The inactivation of microorganisms by high pressure homogenization is also possible for yeasts. The paper [11] describes the inactivation values of Zygosaccharomyces bailii in apricot and carrot juices after the HPH treatments. Zygosaccharomyces bailii inactivation was affected by the pressure applied. In both juices it increased with the number of passes at 100 MPa. The data of this experimental study show the potential of the HPH to modify the texture features of some vegetable and fruit juices and to reduce the cell loads and/or to avoid the proliferation of a spoilage microorganism such as Zygosaccharomyces bailii. However, the HPH technological potentialities were affected by the food matrix employed. In fact, repeated HPH treatments permitted to modify the structure of apricot juice, but they were insufficient to prevent the spoilage of the samples inoculated with Zygosaccharomyces bailii suggesting that, during storage, HPH needs to be supported by other hurdles such as low temperature. On the contrary, when applied for more than 4 cycles, the 100 MPa HPH treatment was able to significantly reduce the cell loads of the inoculated yeast in carrot samples and to prevent its proliferation during the 10 d of storage also at 25°C. This interesting effect on the microbial shelf life was not coupled with appealing modifications of the carrot juice microstructure. Thus, the experimental data suggest also that the multipass-HPH treatment has to be calibrated and combined with different hurdles in relation to the desired shelf life and to the final features to be imparted to the product. Although the scaling-up of multipass process is considered difficult because time and power consuming, it requires a time span comparable to that of single-pass treatments, due to the shortness of each pass (few milliseconds) [11].

Next, the spoilage microflora in beer can also be inactivated by HPH process, implemented to the production technology. The experiments conducted by Franchi and co-workers [8] enabled confirmation that HPH at 250 MPa can be used to inactivate the common beer spoilage microorganisms examined (fig. 3).

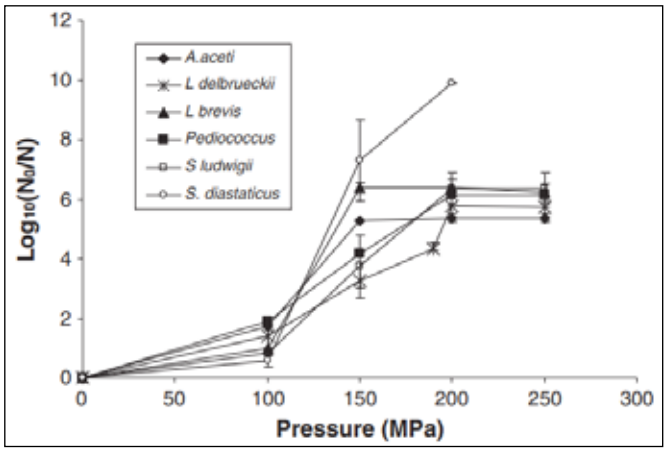

Fig. 3. Inactivation of beer spoilage microorganisms by high-pressure homogenization.

Rys. 3. Inaktywacja szkodliwych mikroorganizmów w piwie poprzez zastosowanie homogenizacji wysokociśnieniowej.

Source: [8]

Źródło: [8]

Moreover, the authors found, that by applying a multi-pass homogenization process (two or three consecutive treatments), it was possible to reduce the requirements of the pressure homogenization to 100–150 MPa. Similarly, this range of homogenization pressure is enough to obtain a stable beer if the HPH process is carried out at 50°C. Therefore, HPH is a promising non-thermal method to obtain microbial beer stability [8].

The experimental data that has been presented in this review yet refers only informations about HPH inactivation of spoilage or dangerous microflora in food products. But, it must also be borne in mind, the microbial inactivation by high-pressure homogenization treatment carries the risk of applies also to microorganisms, which the presence in the food product is beneficial from the point of view of the functionality of the food and the health of the consumer. However, the research results obtained so far do not support these concerns. As the example should be mentioned experiments described in paper [13]. Authors of this article found, that HPH treatment, as performed at 50 MPa, did not affect the viability of cells suspended in MRS medium. In fact, the treatment reduced the strain cell loads by less than 0·2 Log CFU per ml, which was not considered a significant result, confirming the tolerance to moderate pressure.

On the other hand, the severity of HPH treatment was chosen on the basis of previous works demonstrating that pressure level did not affect the cell's viability but, what is equally important, enhanced some probiotic and technological features. The ability to maintain good cell viability is

considered an indicator of probiotic capacity and is included in the selection criteria of innovative treatments that are performed to enhance the strain's probiotic properties [13].

Other, different and interesting data are given from the work relating the microbial inactivation with homogenizer valve shape [7]. In the microbial inactivation tests were used two different lab-scale high pressure homogenizers: a nm-GEN 7400 series system by Stansted Power Fluids (Stansted, UK) and a NanoDeBee 45 by Bee International (South Easton, MA 02375, USA), both equipped with a single pressure intensifier. The homogenizers are characterized by significantly different valve geometries, one based on an adjustable conical piston valve (indicated as SFP) and the other based on an 130 lm orifice gap (indicated as NDB) (fig. 4).

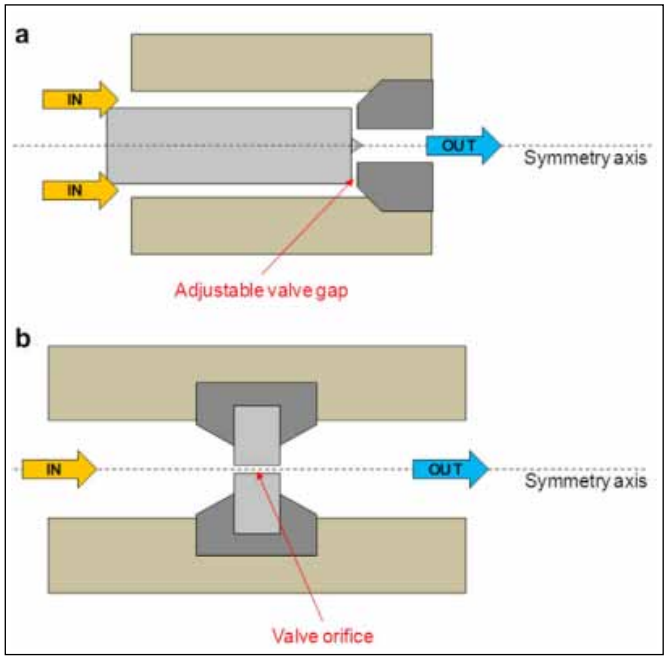

Fig. 4. Schematics of the homogenization valves tested: (a) Stansted Fluid Power (SFP) valve geometry; (b) Nano De Bee 45 (NDB) valve geometry.

Rys. 4. Schematy używanych zaworów homogenizujących: a) geometria Stansled (SPF); geometria Nano De Bee 45 (NDB).

Source: [7]

Źródło: [7]

The kinetics of microbial inactivation by high pressure homogenization (HPH) significantly depended on the geometry of the disruption chamber, with the piston valve resulting more efficient than the orifice valve. Tests conducted on E. coli, L. delbrueckii and S. cerevisiae, clearly showed that similar level of inactivation were always attained at lower pressures and less number of passes when using a piston valve, likely due to the higher probability of mechanical interaction of microbial cells with valve surfaces in such configuration. In the piston valve, the opening through which the microbial suspension is forced to flow is an annular section, whose gap (3–14 lm) is comparable in size with microbial cells. In contrast, in the orifice valve, the characteristic dimension (130 lm) is significantly larger. In addition, the analysis of the fluid-mechanical stresses occurring in the valve through adimensional numbers, such as Reynolds, Weber, Capillary and Cavitation numbers, showed that turbulence and shear and elongational stresses predominate in the orifice valve, while cavitation, which is hence likely to significantly contribute to microbial inactivation, rules in the piston valve. Finally, in order to develop a predictive tool of cell lethality upon HPH treatments, an empirical power law equation (Weibull model) was successfully tested against the experimental data of inactivation of the different microorganisms at varying pressure and number of passes in both valve geometries, resulting in a highly accurate data fit [7].

In terms of impact on microbial disruption, the most important distinctive feature between the two valve geometries is undoubtedly the characteristic size of the valve, which is much larger for the round orifice of NDB (diameter of 130 lm) than for the annular flow section of SFP geometry, characterized by a very thin gap (from 14 to 3 lm), comparable in size with microbial cells (5 lm for yeast cells, 0.1–1 lm for bacteria). The second most important distinctive feature may instead be considered the mean valve velocity, which is much higher for NDB valve (up to 400 m/s), than in the SFP valve (50 m/s) [7].

THE HPH EFFECTS ON ENZYMES ACTIVITY

Some of the effects on enzymes activity causing by high-pressure homogenization were presented by researching teams under the leadership of Alline Tribst and Jose Carbonell [5, 14, 15, 16, 17, 18].

Tribst and co-authors determining the effect of the HPH on the activity and stability of a neutral protease from B. subtilis [15]. The results obtained for the native enzyme and for the pre-heated native enzyme (data not shown) showed no significant differences between them, indicating that the initial heating was not able to partially inactivate the enzyme. The activity of homogenised protease (0 bar) at a high inlet temperature showed a slight enzymatic activity reduction in all evaluated conditions. At 2000 bar, no differences were observed in the enzymatic activity at 55 C, when compared with the non-heated enzyme [15].

These results also demonstrated that the combination of homogenisation and heating can be used in some cases, when enzyme inactivation is desirable. It is interesting to observe that the combination of a mild thermal process and a HPH is also a promising method for the microorganisms inactivation [15].

It was concluded that the HPH can promote reversible or irreversible changes in the B. subitilis neutral protease activity, promoting activation, inactivation and even changing enzyme optimum temperature. The obtained results highlight the HPH as an interesting tool to improve enzyme commercial applications [15] (fig. 5).

Other experiments of this researchers were aimed of determining the effect of the HPH on the activity and the stability of a fungi α-amylase [17].

The activity of high pressure homogenized α-amylase at different pHs presented similar results to the previously obtained for the native enzyme, with a maximum activity at a pH of 5.8 and with same activity at pH levels of 4.0, 5.5

and 6.7. Therefore, no differences were observed between the native and the homogenized α-amylase at each evaluated pH. Consequently, the HPH did not change the activity and/or the stability of the studied fungi α-amylase.

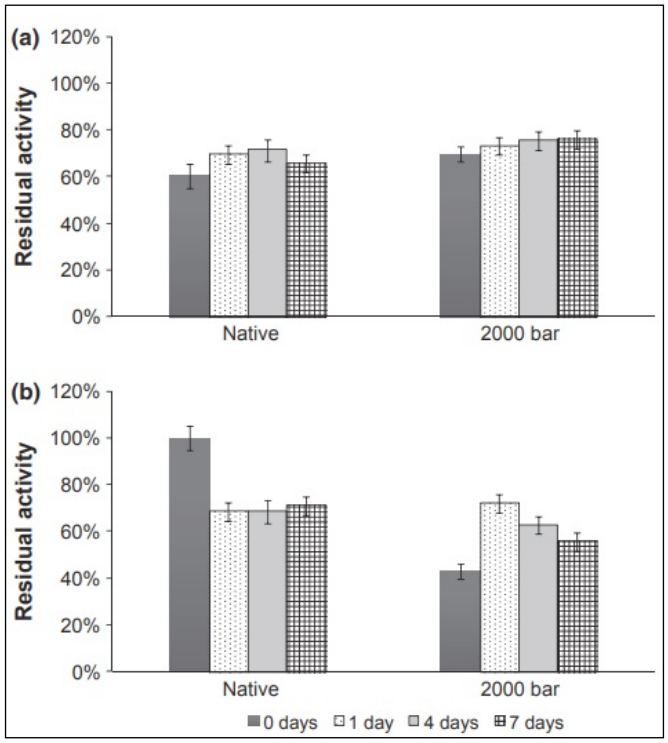

Fig. 5. Stability of native and high pressure homogenised (2000 bar) protease stored at pH 7.5 and 8 C for 1 week. Activity measured at 20 C (a) and 55 C (b).

Rys. 5. Stabilność proteazy w formie natywnej oraz po homogenizacji ciśnieniowej (2000 bar) przechowywanej w pH 7.5 oraz 8 przez 1 tydzień.

Source: [15]

Źródło: [15]

The combination of the HPH and a high inlet temperature again caused no changes in the α-amylase activity. Thus, it can be determined that the HPH at the evaluated conditions was not able to cause significant changes in the α-amylase. This result can be useful for industries that intend to use HPH with products containing α-amylase, since the results indicate, with no doubt, that the homogenization process did not affect the activity and stability of the enzyme. This is mainly interesting to some juice industries that apply α-amylase for juice clarification and viscosity and they can use HPH as a non-thermal process to stabilize juices microbiologically and physically, through particle size reduction.

Summarizing, the α-amylase activity and stability were not affected by the high pressure homogenization up to 1500 bar and the homogenization at a high temperature also caused no changes in the enzyme activity. Therefore, it can be concluded that the fungi α-amylase is stable under high pressure homogenization up to 1500 bar [17] (fig. 6).

A significant part of researches of the 'Tribst group' was the experiments aimed at determining the temperature impact on the activity of glucose oxidase, amyloglucosidase and neutral protease after HPH operation [14, 16, 18].

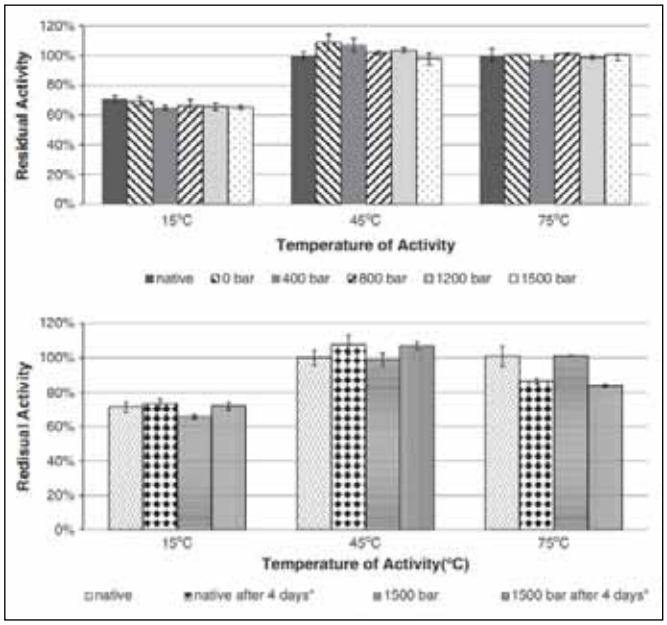

Fig. 6. Up – α-amylase activity at different temperatures after homogenization;
Down – Effect of refrigerated storage on the stability of the homogenized α-amylase.

Rys. 6. Góra – Aktywność α-amylazy w różnych temperaturach po homogenizacji;
Dół – Wpływ przechowywania chłodniczego na stabilność homogenizowanej α-amylazy.

Source: [17]

Źródło: [17]

There were investigated, at the optimum temperatures, only amyloglucosidase showed a slight improvement in activity and only after one pass at 200 MPa. This may indicate that the configuration of native enzyme is the best one to react at the optimum temperature, since this optimum condition was chosen based on the enzyme reaction of the native form. To the contrary, improvements in activity at non-optimum temperatures were observed for all enzymes, and the maximum enzyme activity increase occurred after only one pass for amyloglucosidase and neutral protease and after three passes for glucose oxidase [14, 18].

High pressure homogenization is able to alter the glucose oxidase activity and increase its residual relative activity at high temperature after homogenization at pH 5.7 and 150 MPa. Additionally, the HPH can cause an increment up to 400% on glucose oxidase stability as evaluated after 24 h storage at 8°C, as compared to the native one stored under the same conditions. Therefore, the HPH may be an interesting tool to increase glucose oxidase relative stability, improving the potential applications of glucose oxidase in food industry [16].

