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TECHNOLOGICAL PROGRES IN FOOD PROCESSING

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

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SPIS TREŚCI
CONTENTS

Od Redakcji 4
Editorial

FOOD ENGINEERING
INŻYNIERIA ŻYWNOŚCI

1. **SZWEDZIAK K., P. DOLEŻAL, S. PODSĘDEK, D. KOTYSZ:**
It techniques for the assessment of pollutants in loose food raw materials 5
Techniki informatyczne w ocenie zanieczyszczeń w surowcach spożywczych.

2. **ФАТЫХОВ Ю.А., J. DIAKUN, E. SKARBEK, Z. DOMISZEWSKI:**
Conditions of African sharptooth catfish de-heading process 11
Uwarunkowania operacji odgławiania suma afrykańskiego.

3. **FILIPEK D.:**
Selected issues related to veryfication of visualizations of machanical hazards during use of machines for meat - band saw machine, circular machine and skinning machine 17
Wybrane zagadnienia związane z weryfikacją wizualizacji zagrożeń mechanicznych podczas użytkowania maszyn do mięsa – przecinarek taśmowej i tarczowej oraz skórowaczki.

4. **CICHOŃSKA P., M. ZIARNO:**
Choices and preferences of young women on plant-based beverages 22
Wybory i preferencje młodych kobiet w stosunku do napojów roślinnych.

5. **BURDZY S., A. AUGUSTYŃSKA-PREJSNAR, Z. SOKOŁOWICZ:**
Effect of the addition of inulin on the quality of poultry burgers 29
Wpływ dodatku inuliny na jakość burgerów drobiowych.

6. **SALAMON A., M. PIECYK, M. NAPIÓRKOWSKI, H. KOWALSKA:**
Characteristics of the properties of cane sugar and the assessment of its availability on the local market of Warsaw 35
Charakterystyka właściwości cukru trzcinowego i ocena jego dostępności na lokalnym rynku Warszawy.

7. **URBAŃSKA B., J. KOWALSKA:**
Analysis of 5-hydroxymethylfurfural (HMF) content in conched chocolate milk masses and selected raw materials used for their production 42
Analiza zawartości 5–hydroksymetylofurfuralu (HMF) w konszowanych czekoladowych masach mlecznych i wybranych surowcach użytych do ich wyprodukowania.

8. **WILK A., Z. SOKOŁOWICZ, A. AUGUSTYŃSKA-PREJSNAR:**
Effect of lactic acid concentration on the quality of marinated broiler breast fillets 50
Wpływ stężenia kwasu mlekowego na jakość marynowanych filetów drobiowych.

9. **SIONEK B.:**
Assessment of the Lacticaseibacillus rhamnosus Lock 900 strain for the production of probiotic beetroot juice 56
Ocena przydatności szczepu Lacticaseibacillus rhamnosus LOCK 900 do produkcji probiotycznego soku z buraka ćwikłowego.

10. **WASZKIEWICZ-ROBAK B.:**
Comparison of the content of selected bioactive compounds in infusions of different teas 63
Porównanie zawartości wybranych składników bioaktywnych w naparach herbat.

ANALYTICAL REVIEW ARTICLES
ARTYKUŁY ANALITYCZNO-PRZEGLĄDOWE

11. **BANIEWSKA M., W. BEDNARSKI, K. SZYMAŃSKA, M. ŚLIWIŃSKI:**
The influence of technological factors on the content and composition of saccharides in lactose-free milk preserved by UHT method 72
Wpływ czynników technologicznych na zawartość i skład sacharydów w bezlaktozowym mleku utrwalanym metodą UHT.

12. **SITEK A.:**
The role of selected plant products in the prevention of cadmium-induced toxicity 79
Rola wybranych produktów roślinnych w zapobieganiu toksyczności wywołanej przez kadm.

13. **WIZA P.L.:**
Transformations taking place in the dairy sector in Poland in the years 1995–2020 95
Przekształcenia zachodzące w sektorze mleczarskim w Polsce w latach 1995–2020.

14. **SZWEDZIAK K., K. ŠUSTOVA, P. DOLEŻAL, D. KOTYSZ, S. PODSĘDEK, B. OZIMEK:**
Food enriched with dietary supplements 106
Żywność wzbogacana w suplementy diety.

15. **FRĄCKIEWICZ J.:**
The nutritional and health value of fruit, vegetable and fruit-vegetable juices 112
Wartość odżywcza i zdrowotna soków owocowych, warzywnych i owocowo-warzywnych.

16. **KUCHARCZYK K., T. TUSZYŃSKI, K. ŻYŁA:**
Flocculation Process of Yeast Brewers 120
Proces flokulacji drożdży piwowarskich.

17. BAJERSKI M., K. KLIMCZAK, M. CIOCH-SKONECZNY:
Application of the oak wood chips in brewing 124
Zastosowanie płatków dębowych w browarnictwie.

18. IGNACZAK A., H. KOWALSKA:
Nutritional value of edible insects in relation to consumer acceptance 130
Wartość odżywcza owadów jadalnych wobec akceptacji konsumentów.

19. PIELAK M., E. CZARNIECKA-SKUBINA:
Stevia rebaudiana Bertoni – health benefits and technology applications in food production. A review 141
Stevia rebaudiana Bertoni – przegląd korzyści zdrowotnych oraz technologicznych zastosowań w produkcji żywności.

20. KAWECKA L., S. GALUS:
Wytłoki owocowe – charakterystyka i możliwości zagospodarowania 156
Fruit pomace – characteristics and possibilities of recycling.

21. KRÓLIKOWSKI T.:
The use of the artificial digestive tract model in nutritional sciences 168
Wykorzystanie modelu sztucznego przewodu pokarmowego w naukach żywieniowych.

22. POLAK-ŚLIWIŃSKA M.:
Microbiological safety of fruit and vegetables at the primary production stage 175
Bezpieczeństwo mikrobiologiczne warzyw i owoców na etapie produkcji pierwotnej.

23. WIERZBICKA E.:
Sweeteners as sugar substitutes in food industry – conditions of use and consumer safety 186
Substancje słodzące jako substytuty cukru w przemyśle spożywczym – warunki stosowania oraz bezpieczeństwo konsumenta.

MANAGEMENT IN FOOD PROCESSING
ZARZĄDZANIE W PRZETWÓRSTWIE SPOŻYWCZYM

24. GRUCHELSKI M., J. NIEMCZYK:
Foreign trade in agri-food products and the domestic resource base 197
Handel zagraniczny produktami rolno-żywnościowymi a krajowa baza surowcowa.

25. SZYMAŃSKA M.E.:
Good manufacturing practice in agricultural retail 204
Dobra praktyka produkcyjna w rolniczym handlu detalicznym.

LISTA RECENZENTÓW 209

ZESPÓŁ REDAKCYJNY:

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Przed nami lato, urlopy i nadzieja na lepsze jutro.

Za nami pięćdziesiąty ósmy numer „Postępów Techniki Przetwórstwa Spożywczego". Rozpoczęliśmy trzydziesty rok działalności na rynku naukowych wydawnictw periodycznych. Publikujemy jedynie recenzowane, oryginalne artykuły promujące postęp w technice przetwórstwa spożywczego.

Dotychczas opublikowaliśmy ponad 1150 artykułów. Każdy z nich posiada dwie recenzje, w większości uzyskane od specjalistów zagranicznych.

W bieżącym numerze znajdą Państwo 25 artykułów. Sygnalizuję tylko niektóre z nich, mimo że wszystkie są interesujące.

Pracownicy Politechniki Opolskiej we współpracy z Uniwersytetem w Brnie (Czechy) prezentują innowacyjne techniki oceny poziomu zanieczyszczeń mąki pszennej wykorzystujące analizę obrazu oraz sztuczne sieci neuronowe (SSN). Uniwersalność zastosowanych technik pozwala na ich coraz szersze upowszechnianie w warunkach praktyki przemysłowej przetwórstwa rolno - spożywczego.

Z badań przeprowadzonych na Politechnice Koszalińskiej we współpracy z Uniwersytetem w Kaliningradzie wynika, że przetwórstwo suma afrykańskiego w skali przemysłowej wymaga skonstruowania specjalistycznego urządzenia do odgławiania, ze względu na budowę ciała ryby.

Analiza wyników badań przeprowadzonych na Uniwersytecie Rzeszowskim pozwoliła na stwierdzenie, iż dodatek do burgerów indyczych inuliny w proszku w ilości 2% i 5% przyczynia się do zwiększenia ich atrakcyjności zapachowej oraz lepszej struktury i konsystencji a także smaku.

Istnieje możliwość zastosowania szczepu Lacticaseibacillus rhamnosus LOCK 900 do produkcji probiotycznego soku z buraka ćwikłowego, o liczbie komórek bakterii zgodnej z zaleceniami FAO/WHO. Informują o tym pracownicy Katedry Technologii Gastronomicznej i Higieny Żywności Instytutu Nauk o Żywieniu Człowieka SGGW w Warszawie.

Pracownik Katedry Dietetyki Instytutu Nauk o Żywieniu Człowieka SGGW w Warszawie analizując badania na zwierzętach wykazał korzystny wpływ produktów roślinnych takich jak: kurkuma, imbir, czosnek, cebula, olej z czarnuszki, borówka amerykańska, zielona herbata, hibiskus na zmniejszenie negatywnych skutków zdrowotnych spowodowanych ekspozycją na kadm(Cd). Zasadnym wydaje się stosowanie przez ludzi powyższych produktów.

W ramach badań nad nowymi źródłami żywności pracownicy Instytutu Nauk o Żywności SGGW w Warszawie przedstawili aktualny przegląd literatury dotyczący owadów jadalnych jako alternatywnego źródła składników o wysokiej wartości odżywczej. Analizowano sposoby przetwarzania owadów a także bezpieczeństwo ich spożywania oraz akceptację konsumentów i wymogi prawne.

Zachęcam do lektury wszystkich artykułów.

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

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IT TECHNIQUES FOR THE ASSESSMENT OF POLLUTANTS IN LOOSE FOOD RAW MATERIALS®

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The grain and milling industry deals with the grinding of grain into flour and groats. These processes take place in mills. During the technological process of producing flour and groats, contamination may occur, which reduces the quality of end products. Before the product is introduced into the consumption cycle, the flours and groats are subjected to laboratory analysis, including in terms of product purity. This analysis is based on the organoleptic determination of the amount of contamination in flour and grain products using the sense of sight. The article presents innovative techniques for assessing the quality of the pollution level using image analysis and artificial neural networks (ANNs). Wheat flour was used for laboratory tests.

Key words: image analysis, artificial neural networks, quality assessment, contamination in grain mill products, image recognition.

Przemysł zbożowo-młynarski zajmuje się przemiałem zboża na mąkę i kasze. Procesy te odbywają się w młynach. W czasie procesu technologicznego produkcji mąki oraz kasz, może dojść do zanieczyszczeń, co powoduje obniżenie jakości produktów końcowych. Przed wprowadzeniem produktu do obiegu konsumpcyjnego, mąki i kasze poddawane są analizie laboratoryjnej, między innymi pod względem czystości produktu. Analiza ta polega na organoleptycznym określeniu za pomocą zmysłu wzroku ilości zanieczyszczeń w mące i przetworach zbożowych. W artykule przedstawiono innowacyjne techniki oceny jakości poziomu zanieczyszczeń wykorzystujące analizę obrazu oraz sztuczne sieci neuronowe (SSN). Do badań laboratoryjnych wykorzystano mąkę pszenną.

Słowa kluczowe: analiza obrazu, sztuczne sieci neuronowe, ocena jakości, zanieczyszczenia w produktach przemiału zbóż, rozpoznawanie obrazu.

INTRODUCTION

Quality assessment is a comprehensive process. It includes the assessment of physicochemical, microbiological and sensory parameters.

"Quality is not a coincidence, it is always the result of good intentions, sincere effort, intelligent supervision and skillful execution" [Will Forster]. These words say that in order to obtain a product of its highest quality, one should also pay attention to the method of assessing this value so that it is credible and convinces the consumer of the 21st century. It is necessary to search for innovative, modern and, at the same time, reliable methods for these complex determinations, so far known only from the tedious work of laboratory technicians in laboratories based on chemical methods, where adding one drop of a reagent more or less may cause false results.

Summing up, it can be said that the evaluation of products, with particular emphasis on the quality characteristics taken into account in the commercial evaluation, plays an important role, because it emphasizes their value and has an impact on customer satisfaction. The use of fast and effective methods is absolutely justified, as it allows you to make accurate and quick observations, without using additional complicated laboratory methods. Computer image analysis and neural modeling have a great future in the food industry and agriculture [1].

IMAGE ANALYSIS

Agricultural and food products and raw materials are characterized by the appropriate color and shape, which makes them very easy to recognize. By using digital photos of the tested products, it is possible to objectively determine, for example, color, which in many cases is the leading feature and proves the quality of the raw material or product [3, 11].

Color is one of the basic physical properties that make raw materials and products attractive. It concerns both the external and internal appearance. In the sensory sense, each person has a slightly different way of perceiving colors, because visual

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memory is very poor compared to auditory memory and the memory of colors is limited. Another difficulty in describing color is the fact that the incident light affects its perception.

The phrase "image recognition" is some kind of acronym that is commonly used. The precise definition should be "automatic determination of the affiliation of physical objects to given abstraction classes based on their images" [9].

According to Tadeusiewicz, many useful transformations can be made in pictures, the use of which is aimed at improving the quality of information contained in the picture [8]. Koszela and Werses have applied in their studies a number of morphological transformations that allow to emphasize the features of the shape of the vegetable slices. There are four groups of transformations, which include: geometric transformations (shifts, reflections), point transformations (modified with logical and arithmetic operations), morphological transformations, filters [6, 10].

We divide the colors into achromatic and chromatic ones. The former have only one attribute - brightness or luminosity, and varies from white to shades of gray to black. On the other hand, chromatic colors have three attributes: brightness, hue and saturation.

The type of lighting is a very important factor because the perceived color is not a property of an object but a property of incident light. Depending on whether artificial or natural light falls on the tested sample, the color will be perceived differently.

An important element in image analysis is the correct definition of color and hue, which is important when determining the method of obtaining the image for analysis. Color is a psychophysical feature of visual perception that requires appropriate: light emission, stimulation of the eye's retinal receptors, processing in the cerebral cortex of stimulations transmitted by the optic nerve. In the work of Mantiuk [5, 7], a simple experiment was used to determine the influence of the environment on the perception of color. The colors of the red squares were compared with each other. Based on this experiment, it was found that human perception of color depends, among others, on the color of the environment, the color of lighting, and chromatic adaptation. Color perception can be defined independently of the environment by expressing color in the perceptual space – by calculating luminosity and saturation factors.

The sensation of an object's color being the result of the reflection or transmission of certain parts of the spectrum and the absorption of others, e.g. the object appears green because this is the range it reflects, absorbing the remaining light from the spectrum of white light. White objects transmit almost the full range of the spectrum, while black objects absorb almost the entire spectrum.

The human eye perceives color due to the stimulation of three visual pigments in the retinal cones. One of them receives a wavelength of approx. 630 nm (red), the second one receives a wavelength of approx. 530 nm (green), and the third receives a wavelength of approx. 450 nm (blue). By comparing the strength of the light source for individual component colors, the human brain interprets the color of light. This approach to the problem of color vision has become the basis for the construction of devices generating color images and color models [2, 4].

For the purposes of using to describe products, various mathematical models, often also abstract color descriptions, have been created over several hundred years.

PURPOSE AND SCOPE OF WORK

The aim of the work presented in the article was to determine the state of contamination in wheat flour using an innovative method based on computer image analysis. In the preparatory work, a test stand was made to enable sampling for testing in the form of digital photos, a computer application was developed to assess contamination in the food material tested. The research was carried out in the laboratory by comparing the traditional (weight-sieve) method to computer image analysis.

RESEARCH METHODOLOGY

10 series of tests to assess the quality of wheat flour with various degrees of contamination were performed, and 4 repetitions were performed for each series. (tab.1). For each variant, a sieve analysis was performed, by means of which the percentage of undesirable substances was determined. The same test was taken to obtain a digital image. The obtained photo was analyzed using the computer APR application and the percentage of undesirable substances in the tested sample of flour was also obtained.

Table 1. Percentage of impurities in the sample of flour

Tabela 1. Procentowy udział zanieczyszczeń w próbce mąki

Sample no	Flour weight [g]	Mass of impurities [g]	Share of pollutants in the sample [%]
1	50	2	3,84
2	50	3	5,66
3	50	4	7,40
4	50	5	9,09
5	50	6	10,7
6	50	7	12,2
7	50	8	13,7
8	50	10	16,56
9	50	12	17,98
10	50	14	20,47

Source: The own study

Źródło: Własne

The sieve analysis consisted in sieving the flour and separating the impurities in the flour, and then weighing it on an analytical balance (Fig. 1).

Then, using the computer image analysis stand (Fig. 2), pictures were taken with a digital camera and the tested samples were analyzed using the Leaf computer application (Fig. 4).

Fig. 1. Position for sieve analysis.
Rys. 1. Stanowisko do analizy sitowej.
Source: The own study
Źródło: Badania własne

The selection of appropriate lighting and the location of the acquisition device was very important in the image acquisition process. The stand must ensure a smooth, in terms of intensity, incident light supply, both from the side of the camera and from the side opposite to the camera's position, in relation to the tested material. The illuminated table was an important element thanks to which a high contrast of the object and its background was obtained. Strong, multi-directional lighting from the camera side ensures that any shadows are removed. It is important that the selection of the illuminance should take into account the sensitivity range of the sensors of the image acquisition devices. In particular, the histogram of pixel brightness levels had to be examined in terms of the maximum use of the range (Fig. 3).

Due to the need to maintain repeatability of measurements, the side walls are made of light diffusing material. The main source of lighting was internal lamps. It is important that the external lighting is not intense and does not hit the side walls of the station in points.

Fig. 3. An example of a histogram of pixel brightness levels obtained from digital images analyzed by the application "APR".
Rys. 3. Przykładowy histogram poziomów jasności pikseli uzyskany na podstawie zdjęcia cyfrowego analizowanego przez aplikację „APR".
Source: The own study
Źródło: Badania własne

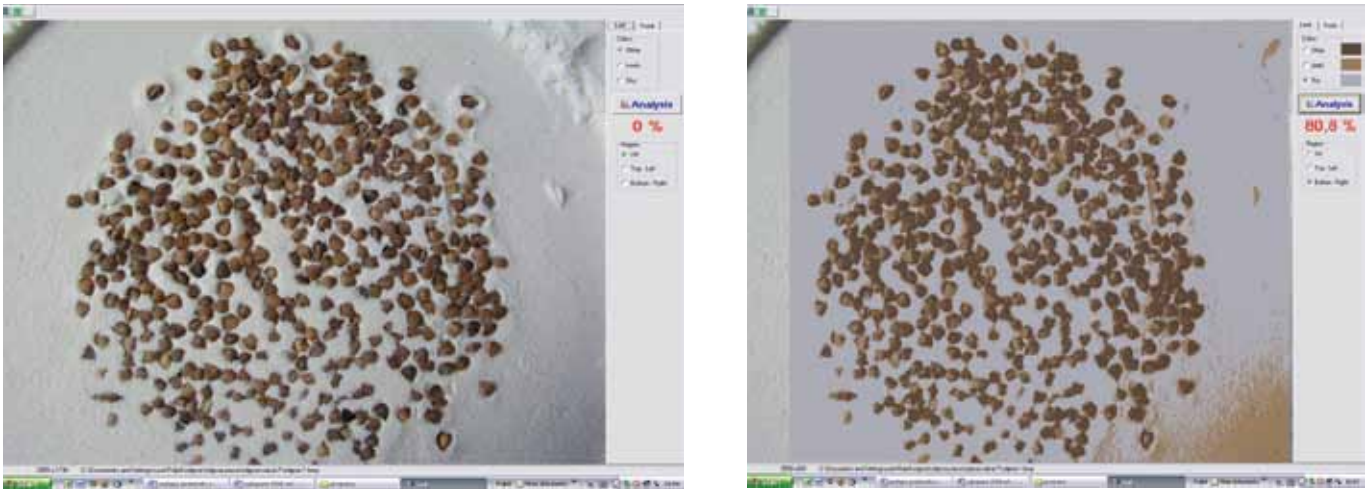
APR (Analyzes Processing Recognition) is an image analysis, processing and recognition application. Its main feature is the ability to build image processing scripts. For this purpose, a scripting language has been built in, which allows to perform a number of graphical operations. Moreover, it is possible to enter commands directly on the command line. Some operations are available from the panel containing the appropriate interface for communication with the user. The basic elements of the user interface consist of three basic windows: main, video and scripts.

The task of the "APR" computer application based on the RGB color description model and the use of the color recognition model was to separate the measured objects from the background and average the RGB components in the object outline:

$$R, G, B = \frac{\sum R_{0-255} \cdot K}{\sum K} \tag{1}$$

Where: R – recording resolution (0-255),
K – the number of pixels with a given resolution.

Fig. 2. General view of the basic module of the computer image analysis stand.
Rys.2. Ogólny widok modułu podstawowego stanowiska do komputerowej analizy obrazu.
Source: The own study
Źródło: Badania własne



a **b**

Fig. 4. Sample images impurities by weight of flour in the dialog box APR applications: a – imported image as bmp, b – analysis of imported pictures.

Rys. 4. Przykładowe zdjęcia zanieczyszczeń w masie mąki w oknie dialogowym aplikacji APR: a – zaimportowane zdjęcie w postaci bmp. b – analiza zaimportowanego zdjęcia.

Source: The own study

Źródło: Badania własne

Having averaged values of the R, G, B components, you can calculate the average brightness of the image according to the formula:

$$I = (R+G+B)/3 \quad (2)$$

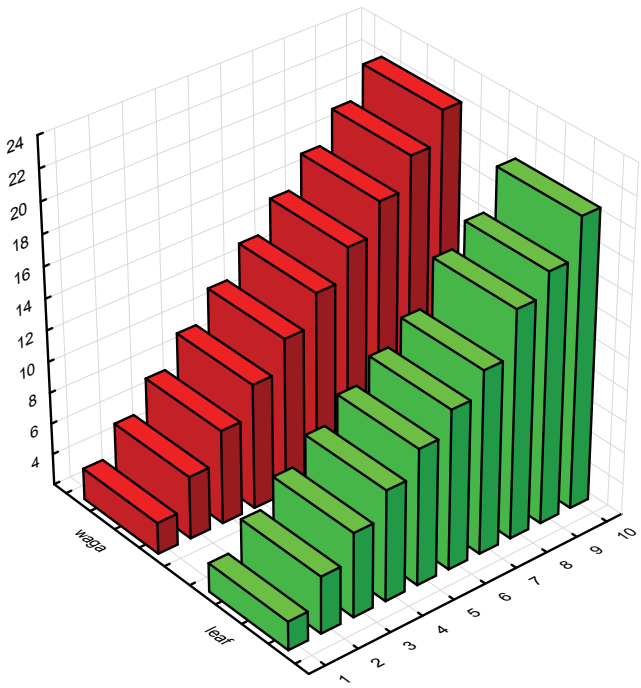


Fig. 5. Percentage of contamination of the flour obtained by the method of sieving and computer image analysis.

Rys. 5. Procentowy udział zanieczyszczeń w mące uzyskany za pomocą metody sitowej i komputerowej analizy obrazu.

Source: The own study

Źródło: Badania własne

ANALYSIS AND DISTRIBUTION OF RESULTS

On the basis of the laboratory tests performed, charts were drawn up to compare the two methods of assessing the percentage degree of flour contamination. The comparison concerned sieve analysis of loose materials and computer image analysis of these materials. (fig. 5). Additionally, descriptive statistics values were plotted (Fig. 6). On the basis of the graphs prepared, it can be concluded that the use of computer image analysis and the Leaf computer application is

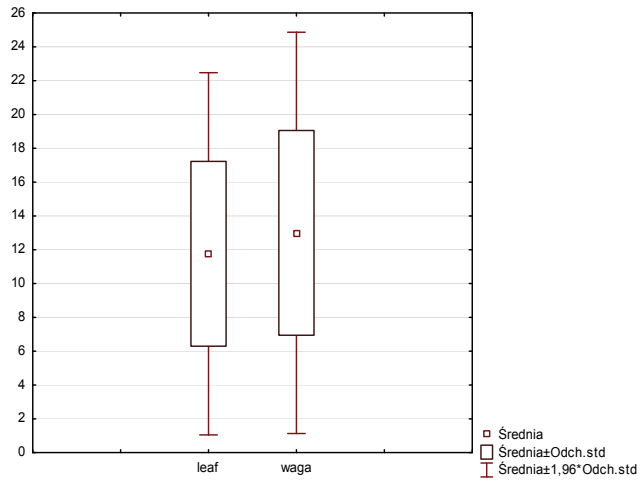


Fig. 6. Graphical interpretation of analysis of variance to assess the contamination of flour by means of computer analysis and gravimetric analysis.