Moreover, the homogenization at high inlet temperature was highly deleterious for amyloglucosidase activity at all evaluated conditions, with activity loss higher than 90%. Considering that reached temperature during the process and HPH at 2000 bar (Fig. 3) were individually not able to promote this level of enzyme inactivation, it was concluded that homogenization associated to temperature had a synergistic effect on amyloglucosidase inactivation.

Also, the activity evaluation after one day of storage at 8°C showed that this inactivation was not reversible, since the relative activity at 65°C of sample homogenized and stored at pH 4.3 was 9.4±1.3%, with no significant difference with sample activity just after homogenization. Therefore, it can be concluded that homogenization at 65°C was deleterious for the enzyme activity. In contrast, the results highlighted that HPH of amyloglucosidase at high inlet temperatures can be a very interesting way to inactivate the enzyme at the end of the hydrolysis process without using heat.

High pressure homogenization was able to relatively keep or increase the amyloglucosidase activity immediately after homogenization, depending on the pH of homogenization and the temperature of activity. Best results were obtained at 80°C, which is very interesting especially when amyloglucosidase is applied in starch saccharification process, which requires enzyme active at higher temperatures, for improving time and energy economy [18].

HPH affected the activity of amyloglucosidase, glucose oxidase and neutral protease, particularly with respect to improving it at nonoptimum temperatures. For amyloglucosidase and neutral protease, the main effects of homogenization were observed after only one pass, indicating that the energy gain of the enzyme under this condition was sufficient to affect the maximum molecular changes caused by homogenization. To the contrary, the continuous improvement in the activity of glucose oxidase can be attributed to the additional molecular change caused by each homogenization pass. Therefore, HPH can be applied to improve enzyme activity and the efficacy of multiple passes is dependent on the kind of enzyme [14]. The optimal conditions to improve activity of investigated enzymes are presented in fig. 7.

Enzyme	Process conditions		Temperature of activity measurement (°C)	[a]Activity increase (%)
	Pressure (MPa)	Number of passes		
AMG	200	1	80	7.5%
GO	150	3	75	78%
Neutral protease	200	1	20	12%

[a] compared with native enzyme activity measured at the same conditions of the HPH enzyme.

Fig. 7. Conditions of HPH process for maximum enzyme activity increase.

Rys. 7. Warunki operacji HPH do uzyskania maksymalnego wzrostu aktywności enzymów.

Source: [14]

Źródło: [14]

The last of presented in this work research is the investigation in the influence of high pressure homogenization and pulp reduction on residual pectinmethylesterase activity, conducted by Carbonell and co-authors [5].

The experiments conducted shows pectinmethylesterase activities found in fresh and homogenized juices. As expected, pectinmethylesterase activity monotonically decreased as a function of the pulp content reduction and the increase of the homogenization temperatures. Hence, LPJs homogenized at 68°C had a residual pectinmethylesterase activity near 10% of the initial value showed by fresh juice, on the contrary to what happened with the homogenized WJ at the same temperature that reached a residual pectinmethylesterase value of about 25%. Moreover, residual pectinmethylesterase activity was increased by reducing the homogenization temperature (such increase was proportional in all assayed juices). These results confirm the intimate relationship between pectinmethylesterase activity and pulp content of juices (mentioned in the introduction section) and clearly indicate that for a considered HPH treatment, once knowing the residual pectinmethylesterase activities of whole juices it would be feasible to predict the residual activities of their pulp reduced derived products [5].

As a conclusion – homogenization at 150 MPa and 68°C preserved acceptability and cloudiness of Lane Late juice for at least 3 months of refrigerated storage at 3°C even with a high residual pectinmethylesterase activity. This methodology can be an interesting alternative to traditional heat treatments above 85°C used by citrus industry that promote losses in the acceptability of commercial orange juices [5].

CONCLUSIONS

The presented research results confirm the high usefulness of the high-pressure homogenization operation. These results show the additional benefits of HPH – causing a decrease in microorganisms number (also pathogenic) in the food products, and thus increasing its safety for the consumer. In addition, it has been shown to reduce the enzymatic activity, which consequently improves the quality of the product by increasing its stability.

PODSUMOWANIE

Przedstawione rezultaty prac badawczych potwierdzają wysoką użyteczność operacji homogenizacji wysokociśnieniowej. Rezultaty te unaoczniają dodatkowe korzyści płynące z HPH – powodowanie spadku liczby mikroorganizmów (także chorobotwórczych) w produkcie spożywczym, a tym samym zwiększenie jego bezpieczeństwa dla konsumenta. Ponadto wykazano zmniejszanie aktywności enzymatycznej, co w konsekwencji powoduje poprawę jakości produktu poprzez zwiększenie jego stabilności.

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THE USE OF PASCALIZATION IN THE POLISH FOOD INDUSTRY – CHARACTERISTICS AND PROSPECTS®

Zastosowanie paskalizacji w polskim przemyśle spożywczym – charakterystyka i perspektywy®

In recent years, pro-health food has become more and more popular. Particular attention is paid not only to unprocessed, nutritional fruit and vegetable products, but also high-quality meat products, dairy products and ready meals. It is the changes in consumer preferences that constitute the main, amongst others, driving force for scientists and food producers who are looking for new concepts and directions to develop the food industry.

One of the hi-tech solutions, in line with the principle of "minimal processing", as well as responding to the market demand, is the method of high-pressure food preservation, often referred to as "pascalization". The advantage of this method is the combination of effective degradation of microorganisms and pathogens while maintaining the high quality of the preserved product. Additionally, it allows to influence the texture, functional properties and sensory features of the product without adversely affecting its nutrients.

Modern technologies of food preservation are still rarely used on the domestic food processing market. This is due, inter alia, to the fact that innovations in the production sector require high capital outlays, and individual food processing plants most often do not have a sufficient capital base to invest in modern technologies. The current limitations in the large-scale application of the high-pressure food preservation method in the Polish food processing sector result directly from the high price of high-pressure systems and higher processing costs than contemporary methods.

The solution to the problem of currently limited use of these technologies on the Polish market should be sought, first of all, in the approach to the issue of capital cooperation between economic entities and in changing the states policy towards small and medium-sized enterprises.

The aim of this article is to present pascalization as an alternative and a modern method of pressure food preservation as well as an indication of the prospects and possibilities of introducing this technology on a large scale in the Polish food processing sector.

Key words: pascalization, food processing, food industry, sustainable development, HPP, high pressure processing, high pressure pasteurization, HHP, high hydrostatic pressure, UHP, ultra high pressure.

W ostatnich latach żywność prozdrowotna cieszy się coraz większą popularnością. Szczególne zainteresowanie budzą nie tylko nieprzetworzone, wartościowe produkty owocowo -warzywne, ale również wysokiej jakości produkty mięsne, nabiał oraz dania gotowe. To właśnie zmiany preferencji konsumentów stanowią główną, choć nie jedyną, przyczynę poszukiwania przez naukowców oraz producentów żywności nowych koncepcji i kierunków rozwoju przemysłu spożywczego.

Jednym z nowoczesnych rozwiązań, zgodnych z zasadą „minimalnego przetwarzania", jak również, odpowiadających na zapotrzebowanie rynku jest metoda wysokociśnieniowego utrwalania żywności, często określana mianem „paskalizacji". Zaletą tej metody jest połączenie skutecznej degradacji drobnoustrojów oraz patogenów z jednoczesnym zachowaniem wysokiej jakości utrwalanego produktu. Dodatkowo, pozwala ona wpływać na kształtowanie tekstury, właściwości funkcjonalne oraz cechy sensoryczne produktu bez wywierania negatywnych skutków na jego składniki odżywcze.

Nowoczesne technologie utrwalania żywności są jeszcze dosyć rzadko wykorzystywane na rodzimym rynku przetwórstwa spożywczego. Wynika to między innymi z faktu, iż innowacje w sektorze produkcyjnym wymagają wysokich nakładów kapitałowych, a pojedyncze zakłady przetwórstwa spożywczego najczęściej nie posiadają wystarczającej bazy kapitałowej pozwalającej na inwestycje w nowoczesne technologie. Obecne ograniczenia w zastosowaniu na szeroką skalę metody wysokociśnieniowego utrwalania żywności w polskim sektorze przetwórstwa spożywczego wynikają bezpośrednio z wysokiej ceny systemów wysokociśnieniowych oraz wyższych, względem metod klasycznych, kosztów przetwarzania.

Rozwiązania problemu ograniczonego obecnie wykorzystania tych technologii na polskim rynku należy szukać, przede wszystkim, w sposobie podejścia do kwestii współpracy kapitałowej pomiędzy podmiotami gospodarczymi oraz w zmianie polityki państwa wobec małych i średnich przedsiębiorstw.

Celem artykułu jest przedstawienie paskalizacji, jako alternatywnej i nowoczesnej metody ciśnieniowego utrwalania żywności oraz wskazanie perspektyw i możliwości wprowadzenia tej technologii na szeroką skalę w polskim sektorze przetwórstwa spożywczego.

Słowa kluczowe: paskalizacja, przetwórstwo spożywcze, przemysł spożywczy, rozwój zrównoważony, wysokociśnieniowe utrwalanie żywności, HPP, HHP, UHP.

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INTRODUCTION

Consumer awareness makes natural and healthy food a standard element of the daily diet of consumers who lead a healthy and active lifestyle. Unprocessed, nutritious fruit and vegetable products are of particular interest [1, 2].

Health-oriented expectations of customers refer not only to products of plant origin, but also to meat products, dairy products and ready meals [3]. Customers expect fresh, healthy and preservative-free products, which are convenient and tasty at the same time [10, 12].

Changes in consumer preferences are the main, but not the only, reason why scientists and food producers are looking for new concepts and directions for the development of the food industry. In addition, companies involved in the development or transport of food products are increasingly looking for new technologies to increase food safety and extend its shelf life [16, 17].

PASCALIZATION – CHARACTERISTICS OF AN ALTERNATIVE METHOD OF PRESERVING FOOD

Pascalization – Introductory issues

Since recently, Polish consumers can learn about new food preservation technology, which is pascalization, i.e. high-pressure treatment. Other names for this process are: HPP (High Pressure Pasteurization), HHP (High Hydrostatic Pressure) and UHP (Ultra High Pressure) [12]. The impact of high pressure is also called pre-pressure or pressurization. The most common name turns out to be the first abbreviation that will also be used in this article.

The advantage of pascalization method is the combination of effective degradation of microorganisms and pathogens while maintaining the high quality of the preserved product. The high pressure targets the microbial cells, causing irreversible changes in them. It can also inactivate enzymes responsible for the deterioration of food quality, such as changes in consistency or color. Thanks to the pascalization, a product with an extended shelf life is obtained, with a quality similar to that of a natural product before the preservation process. Low molecular weight compounds, such as vitamins, dyes and flavors, remain intact, so the high-pressure preserved product does not lose quality [1].

This method not only helps preserve food by destroying harmful microorganisms, but also influences the texture, functional properties and sensory characteristics of the product without adversely affecting its nutrients [4].

The course of the pascalization process

The general principle of the pascalization process is that food put in flexible packages, is placed in a chamber gradually filled with water until the desired pressure is achieved, most often up to 600 MPa [17].

The range of pressures used in industrial practice is usually in the range of 400 - 600 MPa. The high pressure cured product should be in its final packaging to avoid recontamination [1, 6].

The final quality of the manufactured product is largely influenced by both the method and conditions of packaging and storage. There may be post-production hazards, secondary contamination of food caused, inter alia, by: contact with production and commercial personnel, contaminated devices, machines and storage areas. Recontamination often occurs during the portioning and packaging of finished products [16].

The important features of the packaging are not only its durability and flexibility, but also a correspondingly high barrier. It should be taken into account that the water present in the products under the pressure used in the pascalization process has a compressibility of 16%.

The packaging, in addition to high barrier properties, should be flexible and tight. Other parameters that greatly influence the efficiency of the pascalization process are the pressure value, the initial temperature of the product and the process time. The pressure level and the process time are values depending on the specificity of a given product. The parameters are determined on the basis of preliminary tests, carried out individually in order to optimize a given process.

Although the high-pressure setting treatment is classified as a non-thermal process, the increase in pressure causes an adiabatic increase in temperature, which means that an increase in pressure by every 100 MPa increases the temperature of the product by 3-5 ° C. The temperature then returns to its original level at the time of decompression, which marks the end of the process. Compared to the temperature achieved during thermal processes such as pasteurization, this increase is insignificant [1, 6].

The standard system for high-pressure machining consists of four basic parts:

- a pressure vessel with a closure system and a heating mantle that allows to obtain the appropriate temperature;
- pressure generating system;
- pressure and temperature control and monitoring device;
- system for moving the product to and from the tank.

The pressure vessel is usually a cylindrical vessel made of low-alloy, high-tensile steel. The thickness of its walls depends on the maximum working pressure, the diameter of the tank and the number of cycles for which the chamber has been designed. The most frequently used tanks have both vertical and horizontal configuration and internal volume ranging from 30 to 600 liters [4, 5].

Characteristics and scope of use of the pascalization method

The range of products that can be pascalized is very wide:

- juices and soft drinks;
- fruit and vegetable salads;
- ready meals;
- sauces, pastes, soups;
- dairy;
- fish, seafood, shellfish;

- meat;
- food for animals;
- cosmetics;
- pharmaceutics [15, 17].

The pascalization process can be used universally in the food industry. Its main advantages include:

- preserving the taste, color and texture of the product;
- preservation of the nutritional value of the product (as opposed to pasteurization or adding preservatives);
- the possibility of producing low-sodium, and therefore healthier food for the consumer;
- two or even three times longer expiration date (longer transport possible);
- inactivation of food spoiling and pathogenic bacteria: *Listeria*, *E. coli* and *Salmonella* [17].

The classification of bacteria resistance to the level of applied pressures begins with the resistance of bacterial spores, i.e. the most resistant forms. Gram-positive bacteria G(+) are less resistant than them. Gram-negative bacteria G(-) are the most sensitive to high pressure [1].

The pressure levels used in practice can be divided into 3 groups in the range of 200–600 MPa [1, 4, 5]:

- 200–300 MPa – inactivation of yeast and mold;
- 300–400 MPa – inactivation of gram-negative bacteria;
- 500–600 MPa – the highest pressure range used in the food industry – reduction of the most resistant gram-positive bacteria [4, 5].

High pressure technology, in addition to the ability to preserve food, has an impact on the texture of food. For this reason, this method has been indicated as a physical process applicable to the softening (tenderizing) of meat and meat products without the use of additives. Such structural modifications of meat proteins can be used in the food industry in the development of new products and recipes [3, 12].

Furthermore, the high-pressure food preservation method has significant potential for use in the preservation of beer and wine [15].

PASCALIZATION AND THE FOOD PROCESSING MARKET

Demand for modern technologies in food processing

Consumer awareness makes natural and healthy food a staple of the daily diet, and the pro-health expectations of customers refer not only to plant-based products, but also to meat products, dairy products and ready meals. Customers are looking for fresh, healthy and preservative-free products, which are convenient to prepare and, above all, tasty.

Unprocessed, valuable fruit and vegetable products are of particular interest [1, 2]. The widest use of high-pressure processing is currently in the processing of fruit and vegetables. The products most often preserved using pascalization include: juices, smoothies, plant drinks, vegetable pastes, soups and fruit mousses. Both fruit and vegetable juices are products particularly suitable for high-pressure processing. This is because that their favorable pH and high water content favors homogeneous pressure transfer and does not reduce the volume of the product after the process [1, 13, 14].