Rys. 6. Interpretacja graficzna wariancji dla oceny zanieczyszczeń mąki za pomocą analizy komputerowej obrazu oraz analizy wagowej.

Source: The own study

Źródło: Badania własne

justified, because the results obtained using both methods do not differ from each other.

CONCLUSIONS

1. Computer image analysis significantly speeds up the analysis and allows for quick and easy coverage of travel costs.
2. The use of the APR computer application allows to determine the percentage of flour content in the mass.
3. The results obtained by computer image analysis do not differ from those obtained by sieve analysis, which, unfortunately, is time-consuming and labor-intensive.
4. The computer image acquisition station allows for precise taking of pictures by eliminating shadows, which is extremely important in research.
5. Using computerized image analysis over time with agri-food agency applications allows you to quickly set the fat percentage. This method has been verified and compared to the analysis (weight-sieve method). The results of computer image analysis of unprofitable results from the results of the sieve-weight analysis. The only difference was the computation time in the method to methods.
6. Assessment of the quality of agri-food products with the use of IT techniques speeds up the analysis of the production of the tested materials. Computer analysis and individual computer applications "APR" is an application that is easy to compare, accurate and innovative, which can be used in agri-food assessment.

The versatility of the possibilities of the diagnostic tools used for research and neural network tools allows them to be used in industrial practice. For the analysis of the critical state of the critical point for purchase, a random diagnostic photo of a batch of material is sufficient. You can significantly shorten the time of performing analyzes and simplify the method of sampling. The described techniques are characterized by application methods, thanks to which they can be very useful in the food industry processes.

WNIOSKI

1. Komputerowa analiza obrazu znacznie przyspiesza prowadzenie analiz i pozwala na szybkie i łatwe określanie stopnia zanieczyszczenia mąki.
2. Zastosowanie komputerowej aplikacji *APR* pozwala na określenie procentowej zawartości zanieczyszczeń w masie mąki.
3. Wyniki uzyskane za pomocą komputerowej analizy obrazu nie odbiegają od uzyskanych za pomocą analizy sitowej, która jest czasochłonna i pracochłonna.
4. Stanowisko komputerowej akwizycjo obrazu pozwala na precyzyjne wykonanie zdjęć eliminując cienie, co jest niezmiernie ważne w badaniach.
5. Stosowanie komputerowej analizy obrazu w połączeniu z aplikacjami w ocenie produktów rolno-spożywczych pozwala na szybkie określenie procentowej zawartości zanieczyszczeń. Metoda ta została zweryfikowana i porównana do analiz tradycyjnych (metoda wagowo-sitowa). Wyniki komputerowej analizy obrazu nie różniły się znacząco od wyników analizy sitowo – wagowej. Jedyną różnicą był czas wykonanych obliczeń w stosunku do metod tradycyjnych.
6. Ocena jakości produktów rolno-spożywczych za pomocą technik informatycznych znacznie przyspiesza prowadzenie analiz wyglądu zewnętrznego. Komputerowa analiza obrazu oraz poszczególne aplikacje komputerowe „APR", jest aplikacją łatwą w obsłudze, dokładną i innowacyjną, która może znaleźć zastosowanie w przemyśle rolno-spożywczym.

Uniwersalność możliwości zastosowanych narzędzi badawczych połączenia analizy obrazu i sztucznych sieci neuronowych pozwala na ich aplikację w warunkach praktyki przemysłowej. Do analizy stanu zanieczyszczenia ziarna przyjmowanego do skupu wystarczy fotografia wybranej losowo partii materiału. Zdecydowanie można skrócić czas wykonywania analiz i uprościć sposób pobierania prób. Opisane metody i techniki charakteryzują się dużą aplikacyjnością, dzięki czemu mogą być bardzo użyteczne w procesach przemysłu spożywczego.

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CONDITIONS OF AFRICAN SHARPTOOTH CATFISH DE-HEADING PROCESS®

Uwarunkowania operacji odgławiania suma afrykańskiego®

The work was carried out as part of the statutory research of the Faculty of Mechanical Engineering of the Koszalin University of Technology, under the project No. 524.02.2, entitled "Comprehensive management of African catfish in terms of technique and technology of innovative products, including biochemical and nutritional research"

Praca zrealizowana w ramach badań statutowych Wydziału Mechanicznego Politechniki Koszalińskiej, w ramach projektu nr 524.02.2, pt „Kompleksowe zagospodarowanie suma afrykańskiego pod kątem techniki i technologii innowacyjnych produktów z uwzględnieniem badań biochemicznych i żywieniowych"

This article discusses aspects of the de-heading in terms of mechanical nuisance and technological and material efficiency. The specificity of the carcass structure and the skeletal system of the head and spine of the African sharptooth catfish is presented. The conditions, possibilities and limitations of African catfish de-heading are analysed due to its structure.

Key words*:* fish de-heading, African sharptooth catfish.

W artykule omówiono znaczenie operacji odgławiania ze względu na uciążliwość mechaniczną i wydajność technologiczno-materiałową. Przedstawiono specyfikę budowy tuszy i układu kostnego głowy i kręgosłupa suma afrykańskiego. Przeanalizowano uwarunkowania, możliwości i ograniczenia odgławiania suma afrykańskiego ze względu na jego budowę.

Słowa kluczowe*:* odgławianie ryby, sum afrykański.

INTRODUCTION

The African sharptooth catfish (*Clarias gariepinus)* is a fish with significant aquaculture breeding potential. In Poland, in the early 1990s, the breeding was around 60 tons per year and according to The Federation of European Aquaculture Producers (FEAP) data for 2019, the breeding level of this species of fish was around 800 tons. It ranks third in aquaculture after carp and trout. The advantageous aspect compared to carp is that African catfish breeding is not seasonal, but continuous [8, 9]. African catfish meat has an attractive texture comparable to veal, does not have an intense fishy smell, and is a semi-fatty fish with a favourable lipid composition [2, 5].

Catfish is used as a raw material primarily in the gastronomy setting. In this regard, it is, for example, popularised on the website of the local fishing group [10]. Development of breeding and the increase in the potential scale of supply are limited by the possibility of sales. The products, e.g. caned food from industrial processing, appear on the retail market, but on a supply scale, it is essentially symbolic. The development of breeding requires the development of processing on a small processing scale of about 300 tons per year (approx. 1,500 kg daily). Such a scale of processing enables sales of the product for several breeders in the region. At the same time, it enables promoting products on the scale of industrial processing and using not only the main product (fillet), but also by-products of cutting up the carcass including recovery of meat from the spine, skin, roe, and liver [9].

In a mechanical pre-treatment of fish, de-heading is a process that is significant in two aspects. De-heading is cumbersome as a mechanical operation. During pre-treatment

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of the fish carcass, de-heading requires considerable physical strength. De-heading of several fish per minute is already a problem. The second aspect concerns the influence of the method of operation on the technological and material efficiency. The problem of technological and material efficiency can be demonstrated on the example of de-heading of carp, which was presented in research and publications of the team from the National Marine Fisheries Research Institute (MIR) in Gdynia and The Koszalin University of Technology (PK) [3, 4, 6, 7]. The basic de-heading cutting lines performed with machines for small-scale processing are shown in Fig. 1. The simplest in technical implementation is cutting with one knife, rectilinear, as shown in Fig. 1a. V-cut (Fig. 1b) is more advantageous in terms of technological and material efficiency, but it requires the use of two knives. The original development of the team (MIR, PK) is a fish de-heading machine for circular cutting around the gill. The difference in the technological and material efficiency in favour of the V-cut and the gill cut, in relation to the straight cut, is about 3% [3, 6, 7]. With a processing scale of 1 tonne per day, it yields about 30 kg of fish meat.

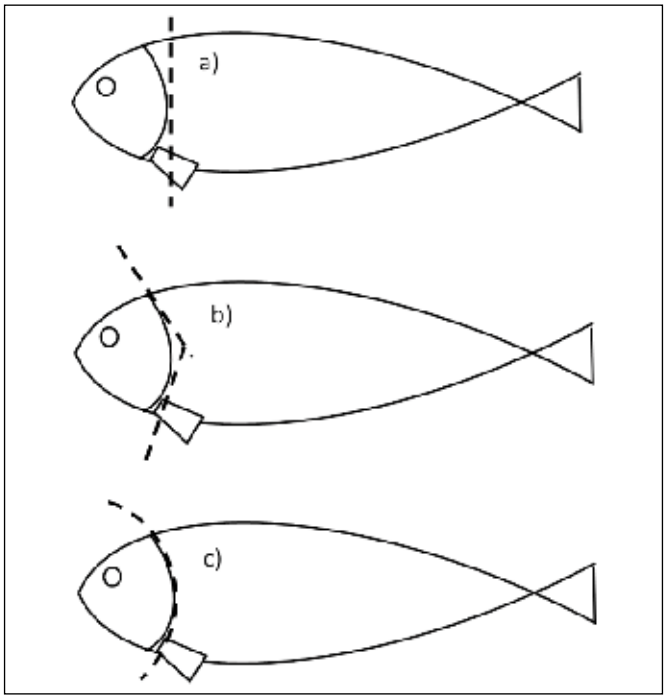

Fig. 1. Examples of de-heading cuts: a) along a straight line, b) V-cut, c) cut in the gill area.

Rys. 1. Przykłady cięć odgławiających: a) po linii prostej, b) typu V, c) okołoskrzelowe.

Source: Own study

Źródło: Opracowanie własne

Fig. 2. Pictures of the African catfish carcass: a) natural positioning on the flat head and soft abdominal area, b) positioning on the flat part of the caudal area.

Rys. 2. Fotografie tuszy suma afrykańskiego: a) naturalne ułożenie na płaskiej głowie i miękkiej strefie brzucha, b) ułożenie na płaskiej części strefy ogonowej.

Source: Own study

Źródło: Opracowanie własne

The aim of the article is to analyse the conditions and possibilities of mechanisation of catfish de-heading due to the shape of the carcass, the morphology of its skeletal system and the arrangement of the abdominal organs.

FORM OF THE CARCASS, MORPHOLOGY OF THE BONE STRUCTURE AND THE INTESTINES

The typical shape of the fish body (carcass), including those from the carp family, is flat-sided – a freely laid fish lies on its side. In this context, the carcass shape of the catfish is not typical. The caudal area is formed traditionally – flat-sided, however the head and the anterior abdominal area is flattened perpendicular to the caudal area. The flat-shaped head and the soft area of the lower abdomen determine the free position of the carcass of the fish. The fish lies on the soft part of the abdomen, as shown in the picture (Fig. 2a). The arrangement of the carcass on its side (flat caudal area), as shown in the picture (Fig. 2b), is unnatural and unstable. The shape of the carcass and its natural arrangement results from the construction of the skeletal system of the head and spine. As it can be seen in the picture – Fig. 3 – the plane of the head

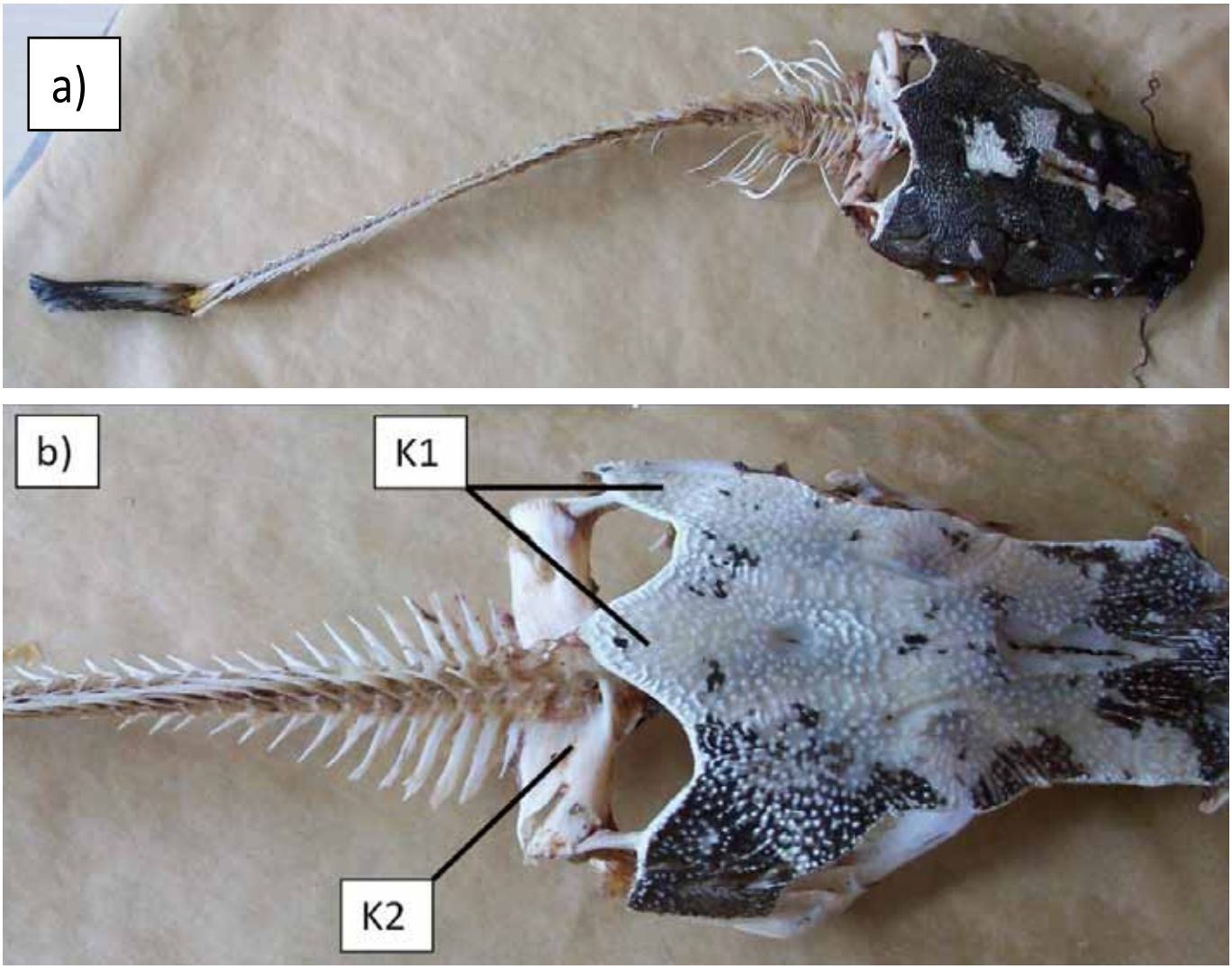

Fig. 3. Bone structure of the head and spine of the African catfish: a) view of the entire skeleton, b) head and part of the spine: K1 – head upper bone flap complex (peterotic), K2 – vertebral parapophysis bone complex (parapophysis of vertebrae); names according to [1].

Rys. 3. Układ kostny głowy i kręgosłupa suma afrykańskiego: a) widok całego szkieletu, b) głowa i fragment kręgosłupa: K1 – zespół kości górnego płata głowy (pterotic), K2 – zespół kości parapofiza kręgu (parapophoysis of vertabera); nazwy wg [1].

Source: Own study

Źródło: Opracowanie własne

Fig. 4. View of the insides of the abdomen of the African catfish.

Rys. 4. Widok wnętrzności brzucha suma afrykańskiego.

Source: Own study

Źródło: Opracowanie własne

determines the arrangement of the carcass of the fish. Due to the shape of the head bones, the bone complexes indicated in Fig. 3b can be distinguished. They are the upper flat bone flap (K1 – peterotic) and the transverse bone complex (K2 – parapophysis of vertebrae). From the K2 bone complex – parapophysis of vertebrae – the vertebrae of the spine begin. These head bone complexes, in combination with the spine, shape the flatness of the catfish head structure, the ventral area behind the head and the transition to the caudal area.

The photo (Fig. 4) shows the arrangement of the abdominal organs of the catfish. As can be seen in the picture, the abdominal cavity with its organs is in the area under the head bone complex K1 and K2 shown in Fig. 3b.

LIMITATIONS AND POSSIBILITIES OF DE-HEADING

The examples of possible de-heading cuts shown in Fig. 1 can be performed for the classic flat-sided fish carcass. The shape of the catfish's body does not allow such de-heading cuts to be conducted. A more natural arrangement of the catfish carcass for the de-heading treatment is the position resulting from the flatness of the head and the soft abdominal area, as shown in Fig. 2a and Fig. 3.

Possible machine cutting lines are shown in Fig. 5. The cutting line immediately behind the flat bone complex of the head upper flap is preferred for the full recovery of the flesh from the fish carcass. However, this incision leaves a parapophysis of vertebrae bone complex in the headless carcass and therefore requires additional cumbersome removal (trimming) procedures. Cutting along the line, behind the parapophysis of vertebrae bone complex, causes loss of a significant part of the carcass meat, thus reducing the technological and material efficiency. Moreover, both cutting planes pass through the abdominal organs of the fish. This is highly unfavourable due to the contamination resulting from the disturbance of the intestines and liver, including the gallbladder.

In case of fish with a standard flat-sided shape, the line of the de-heading cut can be identified by the outline of the gills, as shown in Fig. 1. However, in the case of the catfish, there is no clear, external distinction that would identify the edge of the head bone flap – peterotic (K1 in Fig. 3b) – and define where to cut. In the case of manual processing, the employee can determine the place of cutting by means of a touch evaluation. However, when using mechanised de-heading, such determination of the cutting line with a mechanical knife is difficult. In order to locate the line (spot) of cutting with a mechanical knife, tests of the morphology of the skeletal system depending, for example, on the weight or total length of the fish, or the width of the head are needed, or looking for methods of using the difference in the susceptibility of the fish carcass tissue in places where there is bone and where there are muscles.

Instructions (demonstration) of manual processing of the catfish carcass are shown on the website [10]. The recommended de-heading procedure consists of the following steps: incision of the back muscle of the carcass from the top, at the headbone, to the spine without cutting it; then incision on the abdominal side. The main de-heading is performed not by cutting the spine, but by breaking it at the base of the parapophysis of vertebrae bone (K2 in Fig. 3b). The process carried out in this way maximises the recovery of fish from the carcass and does not affect (does not corrupt) the abdominal organs.

Manual processing on a gastronomic scale (a few pieces daily) is not a problem. For full-industrial processing, the BADER company offers equipment with a capacity of approx. 50 pcs/min (annual scale of 5,000 tons), thus, as the scale of supply shows this is significantly too much, and also it is a process with large losses in the technological and material efficiency. With the processing conditions of the small industrial processing scale (processing with the efficiency of a few pieces per minute), the inconvenience of manual de-heading is a problem. A processing plant of this processing scale should have a machine for a mechanised de-heading procedure.

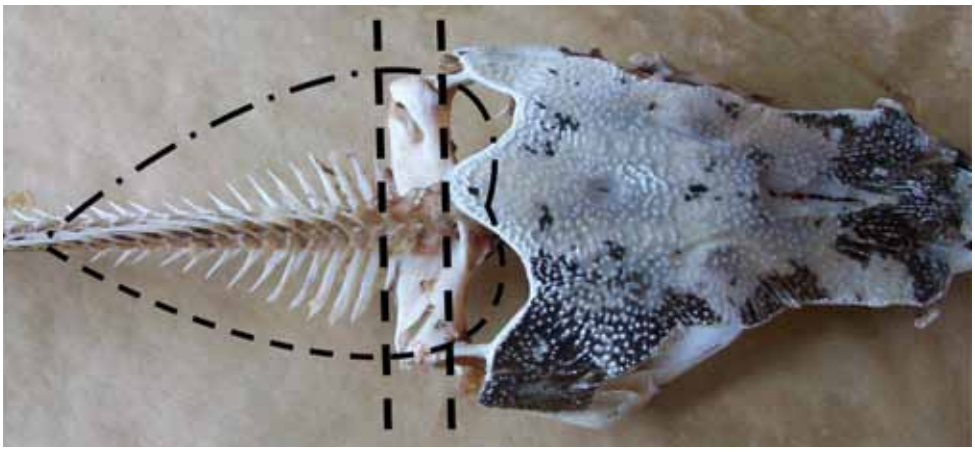

Fig. 5. Skeletal system of the head and part of the spine of the African catfish with marked: the abdominal area (dash-dot line) and the lines of the de-heading cut (dashed lines).

Rys. 5. Układ kostny głowy i fragmentu kręgosłupa suma afrykańskiego z zaznaczonymi: obszarem strefy brzusznej (linia kreska-kropka) oraz liniami cięcia odgławiającego (linie kreskowe).

Source: Own study

Źródło: Opracowanie własne

SUMMARY

1. In the pre-treatment of the fish carcass, the de-heading process is important due to its mechanical nuisance and the aspect of the technological and material efficiency.
2. The methods and devices developed and used for the de-heading of flat-sided fish such as those from the carp family cannot be used for mechanised de-heading of the catfish carcass.

3. Processing of catfish on a small industrial scale requires mechanisation of the de-heading process.
4. Due to the morphology of the catfish body structure, the mechanisation of the de-heading requires construction of a specialised device.

PODSUMOWANIE

1. We wstępnej obróbce tuszy ryby operacja odgławiania jest istotna ze względu na jej uciążliwość mechaniczną i aspekt wydajności technologiczno-materiałowej.
2. Do operacji zmechanizowanego odgławiania tuszy suma nie można zastosować metod i urządzeń opracowanych i stosowanych do odgławiania ryb płasko-bocznych jak ryby karpiowate.
3. Przetwórstwo suma w małej skali przemysłowej wymaga zmechanizowania operacji odgławiania.
4. Ze względu na morfologię budowy ciała suma, mechanizacja odgławiania wymaga skonstruowania specjalistycznego urządzenia.

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SELECTED ISSUES RELATED TO VERYFICATION OF VISUALIZATIONS OF MACHANICAL HAZARDS DURING USE OF MACHINES FOR MEAT – BAND SAW MACHINE, CIRCULAR MACHINE AND SKINNING MACHINE®

Wybrane zagadnienia związane z weryfikacją wizualizacji zagrożeń mechanicznych podczas użytkowania maszyn do mięsa – przecinarek taśmowej i tarczowej oraz skórowaczki®

This paper has been based on the results of a research task carried out within the scope of the fourth stage of the National Programme "Improvement of safety and working conditions" partly supported in 2017–2020 – within the scope of research and development — Ministry of Labour and Social Policy. The Central Institute for Labour Protection – National Research Institute is the programme's main co-ordinator.

Publikacja przygotowana na podstawie wyników badań prowadzonych w ramach „IV etapu programu wieloletniego poprawa bezpieczeństwa i warunków pracy" dofinansowanego w latach 2017–2020 w zakresie zadań służb państwowych Ministerstwo Rodzin, Pracy i Polityki Społecznej, Główny Koordynator: Centralny Instytut Ochrony Pracy – Państwowy Instytut Badawczy

The paper presents selected issues related from verification of visualizations of mechanical hazards for meat cutting: band saw machine, circular machine and skinning machine. This visualiazations was made as OSH training materials or support OSH training materials for users of machines for meat. Therefore visualizations have been subject to veryfcation. This veryfication has been performed with the participation of employees using of this tipe machines. Results of this verification Has been presented on this paper.

Key words: safety, visualizations techniques, meat industry, result analysis, system usability scale.

W artykule przedstawiono wybrane zagadnienia związane z weryfikacją wizualizacji zagrożeń mechanicznych maszyn do rozbioru mięsa: przecinarek taśmowej i tarczowej oraz skórowaczki. Wizualizacje te powstały, jako materiały szkoleniowe bądź wspomagające szkolenia z zakresu BHP podczas obsługi maszyn do mięsa. Zostały one poddane weryfikacji przez osoby związane na co dzień z branżą mięsną, a w szczególności przez pracowników mających styczność z tego typu maszynami. Wyniki tej weryfikacji zostały opisane w niniejszym artykule.

Słowa kluczowe: bezpieczeństwo, techniki wizualizacji, przemysł mięsny, analiza wyników, skala użyteczności systemu.