The best example of products successfully conquering the Polish market are freshly squeezed, unpasteurized fruit juices. For years, producers of juices have been intensively looking for solutions that would allow to maintain the highest nutritional value of manufactured products, while extending their shelf life. Traditional thermal processing of juices damages vitamins and other heat-sensitive compounds. A substance of significant value for human health is vitamin C, i.e. ascorbic acid. It is an antioxidant, but also a thermally highly labile compound. Due to its solubility in water, it is very exposed to oxidation and degradation under conditions of even slightly elevated temperatures. Other compounds of particular value for human health are polyphenols, which like vitamin C, have an antioxidant effect. Their antioxidant potential can be up to 30 times greater than that of ascorbic acid. However, as in the case of ascorbic acid, polyphenols are degraded under the influence of high temperature used in the pasteurization process. The solution allowing to protect these compounds against degradation may be the high-pressure food preservation technology [1, 11, 13].

Despite the fact, that changes in consumer preferences are the main reason why scientists and food producers are looking for new concepts and directions for product development, it should be remembered that also companies dealing with the development or transport of food products are increasingly looking for new technologies to increase food safety and extend its shelf life [16, 17].

The current use of pascalization on the Polish food processing market

There is no doubt that modern technologies of food preservation are still rarely used in the domestic food processing market. This is due, inter alia, to the fact that innovations in the production sector require high capital outlays, and individual food processing plants most often do not have a sufficient capital base to invest in modern technologies.

The current limitations in the large-scale use of the high-pressure food preservation method in the Polish food processing sector result from the high price of high-pressure systems and higher processing costs compared to classic methods. It should be noted that the prices of such systems range from 500,000 up to USD 2.5 million, depending on device capacity and degree of automation, while processing costs range from 9 to 22 cents / kg, including operating costs and depreciation [4].

The use of modern, and at the same time consistent with the principle of "minimal processing", methods of food preservation will allow to obtain low-processed products of high quality. Nevertheless, a solution to the problem of the limited use of these technologies on the Polish market should be sought, first of all, in the approach to the issue of capital cooperation between economic entities and in changing the state's policy towards small and medium-sized enterprises.

Prospects for the large-scale use of modern food preservation methods in the Polish food processing sector

Determining the perspectives for action aimed at enabling the large-scale use of modern methods of food preservation in the Polish food processing sector is a complex issue and goes beyond the scope of this article. However, it is possible to define certain thematic and research areas of the issues raised.

The analysis should begin with the structure of the Polish market and its imperfections, resulting, inter alia, from the political, social and economic changes that took place in the period of the systemic transformation after 1989.

One of the significant disadvantages of the current structure of the domestic market is the existing high fragmentation of private enterprises, which, due to an insufficient capital base, have no chance to compete with large foreign enterprises. One of the solutions to such a situation could be the establishment of multi-industry conglomerates integrating domestic economic entities. There are many forms of business association, including solutions such as: consortia, cooperatives and cooperation based on civil law contracts. However, the form of multi-industry conglomerates is the most comprehensive solution.

In the long term, the state should support, similarly to Asian countries, the creation of mixed multi-industry conglomerates including economic entities, both from the agricultural sector, the agri-food processing industry, and non-agricultural sectors. Conglomerates would include producers, the maximum number of recipients and public sector entities. The ownership structure of conglomerates would be public-private, and with time private-public [7, 8].

Another issue is the need to introduce changes in using EU funds by creating consortia in order to increase the participation of domestic entities in the implementation of tasks co-financed from EU funds and to activate employment [7, 8, 9].

Comprehensive state policy, to be effective, must become a part of a coherent economic policy and be coupled with tax and education policies as well as labor market reform. In its implementation, in addition to state administration, multi-sector conglomerates should play a key role. [8]

Food production, using modern technologies, should not only be competitive, but also more sustainable. When supporting sustainable development, one should be aware of the fundamental relationship between technical and economic development and the natural environment [9].

The advantage of the Polish market is that the raw material base is largely based on domestic agricultural production, often with a low degree of schematization and high quality products. Thus, the use of modern food preservation technologies will enable the introduction to the market on a larger scale of unprocessed, fully valuable fruit and vegetable products.

SUMMARY

Natural and healthy food is becoming a standard element of the daily diet among consumers, and the pro-health expectations of customers refer not only to plant-based products, but also to meat products, dairy products and ready meals.

One of the modern solutions, responding to the market demand, and at the same time in line with the principle of "minimal processing", is pascalization, a high-pressure method of food preservation, the advantage of which is the combination of effective degradation of microorganisms and pathogens while maintaining the high quality of the preserved product. Furthermore, thanks to this method it is possible to influence the texture, functional properties and sensory characteristics of the product without adversely affecting its nutrient The general principle of the pascalization process is that it is food in flexible packages, it is placed in a chamber gradually filled with water until the desired pressure is achieved, most often up to 600 MPa. In this process, high pressure acts on the microbial cells, causing them to change irreversibly. Pascalization can also inactivate enzymes responsible for the deterioration of food quality, such as changes in consistency or color.

As a result, a product with an extended shelf life is obtained with a quality close to that of the natural product before the preservation process. Low molecular weight compounds, such as vitamins, dyes or flavors, remain intact, so that the quality of the high-pressure preserved product remains intact.

The range of products that can be pascalised is very wide and includes, among others: juices and drinks, fruit and vegetable salads, ready meals, sauces, pastes, soups, dairy products, fish, seafood, shellfish, meat, food for animals, cosmetics, pharmaceuticals. The pascalization process can be used universally in the food industry and in other industries.

Modern technologies of food preservation are still rarely used on the domestic food processing market. This is due, inter alia, to the fact that innovations in the production sector require high capital expenditure related to high prices of high-pressure systems and higher, compared to classic methods, processing costs. Single food processing plants most often do not have a sufficient capital base allowing for this type of investments, and also do not have a chance to compete with large foreign enterprises.

A solution to this problem should be sought, first of all, in the approach to the issue of capital cooperation between economic entities and in changing the state's policy towards small and medium-sized enterprises. One solution could be the establishment of multi-industry conglomerates that would integrate domestic economic entities. These conglomerates should include both producers, the maximum number of recipients and public sector entities.

PODSUMOWANIE

Naturalna i zdrowa żywność staje się standardowym elementem codziennej diety wśród konsumentów, a prozdrowotne oczekiwania klientów odnoszą się nie tylko do produktów pochodzenia roślinnego, ale również do produktów mięsnych, nabiału oraz dań gotowych.

Jednym z nowoczesnych rozwiązań, odpowiadających na zapotrzebowanie rynku, a zarazem zgodnych z zasadą „minimalnego przetwarzania", jest paskalizacja, czyli wysokociśnieniowa metoda utrwalania żywności, której zaletą jest połączenie skutecznej degradacji drobnoustrojów oraz patogenów z jednoczesnym zachowaniem wysokiej jakości utrwalanego produktu. Ponadto, dzięki tej metodzie można wpływać na

kształtowanie tekstury, właściwości funkcjonalne oraz cechy sensoryczne produktu, bez wywierania negatywnych skutków na jego składniki odżywcze.

Generalna zasada procesu paskalizacji polega na tym, że żywność w elastycznych opakowaniach zostaje umieszczona w komorze stopniowo wypełnianej wodą, do momentu, aż zostanie osiągnięte pożądane ciśnienie, najczęściej w wysokości do 600 MPa. W procesie tym, wysokie ciśnienie oddziałuje na komórki drobnoustrojów, powodując w nich nieodwracalne zmiany. Paskalizacja może także inaktywować enzymy odpowiedzialne za pogarszanie się jakości żywności, takich jak zmiany konsystencji lub barwy. W rezultacie, uzyskuje się produkt o przedłużonym terminie przydatności do spożycia o jakości zbliżonej do naturalnego produktu przed procesem utrwalania. Związki o niskiej masie cząsteczkowej, takie jak witaminy, barwniki czy związki smakowo-zapachowe, pozostają w formie nienaruszonej, przez co produkt utrwalony metodą wysokociśnieniową nie traci na jakości.

Asortyment produktów, które mogą zostać poddane procesowi paskalizacji jest bardzo szeroki i obejmuje między innymi: soki i napoje, sałatki owocowe i warzywne, dania gotowe, sosy, pasty, zupy, nabiał, ryby, owoce morza, skorupiaki, mięso, żywność dla zwierząt, kosmetyki, farmaceutyki. Proces paskalizacji może mieć uniwersalne zastosowanie w przemyśle spożywczym oraz w innych gałęziach przemysłu.

Nowoczesne technologie utrwalania żywności są jeszcze dosyć rzadko wykorzystywane na rodzimym rynku przetwórstwa spożywczego. Wynika to między innymi z faktu, iż innowacje w sektorze produkcyjnym wymagają wysokich nakładów kapitałowych, związanych z wysokimi cenami systemów wysokociśnieniowych oraz wyższych, względem metod klasycznych, kosztów przetwarzania. Pojedyncze zakłady przetwórstwa spożywczego najczęściej nie posiadają wystarczającej bazy kapitałowej pozwalającej na tego typu inwestycje, jak również, nie mają szansy konkurować z dużymi przedsiębiorstwami zagranicznymi.

Rozwiązania tego problemu należy szukać, przede wszystkim, w sposobie podejścia do kwestii współpracy kapitałowej pomiędzy podmiotami gospodarczymi oraz w zmianie polityki państwa wobec małych i średnich przedsiębiorstw. Jednym z rozwiązań mogłoby być powołanie konglomeratów wielobranżowych, które integrowałyby krajowe podmioty ekonomiczne. Konglomeraty te powinny obejmować zarówno producentów, maksymalną ilość odbiorców oraz jednostki sektora publicznego.

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THE DAIRY INDUSTRY IN POLAND DURING THE CORONAVIRUS PANDEMIC®

Branża mleczarska w Polsce w czasie pandemii koronawirusa®

The COVID-19 virus pandemic, which appeared in Poland at the beginning of March 2020, caused practically the entire economy to stop for almost 2 months. One of the food industries affected by the COVID19 pandemic is the dairy industry. The dairy industry is one of the basic sectors of the domestic agri-food sector. In Poland, milk is one of the most important agricultural products – it has the highest share (16.3% in 2015) in commercial agricultural production. In the preparation of the article, the literature on the subject was used, which was used to present and determine the significance of the introduced restrictions related to the COVID19 pandemic on the dairy industry in Poland. The article uses simple descriptive and cause-effect methods. Based on the analyzes, it was found that the slowdown in the economy and the closure of the borders caused by the COVID-19 pandemic contributed to a decline in the value of exports of dairy products, and dairy companies were obliged to introduce detailed hygienic and sanitary restrictions in connection with the situation related to the coronavirus pandemic.in. on the obligation of each employee to wear a protective mask and gloves, as well as to observe hygiene by frequent disinfection of hands and maintaining distances between work stations.

Key words: dairy industry, COVID-19 pandemic, effects of the pandemic.

Pandemia wirusa COVID-19, która w Polsce pojawiła się na początku marca 2020 roku spowodowała, że na prawie 2 miesiące praktycznie cała gospodarka stanęła. Jedną z branż przemysłu spożywczego, która odczuwa skutki pandemii COVID19 jest branża mleczarska. Branża mleczarska tworzy jeden z podstawowych działów krajowego sektora rolno-spożywczego. W Polsce mleko należy do najważniejszych produktów rolniczych – ma najwyższy udział (w 2015 roku 16,3%) w towarowej produkcji rolnej. W opracowaniu artykułu wykorzystano literaturę przedmiotu, która posłużyła do przedstawienia i określenia znaczenia wprowadzonych ograniczeń związanych z pandemią COVID19 na branżę mleczarską w Polsce. W artykule zastosowano proste metody opisowe i przyczynowo-skutkowe. Na podstawie przeprowadzonych analiz stwierdzono, że zahamowanie gospodarki oraz zamknięcie granic spowodowane pandemią COVID-19 przyczyniło się do spadku wartości eksportu artykułów mleczarskich, a przedsiębiorstwa mleczarskie w związku z zaistniałą sytuacją związaną z pandemią koronawirusa zostały zobowiązane do wprowadzenia szczegółowych restrykcji higieniczno – sanitarnych, polegających m.in. na zobowiązaniu każdego pracownika do noszenia maseczki ochronnej oraz rękawiczek, a także do przestrzegania higieny poprzez częstą dezynfekcję rąk i zachowywania odległości między stanowiskami pracy.

Słowa kluczowe: branża mleczarska, pandemia COVID-19, skutki pandemii.

INTRODUCTION

The COVID-19 pandemic, which appeared in Poland at the beginning of March 2020, meant that practically the entire economy stopped for almost 2 months. Some companies that had such an opportunity decided to introduce remote work, others had to stop production and wait for the regulation that would remove the restrictions, and some companies were forced to reduce employment due to the effects of COVID 19 in our country [18].

One of the food industries affected by the COVID19 pandemic is the dairy industry. The dairy industry is one of the basic sectors of the domestic agri-food sector. In Poland, milk is one of the most important agricultural products – it has the highest share (16.3% in 2015) in commercial agricultural production [10]. The Polish dairy industry is a constant source of income for people working in this sector and guarantees food for a significant number of farms [6, 10].

The aim of the article was to present and determine the significance of the introduced restrictions related to the COVID19 pandemic on the dairy industry in Poland by answering the question of how the coronavirus pandemic changed the functioning of dairy enterprises and farms specializing in milk production. The research was based on a literature study and on the example of activities undertaken by MLEKOVITA and OSM Włoszczowa, i.e. two dairy enterprises operating in Poland.

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WHAT IS COVID19?

The COVID-19 coronavirus was discovered in late December 2019 in Wuhan City, Hubei Province, China. The source of the infection was a fish and seafood market, and more precisely, wild animals sold there. The COVID-19 coronavirus is of the same type of virus as SARS and MERS. It can be transmitted from person to person by droplets. Wuhan city authorities, fearing the spread of the virus, decided to close the city. Most flights were canceled, public transport was restricted and people were told to stay home. The coronavirus, also known as the "Wuhan virus", has, however, managed to spread to other parts of China, as well as go beyond its borders. The COVID-19 coronavirus produces flu-like symptoms. The patient develops high fever and breathing problems. At the moment, there is no effective drug to fight the virus, but scientists say drugs used to treat HIV may help. Work is also underway on a vaccine against a new type of coronavirus [19].

CHARACTERISTICS OF THE DAIRY INDUSTRY IN POLAND

Milk produced on farms and used as a raw material in the processing process is one of the most developed and important items of trade in the food economy. Dairy cattle farming, milk processing and trade in dairy products occupy an important place in the food economy of many countries of the world, including Poland. This is due to the importance of milk production for the income of agricultural producers (as well as all elements beyond the sole sale of milk, such as the maintenance of meadows and pastures for the production of roughage, the use of manure in organic fertilization) and the role of dairy products in the nutrition of the population.

Dairy industry is considered to be a dynamically changing area of economic activity, subject to a constant process of changes [11, 16]. The dairy sector, in combination with milk production at farm level, forms one of the basic sectors of the domestic and EU agri-food sector. In Poland, milk is one of the most important agricultural products - it has the highest share in commercial agricultural production. The agri-food industry is one of the most important and fastest growing branches of the Polish economy, despite the use of traditional technologies [4, 9]. The food industry plays a significant role in the creation of gross domestic product, in international trade and employment [1]. When examining the industry, one should also analyze the economic indicators that characterize its functioning, thanks to which we can assess its economic condition in the economy. One of the branches of the food industry, which is considered to be a dynamically changing area of economic activity, undergoing a constant process of changes, is the dairy industry [2, 3, 11, 16].

The dairy industry is one of the most important sectors of the food industry in Poland. After sixteen years of membership in the EU, the Polish dairy industry stands out from other EU countries in terms of the development of internal demand for dairy products (in 2018 the consumption of milk and products in Poland amounted to 224 l per capita, which results in an increase of 12% compared to until 2005) [12]. From the point of view of international competitiveness, the advantage of the Polish milk market is the relatively low price of the raw material (according to GUS data, in 2019 the average purchase price of milk was around PLN 134 / hl, which stimulates the export of milk and its products) [7, 15]. Since the accession to the EU, the process of sector concentration and production specialization has been observed. The number of farms keeping cows has decreased by more than 40%, the number of wholesalers more than 60% and direct suppliers more than 80%. What distinguishes the Polish dairy sector from the rest of the new Member States is the fact that although in most of them the production of milk and milk products has decreased in recent years, it has increased in Poland. In Poland, there are relatively good natural conditions for cattle breeding. These are mainly regions of central and north-eastern Poland, with a large share of meadows and pastures – there it is possible to develop production in line with traditional animal grazing, which is less susceptible to fluctuations in the supply and prices of forage plants (as opposed to the alcove system). In addition, it creates traditional dairy products with high added value much more often than in industrial production, and contributes to the sustainable development of rural areas through the employment structure [8]. Poland is the fourth producer of dairy products in the EU with an 8% market share [5, 17].

METHODS AND MATERIALS

The research material included, first of all, the literature on the subject, which contributed to defining the significance of the restrictions introduced in the COVID19 pandemic on the dairy industry in Poland. As part of the article, the following research problem was demonstrated: The coronavirus pandemic changed the functioning of dairy enterprises and farms specializing in milk production. The descriptive and cause-and-effect methods were used in the presentation of the research results.

RESULTS AND DISCUSSION COVID19 EFFECTS ON THE DAIRY INDUSTRY

About 30% of Polish dairy production has to be exported because the domestic market is unable to absorb it. Meanwhile, the coronavirus, which disrupted supply chains and largely closed borders, thwarted the plans of dairy companies not only in Poland, but also throughout the European Union. According to preliminary data (GUS), in 2019 the value of Polish exports in total amounted to EUR 235.8 billion and was 5.5% higher than in the previous year. The share of agri-food exports in total exports was 13.3%, the same as in 2018. This is largely due to the dairy industry, which directs approximately 30–35% of its production to foreign markets. Preliminary data of the Ministry of Agriculture and Rural Development show that in the first quarter of 2020, the export of dairy products increased compared to the first quarter of 2019 (from 398 931 to 407 388 tons), mainly due to higher sales of cheese, cottage cheese and whey. According to the report of the Institute of Business, in the first quarter of 2020, the Mlekovita Group exported products worth PLN 400 million (35% of production), which was 30% more than in the first quarter of 2019. OSM Giżycko sold goods worth PLN 120 million abroad and it was 80% of the cooperative's production. Among the countries that adopted significantly larger amounts of Polish milk and cream are Yemen, Mexico, China and Japan [20].

During the lockdown, producers tried to focus on promoting domestic consumption, which resulted in more milk sales, especially UHT and butter, when consumers bought products in stock. In turn, plants that had such an opportunity stored excess production. In December 2019, an expert of the Institute of Agricultural and Food Economics, Teresa Zdziarska, assessed the situation on the European milk market as positive, and the prices of almost all dairy products, except for butter, showed an upward trend. During the three quarters of 2019, an upward trend was also observed in production, including whole milk powder by 23.3%, whey (7.4%) or milk drinks other than yoghurt (4.9%) [20]. In March and April, a downward trend in the prices of dairy products in the EU was observed, including whole milk and skimmed milk powder, affected by a decline in world demand. As emphasized by analysts of PKO Bank Polski (Agro Nawigator on May 5), the European Commission forecast that in 2020 EU exports of skimmed milk powder will decrease by 17% compared to the record level from 2019, and butter – by 10%, while increase in production (due to the fact that producers switched to the production of products with greater durability – milk powders and butter). In response to negative market changes, the European Commission prepared a proposal of a subsidy program for the private storage of dairy products (skimmed milk powder, butter, cheese) aimed at restoring the balance on the EU milk market [20].

According to experts, the pandemic will slightly change sales and consumer habits, for example by increasing grocery shopping online. However, it is hard to expect that the domestic market will use up all surplus production, and Poles will completely give up products manufactured abroad [20].

EFFECTS OF COVID-19 PANDEMI IN OSM WŁOSZCZOWA

The management of OSM Włoszczowa, which observed the growing trend of COVID-19 incidence in Europe, decided that in order for the plant to function without major disruptions, protecting the health of all employees must be a priority. Therefore, already on March 9 this year, i.e. a few days earlier, before the state of epidemiological emergency was announced in Poland, which took place on March 14 this year, a strict sanitary and hygienic regime was introduced in OSM Włoszczowa. At OSM Włoszczowa, as a dairy enterprise, wearing protective masks and gloves by employees operating production lines has been a standard for many years. And from March 9 this year. this obligation also applies to all persons employed in the plant and entering and entering the company. Initially, it was a big surprise for the drivers from the outside, receiving the products of OSM Włoszczowa, because they were not equipped with masks, so the plant made them available from its own resources. Drivers who transport raw materials from farms, who were recommended to distance themselves as much as possible, were also quickly trained; practically seeing the farmers. Milk receipts are left at the agreed place [21].

The COVID-19 pandemic resulted in an increase in spending on hygiene products at OSM Włoszczowa. Hygiene expenses for a food company are natural, but the coronavirus pandemic has caused a shortage of them. Costs for hygiene and compliance with sanitary standards are always borne by dairy companies before a pandemic occurs, and they were not high. However, these costs became more apparent as hygiene measures increased dramatically. An example can be masks, the price of which increased from a few dozen groszy to PLN 6-8. Unfortunately, the dairy companies were forced to accept the increase in these costs because the priority was to protect the health of the workers, without whom the plant could not function [21].

The situation related to the COVID-19 pandemic and the economic downturn for a period of two months resulted in an economic collapse on the market in March and April. The pandemic caused many unfavorable changes on the milk market, including A downward trend in exports was observed at OSM Włoszczowa. Exports abroad fell in March, which was caused by the situation in China. The problem was with logistics, there was a shortage of containers stuck in Chinese ports. Initially, the problem of exports concerned milk powders, and the cooperative in Włoszczowa sells abroad about 90% of powdered whey. Later, block cheese exports suffered greatly due to the situation in Europe. Interest in ready-to-eat, portioned and packaged products has increased. Meanwhile, block cheeses had to be cut in the store and packed, which in the eyes of consumers could pose a threat. In March and April, OSM Włoszczowa recorded a significant drop in exports, which included dried whey and cheese in blocks. Also on the domestic market in March and April sales were not conducive to restrictions in shops concerning both consumers and sellers. The restrictions also applied to gastronomy and hotels, which resulted in a 90% decrease in turnover on the HoReCa market. It can be said that this market segment in the dairy industry has ceased to function. Before the pandemic, the HoReCa market constituted only about 5% of OSM Włoszczowa's turnover, so it was not a big problem for the company. It was felt, first of all, by dairies very much involved in supplying schools, hotels and restaurants with dairy products [21].

Another effect of the COVID-19 pandemic at OSM Włoszczowa was observed in the category of prices that were below production costs. Disruptions in the milk market are reflected in the prices of finished products. Among the global products, the price of skimmed milk powder decreased the most. it cost 11.5 PLN / kg, and before Easter only 7.5 PLN / kg. After Christmas, the prices of this product showed an upward trend, and now you can get PLN 9.2 per kilo. On the other hand, producers from Western Europe were satisfied with very low cheese prices, ie 2.3–2.4 EUR / kg, and even 2 EUR / kg. Before the pandemic, EUR 3.1–3.2 could be obtained per kilogram of Dutch cheese. The cheeses produced by OSM Włoszczowa are mainly exported to the Czech Republic and Slovakia, but due to low prices, it was not decided to sell. It is difficult to accept the price of PLN 9 per kilogram of cheese, when its production costs PLN 14. In this situation, OSM Włoszczowa was accumulating stocks, which in practice means freezing the capital. At the end of April, the warehouses of OSM Włoszczowa were full to the brim. Sales started in May and prices rose to an acceptable level. The drop in exports prompted the management board of OSM Włoszczowa to lower the payment for milk in April by an average of PLN 0.05 / liter [21].

Due to the difficult financial situation caused by the COVID-19 pandemic, lower revenues from milk sales were observed. For cattle farmers and dairy producers, uninterrupted reception of white raw material is crucial. Most of the dairy plants complied with the sanitary and hygienic requirements set by the Polish authorities, thanks to which farmers running farms specializing in milk production do not have problems with receiving the raw material. From a dairy cooperative collecting milk, a farmer received a notification about the obligatory equipping of tanker truck drivers with masks and protective gloves, and about the need to distance himself from other people outside the farm. However, the continued coronavirus pandemic contributed to a decline in the purchase price of milk per liter of raw material. In April this year. the farmer received PLN 0.05 less per liter of raw material. The dairy paid 1.4 zlotys for a liter of milk containing 4.1% fat and 3.3% protein. The reductions were accompanied by an increase in the prices of some inputs. In the initial period of the pandemic, a ton of extraction soybean meal went up by PLN 300, and by 200 PLN more one had to pay for a ton of extraction rapeseed meal. In the opinion of farmers, the period of the application of strict sanitary regulations resulting from the announcement of an epidemic threat also has positive sides. It was an opportunity to strengthen relationships with loved ones, in line with the slogan "Stay at home". Various games had to be organized for children not attending school. The bursting energy aroused interest in the work in the cowshed. Farmers positively evaluate the campaign "Thank you for drinking milk", which also has a family aspect. Entire families of breeders are eagerly involved in photo sessions posted on social networks such as Facebook [21].

GOOD PRACTICES FROM MLEKOVITE DURING THE COVID19 PANDEMIC

SM Mlekovita is the largest dairy company and the largest producer and exporter of dairy products in Central and Eastern Europe. It is a company with an established reputation in the world, the leader of the List of 1000 Greatest Companies in the Food Industry in Poland and the most valuable brand in the production sector of the Polish economy. SM Mlekovita is a company with 100% Polish capital. The plant, which was established in 1928 in Wysokie Mazowieckie, employed 30 people and dealt exclusively with the production of cheese and butter. Currently, the company's development policy pursued consistently by SM Mlekovit means that after 90 years of operation its potential is created by: excellent breeders, modernized and still developing farms, diligence, entrepreneurship and great resourcefulness of farmers, 15 thousand milk suppliers, 20 production plants, 160 lines production centers, 32 own distribution centers, including the first company wholesalers in the Cash & Carry format, over 100 company stores in their own retail network operating under the MLEKOVITKA brand, permission to export to 159 countries on all continents, 5,000 employees, approx. 20% share in the Polish market, a well-recognized brand based on the message: "Polish" [13MLEKOVITA's market success is invariably based on 5 pillars: high-quality raw material and products; a recognizable and well-associated brand, a modern and efficient production, logistics and trade system; good strategy and independent and responsible managers at all levels of the organization; experienced, committed and motivated crew.

As the leader of the Polish dairy industry, "MLEKOVITA" fulfills its socially responsible obligation, carries out orders, functions better and better and we do not slow down, and the production processes run properly. As an inherent agricultural company, it has experience in dealing with specific disease prevention situations, as previously the company had to deal with mad cow disease, avian influenza and ASF [22].

At the time of the coronavirus pandemic, the management board of "MLEKOVITY" introduced limitations in interpersonal contacts to the necessary minimum, using the possibility of remote work, including sending documents by electronic means and cashless transactions. For preventive purposes, personnel surveys were introduced, following local recommendations in farms and production plants in accordance with the recommendations of the Polish government [22].

The MLEKOVITA Group in its 20 production plants processes 8 million liters of milk from Polish suppliers every day, works 7 days a week in a three-shift system. The most important priority is to ensure the supply of products to the Polish market, which is why domestic orders were carried out first. In order to better supply consumers, 32 wholesalers and nearly 130 MLEKOVITKA brand stores [22] are at their disposal.

To meet the expectations of consumers, MLEKOVITA produces both the so-called long shelf life, such as UHT milk, butter or cheese, and the production of products with special health properties, i.e. increasing immunity, i.e. DarPro and WPC 80, was introduced. In addition, direct deliveries to the homes of people under quarantine were introduced, so that no one there was no shortage of dairy products [22].

SUMMARY

Based on a review of the literature on the subject and the conducted research analyzes to determine the effects of the COVID-19 pandemic on the financial situation of selected dairy enterprises in Poland, it can be concluded that:

- The slowdown of the economy and the closure of borders caused by the COVID-19 pandemic contributed to a decline in the value of exports of dairy products;
- Dairy enterprises, in connection with the situation related to the coronavirus pandemic, have been obliged to introduce detailed hygienic and sanitary restrictions, including on the obligation of each employee to wear a protective mask and gloves, as well as to observe hygiene by frequent disinfection of hands and maintaining distances between work stations;
- Dairy companies incurred increased expenses on hygiene products in the period from March to April, which was related to the increase in prices for these products due to the increased demand caused by the COVID-19 pandemic;
- The continuing coronavirus pandemic caused a drop in the price of milk per liter, which contributed to the deterioration of the financial situation of farms specializing in milk production.

Due to the long-standing coronavirus pandemic, which caused the deterioration of the financial situation of dairy enterprises and farms specializing in milk production from August 13 this year, applications may be submitted by agricultural producers who are threatened with a loss of financial liquidity due to restrictions on the agricultural market due to the COVID-19 epidemic and who continue to suffer the financial consequences of last year's drought, hurricane, hail, downpour, spring frosts and floods, and their applications for aid submitted in 2019 in connection with the occurrence of these adverse events, have not been considered. Therefore, agricultural producers whose farms are threatened with a loss of financial liquidity due to restrictions on the agricultural market due to the COVID-19 epidemic and who have not been granted the aid indicated in § 13v para. 1 of the Regulation of the Council of Ministers of 27 January 2015 on the detailed scope and methods of implementation of certain tasks of the Agency for Restructuring and Modernization of Agriculture, after they waive the right to the aid referred to in the above-mentioned § 13v section 1 of the regulation. This means that the pending application must be withdrawn. The declaration on the withdrawal of the application submitted in 2019 is included in the content of the currently submitted application. The amount of aid is determined in accordance with the provisions of § 13v of the above-mentioned regulation. Applications should be submitted to the head of the poviat office of the Agency for Restructuring and Modernization of Agriculture competent for the place of residence or the seat of the agricultural producer, on the form specified by the President of ARMA. Aid may be granted by ARMA only until 31/12/2020 and must be paid by that date. There is no set deadline for submitting applications, but submitting the application as soon as possible guarantees faster payment of the aid. The aid will be in the form of public aid granted on the basis of the decision of the European Commission No. SA.58105 (2020 / N) of July 31, 2020. Legal basis: § 13 of the Regulation of the Council of Ministers of January 27, 2015 on the detailed scope and methods of implementation certain tasks of the Agency for Restructuring and Modernization of Agriculture (Journal of Laws, item 187, as amended) – change published in 2020, in Journal U. item 1375 [14].

National authorities and the EU are aware that maintaining the continuity of food supplies is one of the most important issues in the era of the epidemic. It must be admitted that so far the Polish government responds quickly to the reported problems and helps dairy companies to overcome emerging difficulties.