INTRODUCTION

According to data of Statistic Poland in 2015 about 160 thausend employeds in the food industry have worked during occurrence of hazards condition. Therein directly in hazard conditions – 31708 employeds [8]. This hazards conditions was a relsult of working environment – 59,8%, onerous work – 22,5%, mechanical factor – 5,2%. In 2013 amount of injureds was 1256 people [6], of which about 44% worked one year or less. In 2014 this value of these victims has increased about 6,9% and totaled 50,9% [7]. Therefore in Central Institute For Labour Protection – National Research Institute *actions have been taken* to improve of working safety in food industry. Objective of the job was made OSH training materials or support OSH training materials from meat industry. The aim of the project was made visualizations of mechanical hazards [2, 3] during use of three machines for meat – band saw machine [4], circular machine [5] and skinning machine.

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The first step previously made of visualizations was performer actions such as: hazard identyfication (in cooperation with meat factories), created documentation – photos, videos and drafts., analysed of accident situations during use of these machines for meat and also created of virtual environment [1] with 3D objects – machines, meat room, characters etc.

In the final effect was made six of visualizations during use of meat machines. Three of them related to band saw machine, two of them – circular machine and one of them – skinning machine.

Band saw machine visualizations have the following titles:

- Injury of fingers as result of hand operations in the danger zone of band saw machine.
- Injury of thumb as result of touch to tape saw blade at the time of meat – cutting operation.
- Cut hand as result of contact with moving tape saw blade after hit-and-run of worker.

This visualizations present mechanical hazards and accident situations leading to accidents. In visalization first and second the accident was mainly caused by wrong manual handling during meat and bone cutting operations. But in visalization third the accident was mainly caused by wrong organizations of work (transport of products without demarcate the ways of in – factory transport).

Circular machine visualizations have titles:

- Injury of operator's hand as result of contact with moving circular saw blade without saw blade guard.
- Injury of operator's hand as result of contact with moving circular saw blade without a guard lock arrangement.

This visualizations present accident situations resulting mainly from lack of saw blade guard or bypassing of the safety device. But skinning machine visualization present accident situation during incorrect cleaning of the machine. This visualization has title:

Injury of operator's hand as result of contact with toothes of shaft during of use skinning machine.

VERYFICATION OF THE VISUALIZATIONS OF MECHANICAL HAZARD DURING USE OF MACHINES FOR MEAT

In order to veyfication visualizations of mechanical hazard were carred out two seminars. On this vision and training seminars was presented visualization for emloyees of meat plants preceded by the presentation about work safety. In total twenty employyes was particpated in the seminars. All these employees operate this type of machines every day and

Survey about utility rating from visualizations of mechanical hazards during use machines for meat

Please answer the following questions (To positively indicate any option insert an X) – The survey is completely anonymous

Sex..... Age.....

No.	Question	Strongly agree	Rather angree	No opinion	Rather disagree	Strongly disagree
1.	That type of visualizations can be a good suport from OSH trainings					
2.	Visualizations are too long					
3.	The content of the visualizations understandable for me					
4.	Additional informations is nedded to understand content of visualizations					
5.	Visualizations are easy in reception					
6.	Accident situations are show in a haphazard maaner					
7.	I think for most people content of visualizations will be understandable					
8.	The problems show in visualizations are presented too complicated					
9.	Visualizations have improved my knowledge from safety of use machines for meat					
10.	If you want to watch this visualizations you must has a lot of knowledge from OSH area					

Fig. 1. Survey about utility rating from vizualizations of mechanical hazards during use machines for meat – based on SUS (System Usability Scale).

Rys. 1. Ankieta dotycząca oceny użyteczności wizualizacji zagrożeń mechanicznych podczas użytkowania maszyn do rozbioru mięsa oparta na teście SUS (System Usability Scale – Skala Użyteczności Systemu).

Source: Own study

Źródło: Opracowanie własne

worked at meat cutting. All the participants comleted a survey (on the basis of SUS – System Usability Scale fig. 1) at the end of seminary.

System SUS was created as a tool to usability evaluation through a survey. It consists of a 10 item questionnaire with five response options for respondents (based on Likert scale). The odd amount of answers makes that middle statements are most neutral. A sample person choose of the best answers for his feel.

After collection of test results shall be calculated SUS score. Test result is determined in points. It should be in the range 0 ÷ 100. Every answer should have assigned the values. According to the scheme:

For questions 1,3,5,7,9 – the scoring is as follows:

- Strongly disagree = 0 points
- Rather disagree = 1 point
- No opinion = 2 points
- Rather agree = 3 points
- Strongly agree = 4 points.

For questions 2,4,6,8,10 – the scoring is as follows:

- Strongly disagree = 4 points
- Rather disagree = 3 points
- No opinion = 2 points
- Rather agree = 1 point
- Strongly agree = 0 points.

Obtained amount of points fom all answers and surveys should be summed. Resulting value sould be multiply by 2,5. Next step is calculate the averange (should be in the range 0 ÷ 100 points). The higher the score, the better *usefulness.* SUS score above a 68 would is conside above average (a good score) and anything below 68 is below average.

The table 1 shows the scores of answers all participants of the survey. On this basis have calculated SUS score.

Callculation of SUS score

Sum of points = 696

$$SUS = \frac{696 * 2,5}{20} = 87 > 68 \qquad (1)$$

SUS score has result 87. It's *in relation to the value o*f 68 is good score. The table 1 presents quantity of points obtained from all surveys participants. On this basis in fig. 2 shows the total points from all seminar participants to indevidual questions of the survey and also the percentage values of points obtained by participants from the conrete questions of the survey – fig. 3.

Percentage distribution of ansewers from the concrete questions of the survey based on table 2 is presents on figure 4. Except of questions 2, 4 and 9 participants have don't give 0 and 1 point answers. For rest of questions wasn't actually negative answers. Figure 3 presents percentage distribution of answers. Highest percent of satisfactions obtained answers from question no. 1 – 98,75% relative to the total obtainable points (79 points out of 80 possible). Question no. 1 is about – this type of visualizations can be a good support from OSH trainngs. Lowest percent of satisfactions obtained answers from question no. 9 - 52%. This question is about – have visualizations improved my knowledge from safety of use machines for meat ? It can explain this – most of the seminar participants it was employees with a long internship production. In all of questions percent of obtained points have been more than half.

Table 1. Amount of points obtained from all surveys participants

Tabela 1. Liczba uzyskanych punktów od wszystkich uczestników ankiety

No.		Questions									
		1	2	3	4	5	6	7	8	9	10
Surveys participants	1	4	2	3	2	4	4	4	4	3	2
	2	4	0	4	3	4	4	4	4	4	4
	3	3	2	4	1	4	2	4	3	4	2
	4	4	4	3	2	4	4	3	3	3	2
	5	4	4	4	4	4	4	4	4	4	4
	6	4	1	4	4	4	4	4	4	4	3
	7	4	1	4	0	4	3	4	3	4	3
	8	4	3	4	0	4	3	4	3	4	3
	9	4	4	4	1	3	4	3	3	1	3
	10	4	4	4	4	4	4	4	4	4	4
	11	4	4	4	4	4	4	4	4	0	4
	12	4	4	4	4	4	4	4	4	0	4
	13	4	4	4	4	4	4	4	4	0	4
	14	4	4	4	4	4	4	4	4	0	4
	15	4	4	4	4	4	4	4	4	0	4
	16	4	4	4	4	4	4	4	4	3	4
	17	4	3	3	3	3	3	3	3	3	3
	18	4	4	4	4	4	4	4	4	0	4
	19	4	4	4	4	4	4	4	4	0	4
	20	4	4	4	4	4	4	4	4	0	4

Source: Own study

Źródło: Opracowanie własne

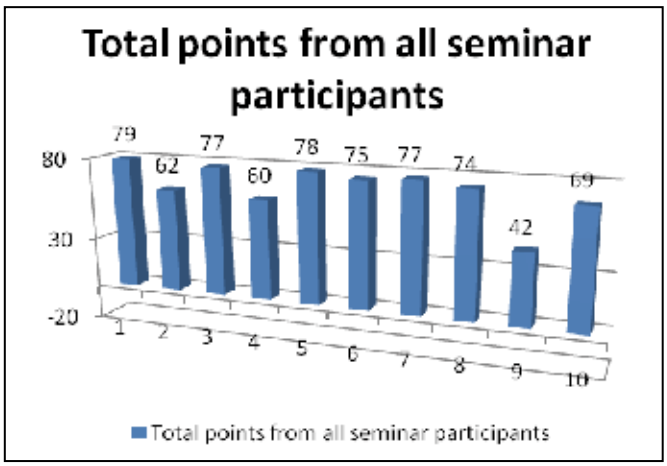

Fig. 2. The total points from all seminar participants to indevidual questions of the survey.

Rys. 2. Suma punktów od wszystkich uczestników seminarium na poszczególne pytania ankiety.

Source: Own study

Źródło: Opracowanie własne

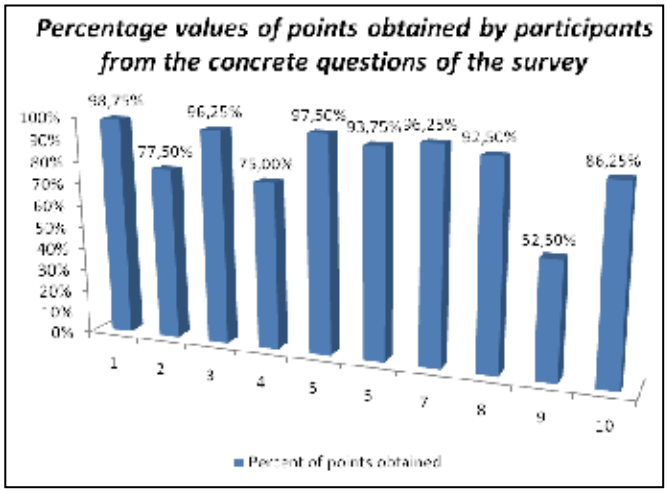

Fig. 3. Percentage values of points obtained by participants from the concrete questions of the survey.
Rys. 3. Procentowe wartości uzyskanych punktów przez uczestników na poszczególne pytania ankiety.

Source: Own study
Źródło: Opracowanie własne

Table 2. Percentage values of points obtained from the conrete questions of the survey
Tabela 2. Procentowa liczba uzyskanych punktów na poszczególne pytania ankiet

No.		Answers				
		4 pkt.	3 pkt.	2pkt.	1 pkt.	0 pkt.
Questions	1	95%	5%	0%	0%	0%
	2	60%	10%	15%	10%	5%
	3	85%	15%	0%	0%	0%
	4	65%	10%	10%	5%	10%
	5	90%	10%	0%	0%	0%
	6	80%	15%	5%	0%	0%
	7	85%	15%	0%	0%	0%
	8	70%	30%	0%	0%	0%
	9	40%	15%	0%	5%	40%
	10	60%	25%	15%	0%	0%

Source: Own study
Źródło: Opracowanie własne

Visualizations have got a positive opinion from seminar paricipants. It's can be confirmed by graph on figure 5. This graph presents the sum of points obtained from all the survey participants. Maximum sum of points realisable by one participant is 40. This score of points obtained from three participants of seminars. Total of points obtained from indyvidual participants of seminars ranges from 29 – 40 points. Only one of participant has a score below 30 points (exactly – 29 points). The most frequent survey score is 4 points fig. 6 but the rarest frequent survey score is 1 point. Obtained in total 698 points (for 800 possible).

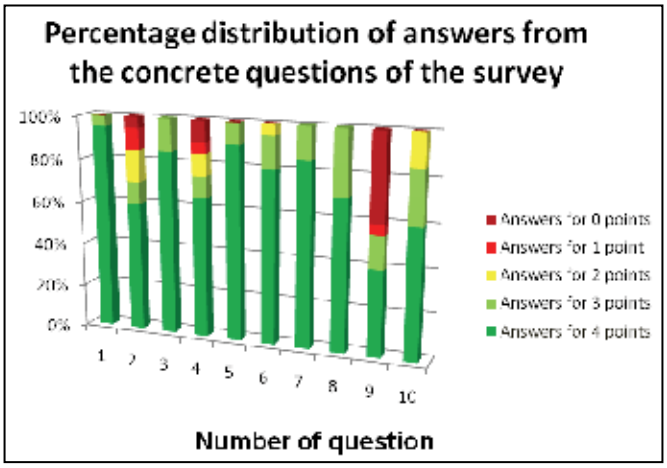

Fig. 4. Percentage distribution of ansewers from the concrete questions of the survey.
Rys. 4. Procentowy rozkład odpowiedzi na poszczególne pytania ankiety.

Source: Own study
Źródło: Opracowanie własne

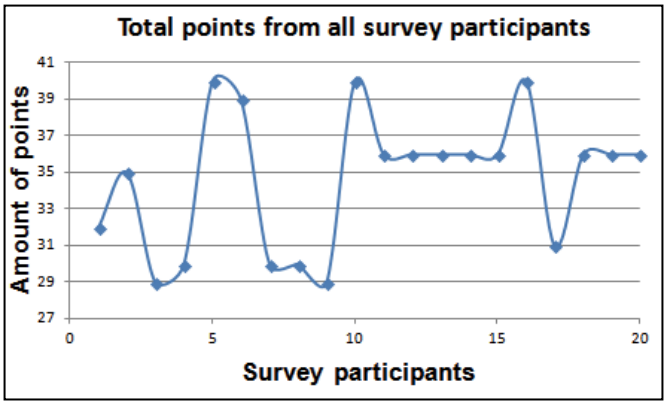

Fig. 5. Total points from all the survey participants.
Rys. 5. Suma punktów uzyskanych przez uczestników ankiety.

Source: Own study
Źródło: Opracowanie własne

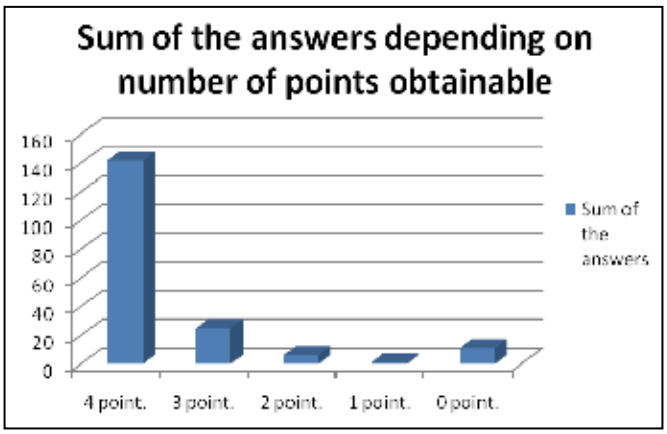

Fig. 6. Sum of the answers depending on amount of points obtainable in the survey.
Rys. 6. Suma odpowiedzi uzyskanych w zależności od liczby punktów możliwych do uzyskania w ankiecie.

Source: Own study
Źródło: Opracowanie własne

CONCLUSION

Rating and veryfication of visualization presenting of dangerous situations was performed during veryfication. Verification was realized during two shows and trainings for employees of meat plants. Veryfication has shown these films can be a good support or basic tool from OSH trainings. This was confirmed by questionnaires carried out from two groups employees of meat plants. This questionnaires have been to quantitative analysis through statistical analysis of results. Quantitative analysis showed that project was needed and correctly executed.

In the seminars participated the employees of meat plants. They use this type of machines every day. So this this type of materials are adressed to specified group of workers. Therefore, *it appears useful for* specified occupationals groups connected with meat industry, fishing industry or gastronomy.

PODSUMOWANIE

Weryfikacja wizualizacji sytuacji niebezpiecznych przeprowadzona w ramach dwóch pokazów i szkoleń dla pracowników zakładów mięsnych pokazała, że takie filmy mogą być dobrym uzupełnieniem bądź nawet podstawowym narzędziem podczas szkoleń BHP. Potwierdziła to zastosowana metoda ankietowa oceny przez dwie grupy uczestników z zakładów mięsnych oraz jej późniejsza analiza ilościowa poprzez statystyczne opracowanie wyników ankiety. Analiza ta wykazała zasadność podjętego projektu i wykonania zadania.

W seminariach uczestniczyli pracownicy, którzy na co dzień obsługują tego typu maszyny. Oczywistym jest że tego typu materiały szkoleniowe skierowane są do pewnej ściśle określonej, ukierunkowanej grupy odbiorców. Wydaje się że celowym jest ukierunkowanie tego typu materiałów i że największym zainteresowaniem mogą cieszyć się one w grupach zawodowych związanych z przemysłem mięsnym, gospodarką rybną oraz gastronomią.

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CHOICES AND PREFERENCES OF YOUNG WOMEN ON PLANT-BASED BEVERAGES®

Wybory i preferencje młodych kobiet w stosunku do napojów roślinnych®

The aim of the work presented in the article was an analysis the choices and preferences of respondents in relation to plant-based beverages and possible directions of extending their assortment on the market. The research material consisted of survey collected via the Internet from 600 people. The surveyed population was mainly young, educated women. Plant-based beverages most often chosen by respondents were those with the most favorable sensory values and the most available on the market. The respondents' satisfaction with the assortment of plant-based beverages available on the market was varied. The respondents declared a high interest in plant-based beverages enriched with vitamins and minerals, as well as beverages packed in packages of various types and volumes. Consumers are increasingly interested in the nutritional value of the food they buy and want to make conscious dietary decisions.

Key words: plant-based beverages, respondents' preferences, respondents' choices, milk substitutes.

Celem pracy przedstawionej w artykule jest analiza wyborów i preferencji respondentów w stosunku do napojów roślinnych i możliwych kierunków poszerzania ich asortymentu na rynku. Materiał badany stanowiły ankiety zebrane drogą internetową od 600 osób. Badaną populację stanowiły głównie młode, wykształcone kobiety. Najczęściej wybieranymi przez respondentów napojami roślinnymi były napoje o najkorzystniejszych walorach sensorycznych i najbardziej dostępne na rynku. Zadowolenie respondentów z asortymentu napojów roślinnych dostępnego na rynku było zróżnicowane. Osoby badane deklarowały duże zainteresowanie napojami roślinnymi wzbogacanymi w witaminy i składniki mineralne, a także napojami pakowanymi w opakowania różnych rodzajów i o różnej objętości. Konsumenci są coraz bardziej zainteresowani składem kupowanej żywności i chcą podejmować świadome decyzje żywieniowe.

Słowa kluczowe: napoje roślinne, preferencje respondentów, wybory respondentów, substytuty mleka.

INTRODUCTION

The popularity of plant-based beverages, which are usually treated as cow's milk substitutes, is growing year by year. The global market for these products is constantly increasing, and in 2018 it reached a value of USD 16.3 billion, and the European market reached around EUR 300 million. Plant-based beverages are mainly obtained through the extraction of properly processed plant materials, such as cereals, legumes, and nuts. The resulting products differ in both physicochemical and sensory properties depending on the raw material from which they were made, so their acceptance by consumers varies [8, 15].

The popularity of plant-based beverages among consumers is due to several factors. They are consumed primarily by people avoiding cow's milk due to the vegan diet or allergy / intolerance to cow's milk proteins and / or lactose. Increasingly important for many consumers is the ethical and environmental aspect of restricting animal products in the diet, and therefore replacing them with plant products. Producers indicate that the production of one liter of plant-based beverage in a carton leads to about 70% less water consumption compared to the production of the same volume of cow's milk. Plant-based beverages are also consumed due to their pro-health values, which vary depending on the type of beverage [9, 13].

Plant-based beverages are colloquially called "plant-based milk" by producers and consumers. However, it is a generalized term without a legal description. According to the law, such a term is a large generalization that may mislead the consumer, because in accordance with the Commission Regulation (EU) No 605/2010 of 2 July 2010 laying down animal and public health and veterinary certification conditions for the introduction into the European Union of raw milk and dairy products intended for human consumption, "raw milk" means " milk produced by the secretion of the mammary gland of farmed animals" [14].

Plant-based beverages are mainly obtained by water extraction of the raw material, and the detailed production technology differs depending on the raw material from which the beverage is made. However, each technology for obtaining plant-based beverages includes the following main stages: soaking the raw material, heating, grinding, solid fraction

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separation, liquid standardization, homogenization and thermal fixation. At the standardization stage, plant beverages are often enriched with various types of nutrients due to the fact that their composition usually differs significantly from that of cow's milk. Most of the plant-based beverages has a lower content of protein, fat and carbohydrates than cow's milk. The composition closest to cow's milk is soy beverage. Most often it is possible to meet the enrichment of this type of products with calcium, B vitamins, and vitamin D [3, 13]. The nutritional values of cow's milk and selected plant-based beverages available on the Polish market are presented in Table 1.

There are plant-based beverages available on the market made of cereals (e.g. oat, rice, spelled), pseudocereals (e.g. quinoa, buckwheat), legume seeds (e.g. soy, pea, lupine), based on nuts (e.g. almond, cashew), as well as beverages made from other ingredients such as coconut, flax, hemp, sesame or amaranth. In Poland, the most popular beverages are soy, coconut, oat and rice. In stores, we can find not only beverages made of various raw materials, but also beverages offered in various flavors (e.g. vanilla, cocoa), sweetened or unsweetened, organic, or enriched with various nutrients. In order to improve the nutritional properties, producers also use the procedure of combining two or more types of plant-based beverages (e.g. rice-coconut beverage) [5, 15, 17].

The aim of the study was to analyze the choices and preferences of respondents in relation to plant beverages and possible directions of extending their assortment on the market.

MATERIALS AND METHODS

The survey was conducted in 2018 using the proprietary questionnaire. The study was conducted online among polish respondents who say they consume plant-based beverages, through publications in discussion groups regarding healthy eating and the use of plant-based diets. The research method used in this study was a survey performed using the diagnostic poll method. The questionnaire consisted of questions pertaining to the demographic details of the respondents, 4 closed questions, and 5 semi-open questions. The survey included questions about the frequency of consumption and the most frequently chosen plant-based beverages, as well as factors influencing the consumption and purchase of these products. The respondents were also asked about the forms of consuming plant-based beverages and the assessment of their assortment available on the market. Moreover, the respondents were asked about their attitude to the enrichment of plant-based beverages and indication of factors negatively affecting their quality. Results presented by abundance and frequency analysis. The research material consisted of questionnaires collected from 600 respondents, with an average age of 23.7 years old. The remaining sociodemographic data are presented in Table 2.

Table 1. The nutritional values of cow's milk and selected plant-based beverages available on the Polish market

Tabela 1. Wartości odżywcze mleka krowiego i wybranych napojów roślinnych dostępnych na polskim rynku

Product	Energy (kcal/ 100 ml)	Protein (g /100 ml)	Carbonhydrates (g/100 ml)	Fat (g/100 ml)	Fibre (g/100 ml)	Fortification
Cow's milk (Mlekovita)	60	3,0	4,7	3,2	-	-
Soy beverage (Alpro)	39	3,0	2,5	1,8	0,5	vit. D, B2, B12; calcium
Soy beverage (Vitanella)	24	0,3	3,0	1,1	0,4	vit. D, B2, B12, E; calcium
Almond beverage (Alpro)	24	0,5	3,0	1,1	0,2	vit. D, B2, B12, E; calcium
Almond beverage (Sante)	12	0,3	0,3	1,0	0,1	-
Coconut beverage (Alpro)	20	0,1	1,9	0,9	0,1	vit. D, B12; calcium
Coconut beverage (The bridge)	23	0,2	1,9	1,6	-	-
Rice beverage (Alpro)	60	0,1	12,2	1,3	-	vit. D, B2, B12; calcium
Rice beverage (Pilos)	59	0,2	12,2	0,9	-	-
Oat beverage (Alpro)	43	1,4	7,0	1,3	1,4	vit. D, B2, B12; calcium
Oat beverage (enerBIO)	40	0,6	6	1,4	0,5	-

Source: The author's own study

Źródło: Opracowanie własne

Table 2. Sociodemographic profile of the studied population

Tabela 2. Profil socjodemograficzny badanej populacji

Sociodemographic criteria		Quantity	%
gender	female	568	94,7
	male	32	5,3
place of residence	city/village up to 50,000 residents	161	26,8
	city 50-200 thousand residents	106	17,7
	city over 200,000 residents	333	55,5
education	primary	81	13,5
	secondary	262	43,7
	higher	257	42,8

Source: The author's own study based on the results of the survey conducted

Źródło: Opracowanie własne na podstawie przeprowadzonych badań

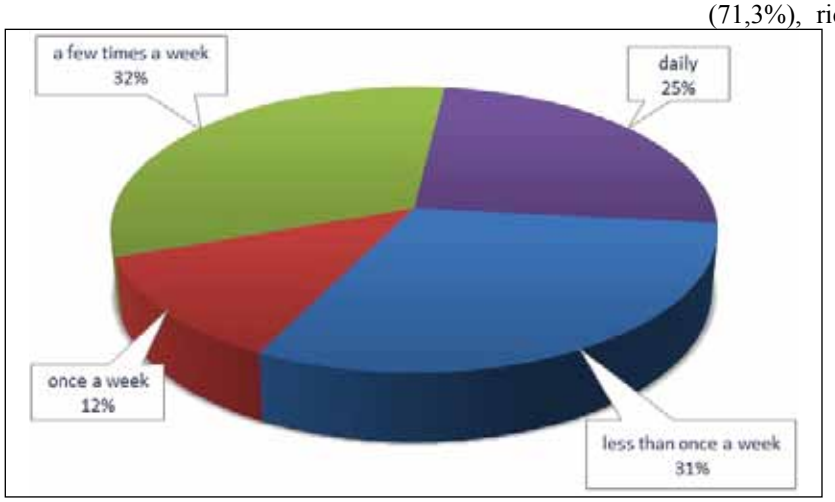

Fig. 1. The frequency of consumption of plant-based beverages by respondents.

Rys. 1. Częstotliwość spożywania napojów roślinnych przez respondentów.

Source: The author's own study based on the results of the survey conducted

Źródło: Opracowanie własne na podstawie przeprowadzonych badań

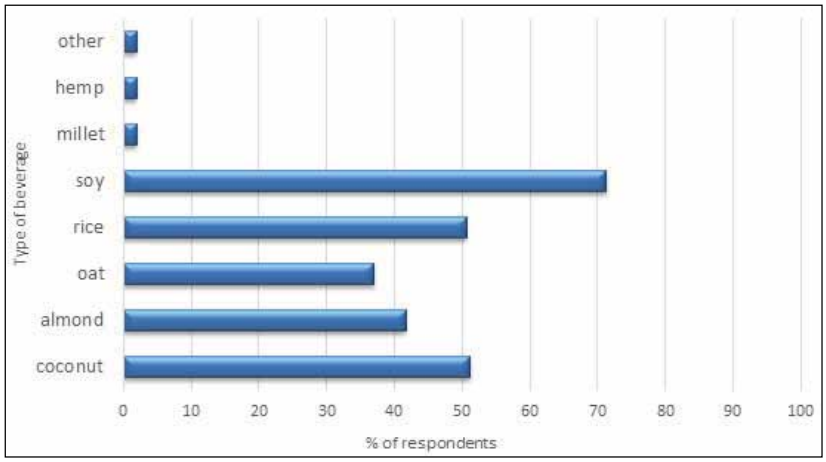

Fig. 2. Plant-based beverages most frequently chosen by respondents.

Rys. 2. Najczęściej wybierane przez respondentów napoje roślinne.

Source: The author's own study based on the results of the survey conducted

Źródło: Opracowanie własne na podstawie przeprowadzonych badań

RESULTS AND DISCUSSION

The surveyed population was mainly young, educated women. Among the 600 people who took part in the survey, 95% were women. This share of women in the study may be due to the fact that the research was conducted mainly on discussion groups on healthy eating and the use of plant-based diets, whose members are mainly women. The people who most often answered the questionnaire were people aged 23 and those with secondary or higher education (Tab. 2). According to Brecic et al. [4], the most frequent buyers of functional foods (which include plant-based beverages enriched with vitamins and minerals) are mainly women and well-educated people who attach the greatest importance to health and comfort in food choices.

The respondents mainly declared the consumption of plant-based beverages less than once a week (30,7%), few times a week (32,3%) or daily (24,8%) (Fig. 1). The most frequently chosen plant-based beverages by the respondents were soy (71,3%), rice (50,7%), coconut (51,2%), almond (41,7%) and oat beverages (37%) (Fig. 2). The study by Hoffmann and Kostyra [5] showed that almond, coconut, soy and walnut beverages are the most desirable, due to their favorable organoleptic characteristics. In a study by Walczak et al. [17] it was found that coconut, soy, rice, almond and oat beverages are the most common in Polish supermarkets. It can therefore be concluded that the beverages most frequently indicated by the respondents are characterized by the most favorable sensory values and the greatest availability on the market. The least frequently respondents indicated consumption of millet and hemp beverages, which, unlike the most frequently chosen beverages, are characterized by much less favorable sensory values and less availability. An answer other than that given was given by 2% of the respondents, including nut, sesame, and buckwheat beverages.

The respondents indicated their diet (80,3%), ethical reasons (41,8%), the taste (45,8%) and the nutritional value (33,7%) as the main reasons for consuming plant-based beverages (Tab. 3). According to Janssen et al. [6] the number of consumers following a vegan diet has increased significantly in many industrialized countries and it is highly likely that this number will continue to increase. Consumers are largely switching to a vegan diet for ethical and health reasons. Moreover, the majority of the respondents were women, and according to Modlińska et al. [10], women prefer plant-based diets more often than men.

The main factors influencing the purchases of plant-based beverages by the respondents were: composition (81%), taste (78,7%) and price (77,7%) (Tab. 3). Similar results were obtained in the study by Niewczas [11], where consumer preferences and criteria for food selection were defined. The respondents indicated that when

choosing food, they most often pay attention to the price and composition of the product. In the study by Barska [2], the similarities and differences in the decision-making process when buying food were found on a sample of young consumers aged 18-29, living in the border regions of Poland, the Czech Republic and Slovakia (most of the respondents were also women there). The study showed that the four main criteria for selecting food products were product freshness, price, quality and taste, similar to the present study. Only 0.3% of the respondents gave an answer other than the one given, and the availability of the product and ethical considerations were mentioned among them.

Table 3. Factors influencing the consumption and purchase of plant-based beverages by respondents

Tabela 3. Czynniki wpływające na spożywanie i zakup napojów roślinnych przez respondentów

Respondents' answers	Quantity	%
Reasons for consuming plant-based beverages		
food allergy / intolerance	103	17,2
diet (vegan, vegetarian, gluten-free etc.)	482	80,3
trends	19	3,2
habits	54	9,0
taste	275	45,8
nutritional value	202	33,7
ethical reasons	251	41,8
other	3	0,5
Factors driving the purchase of plant-based beverages		
price	466	77,7
eco product certificate	122	20,3
gluten-free food certificate	13	2,2
label	36	6,0
brand	48	8,0
shelf life	47	7,8
advertisement	9	1,5
composiotion	486	81,0
taste	472	78,7
product volume	114	19,0
enrichment with vitamins and minerals	266	44,3
confidence in the manufacturer	80	13,3
other	2	0,3

Source: The author's own study based on the results of the survey conducted

Źródło: Opracowanie własne na podstawie przeprowadzonych badań

The number of respondents satisfied with the assortment of plant-based beverages available on the market is similar to the number of dissatisfied people – it was about 40% in both cases (Tab. 4). The respondents showed the greatest interest in plant-based beverages enriched with vitamins and minerals (61,7%) (Tab. 4). The addition of individual nutrients in plant-based beverages is often stated on the label through the nutrition claims. According to Ozimek and Przeździecka-Czyżewska [12], nutritional claims may influence the perception of particular features of a product by consumers, as well as the overall assessment of its quality. Enriching plant-based beverages is extremely important as they are mainly treated as substitutes for cow's milk. Their nutritional value often differs significantly from that of cow's milk, especially in terms of protein, calcium, vitamin D and B vitamins [9]. Consuming plant-based beverages not fortified with calcium and other ingredients that were previously supplied with milk can lead to nutritional deficiencies. However, the enrichment of plant-based beverages is currently not the norm among producers, which should definitely change.

Table 4. Respondents' attitude to the offered assortment of plant-based beverages and possible directions of its expansion

Tabela 4. Stosunek respondentów do oferowanego asortymentu napojów roślinnych i możliwych kierunków jego poszerzenia

Respondents' answers	Quantity	%
„Are you satisfied with the assortment of plant-based beverages available on the market?"		
yes	285	47,5
no	248	41,3
I have no opinion	67	11,2
„What types of plant-based beverages would be most desirable for you?"		
in various volumes	312	52,0
flavored (fruit, cocoa, vanilla)	25	35,8
enriched (with vitamins, minerals, omega-3 acids, etc.)	370	61,7
with an eco certificate	161	26,8
with gluten-free food certificate	18	3,0
with various types of packaging (carton, plastic, glass, etc.)	268	44,7
„Enriching the market with what flavors of plant beverages would be most desirable by you?"		
chocolate	137	22,8
fruity	157	26,2
vanilla	129	21,5
I'm interested only in natural flavors	176	29,3
other	1	0,2
„What, in your opinion, negatively affects the quality of plant-based beverages?"		
addition of sugar	417	69,5
addition of fat	109	18,2
the presence of food additives	406	67,7
off-flavour	86	14,3
other	0	0,0

Source: The author's own study based on the results of the survey conducted

Źródło: Opracowanie własne na podstawie przeprowadzonych badań

The respondents were also interested in plant-based beverages packed in various types of packaging (e.g. glass, carton, plastic) (44,7%) and beverages of various volumes (52%) (Tab. 4). According to Jerzyk [7], in the set of visual elements of the packaging design, its shape and size are decisive for the emergence and recognition of the consumer's needs in the purchasing environment. Today, most plant-based beverages are available on the market in carton packs of 1 liter, so there is a need to expand the range of packaging types with different volumes and materials. Promoting the availability of plant-based beverages in packages with a volume of less than 1 liter would make it possible to spread them also as refreshing drinks that can be taken with and consumed once.

When asked about the desired flavors of plant-based beverages, the respondents to a similar extent indicated three variants: chocolate (22,8%), vanilla (21,5%) and fruity (26,2%) (Tab. 4). An answer other than the proposed one was given by 0.2% of the respondents, and among them flavored plant-based beverages were mentioned, in which sugar was replaced with sweeteners, such as xylitol, erythritol. Offering plant-based beverages in various flavors may improve their acceptance. Some of these products in their natural form are negatively received by consumers, mainly due to the presence of off-flavor [16].

The conducted study showed that the main factors negatively influencing the perception of the quality of plant-based beverages are addition of sugar (69,5%) and the presence of food additives (67,7%) (Tab. 4). According to Asiola [1], some food ingredients, such as food additives, are perceived by consumers as unhealthy and unknown. This phenomenon, often referred to as the „clean label" trend, has prompted the food industry to report whether a specific ingredient or additive is not present or whether the food has been produced using a more „natural" production method. Consumers are increasingly interested in the composition of the food they buy and want to make informed nutritional decisions that allow them to stay healthy longer.

SUMMARY AND CONSLUSIONS

The conducted study analyzed the choices and preferences of respondents in relation to plant-based beverages offered on the market. The surveyed population was mainly young, educated women. The growing popularity of plant-based beverages is related to the increase in the number of consumers following a vegan diet, which is likely to continue to grow. The conducted analysis showed that the beverages most frequently chosen by the respondents (soy 71,3%, rice 50,7%, coconut 51,2%, almond 41,7%, oat 37%) are beverages characterized by the most favorable sensory values and the highest availability on the market.

The respondents' satisfaction with the assortment of plant-based beverages available on the market varied. The respondents declared a great interest in plant-based beverages enriched with vitamins and minerals (61,7% of studied population). The fortification treatment of these products is extremely important, mainly due to the fact that they are treated as substitutes for cow's milk, but it is still not a standard procedure. The composition of plant-based beverages often differs significantly from that of cow's milk, and producers should implement a fortification procedure for more plant-based beverages to prevent nutritional deficiencies in consumers.

Plant-based beverages are available on the market most often in the form of carton packages with a volume of 1 liter. The respondents in this study indicated the interest in products packed in various types of packaging (e.g. glass, carton, plastic) (44,7% of studied population) and beverages offered in various volumes (52% of studied population). Promoting the availability of plant-based beverages in packages with a volume of less than 1 liter would also make it possible to spread them also as refreshing drinks that can be taken with and consumed once. The increase in the number of products offered in various flavors (e.g. vanilla, chocolate) may also contribute to increasing interest in the assortment of plant-based beverages. Some types of plant-based beverages are negatively perceived by consumers due to the presence of off-flavor, the perception of which can be reduced by adding flavor substances.

The popular "clean label" trend affects the consumers of plant-based beverages who have reported a negative perception of the quality of beverages for the production of which sugar and food additives have been used. Consumers are increasingly interested in the composition of food they buy and want to make conscious dietary decisions that allow them to stay healthy longer. The dynamic development of the milk substitutes market prompts producers to expand their product range. It is necessary to familiarize with the expectations of consumers, which allows to create products that meet their requirements.

PODSUMOWANIE I WNIOSKI

Przeprowadzone badanie pozwoliło dokonać analizy wyborów i preferencji respondentów w stosunku do napojów roślinnych oferowanych na rynku. Badaną populację stanowiły głównie młode, wykształcone kobiety. Wzrost popularności napojów roślinnych powiązany jest ze wzrostem liczby konsumentów stosujących dietę wegańską, która to liczba prawdopodobnie nadal będzie wzrastać. Przeprowadzona analiza wykazała, że najczęściej wybierane przez respondentów napoje (sojowe 71,3%, ryżowe 50,7%, kokosowe 51,2%, migdałowe 41,7%, owsiane 37%) charakteryzują się najbardziej korzystnymi walorami sensorycznymi oraz największą dostępnością na rynku.

Zadowolenie respondentów z asortymentu napojów roślinnych dostępnego na rynku było zróżnicowane. Osoby badane deklarowały duże zainteresowanie napojami roślinnymi wzbogacanymi w witaminy i składniki mineralne (61,7% badanej populacji). Zabieg fortyfikacji tych produktów jest niezwykle istotny, głównie, ze względu na fakt, że są one traktowane jako substytuty mleka krowiego, jednak nie jest to procedura standardowa. Skład napojów roślinnych często odbiega znacząco od składu mleka krowiego, w związku z czym producenci powinni wdrażać procedurę fortyfikacji w przypadku większej liczby napojów roślinnych, aby zapobiegać niedoborom pokarmowym u konsumentów.

Napoje roślinne są dostępne na rynku najczęściej w postaci kartonowych opakowaniach o objętości 1 litra. Respondenci przeprowadzonych badań wskazali na zainteresowanie

produktami pakowanymi w opakowania różnych rodzajów (np. szklane, kartonowe, plastikowe) (44,7% badanej populacji) oraz napojami w różnej pojemności (52% populacji). Propagowanie dostępności napojów roślinnych w opakowaniach o mniejszej objętości niż 1 litr pozwoliłoby na rozpowszechnienie ich również jako napojów orzeźwiających, możliwych do zabrania ze sobą i jednorazowego spożycia. Do zwiększenia zainteresowania asortymentem napojów roślinnych może również przyczynić się zwiększenie liczby produktów oferowanych w różnych wariantach smakowych (np. waniliowy, czekoladowy). Niektóre rodzaje napojów roślinnych spotykają się z negatywnym odbiorem konsumentów, ze względu na obecność posmaków roślinnych. Ich odczuwanie może zostać zredukowane poprzez dodatek wsadów smakowych.

Popularny trend „czystej etykiety" wpływa korzystnie na konsumentów napojów roślinnych. Deklarowali oni negatywne postrzeganie jakości napojów, do produkcji których wykorzystano cukier i dodatki do żywności. Konsumenci są coraz bardziej zainteresowani składem kupowanej żywności i chcą podejmować świadome decyzje żywieniowe, pozwalające im na dłuższe utrzymanie zdrowia. Dynamiczny rozwój rynku substytutów mleka skłania producentów do poszerzania ich asortymentu. Niezbędne jest dalsze poznawanie oczekiwań konsumentów, co pozwoli na tworzenie produktów spełniających ich wymagania.

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EFFECT OF THE ADDITION OF INULIN ON THE QUALITY OF POULTRY BURGERS®

Wpływ dodatku inuliny na jakość burgerów drobiowych®

The article presents the results of research concerning the assessment of the effect of inulin on the quality of turkey meat burgers. The physical and sensory characteristics of products without additional and with addition inulin 2% and 5% were assessed after the poultry burgers had cooled down to room temperature. The addition of 2% and 5% inulin in the form of a powder to the recipe composition of poultry burgers contributed to the darkening of the products and the increased desirability of smell as well as a better structure and binding of turkey burgers. Poultry burgers containing 5% inulin were characterized by lower water holding capacity and higher cutting force, compared to burgers with 2% addition and a control product. The obtained research results indicate that both the addition of 2% and 5%can be used in the technology of turkey burger production, obtaining a tasty, good quality product.

Key words: inulin, burgers, turkey meat, quality.

W artykule przedstawiono prezentację wyników badań dotyczących oceny wpływu dodatku inuliny na jakość burgerów drobiowych o stałym składzie surowcowym. Cechy fizyczne i sensoryczne produktów bez dodatku i z dodatkiem 2% i 5% inuliny oceniano po wychłodzeniu burgerów do temperatury pokojowej. Wykazano, że dodatek 2% i 5% inuliny w postaci proszku do składu receptur burgerów drobiowych przyczynił się do przyciemnienia produktów i zwiększenia atrakcyjności zapachowej oraz lepszej struktury i konsystencji burgerów indyczych. Burgery zawierające 5% inuliny charakteryzowały się mniejszą wodochłonnością i większą siłą cięcia w porównaniu z burgerami z dodatkiem 2% i produktem kontrolnym. Uzyskane wyniki badań wskazują, że zarówno dodatek 2%, jak i 5% można zastosować w technologii produkcji burgerów z indyka, uzyskując smaczny, dobrej jakości product.

Słowa kluczowe: inulina, burgery, mięso indycze, jakość.

INTRODUCTION

In the dynamic and fast pace of the development of consumerism, the interest and demand for convenient food has increased [3]. Due to the availability, ease and speed of preparation, convenience food made of poultry meat is very popular [1]. Poultry burgers are classified as more convenient fast food. It is a type of flat disc cutlets made of minced meat, subjected to heat treatment before consumption [12].

Consumers' nutritional awareness if growing, and with it their interest in meat products that not only meet the basic needs of the body, but also have a positive effect on its functioning. Inulin can be used as a fat replacer in meat products to reduce the fat content and develop healthier products [8, 10, 19, 21]. It can influence various characteristics of the products including physiochemical, textural and sensory attributes, although the reported effects were controversial [13]. Effect of inulin on mentioned properties depends on type of inulin, inulin concentration and structure and composition of meat and poultry products [7,22]. In addition, incorporation of inulin can enrich meat and poultry products in terms of dietary fiber that have beneficial health effects [11,23]. However, more researches on diverse effects of inulin in different types of meat and poultry products formulations and process conditions are required.

The aim of this paper is to present the results of research on the assessment of the effect of inulin on the quality of turkey meat burgers.

MATERIAL AND METHODS

The leg muscles of slaughter turkeys were used in the production of burgers. 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. The leg muscles was ground in a meat grinder (Zelmer, Poland) using a mesh with 3.0 mm. Two variants of burgers were produced, differing in the amount of inulin from chicory roots (TARGROCH Filipowice): 2% and 5%. The control group consisted of turkey burgers without the addition of inulin. Apart from the meat raw material, the stuffing consisted of water, the amount of which was 10% in

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relation to the weight of the meat raw material. The amount of the remaining ingredients (pepper 0.5% and salt 1%) was calculated in relation to the weight of the basic ingredients, i.e. meat and water.

The meat aces were mixed in a blender (Kenwood Major Titanium, USA). The meat masses was divided, 2% and 5% inulin were added and again mixed. 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 75 mm and a height of 7 mm. Processing of the burgers was carried out in a hot-air electric oven at 180°C up to reaching 75°C. Physical and sensory characteristics were assessed after the poultry burgers had cooled down to room temperature.

Weight loss(%) was calculated based on the weight difference before and after heat treatment.pH measurements were undertaken using a pH-meter fitted with a dagger electrode (HI 99163, Hanna Company). The water-holding capacity (WHC) was determined based on the volume of free water squeezed from sample using the Whatman no 2 filter papers Grau-Hamm method.All of the measurements were taken by one researcher. Analysis of the colour parameters on the surface of the burgers in CIE L*a*b* space was performed with a CR-400 colorimeter (Konica Minolta, Japan) in accordance with the test methodology recommended by the device manufacturer D65 illuminant and a standard colorimetric observer with a field of view of 2° were used for colour measurements. For each test, a 3-fold measurement was performed. The brittleness was assessed by measuring the cutting force (Fmax) of 8×20×80 [mm] product samples, using the Zwick/Roell BT1-FR1. OTH.D14 resistance machine (Zwick CmbH& Co. KG. Ulm, Germany), using a Warner-Bratzler V-blade knife with a head speed of 100 mm··min-1 and initial force of 0.2 N. 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 burgers 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 sensory evaluation was carried out by a 7-person evaluation team in duplicate. For the proper evaluation, the burgers samples were cooled to room temperature and cut into slices of rectangular parallelepiped shape (1cm x 1cm x 3cm). All samples to be assessed were placed in covered vessels, marked with numerical codes. The samples were randomly assessed. Each panelist assessed a sample in three replications. Between each sample testing, the assessors took a break for 30 s, and rinsed their mouths using mineral water. The test was carried out in a properly prepared a room free from foreign odours, in appropriate temperature and lighting, in conditions enabling independent assessment, ensuring comfort for the assessors, and eliminating all distracting factors.

Results obtained were statistically analysed with the analysis of variance ANOVA using the Statistica 13.3 software package (StatSoft, Inc. 2018). The arithmetic mean ($\bar{x}$) and standard deviation (SD) were determined. The collected data were checked for normality with the Kolmogorov–Smirnov test with Lilliefors correction. To indicate the significance of differences between means in groups, used the test Tukey's at a 95% confidence level (α= 0.05). The results on the effect of inulin addition on the sensory characteristics of turkey burgers were verified with the use of non-parametric Kruskal-Wallis test. Differences were considered as significant if $p<0.05$.

RESULTS AND DISCUSSION

The studies showed that the addition (2% and 5%) of inulin in the form of a powder had no significant effect ($p>0.05$) on the efficiency of poultry burgers (Table 1). Also Ergönül et al. [6] did not show the effect of adding a 2.5% and 5% non-hydrated inulin preparation on the increase of thermal leakage of turkey meat balls. Florowski et al. [10] found that the use of inulin can reduce the fat content of the sausage without a significant increase in weight loss, and with increasing the addition of inulin, the yield of the product also decreases. Also Makała (2003) found a significant decrease in the yield of canned meat with the addition of inulin, which was related to the formation of a too delicate structure by inulin, which was not able to retain and bind water in the product. Cegiełka [4], examining chicken meat burgers with the addition of vegetable oils with 1% inulin content, showed a significant effect of recipe modification on burger performance. A decrease in product yield was observed, especially in the samples where the addition of meat raw material was lower in relation to the introduced mixture of vegetable oils. Méndez-Zamora et al. [17] obtained different results, where the addition of inulin to frankfurters increased the efficiency of the product.

Acidity is one of the basic parameters determining the quality of processed meat products. The conducted studies showed no effect ($p>0.05$) of the applied inulin additives on the pH of the products (Table 1). In the studies carried out by Latoch [14], no significant difference in the acidity of turkey pates with the addition of inulin was also observed.

The addition of the inulin preparation significantly ($p \leq 0.05$) differentiated the water retention capacity in poultry burgers. Both the addition of 2% and 5% of the inulin preparation reduced the water absorption of the obtained products. Estanech et al. [7] showed that the addition of inulin had a significant effect on the ability to retain water in a pate with the addition of inulin, which contributed to a greater binding of the consistency in the product. In turn, the research of Méndez-Zamora et al. [17] indicate that the addition of inulin to frankfurters increased water absorption in the product. Florowski et al. [10], introducing the addition of inulin to the model finely ground sausages, as a fat substitute received a product that was distinguished by a greater ability to maintain its own water compared to the product without the additive.

The colour of the cross-section of poultry burgers with the addition of 2% and 5% inulin was darker than in the control group, as evidenced by a significantly lower value of the L* lightness parameter (Table 1). In the literature review [9,15], there are no clear results on the impact of inulin addition on the quality of meat products. Latoch et al. [14] showed the effect of inulin on the darkening of the colour of poultry pates with the addition of inulin. Zwolan et al. [23] obtained a lightening of the colour for products with the addition of inulin. In turn, Florowski et al. [10] showed that replacing fat with inulin in sausages did not change the colour parameters.