PODSUMOWANIE

W oparciu o przegląd literatury przedmiotu oraz przeprowadzone analizy badawcze w zakresie określenia wpływu pandemii COVID-19 na sytuację finansową wybranych przedsiębiorstw mleczarskich w Polsce można stwierdzić, że:

- Zahamowanie gospodarki oraz zamknięcie granic spowodowane pandemią COVID-19 przyczyniło się do spadku wartości eksportu artykułów mleczarskich.
- Przedsiębiorstwa mleczarskie w związku z zaistniałą sytuacją związaną z pandemią koronawirusa zostały zobowiązane do wprowadzenia szczegółowych restrykcji higieniczno – sanitarnych, polegających m.in. na zobowiązaniu każdego pracownika do noszenia maseczki ochronnej oraz rękawiczek, a także do przestrzegania higieny poprzez częstą dezynfekcję rąk i zachowywania odległości między stanowiskami pracy.
- Przedsiębiorstwa mleczarskie w okresie od marca do kwietnia poniosły zwiększone wydatki na środki higieniczne, co związane było ze wzrostem cen na te środki, w związku ze zmożonym zapotrzebowaniem spowodowanym pandemią COVID-19.
- Utrzymująca się pandemia koronawirusa spowodowała spadek ceny za litr mleka, co przyczyniło się do pogorszenia sytuacji finansowej gospodarstw specjalizujących się w produkcji mleka.

W związku z długotrwale utrzymującą się pandemią koronawirusa, która spowodowała pogorszenie sytuacji finansowej przedsiębiorstw mleczarskich oraz gospodarstw specjalizujących się w produkcji mleka, od dnia 13 sierpnia bieżącego roku wnioski mogą składać producenci rolni, którym zagraża utrata płynności finansowej w związku z ograniczeniami na rynku rolnym spowodowanymi epidemią COVID-19 i którzy w dalszym ciągu odczuwają skutki finansowe zeszłorocznej suszy, huraganu, gradu, ulewy, wiosennych przymrozków i powodzi, a ich wnioski o pomoc złożone w 2019 r. w związku z wystąpieniem tych niekorzystnych zjawisk, nie zostały rozpatrzone. O pomoc mogą ubiegać się więc producenci rolni, których gospodarstwo jest zagrożone utratą płynności finansowej w związku z ograniczeniami na rynku rolnym spowodowanymi epidemią COVID–19 oraz którym nie została przyznana pomoc wskazana w § 13v ust. 1 rozporządzenia Rady Ministrów z dnia 27 stycznia 2015 r. *w sprawie szczegółowego zakresu i sposobów realizacji niektórych zadań Agencji Restrukturyzacji i Modernizacji Rolnictwa*, po zrzeczeniu się przez nich prawa do pomocy, o której mowa w ww. § 13v ust. 1 rozporządzenia. Oznacza to konieczność wycofania wniosku oczekującego na rozpatrzenie. Oświadczenie o wycofaniu wniosku złożonego w 2019 r. jest zawarte w treści aktualnie składanego wniosku. Wysokość pomocy ustalana jest zgodnie z przepisami § 13v ww. rozporządzenia. Wnioski należy składać do kierownika biura powiatowego Agencji Restrukturyzacji i Modernizacji Rolnictwa właściwego ze względu na miejsce zamieszkania albo siedzibę producenta rolnego, na formularzu określonym przez Prezesa ARiMR. **Pomoc może zostać przyznana przez ARiMR tylko do dnia 31.12.2020 r. i do tego terminu musi zostać wypłacona.** Nie został ustalony końcowy termin składania wniosków, jednak jak najszybsze złożenie wniosku gwarantuje szybszą wypłatę pomocy. Pomoc będzie miała **charakter pomocy publicznej** przyznanej na podstawie decyzji Komisji Europejskiej nr SA.58105 (2020 / N) z dnia 31.07.2020 r. **Podstawa prawna**: § 13z rozporządzenia Rady Ministrów z dnia 27 stycznia 2015 r. w sprawie szczegółowego zakresu i sposobów realizacji niektórych zadań Agencji Restrukturyzacji i Modernizacji Rolnictwa (Dz. U. poz. 187, z późn. zm.) – zmiana opublikowana w 2020 r., w Dz. U. poz.1375 [14].

Władze krajowe, jak i UE zdają sobie sprawę, że utrzymanie ciągłości dostaw produktów żywnościowych jest jednym z najważniejszych zagadnień w dobie epidemii. Trzeba przyznać, że póki co polski rząd reaguje szybko na zgłaszane problemy i na bieżąco pomaga przedsiębiorstwom mleczarskim w pokonywaniu pojawiających się trudności.

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PORÓWNANIE INNOWACYJNOŚCI W RÓŻNYCH GAŁĘZIACH POLSKIEGO PRZEMYSŁU Z UWZGLĘDNIENIEM PRODUKCJI ARTYKUŁÓW SPOŻYWCZYCH®

Comparison of innovation in different branches of the polish industry with the production of food products®

Celem artykułu jest przedstawienie innowacyjności w różnych gałęziach polskiego przemysłu z uwzględnieniem produkcji artykułów spożywczych. Omówione zostały istota oraz znaczenie innowacji i innowacyjności, uwarunkowania działalności innowacyjnej przedsiębiorstw, rodzaje innowacji oraz czynnik ludzki w organizacjach innowacyjnych jak również działalność innowacyjna przedsiębiorstw w latach 2016–2018 w świetle analiz statystycznych przeprowadzonych przez Główny Urząd Statystyczny.

Słowa kluczowe: innowacje, innowacyjność, działalność innowacyjna, organizacje innowacyjne, czynnik ludzki, menedżer, przemysł spożywczy.

The aim of the article is to present innovation in various branches of Polish industry, including the production of food products. The essence and significance of innovation and innovation, determinants of innovative activity of enterprises, types of innovation and human factor in innovative organizations as well as innovative activity of enterprises in 2016–2018 in the light of statistical analyzes carried out by the Statistics Poland were discussed.

Key words: innovations, innovativeness, innovative activities, innovative organizations, human factor, manager, food industry.

WPROWADZENIE

Przedsiębiorstwa przemysłu spożywczego muszą radzić sobie z zagrożeniami związanymi z globalizacją, segmentacją rynku i dużymi zmianami w preferencjach klientów. Współcześni konsumenci oczekują z jednej strony wysokiej jakości i zdrowych produktów coraz częściej posiadających cechy wyrobów ekologicznych, ale z drugiej strony mających długi okres przydatności do spożycia. Przedsiębiorstwa muszą też zaspokajać coraz wyższe wymagania swoich wrażliwych na ceny odbiorców. Powoduje to konieczność wdrażania innowacyjnych rozwiązań, które wpłyną na obniżenie kosztów, oraz zwiększenie dynamiki wartości produkcji sprzedanej i poprawę rentowności przedsiębiorstw [35].

Dynamiczny rozwój innowacyjnej gospodarki globalnej ma istotny wpływ na zmianę sposobu podejścia do rozumienia i doskonalenia nowoczesnego napędu rynku innowacyjnego opartego na wiedzy, umiejętnościach i potencjale wyzwań społecznych [59, s. 265]. Innowacje stanowią niekwestionowany determinant rozwoju społeczno-gospodarczego krajów i rejonów. Według wszelkich wskaźników, Polska jest krajem zajmującym jedno z ostatnich miejsc, wśród krajów Unii Europejskiej w rankingach innowacyjności.

Przełom XX i XXI wieku to okres dynamicznego rozwoju koncepcji innowacyjnej gospodarki globalnej opartej na wiedzy, w której pojęcie zrównoważonego partnerstwa między uczestnikami z przestrzeni zarządzania: wiedzą, przedsiębiorczością, finansami oraz środowiskiem, ma szczególne znaczenie [6, 7, s. 366, 37, s. 226–234, 59, s. 265].

ISTOTA ORAZ ZNACZENIE INNOWACJI I INNOWACYJNOŚCI

Słowo innowacja pochodzi z języka łacińskiego *innovatio* – odnowienie; *innovare* – odnawiać, podlega ewolucyjnym zmianom, stale jest uzupełniane i rozszerzane, w związku z pojawianiem się nowych koncepcji [31, s. 16].

W literaturze nie ma ustalonej jednolitej, powszechnie akceptowanej definicji innowacji. Zarówno teoretycy, jak i praktycy posługują się tym terminem w wielu rozmaitych znaczeniach. Innowacje są jednym z najbardziej złożonych i niejednoznacznie zdefiniowanych pojęć w teorii ekonomii. Trudność polega na różnych sposobach postrzegania innowacji. Jak podają W. Janasz i K. Kozioł [24, s. 14], termin „innowacje" jest rozumiany szeroko i odnosi się do wszystkich sfer

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życia, począwszy od nowych rozwiązań dotyczących życia gospodarczego czy społecznego, a skończywszy na nowych prądach myślowych czy kulturowych.

Pojęcie innowacji wprowadził do światowej literatury ekonomicznej J.A. Schumpeter w 1912 roku; traktował on innowacje jako czynnik rozwoju gospodarczego, a jego ujęcie uznawane jest za klasyczne. Według Schumpetera [55, s. 131] innowacje to nowe kombinacje zachodzące w następujących przypadkach:

- wytworzenia nowego produktu lub wprowadzenia na rynek towarów o nowych właściwościach,
- wprowadzenia nowej metody produkcji,
- otwarcia nowego rynku zbytu,
- zdobycia nowych źródeł surowców,
- przeprowadzenia nowej organizacji procesów gospodarczych.

Definicja ta jest punktem wyjścia do rozważań o znaczeniu innowacji w gospodarce. W ujęciu Schumpetera innowacja oznacza wprowadzanie do praktyki nowego rozwiązania, przy czym autor skupiał się przede wszystkim na innowacjach technicznych i ich wpływie na gospodarkę. Jest on twórcą koncepcji tzw. „twórczej destrukcji", która polega na ciągłym niszczeniu starych struktur i nieustannym tworzeniu nowych, coraz bardziej efektywnych.

W późniejszych latach olbrzymi wpływ na kształt współczesnych poglądów na procesy innowacyjne miały między innymi opracowania P.F. Druckera [11], M.E. Portera [50] oraz E.M. Rogersa [12, 52]. P.F. Drucker [11, s. 14] twierdzi, że innowacją jest świadoma korzystna zmiana wynikająca z potrzeb lub systematycznej obserwacji środowiska zewnętrznego. Podkreśla również, że jest ona celową i skoncentrowaną pracą, która wymaga wiedzy i pomysłowości. Bodźcem do powstania innowacji nie musi być czynnik techniczny, lecz zwykła obserwacja rynku. Innowacje mogą być też traktowane w kategoriach absolutnej nowości na skalę światową [58, s. 37].

W literaturze spotyka się też wiele innych podejść do pojęcia innowacji – od ujęć wąskich, przedstawionych przez Ch. Freemana [16, s. 7], dla którego innowacja to pierwsze handlowe zastosowanie nowego produktu, procesu lub urządzenia oraz definicji E. Mansfielda [38, s. 83], z której wynika, że innowację stanowi pierwsze zastosowanie wynalazku, aż do bardziej szerokiego ujęcia reprezentowanego przez Ph. Kotlera [32, s. 322], stwierdzającego, że innowacja odnosi się do jakiegokolwiek dobra, usługi lub pomysłu, który jest postrzegany przez kogoś jako nowy. Według J. Fagerberga [15, s. 155] innowacje to nowe i lepsze niż stosowane do tej pory przez ludzi rozwiązania, które mają wpływ na społeczno -ekonomiczne warunki życia. J. Parker [45, s. 13] za innowacje uznał proces obejmujący wszelkie działania doprowadzające nowy produkt lub metodę wytwarzania do praktycznego zastosowania. Z kolei zgodnie z definicją A.J. Harmana [21, s. 151-169] innowacje polegają na wprowadzeniu nowych lub znacząco udoskonalonych produktów lub procesów na rynek. Ciekawe wytłumaczenie pojęcia innowacji zaprezentował G. Silverberg [56, s. 21], który stwierdził, że są one wynikiem oddziaływania czynników wewnętrznych, takich jak wydatki przeznaczane przez krajowe podmioty gospodarcze na działalność B+R bądź inwestycje w wykształcenie kapitału ludzkiego. Uważał, że dzięki należycie wyszkolonemu personelowi zwiększają się możliwości innowacyjne podmiotów gospodarczych, a tym samym skutkują rozwojem gospodarczym.

Według L. Białoń [4, s. 80] innowacja jest końcowym efektem procesu innowacyjnego. Natomiast proces innowacyjny jest to ciąg zdarzeń od powstania idei innowacyjnej do jej wdrożenia i upowszechnienia, którego bezpośrednim celem jest zmiana produktowa, technologiczna, organizacyjna i społeczna [5, s. 85].

J. Baruk [3, s. 78-94] trafnie podsumował istotę i zakres pojęcia innowacji w opiniach różnych autorów, a nawet wskazał wspólne ich cechy:

- innowacja jest celową i korzystną zmianą w dotychczasowym stanie, która musi znaleźć praktyczne zastosowanie;
- przedmiotem zmian są wyroby, usługi procesy, organizacja, metody zarządzania, rynek, a ich następstwem powinny być określone korzyści techniczne, ekonomiczne i społeczne;
- innowacje są środkiem realizacji celów rozwojowych organizacji oraz nośnikiem postępu technicznego (jeśli przynoszą korzystne efekty ekonomiczne);
- innowacje wymagają określonego zasobu wiedzy technicznej, rynkowej, ekonomicznej i socjopsychologicznej.

W tabeli 1 zaprezentowano wybrane definicje innowacji według polskich naukowców w ujęciu chronologicznym.

Ewolucja pojęcia innowacji, związana z przechodzeniem od gospodarki przemysłowej do gospodarki opartej na wiedzy, spowodowała poszerzenie definicji innowacji. W kolejnych edycjach podręcznika Oslo Manual [42] przez innowacje rozumie się wprowadzenie nowego lub znacząco udoskonalonego produktu (towaru lub usługi), procesu, nowej metody marketingowej lub nowej metody organizacyjnej do środowiska pracy lub zewnętrznych relacji organizacji. Działania takie można uznać za innowacyjne wówczas, gdy produkt, proces, metoda marketingowa lub organizacyjna jest nowa lub znacząco udoskonalona w skali przedsiębiorstwa [28, s. 159–164]. Przytoczona definicja innowacji jest szeroka, uwzględnia zarówno zmiany dotyczące technologii, jak i pozatechnologiczne [18, s. 34].

UWARUNKOWANIA DZIAŁALNOŚCI INNOWACYJNEJ PRZEDSIĘBIORSTW

Na działalność innowacyjną polskich przedsiębiorstw wpływ mają różnego rodzaju uwarunkowania (determinanty[1]), które często określane są zamiennie, jako uwarunkowania, bodźce, stymulatory, impulsy. Czynników warunkujących działalność innowacyjną jest wiele, dlatego konieczne jest ich pogrupowanie i usystematyzowanie. Najogólniej można je podzielić na wewnętrzne i zewnętrzne determinanty działalności innowacyjnej (Tabela 2 i Tabela 3).