Table 1. Effect of inulin addition on physical properties of turkey burgers
Tabela 1. Wpływ dodatku inuliny na cechy fizyczne burgerów z mięsa indyczego

Parameter		Variant of burgers	
	Without additionals	Inulin 2%	Inulin 5%
Weight loss (%)	66,52±4,25	66,32±3,18	66,39±3,65
pH	6,08±0,02	6,06±0,01	6,05±0,15
WHC (%)	35,60^{a} ± 4,12	28,85^{b} ± 5,02	25,05^{b} ± 3,40
Shear force (N)	10,73^{b}±2,10	11,92^{b}±2,26	13,84^{a}±3,12
Colour:			
L*, lightness	59,48^{a} ± 0,74	58,90^{b} ± 2,42	57,75^{b} ± 1,08
a*, redness	8,14 ± 1,34	8,64 ± 1,07	7,81 ± 0,96
b*, yellowness	12,83 ± 0,36	13,09 ± 0,76	13,31 ± 0,56

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. Effect of inulin addition on the sensory characteristics of turkey burgers
Tabela 2. Wpływ dodatku inuliny na cechy sensoryczne burgerów z mięsa indyczego

Parameter		Variant of burgers	
	Without additionals	Inulin 2%	Inulin 5%
Odour intensity	4,80 ± 0,27	4,60 ± 0,42	4,80 ± 0,27
Flavour intensity	4,50 ± 0,35	4,50 ± 0,35	4,60± 0,41
Odour desirability	4,40 ± 0,55	4,60 ± 0,45	4,40± 0,55
Flavour desirability	4,00^{b} ± 0,27	4,50^{b} ± 0,35	4,80± 0,45
Juiciness	4,20 ± 0,27	4,40 ± 0,22	4,50 ± 0,35
Tenderness	4,80^{a} ± 0,35	4,30^{b}± 0,35	3,80^{b} ± 0,27
Connection	3,80^{b} ± 0,55	4,70^{a} ± 0,22	4,60^{a} ± 0,54
Consistenc	4,40 ± 0,27	4,40± 0,22	4,60± 0,45
Structure	3,50^{b} ± 0,50	4,70^{a} ± 0,27	4,80^{a} ± 0,45
Surface color	4,80 ± 0,27	4,80 ± 0,27	4,80 ± 0,27
Color of the section	4,70 ± 0,27	4,80 ± 0,27	4,80 ± 0,27
Total desirability	4,40 ± 0,11	4,60 ± 0,20	4,70± 0,28

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

The brittleness parameter is one of the most important factors in the quality assessment of a meat product. The brittleness of the enriched product depends on many factors, such as temperature, time and the selected method of thermal treatment and the type and amount of additives used. The addition of dietary fibres to meat products does not always improve tenderness [20, 23]. The obtained test results indicate a significant ($p \leq 0.05$) increase in the hardness of products with the addition of inulin (Table 1). Reduction of brittleness by the addition of inulin was shown by Menegas et al. [16]. The authors showed that the fermented poultry sausage was harder and less flexible compared to the control sample. Florowski et al. [10] observed a reduction in the brittleness of products in the study of fat substitution with inulin in sausages. Momchilova et al. [18] in the study of meat and vegetable pates showed that the addition of inulin gel caused a decrease in the hardness of meat products. Research by Cegiełka [4] showed no effect of the addition of 1% inulin on the hardness of burgers. The reason could be the use of a low dose of fibre or modification of the recipe composition.

The authors' own research showed that the addition of inulin to turkey burgers had an impact on the results of the sensory evaluation. The introduction of the addition of inulin in the amount of 2% and 5% significantly ($p \leq 0.05$) impacted the increase of the desirable smell and better structure and binding of turkey burgers. Burgers with the addition of 5% inulin were characterized by greater hardness compared to burgers with 2% addition and no additives, which did not reduce the general desirability of the products. In the work of Janczar-Smuga and Gondek [13], the addition of 3% and 10% of inulin to poultry pates did not improve the taste and aroma of the product. However, an improvement in the consistency of the product was observed with the addition of inulin in an amount of 3% in relation to the product weight. In the studies by Cegiełka and Nadworska [5], where the addition of inulin to burgers was used, the smell of the product deteriorated with increasing doses of inulin. The taste of burgers was characterized by better parameters for burgers with the addition of 2% and 3% inulin. In the studies by Zwolan et al. [23], the addition of the inulin preparation to baked pates did not affect the taste and smell of the tested product. Momchilova et al. [18] showed that the higher concentration of inulin in the meat and vegetable pate was conducive to a lower sensory evaluation and that the addition of inulin contributed to the darkening of the colour of the pates.

SUMMARY

The addition of 2% and 5% inulin in the form of a powder to the recipe composition of poultry burgers contributed to the darkening of colour the cross-section of the obtained products. Poultry burgers containing 5% inulin were characterized by lower water holding capacity and higher cutting force, compared to burgers with 2% addition and a control product.

The addition of 2% and 5% of inulin increased the desirability of smell as well as a better structure and binding of turkey burgers. Burgers with the addition of 5% inulin were characterized by higher hardness compared to burgers with 2% addition and no additives, which did not reduce the overall desirability of the products.

The obtained research results indicate that both the addition of 2% and 5%can be used in the technology of turkey burger production, obtaining a tasty, good quality product.

PODSUMOWANIE

Dodatek 2% i 5% inuliny w postaci proszku do składu recepturowego burgerów z mięsa indyczego wpłynął na pociemnienie barwy przekroju otrzymanych produktów. Burgery drobiowe zawierające 5% inuliny charakteryzowały się mniejszą wodochłonnością i większą siłą cięcia w porównaniu z burgerami z dodatkiem 2% inuliny i produktem kontrolnym. Dodatek 2% i 5% inuliny zwiększył atrakcyjność zapachu oraz wpłynął na lepszą strukturę i konsystencję burgerów indyczych.

Burgery z dodatkiem 5% inuliny charakteryzowały się większą twardością w porównaniu do burgerów z dodatkiem 2% i bez dodatków, co nie obniżyło ogólnej pożądalności wyrobów.

Uzyskane wyniki badań wskazują, że dodatek 2% i 5% może być stosowany w technologii produkcji burgerów z mięsa indyczego uzyskując produkt smaczny, dobrej jakości.

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CHARACTERISTICS OF THE PROPERTIES OF CANE SUGAR AND THE ASSESSMENT OF ITS AVAILABILITY ON THE LOCAL MARKET OF WARSAW®

Charakterystyka właściwości cukru trzcinowego i ocena jego dostępności na lokalnym rynku Warszawy®

The article presents issues related to the consumption of sugar in the diet, describes the properties of cane sugar and assesses its availability on the local market, taking into account organic products. The research was based on the information provided by the producers on the packages of cane sugars available in selected stationary and online stores in Warsaw. The research material included 185 samples of sugar cane products, such as: sugar, powder sugar, sugar cubes and sticks, and cane syrup. Market analysis of the cane sugar concerned the availability of cane sugar, the variety of products, the market share of manufacturers and prices per 1 kg of product. The variety of cane sugars offered by online and stationary stores was comparable. Among the analyzed groups of cane products, sugar was the most accessible, whereby Demerara unrefined sugar having the highest market share. More than 1/2 of the cane sugar market was represented by Diamant, Sante and Królewski brands. Organic products accounted for about 30% of all products. The differentiating factor was the price of sugar cane products.

The range of cane sugars available on the market was significantly more expensive than sugar from sugar beets. Organic products were about 2 times more expensive than conventional products. The analysis of the declared energy value of cane sugars showed that most of the assessed products advertised by producers as unrefined may be refined sugar with the addition of cane molasses.

Key words: cane sugar, properties, local market analysis, organic products.

W artykule przedstawiono zagadnienia związane ze spożyciem cukrów w diecie, opisano właściwości cukru trzcinowego i dokonano oceny jego dostępności na lokalnym rynku, z uwzględnieniem produktów ekologicznych. Badania przeprowadzono w oparciu o informacje podane przez producentów na opakowaniach cukrów trzcinowych dostępnych w wybranych sklepach stacjonarnych i internetowych na terenie Warszawy. Materiał badawczy obejmował 185 próbek produktów z trzciny cukrowej, jak: cukier, puder, cukier w kostkach i saszetkach oraz syrop trzcinowy. Analiza rynku cukrów trzcinowych dotyczyła dostępności cukru trzcinowego, różnorodności asortymentu, udziału producentów w rynku oraz ceny za 1 kg produktu. Wykazano, że dostępność asortymentu cukrów trzcinowych oferowana przez sklepy internetowe i stacjonarne była porównywalna. Wśród analizowanych grup produktów trzcinowych najłatwiej dostępny był cukier, przy czym największy udział w rynku miał cukier nierafinowany Demerara. Ponad 1/2 rynku cukrów trzcinowych była reprezentowana przez marki Diamant, Sante i Królewski. Produkty ekologiczne stanowiły około 30 % rynku cukrów trzcinowych. Czynnikiem różnicującym była cena produktów trzcinowych. Dostępny na rynku asortyment cukrów trzcinowych był dużo droższy niż cukier biały buraczany. Produkty ekologiczne były ok. 2 razy droższe niż produkty konwencjonalne. Analiza deklarowanej wartości energetycznej cukrów trzcinowych wykazała, że większość ocenianych produktów reklamowana przez producentów jako produkt nierafinowany mogła stanowić cukier rafinowany wtórnie zmieszany z melasą trzcinową.

Słowa kluczowe: cukier trzcinowy, właściwości, analiza rynku, produkty ekologiczne.

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INTRODUCTION

Civilization diseases are a significant social problem in economically developed countries. Qualitative and quantitative inadequate nutrition and physical inactivity are important factors in the etiology of many chronic non-communicable diseases, such as overweight and obesity, insulin resistance, type II diabetes, ischemic heart disease, metabolic syndrome, cancer, non-alcoholic fatty liver disease or tooth decay [11, 12, 17].Generally, it is believed that the occurrence of the above-mentioned diet-related diseases are caused by the excessive consumption of highly processed, carbohydrate-rich foods, in particular sugars added to food and beverages in the production process during the preparation of sweeteners for food and beverages by consumers [8, 19]. However, it cannot be unequivocally stated that overconsumption determines their formation, because they are most often multi-factorial diseases [2, 5, 8, 11].

The energy of the entire daily diet from sugars naturally occurring in food and added sugars should be 10–15%, as determined by the World Health Organization (WHO) [4]. Standards of total carbohydrate consumption recommended by the Food and Nutrition Institute for the Polish population are 45-65% of the daily energy value of the diet [12]. Intensive sweeteners can be an alternative to sugar consumed and used in the food industry [20].

Contrary to the commonly accepted belief that sugar has a „bad" effect on human health and the legal regulations limiting its consumption [18], the average consumer is not aware of the physiological functions of carbohydrates in the body. Energy obtained from burning sugars is used, among others to maintain body temperature, work of internal organs and physical activity. In turn, the consumed carbohydrates are broken down into monosaccharides and converted in liver into glucose, which is a physiological sugar necessary for the proper functioning of brain, nervous and circulatory system, muscles, intestines and heart [3, 12]. Additionally, sugar supplied to body releases the production of serotonin, which is responsible for improving the well-being [6].

Worldwide, cane sugar is the main source of carbohydrate in the diet, right after beet (white) sugar. Refined sugars contain up to 100% sucrose, therefore refined cane sugar is not a „healthy" substitute for traditional white beet sugar. The energy value of refined sugar is approx. 400 kcal / 100 g (approx. 1700 kJ / 100 g), but unrefined cane sugars, thanks to the natural molasses they contain, differ from refined sugar mainly with less sucrose, color and consistency and a unique taste and aroma. From a health point of view, brown cane sugar contains small amounts of valuable minerals, B vitamins and compounds with bioactive properties [3, 14, 15].

The aim of this study is to present the properties of cane sugar and to assess its availability on the local market, taking into account organic products.

PROPERTIES OF CANE SUGAR

Cane sugar, as the name suggests, is made from sugarcane (*Saccharum officinarum L.*) – a perennial plant grown in tropical and subtropical climates. About 70% of world sugar production is cane sugar and the main producers are: Brazil, India, China and Thailand [6].

Sugarcane is used in traditional Ayurvedic and unani medicine. Sugarcane juice is widely considered a nutritional drink and a unique source of various ingredients with significant biological activity, it is recommended for people with liver and kidney problems. Pharmacological studies based on the assumptions of Indian medicine have shown that sugarcane has anti-inflammatory, analgesic, antihyperglycemic, diuretic and hepatoprotective properties [9, 10, 16]. Research is being conducted on the use of flavonoids contained in by-products from the production of cane sugar for the production of nutraceuticals and pharmaceuticals [10].

Cane sugar has a characteristic caramel taste, specific aroma and color, which depend on the degree of purification of the sugar from molasses. During the refining of cane sugar, most of the bioactive substances present in the juice are removed and only unrefined products may contain some polyphenolic compounds such as phenolic acids, flavonoids and various glycosides [1, 10, 15, 16]. Older people living in Okinawa in Japan attribute their above-average life expectancy to eating kokutou – a natural cane sugar [3].

The production of cane sugar involves many steps, such as extraction of cane juice, clarification, defecation (pH adjustment), filtering, evaporation, crystallization and centrifugation to separate the crystals from the molasses. The raw sugar obtained in this way can be refined, i.e. further purified [3].

Several types of cane sugar are available on the food market [14]. Natural sugars include crude molasses which, depending on the region, are known by different names such as jaggery, panela, gur, chancaca, rapadura, etc. Among the unrefined sugars that have undergone centrifugation or minimal refining, special sugars such as demerara, muscovado and turbinado are mentioned. As a result of refining raw sugar, white or brown sugars are obtained with a sucrose content of up to 100%, a light golden to dark brown color, fine crystals and a moisture content of up to 5% [3]. The content of molasses in the final product has a significant influence on the color of cane sugar. On the other hand, molasses owes its color to caramel and melanoids, which are produced in the technological process [15].

Unrefined cane sugars, as a source of valuable substances with pro-health properties, have been the subject of interest of many researchers [1, 3, 5, 7, 15]. The results of sugar jaggery research indicate that their main ingredient is sucrose (74.3–92.0%), they contain glucose (4.1-14.4%), fructose (3.8–11.2%) and water (1.8–6.4%) and inorganic ash (0.3–3.6%), protein (0.37–1.7%) and fat (0–0.1%) [1, 7]. The following minerals were identified: calcium, potassium, sodium, magnesium, iron, copper and small amounts of manganese and zinc. The presence of B vitamins (thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, folic acid) and vitamin C has been found too.

Barrera et al. [1] prove that the most polyphenols and flavonoids were contained in jaggery and muscovado sugars, and there were trace amounts in refined sugars [15]. Phenolic acids such as cinnamic, chlorogenic, caffeic, sinapic, coumaric and ferulic acids, and flavones such as luteolin, tricin and apigenin were identified from phenolic profile analysis. Tricin and apigenin are both considered nutraceuticals [1, 15].

The interests of many researchers [1, 10, 15] also included the antioxidant potential of unrefined cane sugars. It was proved that the antioxidant activity of the assessed products depended on their purification from molasses. Cane honey and jaggery sugars had the best ability to scavenge free radicals. Moreover, some of the analyzed jaggery and muscovado sugar samples showed strong antibacterial properties against *Streptococcus mutant* and *Streptococcus sobrinus* [1].

The results of Eggleston [3] show that unrefined cane sugars contain oligosaccharides with prebiotic properties. These compounds have a positive effect on human health because they stimulate the growth of probiotic bacteria in the large intestine. These include fructo-oligosaccharides and fructans from the kestose group (trisaccharides).

AVAILABILITY OF CANE SUGAR ON THE LOCAL MARKET

The research material consisted of information provided by the manufacturer on the packaging of selected cane sugars and information placed next to these products on the websites of stores. Market research was conducted in January and February 2021.

The cane sugar market assessed 17 stationary stores in Warsaw, including: hypermarkets (Auchan, E.Leclerc, Carrefour, Kaufland), supermarkets (Eurospar, Aldi, Carrefour Express 7–24), discount stores (Biedronka, Lidl), local stores (Carrefour Express, Żabka, Lewiatan, Mokpol, Grosik, Wierzejki) and organic food stores (Organic Farma Zdrowia, BioBrain). Ecological stores were among the 9 evaluated online stores (www.biosklep.com.pl, www.marketbio.pl, www.biogo.pl, www.bioboo.pl, www.organic24.pl) and stores of large retail chains (www. auchandirect.pl, www.carrefour.pl, www.frisco.pl, www.leclerc-online.pl).

Information on 185 samples of sugarcane products was collected in the stores selected for the study (one product is one type of assortment from one manufacturer). The reference samples were beetroot sugars (71 products), including white (88.7%) and brown sugars (11.3%).

The cane sugar market analysis included: availability of cane sugars, variety of assortment, market share of producers, prices per 1 kg of product and availability of cane sugars with a declaration of organic origin.

Comparable amounts of cane sugars were available in online (50.3%) and in stationary (48.6%) stores. In traditional and online stores, 135 sugar samples were available, of which conventional products accounted for 88.9% (120 samples), and organic products – 11.1% (15 samples). Organic food stores, on the other hand, offered 50 products, most of which were organic sugars (82.0%).

Assessing the availability of cane sugar in stationary and online stores of large retail chains, such as Carrefour, Auchan and E.Leclerc, the assortment was richer in stationary stores than online. The differences in the assortment concerned 1–5 products. Perhaps the lower availability of cane sugars in these online stores was due to the fact that during the COVID-19 pandemic, Warsaw residents prefer to shop online without leaving home.

Market analysis in terms of the availability of cane sugars in the analyzed stationary stores (Fig. 1) showed that the largest assortment was available in stores belonging to the Carrefour chain (33.4%). The commercial offer of Carrefour hypermarket included 15 products, on Carrefour Express 7–24 store – 9 products, and in Carrefour Express local store – 7 products. In Kaufland and Eurospar stores, the assortment of cane sugars accounted for approx. 10% of the market, while at discounters Lidl and Biedronka, only one product from the assessed assortment was available.

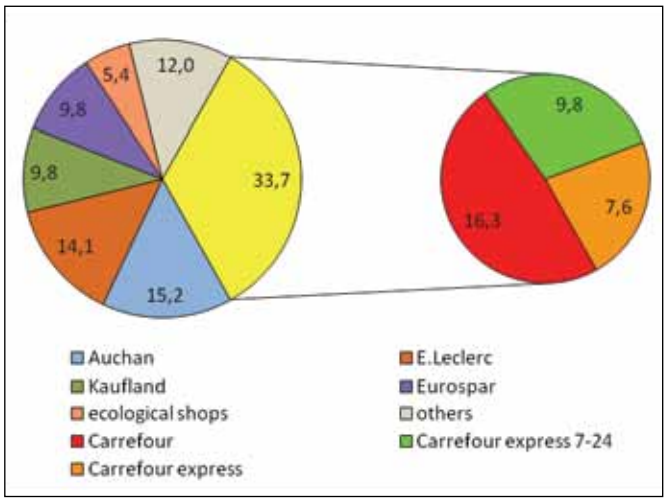

Fig. 1. Availability of cane sugars in stationary stores (%).

Rys. 1. Dostępność cukrów trzcinowych w sklepach stacjonarnych (%).

Source: Own study

Źródło: Badania własne

The data presented in Fig. 2 shows that among the analyzed online stores, the largest assortment of cane sugars was in: Frisco store and Bioboo store with organic food, in which 15 products were available, which accounted for 16.1% of the market. This was followed by Carrefour store (15.1%), organic stores Biogo (12.9%) and Biosklep (10.8%) and E.Leclerc online store (10.8%).

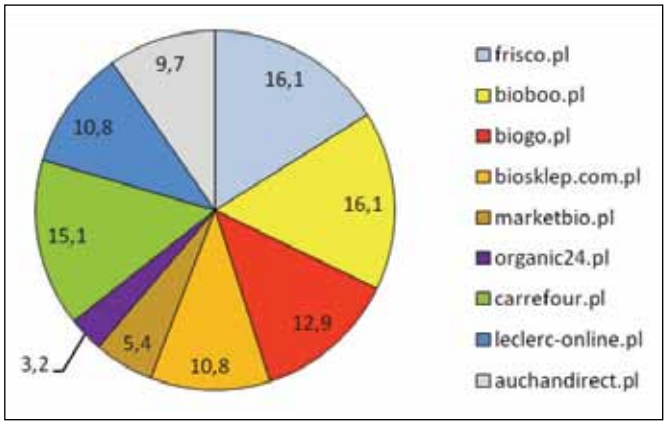

Fig. 2. Availability of cane sugars in online stores (%).

Rys. 2. Dostępność cukrów trzcinowych w sklepach internetowych (%).

Source: Own study

Źródło: Badania własne

The assessment of the local market in terms of the availability of the cane sugar assortment in individual stationary and online stores shows that 11–15 products were available in 26.9% of the analyzed stores. The same percentage (26.9%) was constituted by stores offering 6–10 products, and 3–5 products were sold by 11.5% of stores. 2 products were available in 15.4% of the stores, and one type of cane sugar could be purchased in 19.2% of the evaluated stores.

Five groups of sugar cane products were commercially available (Fig. 3). Sugars constituted 78.5% of the analyzed assortment, cube sugar – 12.4%, sugar sticks – 4.3%, powder sugar – 4.3%, including powder sugar with tapioca starch and invert cane sugar syrup – 0 5%. Diamant golden cane syrup was available only at Auchan hypermarket. Demerara sugars (51.7%) were the most numerous group of the assessed 145 samples of cane sugars, followed by products called cane sugar and unrefined sugar (17.2%), muscovado sugars (9.0%), brown sugars (9.0%), golden sugars (3.4%), light sugars (4.8%), jaggery and panela sugars (4.8%). Among the analyzed sugars, there were 3 gluten-free organic products.

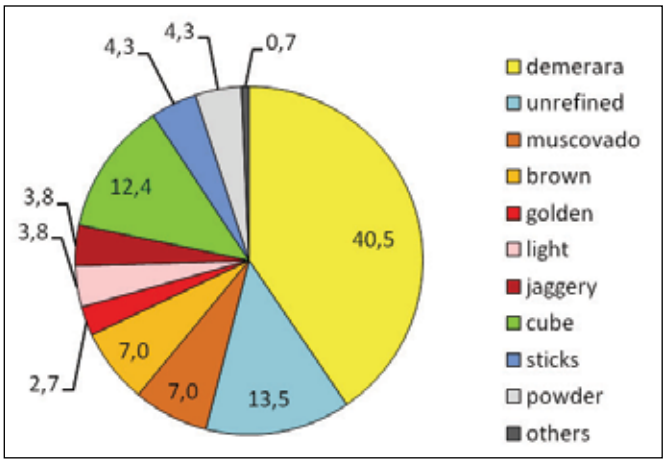

Fig. 3. Availability of the assortment of sugarcane products in the analyzed stores (%).

Rys. 3. Dostępność asortymentu produktów z trzciny cukrowej w analizowanych sklepach (%).

Source: Own study

Źródło: Badania własne

In this study (Fig. 4), 30 brands of cane sugar were available on the market, of which 7 were private labels offered by Carrefour, E.Leclerc, Eurospar and Auchan stores. More than half of the cane sugar market was represented by three brands, incl.: Diamant (22.1%), Sante (17.4%) and Królewski (14.5%). Bio Planet, a brand offering organic products, took fourth place (9.3%). Diamant cane sugars were in the commercial offer of 13 analyzed stores. In turn, Sante products were available in 16 stores, Królewski – in 6, and organic products of the Bio Planet brand in 7 online stores, including 6 organic ones.

The Diamant brand was characterized by the greatest variety of products (8 items). On the other hand, the Królewski and Bio Planet brands had 6 products each, while Sante and Alternativa – 4 products. The remaining brands accounted for 39.2% of the market and were represented by 1–2 groceries.

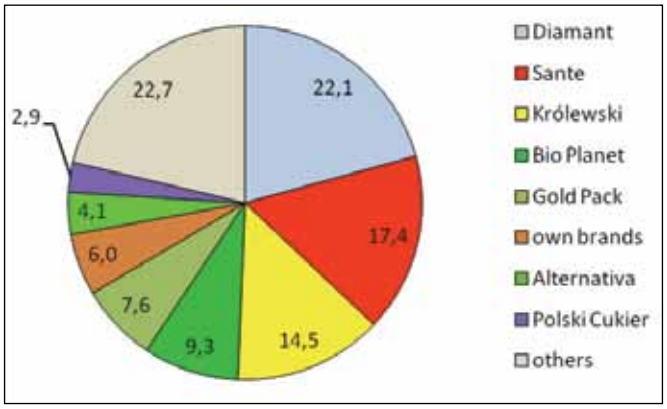

Fig. 4. Availability of the assortment of cane sugars by product brand (%).