1 Najczęściej determinanty rozumiane są jako czynniki powodujące określone działania [53].

Table 1. Selected definitions of the innovation of Polish scientists in chronological order

Tabela 1. Wybrane definicje innowacji polskich naukowców w ujęciu chronologicznym

Autor	Definicja innowacji
Z. Pietrasiński [1970]	Innowacje to zmiany celowo wprowadzone przez człowieka lub zaprojektowane przezeń układy cybernetyczne, które polegają na zastępowaniu dotychczasowych stanów rzeczy innymi ocenianymi dodatnio w świetle określonych kryteriów i składającymi się w sumie na postęp.
S. Kasprzyk [1980]	Innowacje to nowy, nieznany dotychczas sposób zaspokojenia nowych potrzeb.
W. Grzywacz [1995]	Innowacja to kategoria ekonomiczna, która musi przynieść korzyści przez efektywniejsze wykorzystanie zasobów.
A. Pomykalski [2001]	Innowacja to całość działań związanych z kreowaniem pomysłu, powstawaniem wynalazku, a następnie wdrożeniem nowego lub ulepszonego produktu lub procesu.
W.M. Grudzewski, I.K. Hejduk [2004]	Innowacją jest każda zmiana pozwalająca sprawniej poruszać się na rynku.
J. Koch [2004]	Innowacja to zmiana przynosząca zysk.
W. Świtalski [2005]	Innowacja jest efektem zmiany modyfikującej lub wprowadzającej zupełnie nowe elementy do sposobów lub wyników funkcjonowania określonego podmiotu.
L. Białoń [2006]	Innowacja to efekt wdrożenia po raz pierwszy w przedsiębiorstwie nowego lub istotnie ulepszonego produktu, procesu, systemu lub urządzenia.
S. Marciniak [2010a]	Innowacje to rozwiązania, które zmieniają dotychczasowy stan rzeczy, wprowadzają nowości i mają charakter twórczy.
W. Janasz, K. Kozioł-Nadolna [2011]	Innowacja to zmiana w metodach wytwarzania i produktach bazująca na nowej lub niewykorzystanej dotychczas wiedzy.

Source: [46, p. 9]; [29, p. 26]; [20, p. 133]; [47, p. 8]; [19, p. 156]; [30, pp. 123–132]; [60, p. 148]; [7, p. 366]; [39, p. 167]; [25, p. 56] – adopted after [18]

Źródło: [46, s. 9]; [29, s. 26]; [20, s. 133]; [47, s. 8]; [19, s. 156]; [30, s. 123–132]; [60, s. 148]; [7, s. 366]; [39, s. 167]; [25, s. 56] – adoptowane za [18]

Według Oslo Manual [42] można wydzielić czynniki kształtujące działalność innowacyjną na poziomie otoczenia i samego przedsiębiorstwa. Obok czynników działających na poziomie przedsiębiorstwa, które są zwane dynamem innowacyjnym, działają czynniki transferu, czyli czynniki: ludzkie, społeczne i kulturowe, które wpływają na transfer informacji do przedsiębiorstw i na proces uczenia się w przedsiębiorstwach.

Klasyfikację i charakterystykę wewnętrznych uwarunkowań (determinant) innowacyjności przedsiębiorstw przedstawia tabela 2.

Skłonność przedsiębiorstw do podejmowania działalności innowacyjnej warunkowana jest ich zdolnością do szybkiego reagowania na bodźce pochodzące z otoczenia. Według Oslo Manual [42] można wydzielić czynniki kształtujące działalność innowacyjną na poziomie otoczenia.

Table 2. Classifications and characteristics of internal conditions (determinants) of enterprise innovativeness

Tabela 2. Klasyfikacje i charakterystyka wewnętrznych uwarunkowań (determinant) innowacyjności przedsiębiorstw

Autor	Charakterystyka wewnętrznego uwarunkowania
J. Bogdanienko, M. Haffer, W. Popławski [8]	Czynniki wewnętrzne przedsiębiorstwa decydują w dużym stopniu o efektach w postaci innowacji. Poprawa innowacyjności podmiotów gospodarczych (firm) wymaga szczególnego sposobu zarządzania: elastycznego, kompleksowego i zapewniającego minimalizację naturalnego oporu wobec zmian. Sukces w skutecznym wdrażaniu innowacji może zapewnić menedżer firmy, który poprzez wcześniej przeprowadzone badania określa branżę, w której działa firma, a także obszar rynku, na którym funkcjonuje i będzie się rozwijała. Poza tym dobry menedżer powinien rozumieć specyfikę swojej firmy, dzięki czemu będzie w stanie wybrać odpowiednie osoby do realizacji poszczególnych funkcji przedsiębiorstwa. Główne kierownictwo powinno stworzyć i koordynować system komunikacji, w celu określenia przebiegu współpracy pomiędzy działami oraz wspierać inicjatywy pozostałych członków zespołu. Należy również pamiętać, że innowacyjne pomysły może mieć nie tylko kadra kierownicza, ale także pracownicy niższych szczebli. Z tego względu należy zwiększać motywacje wszystkich pracowników przedsiębiorstwa do zaangażowania się w działalność innowacyjną firmy.

Autor	Charakterystyka wewnętrznego uwarunkowania
H. Mizgajska [41]	Jednym z czynników determinujących aktywność innowacyjną przedsiębiorstw jest sposób zarządzania.
W. Popławski [49]	Proponuje nazwać kulturę sprzyjającą innowacjom kulturą innowacyjną, której synonimem jest klimat innowacyjny. Według niego na kulturę innowacyjną składa się m.in.: ✦ poziom wykształcenia i ogólnej wiedzy menedżerskiej, ekonomicznej, społecznej, ✦ sprawne systemy komunikowania się w organizacji, ✦ ambicje i atmosfera współzawodnictwa, ✦ systemy motywacyjne, nagradzanie sukcesu innowacyjnego i jednocześnie niekaranie za błędy, ✦ brak arogancji i postaw egoistycznych, ✦ upublicznienie autorów sukcesu i tych, którzy ten proces wspomagali.
B. Barczak, J. Walas-Trębacz [1]	Ważnym czynnikiem wpływającym na działalność innowacyjną przedsiębiorstw jest kultura organizacyjna, określana jako sposób myślenia oraz działania pracowników. Tworzenie i wdrażanie innowacji możliwe jest między innymi dzięki wykorzystaniu kreatywności pracowników. Wewnętrzne czynniki innowacyjności bardzo często zależą od cech osobowościowych zarządzających, a także od zaangażowania personelu oraz odpowiedniego zarządzania zasobami materialnymi i infrastrukturą firmy.
M. Dworczyk, R. Szlasa [13]	Wymienili między innymi następujące uwarunkowania: ✦ umiejętność określania potrzeb bieżących i długoterminowych w zakresie innowacji produktowych, procesowych i organizacyjno-ekonomicznych, ✦ umiejętność przygotowania programu i jego optymalizacji przez kierownictwo, ✦ umiejętność kierowania realizacją poszczególnych etapów wprowadzania innowacji, ✦ umiejętność wdrażana projektów innowacyjnych i środków technicznych do produkcji, ✦ umiejętność projektowania rozwiązań innowacyjnych dzięki wykwalifikowanej kadrze inżynierskiej i pomocniczej, ✦ umiejętność zapewnienia i sprawnego gospodarowania środkami finansowymi przeznaczonymi na działalność innowacyjną, ✦ umiejętność wykorzystania potencjału innowacyjnego pracowników.

Source: [8, pp. 156, 189], [41, p. 44]; [49, p. 5]; [1, p. 407]; [13, pp. 171-180]

Źródło: [8, s. 156, 189], [41, s. 44]; [49, s. 5]; [1, s. 407]; [13, s. 171-180]

Table 3. Classifications and characteristics of general (external) conditions (determinants) of enterprise innovativeness

Tabela 3. Klasyfikacje i charakterystyka ogólnych (zewnętrznych) uwarunkowań (determinant) innowacyjności przedsiębiorstw

Autor	Charakterystyka uwarunkowań ogólnych (zewnętrznych)
W. Janasz [26]	Na działalność innowacyjną poza posiadanymi zasobami, czyli czynnikami wewnętrznymi, wpływ ma także otoczenie przedsiębiorstwa, na które składają się czynniki: ✦ kulturowe, ✦ prawne, ✦ ekonomiczne, ✦ techniczne.
B. Barczak, J. Walas-Trębacz [2]	Do uwarunkowań ogólnych działań innowacyjnych należą instytucje i warunki determinujące innowacje oraz baza naukowo-inżynieryjna, na które składają się instytucje naukowo-badawcze wspierające dynamo innowacyjne. Uwarunkowania (determinanty) zewnętrzne, ze względu na swój charakter mogą zarówno stymulować, jak i ograniczać skłonność przedsiębiorstwa do podejmowania przedsięwzięć innowacyjnych.
W. Wiszniewski [62]	Zaproponował podział zewnętrznych uwarunkowań (determinant) innowacyjności. Wyróżnił on: uwarunkowania ogólne, obejmujące instytucje oraz ogólne warunki, które determinują wprowadzanie innowacji, bazę naukowo-techniczną, a więc instytucje naukowo-techniczne wspierające dynamo innowacyjne, czynniki transferu technologii, w skład których wchodzą zarówno czynniki ludzkie, społeczne, jak i kulturowe, dynamiczne czynniki kształtujące proces innowacyjny w przedsiębiorstwie, czyli dynamo innowacyjne.

Source: [26, p. 41]; [2, p. 404]; [62, p. 13]

Źródło: [26, s. 41]; [2, s. 404]; [62, s. 13]

W tabeli 3 została zaprezentowana klasyfikacja i charakterystyka ogólnych (zewnętrznych) uwarunkowań (determinant) innowacyjności przedsiębiorstw.

RODZAJE INNOWACJI

Innowacje można interpretować w szerokim albo w wąskim rozumieniu. Innowacją w szerokim rozumieniu jest każde usprawnienie czy zmiana w produkcji związana z przyswojeniem wiedzy[2], a wąsko rozumiane innowacje polegają na zmianach w produkcji (zarówno produktach, jak i metodach wytwarzania) wynikających wyłącznie z nowej lub dotąd nie stosowanej wiedzy. W danych prezentowanych przez GUS poprzez innowacje rozumie się wprowadzenie produktów, metod organizacyjnych i marketingowych, które nie muszą

2 Obecnie te innowacje według [35, s. 60] określane są często mianem imitacji (naśladownictwa).

być restrykcyjnie rozumianą nowością na rynku, ale są nowością we wdrażającym je przedsiębiorstwie, a więc jest to szerokie rozumienie innowacji [35, s. 60].

Innowacje można klasyfikować ze względu na przedmiot i rodzaj związanych z innowacją efektów. Zgodnie z tym klasycznym podziałem wyróżnić można *innowacje produktowe* – obejmujące zmiany fizycznej charakterystyki lub osiągów istniejących produktów i usług oraz *innowacje procesowe* – obejmujące zmiany w sposobach wytwarzania lub dystrybucji produktów i usług. Wdrożenie innowacji produktowych prowadzi zazwyczaj do wyeliminowania produktów przestarzałych i rozszerzenia asortymentu wyrobów, co pozwala utrzymać dobrą pozycję firmy na rynku i prowadzi do otwarcia nowych rynków zbytu. Korzyści wynikające z wdrożenia innowacji procesowych wiążą się zazwyczaj z obniżeniem kosztów produkcji, poprawą możliwości elastycznego projektowania produkcji w zależności od potrzeb i warunków, zmniejszeniem zanieczyszczania środowiska, a także poprawą warunków pracy [35, s. 60].

Autorzy trzeciego wydania podręcznika Oslo Manual [43], cytowanego wcześniej, po raz pierwszy, podzielili innowacje na dwie grupy. Obok innowacji o charakterze technologicznym, wyróżnili problematykę innowacji nietechnologicznych. W efekcie zakres pojęcia innowacji został ujęty w dwóch wymienionych typach: innowacje marketingowe oraz organizacyjne, przy czym innowacje technologiczne uwzględniały innowacje produktowe/usługowe i procesowe, a innowacje nietechnologiczne, odpowiednio marketingowe i organizacyjne.

Tabela 4 przedstawia podział innowacji w ujęciu chronologicznym proponowany przez polskich autorów.

Table 4. Breakdown of innovations in chronological order proposed by Polish authors

Tabela 4. Podział innowacji w ujęciu chronologicznym proponowany przez polskich autorów

Autor	Proponowany podział innowacji
Z. Madej 1970	Proponuje podział innowacji ze względu na kwalifikacje i wiedzę pracowników oraz dziedzinę wiedzy lub życia społeczno-gospodarczego. Wyróżnia on innowacje: ✦ techniczne i technologiczne (technika i technologia wpływają na opracowywanie i wdrażanie nowych procesów innowacyjnych, produktów czy usług), ✦ ekonomiczno-organizacyjne (innowacje tworzy organizacja), ✦ społeczne i socjalno-bytowe (innowacje przeprowadzane w dziedzinie pozaprodukcyjnej działalności przedsiębiorstwa).
B. Ileczko 1979	Proponuje podział innowacji, ze względu na obszar życia lub obszar funkcjonalny organizacji, dzieląc je na: ✦ antropocentryczne, tzn. dotyczące różnych przejawów życia, ✦ społeczne – dotyczące stosunków międzyludzkich, ✦ biotyczne – czyli innowacje w zakresie przyrody, ✦ techniczne – zmiany w technice i technologii.
L. Białoń 1996	Przyjmując jako kryterium przedmiot, wyróżnia innowacje: ✦ produktowe, ✦ procesowe, ✦ organizacyjne.
J. Lichtarski 1997	Ze względu na mechanizm pobudzania do innowacji podzielił innowacje na dwie grupy: ✦ innowacje podażowe (inicjowane przez naukę i technikę), ✦ innowacje popytowe (inicjowane przez rynek).
J. Dąbrowski, J. Kodałkiewicz 1998	Ze względu na skalę zmian wywołanych przez nie, innowacje dzielą na: ✦ radykalne, polegające na wprowadzeniu nowych produktów, procesów technologicznych, sposobów zarządzania. Przez innych autorów innowacje te nazywane są często jako podstawowe, rewolucyjne czy kreatywne [24, s. 25-30], ✦ rekombinacyjne (usprawniające), które polegają na wykorzystaniu już istniejących rozwiązań technicznych, produkcyjnych, organizacyjnych w celu tworzenia nowych produktów i technologii. Opierają się na istniejących w przedsiębiorstwie zasobach i wiedzy, ✦ modyfikacyjne, polegające na nieznacznych zmianach (modyfikacjach) w istniejących produktach, technologiach, czy systemach organizacyjnych.
M. Brzeziński, 2001	Biorąc za podstawę klasyfikacji przedmiot innowacji, wyróżnia trzy rodzaje przedsięwzięć: ✦ Innowacje w produkcie, które obejmują wszelkie zmiany polegające na doskonaleniu wyrobu już produkowanego bądź na rozszerzeniu struktury asortymentowej o nowy produkt, a następnie wprowadzeniu go na rynek; ✦ Innowacje w procesie wytwórczym, obejmujące zmiany w stosowanych metodach wytwórczych; ✦ Innowacje organizacyjne, dotyczące zmian jedynie w organizacji procesu produkcyjnego, bez uwzględnienia zmian organizacyjnych.
A. Pomykalski 2001	Zaproponował ogólny podział innowacji podobny do klasyfikacji OECD, wyróżniając innowacje: ✦ produktowe, ✦ procesowe, ✦ marketingowe, ✦ organizacyjne.

Source: [36, p. 133]; [23, pp. 497-515]; [4, p. 82]; [34, p. 149]; [10, pp. 138-140]; [9, p. 35]; [48, p. 13]

Źródło: [36, s. 133]; [23, s. 497-515]; [4, s. 82]; [34, s. 149]; [10, s. 138-140]; [9, s. 35]; [48, s. 13]

Innowacje (nowe, lepsze, atrakcyjniejsze produkty i usługi skierowane do konsumenta), pozwalają osiągnąć większy udział w rynku, zdobyć przewagę konkurencyjną, innowacje procesowe wprowadzają nowe rozwiązania technologiczne i mają za zadanie zwiększyć w przedsiębiorstwie opłacalność produkcji przez obniżenie kosztów i większą efektywność [18, s. 53].

Wpływ innowacji technologicznych na wzrost gospodarczy uznawano za kluczowy już od czasów J. Schumpetera [54, s. 455] czy R.M. Solowa [57, s. 65-94]. Współczesne podejście do innowacji zmieniło się wraz z pojawieniem się nowych koncepcji procesu innowacyjnego. Do najbardziej widocznych i istotnych tendencji w tym zakresie zaliczyć należy wyjście poza technologiczne aspekty innowacyjności. w kontekście pobudzania działań innowacyjnych przedsiębiorstw zyskują coraz częściej na znaczeniu innowacje o charakterze nietechnologicznym.

CZYNNIK LUDZKI W ORGANIZACJACH INNOWACYJNYCH

Innowacyjność występuje w organizacjach, gdzie dominuje nastawienie na intelektualizację czynności zawodowych, tj. aktywny stosunek do własnej pracy, rozpatrywanej przez pryzmat celów oraz krytyczne podejście do tego, co się robi. W takich organizacjach nacisk kładziony jest na radzenie sobie w trudnych sytuacjach. Ceniona jest zdolność do częstego przekształcania celów, metod i form organizacyjnych działalności [44, s. 33].

Aby zapewnić innowacyjność trzeba zadbać o sprzyjającą wyzwalaniu inwencji atmosferę w firmie. Kierownictwo najwyższego szczebla powinno w umiejętny sposób pobudzać kreatywność wszystkich pracowników, porzucając tradycyjne przekonanie, że tylko kadra menedżerska powinna projektować zmiany, gdyż niejednokrotnie najbardziej innowacyjne pomysły rodzą się w głowach specjalistów niższego szczebla [8, s. 39].

Czynnik ludzki, a szczególnie zarządzanie zasobami ludzkimi jest obecnie postrzegane jako kluczowy element sukcesu w zakresie innowacyjności, dlatego też od tego momentu ten wymiar zarządzania wpisał się już na stałe do całego procesu innowacyjności [17]. Nie ma dobrych technologii czy dobrej innowacyjności bez kompetentnych ludzi, którzy potrafią adekwatnie wykorzystać je i czerpać z nich korzyści [27, s. 265].

Jeśli organizacja chce być innowacyjna, to nie obejdzie się bez ponoszenia ryzyka – uważa F. Horibe [22, s. 26]. Jego zdaniem niemożliwe jest bycie innowacyjnym przy zachowaniu stałości organizacyjnej (unikanie zmian, ryzyka). Jeśli wszystko jest bez zmian, to taki stan oznacza, że innowacyjność właśnie umiera. Według niego należy odejść od powszechnie panującego poglądu, propagowanego przez prawników i księgowych, mówiącego o tym, że najlepszym poziomem ryzyka jest poziom zerowy.

Dla kształtowania w przedsiębiorstwach postaw proinnowacyjnych ważne jest zwłaszcza stworzenie środowiska organizacji, które sprzyja kreatywnemu i twórczemu działaniu [33, s. 60]. Innowacyjność przedsiębiorstwa zależy w dużym stopniu od sposobu traktowania kreatywności przez właściciela, menedżera i pracowników. Zadaniem przedsiębiorstwa innowacyjnego jest stosowanie systemu motywacyjnego, który w istotny sposób wzmacnia kreatywność i zaangażowanie pracowników. Zarządzanie wiedzą przynosi organizacjom określone korzyści w obszarze wzrostu skuteczności decyzji, lojalności, zaufania, kultury jakości i wiedzy. Doświadczenia wielu przedsiębiorstw potwierdzają istnienie związków pomiędzy uczeniem się, kompetencjami, kreatywnością, innowacyjnością i konkurencyjnością organizacji [33, s. 62].

Duże znaczenie dla innowacji i konkurencyjności firm ma nie tylko wykształcenie pracowników, ale także ich kompetencje. Kompetencje zawodowe pracowników można podzielić na ramowe (poznawcze, osobiste i społeczne) oraz umiejętności firmowe, biznesowe i menedżerskie [59, s. 269].

Główny Urząd Statystyczny zaprezentował niedawno wyniki zrealizowanych w 2019 r. w Polsce badań działalności innowacyjnej prowadzonej w latach 2016–2018 przez przedsiębiorstwa przemysłowe i usługowe. Badania te przeprowadzono w ramach Wspólnotowego Badania Innowacji (CIS – Community Innovation Survey), na podstawie formularza modelowego opracowanego przez narodowe urzędy statystyczne krajów Unii Europejskiej i Norwegii. Pierwszy zaprezentowany w publikacji blok tematyczny dotyczy struktury badanej zbiorowości przedsiębiorstw przemysłowych i usługowych. Drugi rozdział charakteryzuje działalność innowacyjną przedsiębiorstw aktywnych innowacyjnie i przedsiębiorstw innowacyjnych w zakresie innowacji produktowych i procesów biznesowych. W trzeciej części zaprezentowano ekonomiczne aspekty działalności innowacyjnej przedsiębiorstw. Koncentruje się ona wokół trzech zagadnień: udziału przychodów ze sprzedaży nowych lub ulepszonych produktów w przychodach ze sprzedaży ogółem, nakładów na działalność innowacyjną (ich wielkości i struktury) oraz publicznego wsparcia dla działalności innowacyjnej. Czwarty rozdział publikacji przedstawia wyniki współpracy w działalności innowacyjnej przedsiębiorstw, w tym także w ramach tzw. inicjatywy klastrowej. Zobrazowano w nim również aktywność przedsiębiorstw przemysłowych w zakresie technologii i ochrony własności intelektualnej. Ostatnia część publikacji zawiera uwarunkowania działalności przedsiębiorstw. Obejmuje strategie, źródła pozyskiwania wiedzy, metody organizacji pracy oraz oddziaływanie przepisów prawa i innych czynników na działalność innowacyjną [14, s. 17].

Strukturę badanych przedsiębiorstw przemysłowych przez GUS według działów PKD w 2018 r. prezentuje tabela 5.

Tabela 5. Struktura wybranych przedsiębiorstw przemysłowych według działów PKD w 2018 r.

Table 5. Structure of surveyed industrial enterprises by NACE divisions in 2018

Działy PKD NACE divisions	**W %** In %
Produkcja artykułów spożywczych Manufacture of food products	**14,4**
Produkcja napojów Manufacture of beverages	**0,5**
Produkcja wyrobów tytoniowych Manufacture of tobacco products	**0,0**
Produkcja papieru i wyrobów z papieru Manufacture of paper and paper products	**2,3**

Działy PKD NACE divisions	W % In %
Produkcja wyrobów farmaceutycznych Δ Manufacture of pharmaceutical products Δ	**0,4**
Produkcja urządzeń elektrycznych Manufacture of electrical equipment	**2,4**
Produkcja maszyn i urządzeń Δ Manufacture of machinery and equipment Δ	**5,0**
Naprawa, konserwacja i instalowanie maszyn i urządzeń Repair and installation of machinery and equipment	**5,2**
Wytwarzanie i zaopatrywanie w energię elektryczną, gaz, parę wodną, gorącą wodę Δ Electricity, gas, steam supply Δ	**1,5**
Pobór, uzdatnianie i dostarczanie wody Water collection, treatment and supply	**1,6**
Odprowadzanie i oczyszczanie ścieków Sewerage	**1,1**
Gospodarka odpadami; odzysk surowców Δ Waste management; materials recovery Δ	**3,1**
Rekultywacja Δ Remediation Δ	**0,2**

Source: [14, p. 25-26]

Źródło: [14, s. 25-26]

Z omawianej grupy przedsiębiorstw przemysłowych w 2018 r. najwięcej podmiotów prowadziło działalność w zakresie Produkcji artykułów spożywczych – 14,4%. Produkcja napojów nie należała do grona dominujących i wynosiła jedynie 0,5%. Natomiast najmniej było podmiotów prowadzących działalność związaną z Produkcją wyrobów tytoniowych.

Kolejna – tabela 6 – przedstawia dane dotyczące Przedsiębiorstw przemysłowych aktywnych innowacyjnie w latach 2016–2018 według wybranych Działów PKD.

Table 6. Innovation active industrial enterprises in the years 2016–2018 by selected NACE divisions

Tabela 6. Przedsiębiorstwa przemysłowe aktywne innowacyjnie w latach 2016–2018 według wybranych Działów PKD

Działy PKD NACE divisions	W % In %
Produkcja wyrobów farmaceutycznych Δ Manufacture of pharmaceutical products Δ	**58,4**
Produkcja urządzeń elektrycznych Manufacture of electrical equipment	**49,3**
Produkcja maszyn i urządzeń Δ Manufacture of machinery and equipment n.e.c.	**43,4**
Produkcja wyrobów tytoniowych Manufacture of tobacco products	**38,5**
Produkcja napojów Manufacture of beverages	**32,9**
Wytwarzanie i zaopatrywanie w energię elektryczną, gaz, parę wodną, gorącą wodę Δ Electricity, gas, steam and air conditioning supply Δ	**30,1**
Produkcja papieru i wyrobów z papieru Manufacture of paper and paper products	**27,9**
Produkcja artykułów spożywczych Manufacture of food products	**21,9**
Odprowadzanie i oczyszczanie ścieków Sewerage	**21,6**
Pobór, uzdatnianie i dostarczanie wody Water collection, treatment and supply	**20,8**
Naprawa, konserwacja i instalowanie maszyn i urządzeń Repair and installation of machinery and equipment	**17,6**
Gospodarka odpadami; odzysk surowców Δ Waste collection, treatment and disposal activities; materials recovery	**16,7**
Rekultywacja Δ Remediation activities Δ	**9,3**

Source: [14, p. 30]

Źródło: [14, s. 30]

Dla GUS przedsiębiorstwo aktywne innowacyjnie to takie, które w badanym okresie wprowadziło przynajmniej jedną innowację produktową lub procesów biznesowych, albo realizowało w tym okresie przynajmniej jeden projekt innowacyjny, który został przerwany lub zaniechany w trakcie badanego okresu (niezakończony sukcesem), bądź nie został do końca tego okresu ukończony (tzn. jest kontynuowany). Przedsiębiorstwo innowacyjne w zakresie innowacji produktowych i procesów biznesowych jest to przedsiębiorstwo, które w badanym okresie wprowadziło na rynek przynajmniej jedną innowację produktową lub procesów biznesowych (nowy lub ulepszony produkt bądź nowy lub ulepszony proces biznesowy).

W latach 2016–2018 w Przetwórstwie przemysłowym największy odsetek przedsiębiorstw aktywnych innowacyjnie wystąpił w dziale Produkcja wyrobów farmaceutycznych (58,4%). Przedsiębiorstwa zajmujące się Produkcją napojów legitymowały się aktywnością na poziomie 32,9% zaś te z Produkcji artykułów spożywczych – 21,9%. Najmniejszą aktywność innowacyjną z analizowanej grupy w Przetwórstwie przemysłowym wykazały firmy zajmujące się Rekultywacją – 9,3% [14, s. 29–35].

W tabeli 7 zaprezentowano dane dotyczące Przedsiębiorstw przemysłowych innowacyjnych w latach 2016–2018 według wybranych działów PKD.

Table 7. Industrial innovative enterprises in the years 2016–2018 by selected NACE divisions

Tabela 7. Przedsiębiorstwa przemysłowe innowacyjne w latach 2016–2018 według wybranych działów PKD

Działy PKD NACE divisions	W % In %
Produkcja wyrobów farmaceutycznych Δ Manufacture of pharmaceutical products Δ	**52,0**
Produkcja urządzeń elektrycznych Manufacture of electrical equipment	**45,4**
Produkcja maszyn i urządzeń Δ Manufacture of machinery and equipment n.e.c.	**40,8**

Działy PKD NACE divisions	**W %** In %
Produkcja wyrobów tytoniowych Manufacture of tobacco products	**38,5**
Produkcja napojów Manufacture of beverages	**31,2**
Produkcja papieru i wyrobów z papieru Manufacture of paper and paper products	**25,9**
Wytwarzanie i zaopatrywanie w energię elektryczną, gaz, parę wodną, gorącą wodę Δ Electricity, gas, steam and air conditioning supply Δ	**25,1**
Produkcja artykułów spożywczych Manufacture of food products	**20,9**
Pobór, uzdatnianie i dostarczanie wody Water collection, treatment and supply	**19,7**
Odprowadzanie i oczyszczanie ścieków Sewerage	**18,4**
Naprawa, konserwacja i instalowanie maszyn i urządzeń Repair and installation of machinery and equipment	**16,2**
Gospodarka odpadami; odzysk surowców Δ Waste collection, treatment and disposal activities; materials recovery	**14,8**
Rekultywacja Δ Remediation activities Δ	**7,4**

Source: [14, p. 35]

Źródło: [14, s. 35]

Analizując Przedsiębiorstwa przemysłowe innowacyjne w latach 2016–2018 według wybranych działów PKD na pierwszym miejscu ponownie znalazły się te reprezentujące firmy zajmujące się Produkcją wyrobów farmaceutycznych – 52%. W tej grupie Przedsiębiorstw przemysłowych firmy z branży Produkcja napojów legitymowały się wynikiem 31,2%, a reprezentujące firmy z branży Produkcji artykułów spożywczych – 20,9%. Najmniejszą grupę z analizowanej grupy w Przetwórstwie przemysłowym stanowiły firmy zajmujące się Rekultywacją – 7,4% [14, s. 35].

W poniższej tabeli 8 zaprezentowane zostały dane dotyczące Przedsiębiorstw przemysłowych innowacyjnych w latach 2016–2018 według rodzajów innowacji.

Table 8. Innovative enterprises in the years 2016–2018 by innovation types

Tabela 8. Przedsiębiorstwa przemysłowe innowacyjne w latach 2016–2018 według rodzajów innowacji

Wyszczególnienie / Specification **Przedsiębiorstwa, które wprowadziły:**	**w %** in %
innowacje Enterprises which introduced innovations	**24,0**
nowe lub ulepszone produkty new or improved products	**16,8**
nowe lub ulepszone procesy biznesowe new or improved business processes	**19,9**
w tym: / of which:	
metody wytwarzania (produkcji) wyrobów lub świadczenia usług (w tym rozwoju wyrobów lub usług) methods for producing goods or providing services (including methods for developing goods or services)	**12,3**
metody z zakresu logistyki, dostaw lub dystrybucji logistics, delivery or distribution methods	**6,8**
metody przetwarzania informacji lub komunikacji methods for information processing or communication	**8,2**
metody księgowania lub inne czynności administracyjne methods for accounting or other administrative operations	**8,3**
zasady działania wewnątrz przedsiębiorstwa lub w relacji z otoczeniem business practices for organising procedures or external relations	**8,6**
metody podziału zadań, uprawnień decyzyjnych lub zarządzania zasobami ludzkimi methods of organising work responsibility, decision making or human resource management	**10,7**
metody marketingowe w zakresie opakowań, kształtowania cen produktów, technik promocji, lokowania produktów lub usług posprzedażowych marketing methods for promotion, packaging, pricing, product placement or after sales services	**8,5**

Source: [14, p. 40-41].

Źródło: [14, s. 40-41].

Biorąc pod uwagę wszystkie Przedsiębiorstwa przemysłowe innowacyjne w latach 2016–2018 według rodzajów innowacji, na pierwszym miejscu znalazły się przedsiębiorstwa, które w latach 2016–2018 wprowadziły innowacje – 24,0%. Na drugim miejscu te przedsiębiorstwa, które wprowadziły nowe lub ulepszone procesy biznesowe – 19.9% a na trzecim, te które wprowadziły nowe lub ulepszone produkty – 16,8%.