Rys. 4. Dostępność asortymentu cukrów trzcinowych wg marek produktów (%).

Source: Own study

Źródło: Badania własne

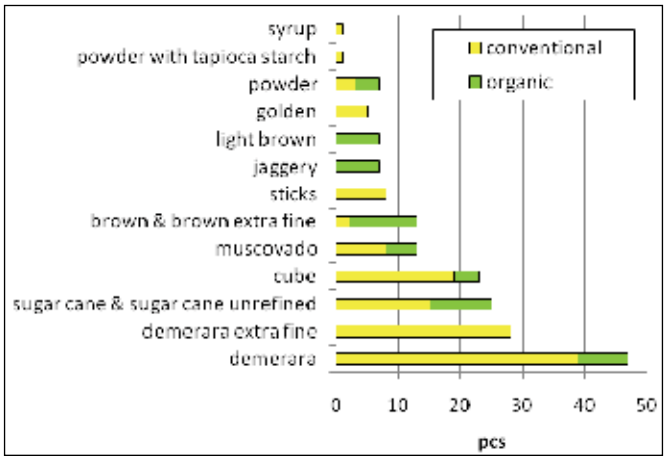

Fig. 5. Availability of the assortment of cane sugars from organic and conventional farming.

Rys. 5. Dostępność asortymentu cukrów trzcinowych pochodzących z upraw ekologicznych i konwencjonalnych.

Source: Own study

Źródło: Badania własne

The assessment of the availability of cane sugars with the declaration of organic origin in the analyzed stores showed that these sugars accounted for 30.3% of the market. The collected data (Fig. 5) shows that among organic products, there were 7 samples of jaggery sugar and 7 samples of light brown sugar, which accounted for 100% of a given assortment on the market. In the case of brown and fine brown sugar – BIO products accounted for 84.6% of this assortment on the market, followed by powder sugar (57.1%), products described as cane sugar and unrefined cane sugar (40.0%), muscovado sugar (38.5%), cubes sugar (17.4%) and demerara brown sugar (10.7%). Conventional products, on the other hand, represented the remaining range of the cane sugar market.

The vast majority of cane sugars marked as BIO were available at organic stores (73.2%), while the remaining were an assortment of purchasing traditional shops. One ecological product each could be found on the shelves of stationary stores

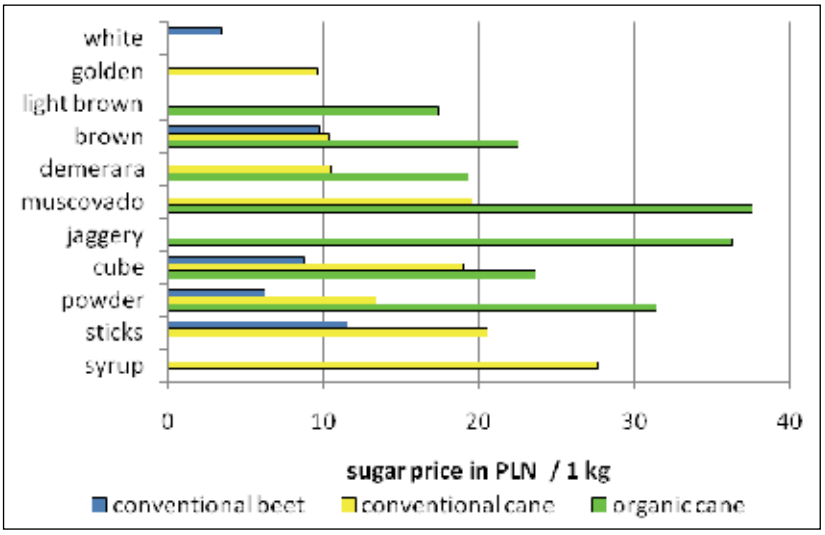

Fig. 6. Average price in PLN for 1 kg of organic and conventional cane sugar compared to beet sugar, depending on the assortment.

Rys. 6. Średnia cena w PLN za 1 kg cukru trzcinowego ekologicznego i konwencjonalnego w porównaniu z cukrem buraczanym w zależności od asortymentu.

Source: Own study

Źródło: Badania własne

such as Auchan, E.Leclerc, Eurospar and the Carrefour group. The Carrefour hypermarket offered 2 organic products, one of which was a private label.

Fig. 6 shows the average prices of 1 kg of organic and conventional cane sugar. The reference samples were beet sugars. Based on the analysis of sugars prices available on the market, it was found that cane sugars were much more expensive (5.99-49.68 PLN / kg) than white beet sugar (3.44 ± 1.05 PLN / kg). On the other hand, the prices of the assortment of cane products, such as powder sugar, sugar in cubes and sticks, were approx. 2 times higher than their beetroot counterparts. Only the purchase cost of brown sugar produced from sugar beet, i.e. white sugar coated with caramel (average 9.78 PLN / kg) was similar to the price of unrefined brown cane sugar (average 10.37 PLN / kg). Therefore, it is assumed that the term „brown sugar" may have been used by the producer of this sugar to mislead the consumer, suggesting that it is cane sugar, which would also be indicated by the price of the product. Consumers should read the information on the packaging carefully to avoid mistakes.

Overall, organic cane sugars cost about 2 times more than conventional products. Among the analyzed BIO cane sugars, the most expensive products were not purified from molasses, i.e. muscovado sugar (average 37.35 PLN / kg) and jaggery sugar (average 36.29 PLN / kg). However, in the case of conventional products, the most expensive product was Diamant golden cane syrup (27.65 PLN / kg), and the cheapest – Sante Golden unrefined cane sugar (8.99–10.44 PLN / kg). Differences in the price of a given product depended on the store, e.g. for Diamant Dry Demerara unrefined cane sugar, available in 8 stores, you had to pay from 9.28 to 13.98 PLN / kg (the difference in the price of 1 kg was 4.70 PLN).

In accordance with the guidelines of the EU Regulation No. 1169/2011 [13], the analyzed cane sugars contained information about nutritional value in 100 g of the product. The declared energy value of the analyzed sugar samples ranged from 356 kcal / 1491 kJ (jaggery sugars) to 400 kcal / 1700 kJ (unrefined sugars). Data analysis shows that the energy value of the samples of unrefined cane sugar and refined beet sugar was similar. Consequently, it is suspected that producers are deliberately placing various types of cane sugars on the market advertised as „unrefined" because consumers find unprocessed products more attractive. In fact, commercially available brown sugars may be refined products mixed with cane molasses. As reported by Hryszko and Szajner [6], as a result of the implementation of the sugar market reform in Europe, raw cane sugar is imported to Poland for refining, which sugar factories carry out after the end of the beet campaign. Thus, the cane sugar available on the market may come from Polish sugar refineries or directly from import.

According to the principles of healthy eating, limiting sugar consumption and sufficient knowledge of consumers about the calorific value of products, the availability of the assortment of cane sugars on the market and their origin may be helpful in making purchasing decisions and properly balancing the daily diet.

CONCLUSIONS

1. The availability of the assortment of cane sugars offered in online and stationary stores was comparable. Conventional products were available primarily in traditional stores (88.9%), but were also sold in organic stores (18.0%).
2. Five groups of cane products were traded on the market, such as sugar, cube, powder, sticks and syrup. Almost 80% of the products available on the market was sugar, with Demerara unrefined sugar having the largest share in the market (40.5%).
3. More than half of the cane sugars available for sale were represented by the Diamant, Sante and Królewski brands. Next are the ecological products of the Bio Planet brand.
4. Products with an organic farming declaration accounted for around 30% of the cane sugar market. Most of the BIO products were offered in organic stores (73.2%).
5. The range of cane sugars available on the local market was significantly more expensive compared to white beet sugar. Organic products cost about twice as much as conventional products. Among the analyzed products, the most expensive were BIO sugars - muscovado and jaggery.
6. The analysis of the declared energy value of cane sugars showed that most of the assessed products advertised by producers as unrefined may be refined sugar with the addition of cane molasses. The various types of cane sugars available on the market may come from sugar factories refining imported raw cane sugar under the provisions of the sugar market reform in the European Union or directly from import.

WNIOSKI

1. Dostępność asortymentu cukrów trzcinowych oferowana przez sklepy internetowe i stacjonarne była porównywalna. Produkty konwencjonalne były dostępne przede wszystkim w sklepach tradycyjnych (88,9%), ale były też w sprzedaży sklepów z żywnością ekologiczną (18,0%).
2. W obrocie handlowym znajdowało się 5 grup asortymentowych produktów trzcinowych, jak cukier, kostka, puder, saszetki i syrop. Prawie 80% dostępnych na rynku produktów stanowił cukier, przy czym największy udział w rynku miał cukier nierafinowany Demerara (40,5%).
3. Ponad połowa dostępnych w sprzedaży cukrów trzcinowych była reprezentowana przez marki Diamant, Sante i Królewski. W dalszej kolejności znalazły się produkty ekologiczne marki Bio Planet.
4. Około 30% rynku cukrów trzcinowych stanowiły produkty z deklaracją o pochodzeniu z rolnictwa ekologicznego. Większość produktów BIO znajdowała się w ofercie sklepów ekologicznych (73,2%).
5. Dostępny na lokalnym rynku asortyment cukrów trzcinowych był dużo droższy w porównaniu do cukru białego buraczanego. Za produkty ekologiczne trzeba było zapłacić ok. 2 razy więcej niż za produkty konwencjonalne. Spośród analizowanych produktów najwięcej kosztowały cukry BIO – muscovado i jaggery.
6. Analiza deklarowanej wartości energetycznej cukrów trzcinowych wykazała, że większość ocenianych produktów reklamowana przez producentów jako produkt nierafinowany mogła stanowić cukier rafinowany wtórnie zmieszany z melasą trzcinową. Dostępne na rynku różne rodzaje cukrów trzcinowych mogły pochodzić z cukrowni prowadzących rafinację importowanego surowego cukru trzcinowego w ramach postanowień reformy rynku cukru w Unii Europejskiej lub bezpośrednio z importu.

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ANALYSIS OF 5-HYDROXYMETHYLFURFURAL (HMF) CONTENT IN CONCHED CHOCOLATE MILK MASSES AND SELECTED RAW MATERIALS USED FOR THEIR PRODUCTION®

Analiza zawartości 5-hydroksymetylofurfuralu (HMF) w konszowanych czekoladowych masach mlecznych i wybranych surowcach użytych do ich wyprodukowania®

The aim of the work presented in the article is to compare the HMF content in chocolate milk mass after the conching process and in selected raw materials used to obtain them. The conching process was carried out under changing conditions of time and temperature. A statistically significant effect of roasting and conching time and temperature on the tested parameter was demonstrated in cocoa beans and chocolate milk masses, respectively.

Key words: 5-hydroxy-methylfurfural, powdered milk, cocoa beans, chocolate mass, chocolate.

Celem pracy przedstawionym w artykule była analiza porównawcza zawartości HMF w czekoladowych masach mlecznych po procesie konszowania oraz w wybranych surowcach wykorzystanych do ich otrzymania. Proces konszowania prowadzono w zmiennych warunkach czasu i temperatury. Wykazano statystycznie istotny wpływ prażenia oraz czasu i temperatury konszowania na badany parametr odpowiednio w ziarnach kakaowych i czekoladowych masach mlecznych.

Słowa kluczowe: 5-hydroksymetylofurfural, mleko w proszku, ziarna kakaowe, masa czekoladowa, czekolada.

INTRODUCTION

The use of raw materials with the right characteristics in chocolate production is very important [7], but it must be combined with proper knowledge of the processes and their influence on the quality of the final product. By modifying the processing conditions of cocoa beans or semi-finished products that will be made from them, one can control the properties of the final product such as gloss, hardness, taste or smoothness, as well as the content of bioactive components.

In addition to sensory impressions or technological aspects, product quality also includes product safety. Contaminants can be introduced with the raw material come from the environment, but they can also arise in the technological process, e.g. 5-hydroxymethylfurfural. Legislation defines acceptable levels of contaminants in chocolate products, which are monitored in this regard.

HMF is a widespread heat-induced food contaminant. 5-Hydroxymethylfurfural (HMF), which is considered carcinogenic in high concentrations. HMF is widely used in food analysis as an indicator compound that provides evidence of the degree of heat treatment of products [13]. It has been attributed genotoxic and carcinogenic effects, so monitoring its presence in raw materials and products is very important. Studies indicate that the average daily human intake of HMF ranges from 30 to 150 mg. Acceptable limits for HMF in food have not yet been established, but the European Food Safety Authority (EFSA) has set a theoretical maximum daily intake of 16 mg/day [3, 14].

The aim of this study was to analyze the comparative content of 5-hydroxymethylfurfural (HMF) in chocolate milk masses after conching process and in the raw materials used to obtain them.

RESEARCH METHODOLOGY

Research material

Analyzed were: 5 milk powders (3 milks produced by spray drying and 2 milks produced by roller drying), roasted and unroasted cocoa beans, 5 chocolate liquor from 3 different manufacturers, obtained from roasted and unroasted cocoa beans [Tab.1].

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Table 1. The types of raw materials used for the tests and the marking of samples

Tabela 1. Rodzaje surowców użytych do badań oraz oznaczenie próbek

Research material	Manufacturer	Sample Code
Roasted cocoa beans	Z	Z1
Unroasted cocoa beans	Z	Z2
Cocoa liquor/roasted beans/Ghana	X	MZG1
Cocoa liquor/roasted beans/Ghana	X	MZG2
Cocoa liquor/roasted beans/Ghana	X	MZG3
Cocoa liquor/roasted beans/Ivory Coast	Y	MZG4
Cocoa liquor/unroasted beans/Peru	Z	MZG5
Milk preparation (cylindrical drying technique)	X	MLK1
Milk preparation (cylindrical drying technique)	W	MLK2
Whole-milk powder (drying technique)	X	MLK3
Whole-milk powder (drying technique)	X	MLK4
Whole-milk powder (drying technique)	Y	MLK5
Milk chocolate	S	CZ1

Source: The own study

Źródła: Badania własne

Preparation of chocolate masses

Chocolate masses were prepared in Thermomix device according to the developed recipe. On the basis of the results of analyses of physico-chemical properties obtained for the raw materials for the preparation of masses, 5 out of 19 analysed milks were selected (Table 1) [15], cocoa mass based on unroasted beans, deodorized cocoa butter, powdered whey, powdered sugar, lecithin, ethyl vanillin..

Table 2. Parameters of the chocolate mass preparation process and sample marking

Tabela 2. Parametry procesu przygotowywania mas czekoladowych oraz oznaczenie próbek

Process time	Process temperature			
	50°C	60°C	70°C	80°C
	MC1	MC2	MC3	MC4
35 minutes	MC11	MC21	MC31	MC41
45 minutes	MC12	MC22	MC32	MC42
55 minutes	MC13	MC23	MC33	MC43
65 minutes	MC14	MC24	MC34	MC44
75 minutes	MC15	MC25	MC35	MC45
85 minutes	MC16	MC26	MC36	MC46
95 minutes	MC17	MC27	MC37	MC47
105 minutes	MC18	MC28	MC38	MC48
120 minutes	MC19	MC29	MC39	MC49

Source: The own study

Źródła: Badania własne

The first step in making the chocolate mass was to liquefy the fat and chocolate liquor. The fat was dissolved at 60°C, while the liquor was dissolved at 50°C for about 5 minutes. After obtaining a liquid consistency, the liquor, 10% fat, sugar, milk powder and whey were combined together. The ingredients were mixed for 10 minutes at medium speed of the mixer at 40°C. Then the remaining fat, lecithin and ethylowanilin were added. Thus combined ingredients were conched (mixed) at four temperature ranges (50, 60, 70 and 80°C) for 35 to 120 minutes, taking a sample of the mass for analysis every 10 minutes (Table 2). Conching parameters were determined based on information obtained from chocolate manufacturers.

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Analytical methods

Determination of dry matter content [11].

Determination of the dry matter content was carried out using a standardized method based on PN-84/A-88027. It consisted in evaporation of the water present in the sample during drying at 105°C for 3 hours (with reduction to a constant weight), and then weighing the sample after the process was completed. The dry matter content was calculated from the difference in weight of the sample before and after drying. The final result was obtained by calculating the arithmetic mean of three parallel replicates that did not differ by more than 0.2%.

The dry matter content was calculated according to the formula:

$$s.s.=100-[(mps)-mw)/(mps)]x\ 100\% \quad (1)$$

where: mw – mass of test material after drying [g],

mps – mass of the test material before drying [g].

Determination of 5 - hydroxymethylfurfural [8, 12]

HMF determination in the studied raw materials was carried out by spectrophotometric method using thiobarbituric acid (TBA).

The preparation of samples for analysis consisted in measuring with a pipette 10 ml of regenerated milk into a conical flask, adding 5 ml of 0.3N oxalic acid solution and thorough mixing of the flask contents. The flasks were covered with foil and transferred to a boiling water bath for about 1 hour, after which the samples were cooled to 20°C. 5 ml of 40% trichloroacetic acid (TCA) solution was added to the flask, mixed and filtered through tissue paper. Then 4 ml of the resulting filtrate was transferred to a test tube and 1 ml of 0.05 mol TBA solution was added to it. The samples were placed in a water bath for 30–40 minutes at 40°C. After the samples were removed from the bath and cooled to room temperature, their absorbance was measured in a spectrophotometer at λ = 443 nm against distilled water.

The beans, cocoa liquor,and chocolate masses were weighed into conical flasks in an amount of about 5 g and poured with 30 ml of water. The resulting mixture was fluidized and homogenized, and then 10 ml of solution was taken. In further steps of the determination, the procedure was analogous to that for milk powder.

The hydroxymethylfurfural content (µmol/l) was calculated according to the formula

$$HMFGeneral = (A - AH_2 0) * 72.6 - 0.55 \quad (2)$$

where: A – measured absorbance value for individual samales.

Calculation methods

Statistical analysis was performed to investigate the significance of the effect of selected parameters of the chocolate mass production process on specific parameters characterizing their quality. For this purpose, the Excel 2010 program was used, in which the standard deviation was calculated, which is a measure of the deviation of the tested value from its arithmetic mean, and the Statistica 13.1 program, was used ANOVA analysis of variance and industrial DoE statistic at the significance level α=0.05.

RESULTS AND DISCUSSION

The content of dry matter in chocolate milk masses

The conching stage in the manufacturing process of chocolate has many functions, among others it is aimed at a thorough mixing of all ingredients, allows to obtain the right consistency, as well as to reduce the content of water present in the chocolate mass and to get rid of the residue of undesirable acetic acid [10].

The dry matter content of the chocolate paste can vary due to the use of ingredients with different water content and also due to different process parameters. Gutierrez [5] and Hinneh et al. [6] state that the dry matter content of chocolate masses should be a minimum of 99%.

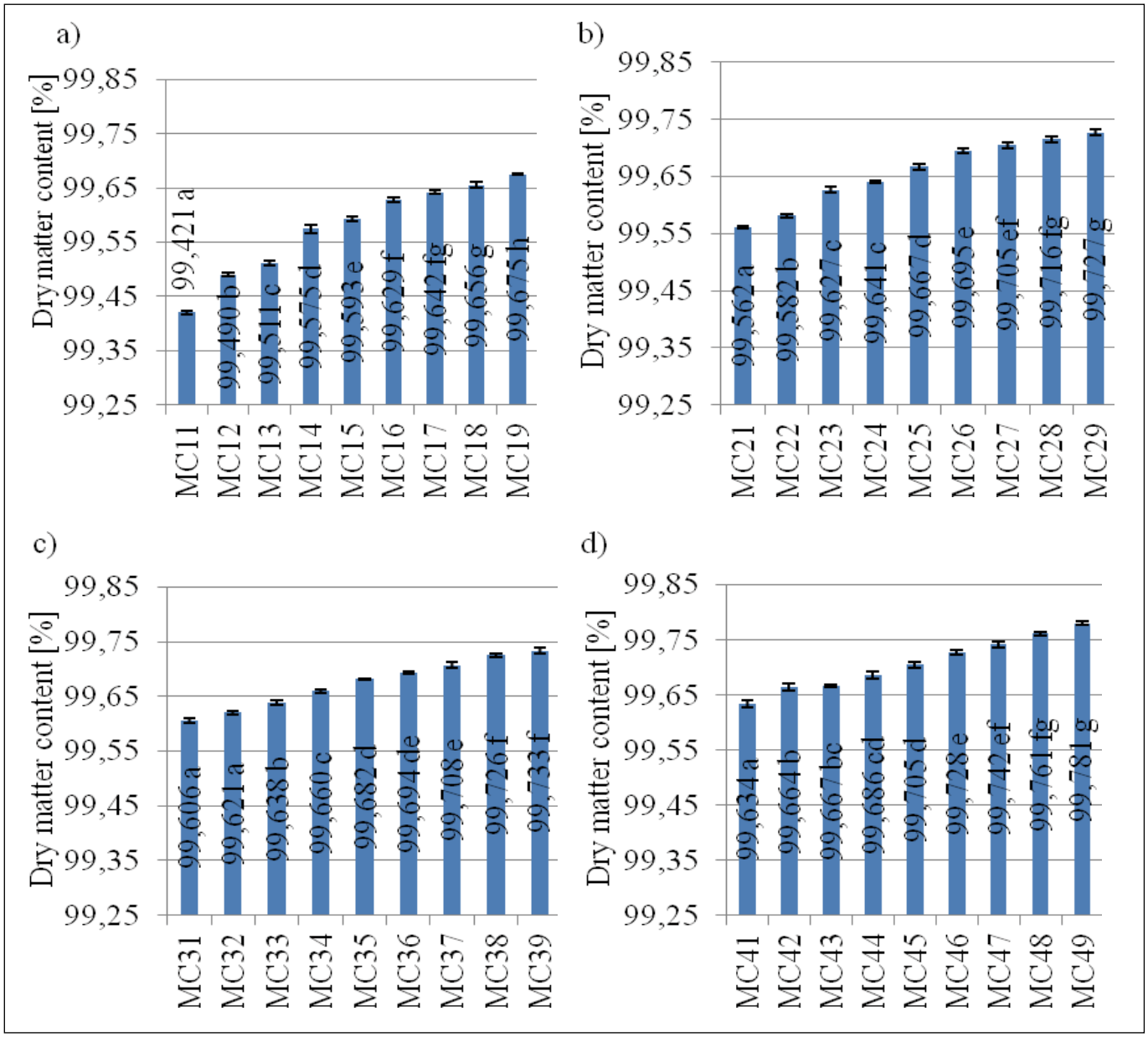

Fig. 1. The average dry matter content of a) MC1 chocolate liquor, b) MC2 chocolate liquor, c) MC3 chocolate liquor, d) MC4 chocolate liquor (sample designations – Tab. 2).

Rys. 1. Średnia zawartość suchej substancji w a) w masie czekoladowej MC1, b) w masie czekoladowej MC2, c) w masie czekoladowej MC3, d) w masie czekoladowej MC4 (oznaczenia próbek – Tab. 2).

Source: The own study

Źródła: Badania własne

In all the masses analyzed in this study, dry matter content above 99.4% was determined, which is confirmed by the studies of the authors quoted.

HMF content in the investigated milk powders

Among the analyzed milks, MLK2 rolled milk enriched with sugar addition had the highest HMF content (Figure 1). Statistical analysis showed a significant difference between milk obtained by the same technology MLK1, whose average level of 5-hydroxymethylfurfural was lower by as much as over 70 µmola/litre. One of the reasons for such a large discrepancy in the results may be the analytical method, whose main drawback is the lack of specificity of the reaction with thiobarbituric acid. This may result in the reaction of this acid with other carbonyl groups contained in the milk (e.g. from added sucrose), which in turn may cause unexpected overestimation of the results [4]. Additionally, hexoses, which include the glucose and fructose that make up sucrose, are precursors to 5-hydroxymethylfurfural. Ferrer et al. [4] comparing the HMF content of whole milk powder and milk powder enriched with 21.6% maltodextrin addition showed more than three times higher HMF content in the enriched milk, which confirms the results obtained in this study presented in Fig. 2.

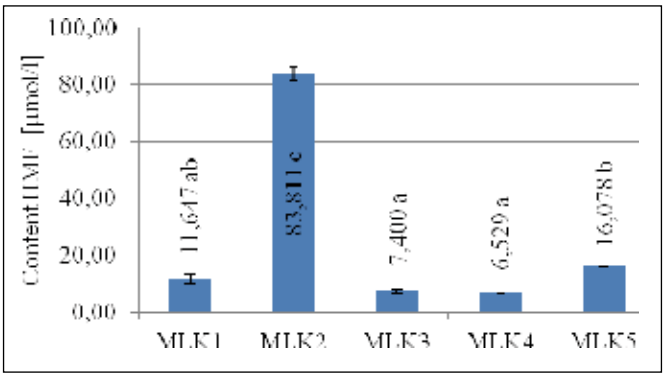

Fig. 2. The average content of HMF in the tested milk powders (the same letters mean no significant differences between the compared means for the assumed significance level a-0.05).

Rys. 2. Średnia zawartość HMF w badanych proszkach mlecznych (jednakowe oznaczenia literowe oznaczają brak istotnych różnic pomiędzy porównywanymi średnimi dla założonego poziomu istotności a-0,05).

Source: The own study

Źródła: Badania własne

MLK3 and MLK4 milks from the same producer (spray-dried) did not differ significantly in HMF content. Similar levels were recorded by Chudy et al. [2] determining the amount of HMF depending on the storage time of milk powder (1, 6, 12 months, respectively) at 7.25 µmola/litre, 9.90 µmola/litre and 15.90 µmola/litre. Statistical inference revealed a statistically significant difference between MLK1 and the analyzed spray-dried milk powders (MLK3, MLK4, MLK5), while comparison of HMF content in the spray-dried milks classified them into two homogeneous groups, indicating small but significant differences in the content of the analyzed compound.

HMF content in roasted and unroasted cocoa beans

The formation of 5-hydroxymethylfurfural in food can take place in two ways. One of them is long term heating of the product rich in sugars at temperature above 150°C in acidic environment (cocoa beans before roasting have pH about 5.7). This leads to caramelization of sugars, which is most easily done by glucose, fructose, xylose or ribose [9].

Due to the high roasting temperature of cocoa beans of about 150°C, we decided to investigate the differences in HMF content between roasted and unroasted beans (Fig. 3).

The roasted Z1 beans had significantly higher 5-hydroxymethylfurfural content in comparison with the unroasted Z2 beans. This indicates a significant effect of high temperature on HMF content in the final product.

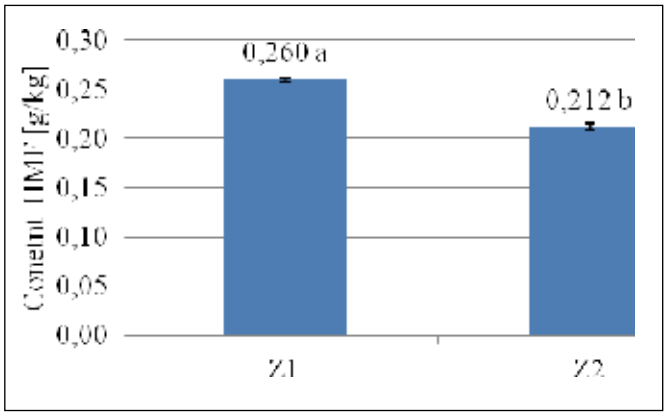

Fig. 3. Average HMF content in roasted beans Z1 and unroasted Z2.

Rys. 3. Średnia zawartość HMF w ziarnie prażonym Z1 i nieprażonym Z2.

Source: The own study

Źródła: Badania własne

Studies conducted by Sacchetti et al. [13] show a higher content of 5 - hy-droxymethylfurfural in roasted beans than in beans not subjected to this process. In addition, the analysis carried out on the effect of increasing time and temperature of liquor conching showed that higher process parameters favor the formation of higher amounts of this genotoxic compound.

HMF content in cocoa masses

The obtaining of cocoa bean liquor is not accompanied by any high-temperature process that could significantly affect the content of 5-hydroxymethylfurfural in its composition. However, HMF is not only an indicator of the degree of temperature cycling, but also an indicator of "aging" of the product. As a result of non-enzymatic browning reactions taking place in the product, the 5-hydroxymethylfurfural content can increase Quiroz – Reyes and Fogliano [16].

Five chocolate liquor from different producers and obtained from cocoa beans harvested in different seasons were analyzed (Figure 4). The statistical inference performed to separate homogeneous groups did not show significant differences between the HMF content of the analyzed liquor. The lowest HMF content was characterized by liquor MZG1 (producer X) obtained from beans harvested in April 2018. The liquor MZG2 and MZG3 from the same producer were distinguished by a higher value, but not exceeding 0.02 g/kg.

These liquor were obtained from beans harvested in July 2017, so they were a year older. It can be presumed that it is the "age" of the liquor that may indicate a higher HMF content in their composition, but due to the lack of a statistically significant difference shown in this study, no such conclusion can be made. A more extensive study on a larger amount of study material would have to be conducted to confirm this thesis.

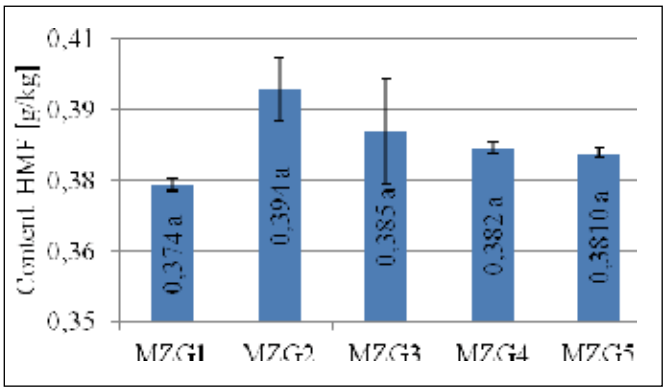

Fig. 4. Average HMF content in cocoa liquors.
Rys. 4. Średnia zawartość HMF w miazgach kakaowych.
Source: The own study
Źródła: Badania własne

The MZG5 liquor (producer Z, no data available for the date of bean harvest) made from unroasted cocoa beans was characterized by similar HMF content compared to MZG4 liquor (producer Y, no data available for the date of bean harvest). In this case, there is no significant difference between the HMF content of the products obtained from roasted and unroasted beans as shown in the beans analysis (Figure 4).

This difference can be attributed to a number of factors. The most important one is the different origin of the roasted beans. MZG5 liquor and Z2 unroasted beans were obtained from producer Z. Whereas MZG4 liquor and Z1 roasted beans were obtained from producers Y and Z, respectively. Producer Y did not provide information on the date of harvest of beans from which the liquor was produced nor on the parameters of the beans processing, which can significantly differentiate the HMF content in the final product.

HMF content in conched chocolate mash under varying time and temperature parameters.

Conching is the last stage in chocolate production where elevated temperature is used. Tempering, which follows conching, is carried out at temperatures not exceeding 50°C, so it can be assumed that it does not significantly affect the formation of Maillard reaction by-products. Due to the thermal induction of the 5-hydroxymethylfurfural formation reaction, it was considered reasonable to trace the effect of varying temperature parameters and conching time on the HMF content of chocolate [1].

Figure 5 shows the average HMF content in conching chocolate masses at varying temperatures (50°C, 60°C, 70°C, 80°C, respectively).

The MC1 mass conched at 50°C was characterized by the lowest HMF content. Its result was on average 0.16 g/kg lower than the other masses, in which the HMF content slightly increased in direct proportion to the increase of conching temperature. Nevertheless, statistical analysis showed no significant differences between the samples, classifying all of them in one homogeneous group.

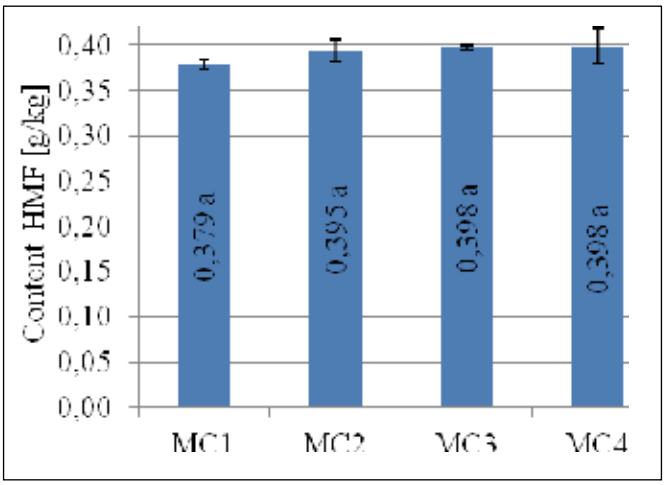

Fig. 5. Average HMF content in conched chocolate masses at various temperatures: MC1 (50°C), MC2 (60°C), MC3 (70°C), MC4 (80°C) (sample markings – tab. 2).
Rys. 5. Średnia zawartość HMF w masach czekoladowych konszowanych w różnych temperaturach: MC1 (50°C), MC2 (60°C), MC3 (70°C), MC4 (80°C) (oznaczenia próbek – tab. 2).
Source: The own study
Źródła: Badania własne

The distribution of 5-hydroxymethylfurfural content in individual chocolate masses was also analyzed taking into account the initial and final conching times (45 minutes and 120 minutes). Statistical analysis of MC1, MC2 and MC4 masses showed significant differences between 45 and 120 minutes of conching. However, in the masses conched at 70°C this difference was not shown.

There is a lack of literature data relating to the analysis of HMF content in cocoa masses, but a study by Sacchetti et al. [13] addresses the issue of the effect of roasting time and temperature on 5-hydroxymethylfurfural content in cocoa beans. This study showed a positive correlation between HMF content and increasing roasting time and temperature.

Similar correlations were obtained in the present study (Fig. 7), but even so, the correlation test based on them did not show a relationship between increasing time and conching temperature. Even for MC3 mass, in which there was no significant difference between the initial and final conching time, there was a non-significant increase in the content of one of the intermediate products of the Maillard reaction.

CONCLUSION

1) The content of HMF in milk powders was on a similar level, with the exception of milk preparation MLK2. This product had more than seven times higher content of 5 - hydroxymethylfurfural due to the presence of sugar in its composition, which is a precursor of this compound.
2) Unroasted beans contained significantly less HMF in its composition in comparison with roasted beans. However,

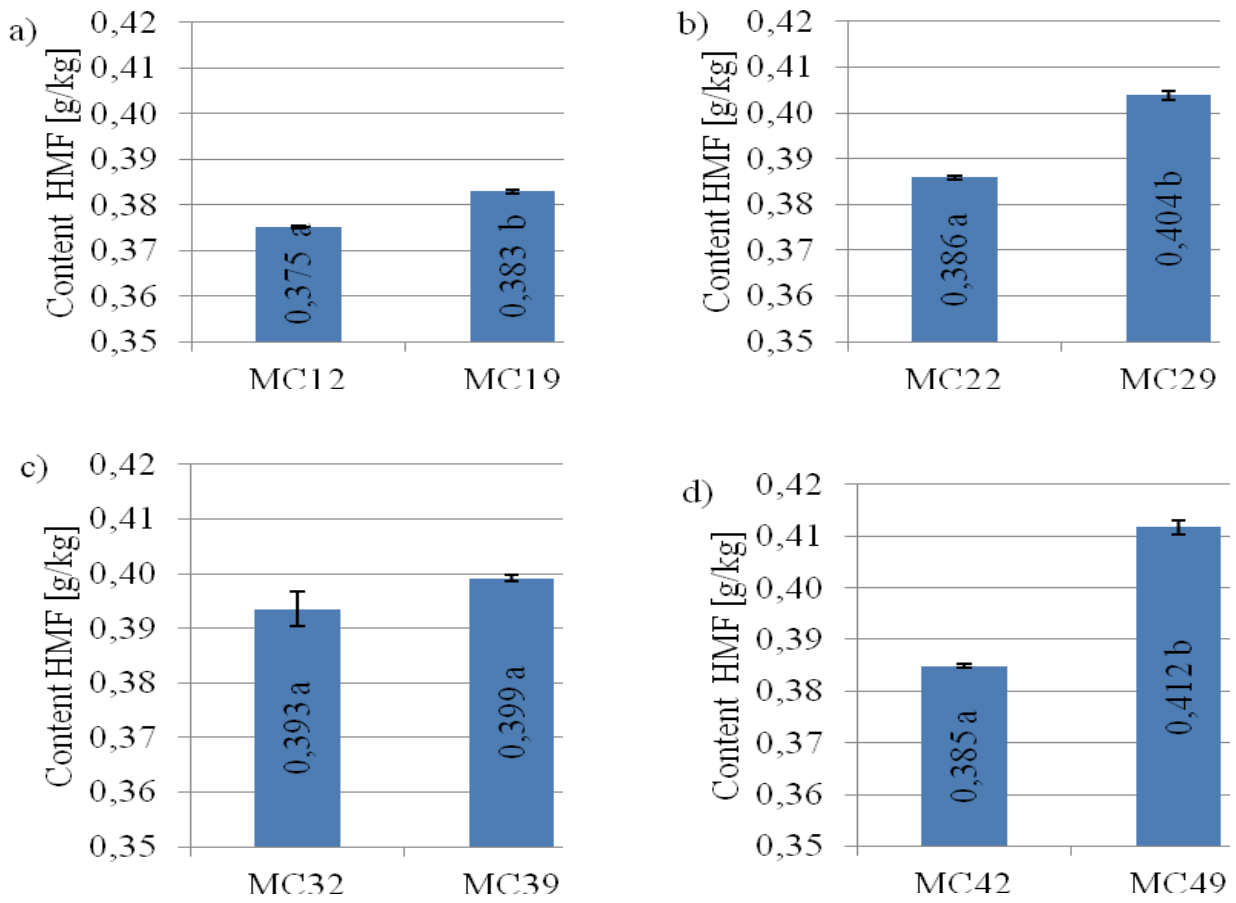

Fig. 6. Average HMF content in conched chocolate masses for 45 and 105 minutes: a) at 50°C, b) at 60°C, c) at 70°C, d) at 80°C (sample markings – tab. 2).

Rys. 6. Średnia zawartość HMF w masach czekoladowych konszowanych przez 45 i 105 minut: a) w temperaturze 50°C, b) w temperaturze 60°C, c) w temperaturze 70°C, d) w temperaturze 80°C (oznaczenia próbek – tab. 2).

Source: The own study

Źródła: Badania własne

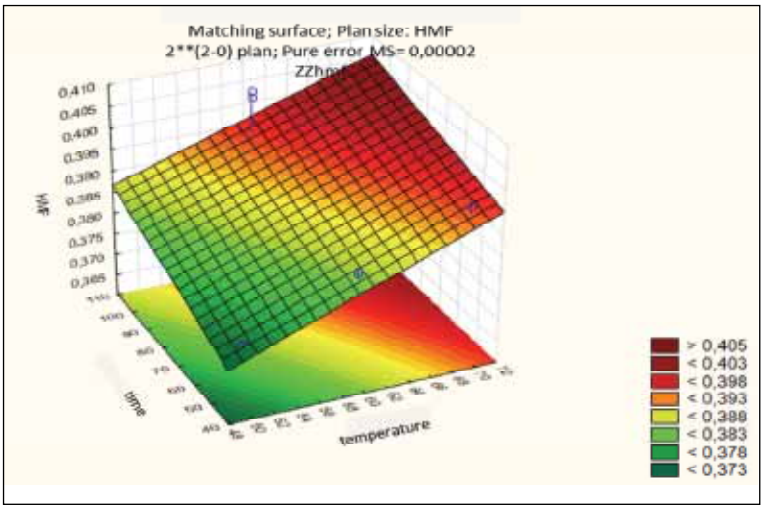

Fig. 7. Average HMF values for all conched chocolate mixes in different time and temperature parameters.

Rys.7. Średnie wartości HMF dla wszystkich mieszanek czekoladowych konszowanych w różnych parametrach czasu i temperatury.

Source: The own study

Źródła: Badania własne

there was no statistically significant difference in HMF content in the mash obtained from roasted and unroasted beans.

3) Chocolate masses conched at higher temperatures and for longer time cha-racterized significantly higher share of 5 - hydroxymethylfurfural in their composition.

4) The thermal processes applied have an influence on the content of HMF, which are formed under the influence of high temperature in products containing sugars.

PODSUMOWANIE

1) Zawartość HMF w mleku w proszku była na podobnym poziomie, z wyjątkiem preparatu mlecznego MLK2. Produkt ten posiadał ponad siedmiokrotnie wyższą zawartość 5-hydroksymetylofurfuralu ze względu na obecność w swoim składzie cukru, który jest prekursorem tego związku.

2) Ziarna nieprażone zawierały w swoim składzie znacznie mniej HMF w porównaniu z ziarnami

prażonymi. Nie stwierdzono jednak statystycznie istotnej różnicy w zawartości HMF w miazgach otrzymanych z ziaren prażonych i nieprażonych.

3) Masy czekoladowe konszowane w wyższych temperaturach i przez dłuższy czas charakteryzowały się istotnie większym udziałem 5 - hydroksymetylofurfuralu w ich składzie.

4) Stosowane procesy termiczne mają wpływ na zawartość HMF, które powstają pod wpływem wysokiej temperatury w produktach zawierających cukry.

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EFFECT OF LACTIC ACID CONCENTRATION ON THE QUALITY OF MARINATED BROILER BREAST FILLETS®

Wpływ stężenia kwasu mlekowego na jakość marynowanych filetów drobiowych®

*The aim of the study presented in this paper was to evaluate the effect of lactic acid concentration in marinade on the quality of baked chicken breast fillets. Poultry fillets were marinated in 1, 2 and 4% lactic acid solution. The evaluation of physical characteristics of fillets included measuring pH, assessing color according to the L*a*b* scale, as well as water absorption and tenderness of meat. The organoleptic evaluation included the intensity and desirability of the aroma, the intensity and desirability of the flavor, as well as the juiciness and tenderness of meat. Lactic acid marinating was shown to affect the brightness (L*), as well as red a* and yellow b* color saturation of the fillets. Marinating in 1 and 2% lactic acid solution had beneficial effects on physicochemical and sensory characteristics of marinated poultry meat after baking, whereas marinating in 4% lactic acid solution caused deterioration of flavor and smell of baked meat.*

Key words: broiler chickens fillets, marinating, lactic acid, sensory properties.

*Celem badań przedstawionych w artykule była ocena wpływu stężenia kwasu mlekowego w marynacie na jakość pieczonych filetów z piersi kurcząt brojlerów. Filety drobiowe marynowano w 1, 2 i 4% roztworze kwasu mlekowego. W ocenie cech fizycznych filetów uwzględniono pomiar pH, ocenę barwy w skali L*a*b* oraz wodochłonność i kruchość mięsa. W ocenie organoleptycznej uwzględniono natężenie i pożądalność zapachu, natężenie i pożądalność smaku oraz soczystość i kruchość mięsa. Wykazano, że marynowanie kwasem mlekowym ma wpływ na jasność (L*) oraz wysycenie barwy czerwonej a* i żółtej b* barwy filetów. Marynowanie w 1 i 2% roztworze kwasu mlekowego miało korzystny wpływ na cechy fizykochemiczne i sensoryczne marynowanego mięsa drobiowego po pieczeniu, natomiast marynowanie w roztworze kwasu mlekowego o stężeniu 4% spowodowało pogorszenie smaku i zapachu mięsa pieczonego.*

Słowa kluczowe: filety drobiowe, marynowanie, kwas mlekowy, cechy sensoryczne.

INTRODUCTION

Marinating is increasingly used in the culinary processing of poultry meat to increase the attractiveness and variety of poultry products. During the marinating process, meat is treated with a marinade solution containing various acids [8, 20]. The marinating process can be performed with the dipping method or the injection method [1, 21]. The dipping method involves immersing the meat in a marinade solution. During this process, the marinade solution is absorbed by the meat through diffusion. Marinating meat with acidic marinades is a widespread method of improving the quality characteristics, taste, and smell of meat, as well as extending its shelf life [23]. The marinating process is particularly important in the case of broiler chicken meat, as it brings out its delicate flavor, aroma, and color [1, 16, 19, 23, 26]. Previous studies have shown that marinating also improves the quality and yield of the product [13, 18]. Marinating also affects the juiciness and tenderness of the meat [1]. The effectiveness of the marinating process is affected by numerous factors, including the marinating method and time, as well as the type and pH of the marinade [1, 2, 3, 4]. The pH of the marinade affects, among other things, the water retention capacity, tenderness, juiciness, and color of the meat [15, 16, 23].

Lactic acid and its salts, as well as cultures of lactic acid bacteria may be ingredients of acidic marinades [25].

The aim of the study was to evaluate the effect of lactic acid concentration in marinade on the quality of baked poultry fillets.

MATERIALS AND METHOD

To evaluate the effect of lactic acid concentration on meat quality, 40 breast muscles (fillets) of broiler chickens purchased at retail were used and randomly assigned to four

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groups. Group K consisted of unmarinated fillets, group KM-1 of fillets marinated with 1% lactic acid, group KM-2 of fillets marinated with 2% lactic acid and group KM-3 of fillets marinated with 4% lactic acid. The fillets were marinated using the immersion method for 2 hours.

pH measurements were achieved using a dagger electrode, fitted with a (HI 99163 from Hanna) pH meter.

Sample's water holding capacity (WHC) determined using the Grau and Hamm method was based on the amount of juice squeezed from it.

The reading of the measurement results was achieved in a CIE LAB colorimetric system, with L* (lightness), a* (redness) and b* (yellowness). Brittleness was measured based on the cutting force (Fmax), using a Zwick/Roell machine BT1-FR1.OTH.D14 (from Zwick CmbH& Co.KG. Ulm, Germany), applying a wide-width Warner-Bratzler (V-blade) with a head speed of 100 mm··min^{-1} and a 0.2 N pre-cut force. The cutting was carried out on not marinated and marinated breast muscles with a cross section of 100 mm^2 and length of 50 mm). Weight loss (%) was calculated based on the weight difference before and after heat treatment.

Not marinated and marinated breast muscles were weighed with an accuracy of 0.1 g and processed using an electric oven at 180ºC to achieve a temperature of 80ºC±2ºC inside the muscle sample. The temperature inside the muscles was measured with a digital thermometer with an external K-type thermocouple probe (Therma plus, England), then cooling at room temperature. The colour assessment of the cross-sectional surface of not marinated and marinated breast muscles was determined, based on the reflection method, using the Chrome Meter colorimeter (Konica Minolta Osaka, Japan), fitted with a CR 400 head (ø=11mm).

In the organoleptic evaluation of baked unmarinated and marinated fillets, the following were considered: intensity and desirability of smell, intensity, and desirability of taste, as well as juiciness and tenderness. The organoleptic evaluation was carried out by a team of 7 people on a 5-point scale, where 1 point meant the least desirable evaluation and 5 points the most desirable.

The obtained data were collated and submitted for statistical analysis using Statistica 13.3 (StatSoft, Visual Basic, TIBCO Software Inc., PL) Significant differences between the means in groups were estimated with Duncan's test. The differences were considered to be statistically significant when P<0.05. The results on the effect of marinating on sensory properties of roast products were verified with the use of non-parametric Kruskal–Wallis tests. Differences were considered as significant if P<0.05.

RESULTS AND DISCUSSION

The results of studies conducted to determine the effect of lactic acid concentration in the marinade on the quality of raw and heat-treated broiler chicken meat are presented in Tables 1–3.

In our study, the pH value of raw non-marinated poultry meat was 5.74, which indicates that meat intended for marinating, due to its pH, was normal meat, not affected by DFD or PSE type defects. This result is close to the one obtained by [12]. The acidity of poultry meat marinated with marinade containing 1, 2 and 4% lactic acid was lower than that of unmarinated meat (p<0.05) (Table 1). The study showed that as the concentration of lactic acid in the marinade increased, the pH of meat decreased. In addition, the results of studies by other authors have shown that the pH of breast muscle after marinating with acidic marinades depends on the marinade pH [21,22]. Acidity of poultry meat (pH) is an important factor determining its usefulness not only for technological purposes, but also for consumption. pH plays an important role in shaping the physical characteristics of poultry meat, such as color, water absorption and tenderness of meat.