Warto zaznaczyć, że w przedsiębiorstwach, które wprowadziły nowe lub ulepszone procesy biznesowe na pierwszym miejscu znalazły się metody wytwarzania (produkcji) wyrobów lub świadczenia usług (w tym rozwoju wyrobów lub usług) – 12,3%, na drugim metody podziału zadań, uprawnień decyzyjnych lub zarządzania zasobami ludzkimi – 10,7%.

Najczęściej innowacje produktowe lub procesów biznesowych wprowadzały podmioty o liczbie pracujących 250 osób i więcej (62,3% przedsiębiorstw przemysłowych) [14, s. 40-41].

Zestawione dane dotyczące Przedsiębiorstw przemysłowych innowacyjnych w latach 2016–2018 według rodzajów innowacji i wybranych działów PKD są zawarte w tabeli 9.

Wśród przedsiębiorstw przemysłowych, które w latach 2016–2018 wprowadziły innowacje produktowe, największy odsetek odnotowano w dziale Produkcja wyrobów farmaceutycznych (47,2%). Jeśli chodzi o Produkcję napojów to wynosiła ona – 22,5% zaś Produkcja artykułów spożywczych – 15.3%. Najmniejszy udział w przedsiębiorstwach przemysłowych wprowadzających nowe lub ulepszone produkty wystąpił w dziale Pobór, uzdatnianie i dostarczanie wody oraz Rekultywacja (po 3,7%), natomiast innowacje procesów biznesowych najrzadziej wdrażano w przedsiębiorstwach z działu Rekultywacja (3,7%) [14, s. 41].

Zgodnie z zaleceniami zawartymi w Podręczniku Oslo, udział w badanym roku przychodów ze sprzedaży nowych lub ulepszonych produktów wprowadzonych na rynek w ciągu ostatnich trzech lat w wartości przychodów ze sprzedaży

Table 9. Industrial innovative enterprises in the years 2016–2018 by innovation types and selected NACE divisions

Tabela 9. Przedsiębiorstwa przemysłowe innowacyjne w latach 2016–2018 według rodzajów innowacji i wybranych działów PKD

Działy PKD NACE divisions	**Przedsiębiorstwa, które wprowadziły nowe lub ulepszone** Enterprises which introduced new or improved		
	produkty products	**procesy biznesowe** business processes	**produkty i procesy biznesowe** products and business processes
	w % ogółu przedsiębiorstw danego rodzaju działalności as the share of total enterprises of a given economic activity		
Produkcja artykułów spożywczych Manufacture of food products	15,3	16,6	11,0
Produkcja napojów Manufacture of beverages	22,5	24,3	15,6
Produkcja wyrobów tytoniowych Manufacture of tobacco products	15,4	38,5	15,4
Produkcja papieru i wyrobów z papieru Manufacture of paper and paper products	17,9	21,9	13,9
Produkcja wyrobów farmaceutycznych Manufacture of pharmaceutical products	47,2	37,6	33,6
Produkcja urządzeń elektrycznych Manufacture of electrical equipment	36,3	36,5	27,3
Produkcja maszyn i urządzeń Δ Manufacture of machinery and equipment n.e.c.	33,2	32,5	24,9
Naprawa, konserwacja i instalowanie maszyn i urządzeń Repair and installation of machinery and equipment	8,4	14,3	6,4
Wytwarzanie i zaopatrywanie w energię elektryczną, gaz, parę wodną i gorącą wodę Δ Electricity, gas, steam and air conditioning supply	6,5	23,6	5,0
Pobór, uzdatnianie i dostarczanie wody Water collection, treatment and supply	3,7	19,1	3,1
Odprowadzanie i oczyszczanie ścieków Sewerage	5,1	18,1	4,9
Gospodarka odpadami; odzysk surowców Δ Waste collection, treatment and disposal activities; materials recovery	5,8	14,1	5,1
Rekultywacja Δ Remediation activities Δ	3,7	3,7	–

Source: [14, p. 41-43]

Źródło: [14, s. 41-43]

ogółem jest traktowany jako wskaźnik oceny efektów działalności innowacyjnej przedsiębiorstwa. Wskazuje on na zmiany w zakresie unowocześnienia asortymentu produktów oraz ich konkurencyjności. Przychody ze sprzedaży ogółem obejmują:

- przychody netto ze sprzedaży produktów (wyrobów i usług),
- przychody netto ze sprzedaży towarów i materiałów.

Przychody netto ze sprzedaży produktów są to kwoty należne z tytułu sprzedaży wyrobów gotowych w podmiotach wytwarzających te wyroby [14, s. 55].

W badaniach przychodów ze sprzedaży produktów nowych lub ulepszonych uwzględnia się:

- produkty nowe lub ulepszone dla rynku, na którym działa przedsiębiorstwo, wprowadzone na rynek w ciągu ostatnich trzech lat,
- produkty nowe lub ulepszone tylko dla przedsiębiorstwa, wprowadzone na rynek w ciągu ostatnich trzech lat [14, s. 55].

Tabela 10 przedstawia udział przychodów przedsiębiorstw przemysłowych ze sprzedaży produktów nowych lub ulepszonych w przychodach ze sprzedaży ogółem według wybranych działów PKD w 2018 r.

W 2018 r. udział przychodów netto ze sprzedaży produktów nowych lub ulepszonych wprowadzonych na rynek w latach 2016–2018 w przychodach ze sprzedaży ogółem wyniósł dla przedsiębiorstw przemysłowych 9,1%, tj. o 2,0 p. proc. więcej niż udział przychodów w 2017 r. ze sprzedaży takich produktów (wprowadzonych w latach 2015–2017). W 2018 r. w porównaniu z rokiem poprzednim w przedsiębiorstwach przemysłowych odnotowano nieznaczny spadek

w przychodach ze sprzedaży ogółem udziału przychodów ze sprzedaży produktów innowacyjnych nowych dla rynku (o 0,2 p. proc.), natomiast wzrost produktów nowych tylko dla przedsiębiorstwa (o 2,3 p. proc.).

Table 10. Revenues of industrial enterprises from sales of new or improved products as the share of total revenues from sales in selected NACE divisions in 2018

Tabela 10. Udział przychodów przedsiębiorstw przemysłowych ze sprzedaży produktów nowych lub ulepszonych w przychodach ze sprzedaży ogółem według wybranych działów PKD w 2018 r.

Działy PKD NACE divisions	**W %** In %
Produkcja urządzeń elektrycznych Manufacture of electrical equipment	**26,0**
Produkcja maszyn i urządzeń Δ Manufacture of machinery and equipment n.e.c.	**14,0**
Produkcja papieru i wyrobów z papieru Manufacture of paper and paper products	**13,5**
Naprawa, konserwacja i instalowanie maszyn i urządzeń Repair and installation of machinery and equipment	**11,1**
Produkcja wyrobów farmaceutycznych Δ Manufacture of pharmaceutical products Δ	**9,4**
Produkcja wyrobów tytoniowych Manufacture of tobacco products	**7,5**
Produkcja napojów Manufacture of beverages	**6,3**
Produkcja artykułów spożywczych Manufacture of food products	**5,1**
Gospodarka odpadami; odzysk surowców Δ Waste collection, treatment and disposal activities; materials recovery	**2,0**
Pobór, uzdatnianie i dostarczanie wody Water collection, treatment and supply	**1,3**
Wytwarzanie i zaopatrywanie w energię elektryczną, gaz, parę wodną, gorącą wodę Δ Electricity, gas, steam and air conditioning supply Δ	**0,5**
Odprowadzanie i oczyszczanie ścieków Sewerage	**0,4**
Rekultywacja Δ Remediation activities Δ	**0,1**

Source: [14, p. 55]

Źródło: [14, s. 55]

Wyniki zaprezentowane na tablicy 10 wskazują, że jeśli chodzi o udział przychodów przedsiębiorstw przemysłowych ze sprzedaży produktów nowych lub ulepszonych w przychodach ze sprzedaży ogółem według wybranych działów PKD w 2018 r. to najlepszy wynik osiągnęły firmy branży Produkcja urządzeń elektrycznych – 26,0 %. Na tym tle wyniki firm z branży Produkcja napojów 6,3% oraz z branży Produkcja artykułów spożywczych – 5,1% nie wyglądały imponująco [14, s. 55].

PODSUMOWANIE

Daje się słyszeć głosy [51], że innowacyjność to zagmatwany proces, który trudno mierzyć i nim zarządzać. Większość ludzi dostrzega ją wyłącznie wtedy, gdy prowadzi ona do znacznego wzrostu przychodu. Gdy przychody i zyski maleją w czasie recesji, wielu menedżerów dochodzi do wniosku, że innowacyjne działania nie są warte wkładanego w nie wysiłku. Uważają, że może innowacyjność nie jest taka ważna. To wysokiej rangi menedżerowie mówią, że innowacyjność jest bardzo istotna, lecz w ich firmach często dochodzi się do niej nieformalnie, a liderzy nie są pewni swych decyzji dotyczących innowacji [40].

Jak pokazuje globalne badanie opinii 765 prezesów zarządów i liderów firm opublikowane przez IBM – wśród trzech najważniejszych źródeł innowacyjnych pomysłów są pracownicy a w dalszej kolejności partnerzy biznesowi oraz klienci [61, s. 2].

W świetle badań GUS działalności innowacyjnej w latach 2016–2018 aktywne innowacyjnie przedsiębiorstwa przemysłowe stanowiły 26,1% ogólnej liczby tych podmiotów. Największy odsetek podmiotów aktywnych innowacyjnie występował wśród jednostek o liczbie pracujących 250 osób i więcej. W latach 2016–2018 udział innowacyjnych przedsiębiorstw przemysłowych wyniósł 24,0%. Innowacje produktowe lub procesów biznesowych najczęściej wprowadzały podmioty o liczbie pracujących 250 osób i więcej (62,3% przedsiębiorstw przemysłowych). W analizowanym okresie w przemyśle relatywnie najwięcej przedsiębiorstw innowacyjnych było w dziale Produkcja wyrobów farmaceutycznych – 52,0%. W dziale Produkcja napojów – 31,2% zaś dziale Produkcja artykułów spożywczych – 20,9%. Wyniki badania wskazują też, że w przedsiębiorstwach przemysłowych wyższy był udział podmiotów, które w latach 2016–2018 wprowadziły innowacje procesów biznesowych (nowe lub ulepszone procesy biznesowe) niż innowacje produktowe (nowe lub ulepszone produkty). Przeprowadzone badania wykazały dość niski poziom innowacyjności w działających w Polsce przedsiębiorstwach przemysłu spożywczego [14, s. 19].

SUMMARY

Although voices can be heard [51] that innovation is a confusing process that is difficult to measure and manage. Most people only see it when it leads to a significant increase in it. When revenues and profits diminish in a recession, many managers find that the innovative actions are not worth the effort. They believe that maybe innovation is not that important. It is high-level managers who say that innovation is very important, but their companies often come to it informally, and leaders are unsure of their decisions about innovation [40].

As shown by the global opinion poll of 765 CEOs and company leaders published by IBM – among the three most important sources of innovative ideas are employees, and then business partners and customers [61, p. 2].

According to the research conducted by the Statistics Poland on innovative activity, in 2016–2018 innovative industrial enterprises accounted for 26.1% of the total number of these entities. The highest percentage of innovatively active entities occurred among units employing 250 people

and more. In 2016–2018, the share of innovative industrial enterprises amounted to 24.0%. Product or business process innovations were most often introduced by entities employing 250 people or more (62.3% of industrial enterprises). In the analyzed period, the relatively largest number of innovative enterprises in industry was in the section Manufacturing of pharmaceutical products – 52.0%. Whereas in the section Manufacture of beverages – 31.2%, and in section Manufacture of food products – 20.9%. The results of the study also indicate that in industrial enterprises the share of entities that introduced business process innovations (new or improved business processes) was higher than product innovations (new or improved products) in 2016–2018. The conducted research showed a relatively low level of innovativeness in the food industry enterprises operating in Poland [14, p. 19].

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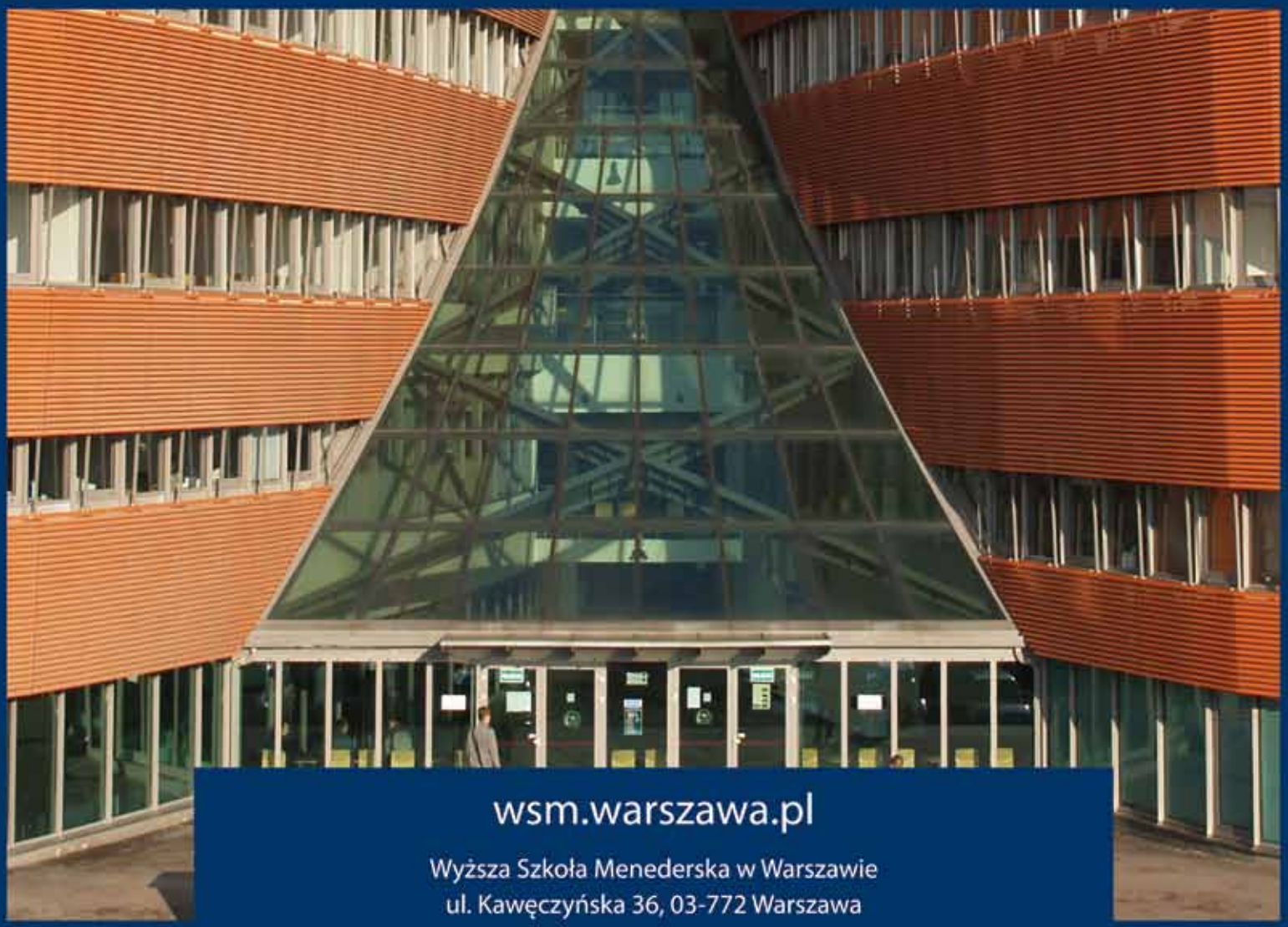

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