Table 1. Effect of lactic acid concentration in marinade on physicochemical properties of raw poultry fillets

Tabela 1. Wpływ stężenia kwasu mlekowego w marynacie na cechy fizykochemiczne surowych filetów drobiowych

Parameter	Group			
	K	MK-1	MK-2	MK-3
pH	5,74 ±0,08^a	5,68 ±0,02^b	5,41 ±0,03^c	5,27 ±0,05^d
WHC (%)	10,50 ±0,71^a	12,00 ±1,41^b	12,50 ±0,71^b	10,50 ±1,12^a
Colour: L*- lightness a*- redness b*- yellowness	 66,08 ±0,24^a 1,61 ±0,16^a 6,01 ±0,11^a	 65,19 ± 0,54a^b 1,00 ±0,09^b 6,70 ±0,11^b	 66,55 ±0,47^{ab} -0,21 ±0,13^c 6,69 ±0,16^b	 68,52 ±0,07^b 0,56 ±0,11^d 7,46 ±0,13^c
Shear force (N)	8,92 ±0,54^a	7,26 ±0,34^b	7,63 ±0,06^c	9,16 ±0,59^a

K-control group – non-marinated, MK-1 – marinated with 1% lactic acid, MK-2 marinated with 2% lactic acid, MK-3 marinated with 4% lactic acid

Explanations: ($\bar{x}$ ± s) arithmetic mean±standard deviation, the mean values in rows with different letters differ significantly p < 0.05

Objaśnienia: ($\bar{x}$ ± s) średnia arytmetyczna ± odchylenie standardowe, wartości średnie oznaczone różnymi literami w wierszach różnią się statystycznie istotnie przy p ≤ 0.05

Source: Own study

Źródło: Opracowanie własne

Water holding capacity (WHC), defined as water absorption of poultry meat, is a decisive factor in terms of its processing and technological usefulness. In our study, marinated broiler chicken meat was characterized by higher water absorption than meat marinated in lactic acid solution (Table 1). Similar results were obtained by [21]. Poultry meat color is one of the most important characteristics for consumers when choosing the meat to buy. Color is also one of the most important quality characteristics of meat, determining its suitability for processing [20, 21, 26]. The color of poultry meat depends on muscle pigments, including deoxymyoglobin responsible for dark red color, light red color is provided by oxymyoglobin, and grey-brown color is determined by metmyoglobin. Light red is the most desirable color for consumers, while the grey-brown is the least desirable color [6, 10, 24]. When analyzing the results obtained in the original study in terms of color measurement (Table 1), it was found that marinating chicken breast muscle fillets in marinade with 1% and 2% lactic acid had no significant effect on the color lightness (L*) of meat, while marinating in marinade with 4% lactic acid solution resulted in meat color brightening ($p<0.05$). The study also confirmed the effect of marinating on the color saturation parameter towards red a* and yellow b* (Table 1). A similar direction of changes in red color's brightness and saturation was found by [21] in studies on the color of chicken breast muscles marinated in acidic marinade.

Tenderness and juiciness are the two main textural characteristics of poultry meat. Myofibrillar proteins and muscle fiber cytoskeleton proteins play the most important role in forming meat tenderness [9]. Heat treatment also plays an important role in the texture development of broiler chicken meat, as heating denatures proteins, making the meat firmer [17]. In our study, meat marinated in 4% lactic acid solution (MK-3) was characterized by the highest cutting force (9.16 N), whereas meat marinated in 1% lactic acid solution (MK-1) was characterized by the lowest one, matching the results of the studies by Marcinkowska-Lesiak et al. [14]. The obtained results indicate good tenderness of the meat, as according to Corzo et al. [7], the cutting force value of broiler chicken meat suitable for the impression of tenderness should not exceed 30 N.

The results of pH and meat color measurement after roasting showed that, similarly to raw meat, the pH value of marinated poultry fillets decreased with the increase of lactic acid concentration in the marinade (table 2.). The meat marinated in 4% marinade (MK-3) had the lowest pH value after baking, whereas the meat marinated in 1% lactic acid (MK-1) had the highest pH value. The results showed that higher concentrations of lactic acid (4%) in the marinade not only caused acidification of raw marinated meat, but this acidification also persisted after heat treatment. The results obtained are similar to those obtained by [2, 3, 4] who achieved similar pH measurement results in studies on breast muscles of organically raised hens with buttermilk and whey.

In the conducted study, marinated meat after heat treatment did not differ from unmarinated meat ($p<0,05$) in terms of the L* parameter, yet there was an increase in the a* red color saturation in the marinated meat. The saturation of yellow color (b*) in the meat marinated with marinade containing 1 and 2% lactic acid concentration was higher than in unmarinated meat ($p<0.05$). The obtained results correspond to the results of the study [3] and to the results obtained by [5], who stated that during marinating, there are no significant changes in the meat brightness parameter L*, while there is an increase in the saturation of red a* and yellow b* colors.

Measurements of the cutting force of heat-treated fillets showed a decrease in the value of this parameter compared to raw meat, in case of meat marinated with 2% and 4% lactic acid, while the greatest increase in the cutting force was observed in case of meat marinated with 1% lactic acid. The obtained results prove that higher concentration of lactic acid in marinade decreases the value of force needed to cut the roasted poultry meat, indicating increased tenderness of fillets after marinating.

Consumers most often associate marinated poultry meat with activities aimed at enhancing the sensory qualities of a product [11]. The conducted study (Table 3) indicates that marinating fillets using a marinade with a certain lactic acid concentration can have a beneficial effect on the sensory characteristics of the product, also after heat treatment.

Table 2. Effect of lactic acid concentration in marinade on physicochemical characteristics of baked poultry fillets

Tabela 2. Wpływ stężenia kwasu mlekowego w marynacie na cechy fizykochemiczne pieczonych filetów drobiowych

Parameter	Group			
	K	MK-1	MK-2	MK-3
pH	5,90 ±0,03[a]	5,70 ±0,01[b]	5,10 ±0,30[c]	4,50 ±0,10[d]
Colour: L*- lightness a*- redness b*- yellowness	 80,33 ±1,45 1,30 ±0,07[a] 10,50±0,29	 78,69 ±1,81 1,88 ±0,31[b] 12,35 ±0,37	 80,28 ±0,16 2,15 ±0,28[b] 11,41 ±0,16	 80,99 ±1,12 1,95 ±0,07[c] 10,99 ±0,10
Shear force (N)	24,95 ±2,31[a]	26,05 ±2,63[a]	20,85 ±3,53	21,85 ±4,86

K-control group control group – non-marinated, MK-1 – marinated with 1% lactic acid, MK-2 marinated with 2% lactic acid, MK-3 marinated with 4% lactic acid

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: Own study

Źródło: Opracowanie własne

Table 3. Effect of lactic acid concentration in marinade on sensory attributes of baked poultry fillets

Tabela 3. Wpływ stężenia kwasu mlekowego na cechy sensoryczne pieczonych filetów drobiowych

Traits	Group			
	K	MK-1	MK-2	MK-3
Odour intensity	4,36±0,28[a]	4,18±0,31[a]	4,96±0,21[b]	4,82±0,31[b]
Flavour intensity	3,85±0,22[a]	3,54±0,20[a]	4,48±0,28[b]	4,96±0,27[b]
Odour desirability	4,36a ±0,20	4,56[a]±0,32	3,56[b]±0,27	3,20[b]±0,32
Odour desirability	4,18±0,31[a]	4,62±0,34[a]	3,62±0,21[b]	3,00±0,34[b]
Juiciness	4,27±0,31[a]	4,94±0,27[b]	5,00±0,22[b]	4,18±0,18[a]
Tenderness	3,85±0,22[a]	4,18±0,31	4,94±0,18[b]	4,92 ±0,31[b]

K-control group control group – non-marinated, MK-1- marinated with 1% lactic acid, MK-2 marinated with 2% lactic acid, MK-3 marinated with 4% lactic acid

Explanations: ($\bar{x}$ ± s) arithmetic mean±standard deviation, the mean values in rows with different letters differ significantly $p < 0.05$

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: Own study

Źródło: Opracowanie własne

The results of organoleptic evaluation of baked marinated fillets showed that poultry meat marinated in 2% and 4% marinade (MK-2 and MK-3) was characterized by the highest intensity of smell and flavor, whereas meat marinated in 1% marinade was characterized by the lowest intensity of these features. Meat marinated in 1% solution (MK-1) and unmarinated meat had the highest smell desirability, while meat marinated in 4% marinade had the lowest one. In terms of assessing the taste desirability, meat marinated in 1% lactic acid marinade received the highest marks, while meat marinated in 4% lactic acid received the lowest marks, as the sour taste of the marinade was perceptible during its evaluation. According to consumer assessment, juiciness is an important quality parameter of heat-treated meat. In our study, meat marinated in 1% and 2% marinade (MK-1 and MK-2) was characterized by the highest juiciness, whereas meat marinated in 4% marinade (MK-3) and unmarinated meat were characterized by the lowest juiciness. In our study, broiler chicken meat marinated in 2% lactic acid (MK-2) was characterized by the best tenderness, whereas meat no marinated received the lowest scores for this property.

The obtained results correspond to those obtained by [3,4] who, in a study of breast muscles marinated in buttermilk and whey, demonstrated that marinating has a beneficial effect on sensory characteristics of poultry meat.

SUMMARY

The study showed that the pH value of both raw and baked broiler chicken breast fillets decreased with the increasing lactic acid concentration in marinade. Marinating with lactic acid did not affect the brightness of color (L*) but influenced the saturation of yellow b* and red a* colors of poultry fillets. Marinated muscles were characterized by lower cutting force, i.e., greater tenderness. Marinating in 1 and 2% lactic acid solution had beneficial effect on sensory attributes of baked poultry fillets, whereas marinating fillets with 4% lactic acid was less beneficial, because acidic marinade taste was perceptible in meat after baking.

PODSUMOWANIE

Przeprowadzone badania wykazały, że wraz ze wzrostem stężenia kwasu mlekowego w marynacie zmniejsza się wartość pH zarówno surowych jak i pieczonych filetów z piersi kurcząt brojlerów. Marynowanie kwasem mlekowym nie miało wpływu na jasność barwy (L*) ale miało wpływ na wysycenie barwy żółtej b* i czerwonej a* filetów drobiowych. Mniejszą siłą cięcia, czyli większą kruchością charakteryzowały się mięśnie marynowane. Marynowanie w 1 i 2% roztworze kwasu mlekowego miało korzystny wpływ na cechy sensoryczne pieczonych filetów drobiowych, natomiast marynowanie filetów 4% kwasem mlekowym było mniej korzystne, gdyż po pieczeniu był wyczuwalny kwaśny posmak marynaty w mięsie.

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ASSESSMENT OF THE LACTICASEIBACILLUS RHAMNOSUS LOCK 900 STRAIN FOR THE PRODUCTION OF PROBIOTIC BEETROOT JUICE®

Ocena przydatności szczepu Lacticaseibacillus rhamnosus LOCK 900 do produkcji probiotycznego soku z buraka ćwikłowego®

Lactic acid bacteria play an important role in the development of new functional products. The addition of probiotic bacteria strain can give the product features of functional food. The aim of the study was to assess the possibility of using the probiotic Lacticaseibacillus rhamnosus LOCK 900 strain for the production of functional red beet juice (Beta vulgaris) with a satisfactory sensory quality and determination of the health safety of the proposed product in terms of the content of biogenic amines. In our research it was found that the number of Lb. rhamnosus LOCK 900 bacteria strain until the 12th day of storage at 4°C was at a high level, above 8 log cfu/ml and was suitable for probiotic products, in accordance with FAO/WHO recommendations. The overall quality of fermented beet juice supplemented with LOCK 900 strain stored at 4 °C was high until the end of storage period. It is possible to use the Lacticaseibacillus rhamnosus LOCK 900 strain to obtain fermented beetroot juice with the number of cells in accordance with the FAO/WHO recommendations for probiotic products.

Key words: probiotic, beet juice, *Lactobacillus*, starter culture, functional food.

Bakterie kwasu mlekowego odgrywają ważną rolę w rozwoju nowych produktów funkcjonalnych. Dodanie szczepu bakterii probiotycznych pozwala na zaliczenie produktu do żywności funkcjonalnej. Celem badania była ocena możliwości wykorzystania szczepu probiotycznego Lacticaseibacillus rhamnosus LOCK 900 do produkcji fermentowanego soku z buraka ćwikłowego (Beta vulgaris), charakteryzującego się dobrą jakością sensoryczną i bezpieczeństwem zdrowotnym pod względem zawartości amin biogennych. Stwierdzono, że liczba bakterii szczepu *Lb. rhamnosus* LOCK 900 do 12 dnia przechowywania w 4°C była powyżej 8 log jtk/ml i była zgodna z wymaganiami FAO/WHO dla produktów probiotycznych. Jakość ogólna fermentowanego soku z buraków z dodatkiem szczepu LOCK 900 przechowywanego w temperaturze 4 °C była wysoka do końca okresu przechowywania.. Istnieje możliwość zastosowania szczepu *Lacticaseibacillus rhamnosus* LOCK 900 do otrzymania fermentowanego soku z buraka ćwikłowego o liczbie komórek zgodnej z zaleceniami FAO/WHO dla produktów probiotycznych.

Słowa kluczowe: probiotyk, sok z buraka, *Lactobacillus*, kultura startowa, żywność funkcjonalna.

INTRODUCTION

Currently, people are looking for the products that promote well-being and health. Fermented milk drinks with the addition of bacteria are now popular probiotic foods. Some consumers, however, cannot consume them for a reason of allergies, lactose intolerance or cholesterol content. The fermented vegetable products (i.e. juices) made of vegetables, fruits, cereals and legumes can complement the offer [12, 15, 16]. The addition of probiotic bacteria strain can give the product features of functional food. The use of a starter culture of a selected bacterial strain ensures the proper course of fermentation. Starter cultures of lactic acid bacteria used for the production of such juices should be of good viablity in an acidic environment to the end of its use-by date consumption [2]. Lactic acid bacteria (LAB) play an important role in the development of new functional products. In addition to preserving food, LAB change the sensory characteristics of the product and inhibit the growth of pathogenic bacteria. Probiotic bacteria when added to food, give a beneficial effect on the host's organism by improving its intestinal ecosystem [24]. Currently, traditional food preservation processes such as fermentation are becoming more popular. An attractive healthy product may be a fermented beet juice. Beetroot is seen as a food with a positive effect on health, as it contains a large number of antioxidants. The consumption of beetroot may contribute to lowering the risk of cardiovascular diseases and cancer [13]. The addition of probiotic bacteria strains to beet juices may increase the attractiveness of the products offered to consumers. Obtaining the viability of strains of

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probiotic microorganisms at an appropriate level in products derived from red beet makes it possible to classify them as functional food.

The aim of the study was to assess the possibility of using the probiotic *Lacticaseibacillus rhamnosus* LOCK 900 strain for the production of functional red beet juice with a satisfactory sensory quality and determination of the health safety of the proposed product in terms of the content of biogenic amines.

MATERIAL AND METHODS

The research material was juice made of roots of red beet (*Beta vulgaris L. ssp. vulgaris*, Wodan) from the crops of the Warsaw University of Life Sciences, without the use of plant protection products. Beetroots were washed, sliced, then juice was pressed using Kenwood JE 500, Germany juice extractor. Saccharose was added in the amount of 2% of the juice volume, then the juice was pasteurised (90°C, 15 minutes), chilled to 40°C and juice was inoculated with probiotic starter culture *Lb. rhamnosus* LOCK 900 and kept in the cooling temperature.

The pure probiotic strain LOCK 900 (strain deposit number: CP005454) was obtained from a collection from the Pure Culture Collection of the Technical University of Łódź in Poland [1]. Preparation of the probiotic strain consisted of activating frozen bacteria, suspending them in food broth and then inoculating the juice with them [19]. The inoculum before being added to the juice was approximately 9.0 log cfu/mL.

The number of *Lb. rhamnosus* LOCK 900 bacteria was determined adopting a plate method on the MRS Agar (BIOCAR Diagnostic) at 37°C for 48 h.

The pH value was measured using digital pH meter (Lab 860 Schott Instruments) equipped with a pH electrode.

Determining of biogenic amines with using High-Performance Liquid Chromatography (Alliance Separation Module 2695, Waters Alliance, Milford, USA) in reversed phase (RP-HPLC). Chromatographic separation was perform using column: Kromasil C18 (5 µm, 250 mm × 4,6 mm ID, with proper precolumn precolumn). Column was maintained at 25ºC. Analytes were detected at the wavelength of 254 nm. The sampler temperature was 4ºC, the mobile phase (acetonitryl : water) flow rate was 1 cm^3 /min. The gradient elution program was as follows: [%]: 1 min – 35:65, 10 min – 20:80, 12 min – 10:90, 16 min – 0:100, 23 min – 0:100. The retention time (RT) for the determination of one sample of biogenic amines was 23 min. The individual amine content results were calculated with the equation: y = cAB (Tyr, Pu, Hi) /cI × b and are given in mg/kg.

For sensory evaluation QDA method was applied. An unstructured, linear graphical scale (0–10 conventional units) was used (ISO 13299:2016-05 ISO 8586:2014-03). In trained person panel discussion 13 descriptors and overall quality were chosen [9,10].

The data were evaluated statistically using STATISTICA ver. 12 (Statsoft, Isc. 2011) and Microsoft Excel 2007 program. The results were analysed using one-way analysis of variance and Tukey test. The significance of differences between means were calculated at the level P= 0.05.

RESALTS AND DISCUSSION

In the first stage of the research to ensure growth of *Lacticaseibacillus rhamnosus* LOCK 900 strain in environment of beet juice the addition of sugar (sucrose) was checked. As a result of juice fermentation (37 °C for 24 hours) with the *Lb. rhamnosus* LOCK 900 strain, the number of bacteria increased more than 1 logarithmic level to the values for juice without and with sucrose respectively: 8.82 log cfu/ml and 8.62 log cfu/ml.

In our research, sensory evaluation was used as a criterion for product selection by the consumer. The general quality of the juice with the addition of sucrose was statistically significantly higher than the juice without added sugar, which could be influenced by higher scores of positive discriminants: sweet flavour and sweet odour for this variant (Fig. 1). The variant of the juice with added sugar was selected for further research.

The next stage of the research was to evaluate survival of the *Lb. rhamnosus* LOCK 900 in fermented beet juice. The beetroot juice was fermented at 37 °C and stored for 16 days at 4 °C and 8 °C. The storage time and temperature influenced the viability of the tested strain and the pH. During the storage of the juice at 4 °C, there was a significant increase in the number of bacteria of the tested strain up to the 4th day of storage, after which the number of bacteria decreased (Fig. 2a). A probiotic product should contain a sufficient number of living, defined, health-promoting microorganisms, the general recommendation is 10^6 cfu/g. [7]. In our research it was found that the number of LOCK 900 bacteria until the 12th day of

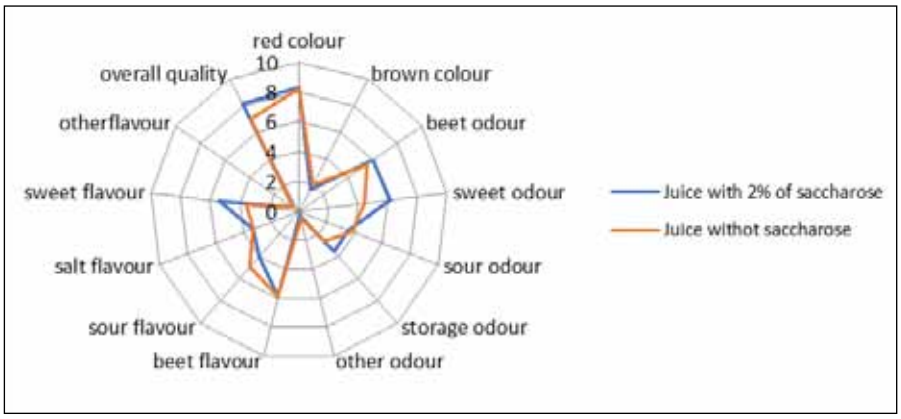


Fig. 1. Evaluation of intensity of sensory attributes of fermented beet juice without saccharose and with 2% saccharose added during storage (QDA method, n=16).

Rys. 1. Ocena intensywności wyróżników sensorycznych fermentowanego soku z buraka ćwikłowego bez oraz z dodatkiem 2% sacharozy (metoda QDA, n=16).

Source: The own study

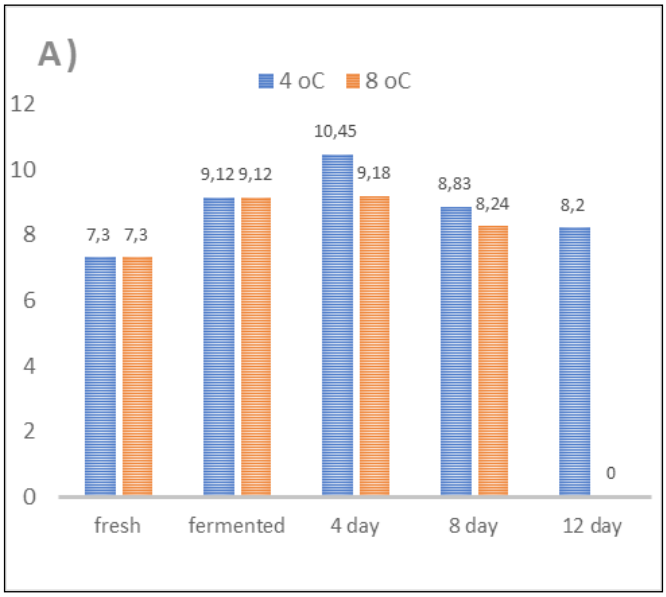
Źródło: Badania własne

storage at 4°C was at a high level, above 8 log cfu/ml (Fig. 2A) and was suitable for probiotic products, in accordance with FAO/WHO recommendations. During storage at 4°C a significant decrease in pH on day 4 was observed, which proves the presence of live cells of lactic acid bacteria, which by consuming the sugars contained in the food matrix (beet juice) cause acidification of the environment (Fig. 2B). The juice stored at 8 °C also showed an increase in the number of bacteria up to the 4th day of storage, although not statistically significant. Until the 8th day of storage, the number of probiotic bacteria was above 8 log cfu/ml (Fig. 2A), while after 12 days no viable *Lb.rhamnosus* LOCK 900 cells were found. At a higher temperature (8°C), sugar is metabolized faster by LOCK 900 bacteria, hence their reduced survival is observed. Baráth et al (2004) also found a reduction in the number of *Lb. curvatus* 2770 and *Lb. casei pseudo plantarum* from the values of 8.85 and 8.0 log cfu/ml, respectively, to a level of about 6.0 log cfu/ml during the refrigerated storage of beet juice for 28 days [3]. Diversified survival of different LAB strains was also demonstrated in research of [25]. They found good survival of the *Lb. plantarum* and *Lb. acidophilus*, but did not find the presence of viable *Lb. plantarum* cells after 2 weeks of storage of red beet juice at 5°C. It can be assumed that the viability of bacteria in the fermented juice during storage may be dependent on the strain used. The viability of bacterial strains may also be related to the food matrix. Yuasa et.al. (2021) used *L. plantarum* SI-1 and *L. pentosus* MU-1 in citrus juice fermentation. The viable cell counts tended to be lower in fermented citrus *Haruca* juice than in mandarin and orange juices for both bacteria [26].

The overall quality of the beet juice supplemented with LOCK 900 strain stored at 4°C was high until the end of storage (Fig. 3). The highest general quality of juice (7.33 c.u.) was observed after 8 days, which could have been influenced by an increase, although not statistically significant, of positive qualitative characteristics: beetroot taste, sweet taste, sweet smell, red colour and clarity. The taste and smell of beetroot were best assessed after fermentation (6.63 c.u. and 6.23 c.u. respectively). The juice stored at 8°C was of satisfactory sensory quality until the 8th day of storage (Fig. 3). There were no statistically significant differences between the examined discriminants during storage. The overall quality of the juice decreased on the 16th day of storage to 4.9 c.u. and the product was not sensory acceptable.

The basic requirement for food is its safety. According to the definition of Codex Alimentarius food safety is defined as "assurance that food will not cause harm to the consumer when it is prepared and / or eaten according to its intended use" [6]. Biogenic amines occurring in food may pose a threat to human health therefore monitoring their presence is very important. The presence of amines was found in fresh and preserved vegetables and fermented plant juices [11, 14, 17, 26] and their type may depend on the strain of bacteria [21]. There are many factors influencing the formation of biogenic amines, including temperature, pH, substrate availability, salt and sugar content. In products containing biogenic amines, the microorganisms responsible for their formation have also been identified [8].

Histamine is considered to be the most toxic amine found in food. No histamine was found in the juice after



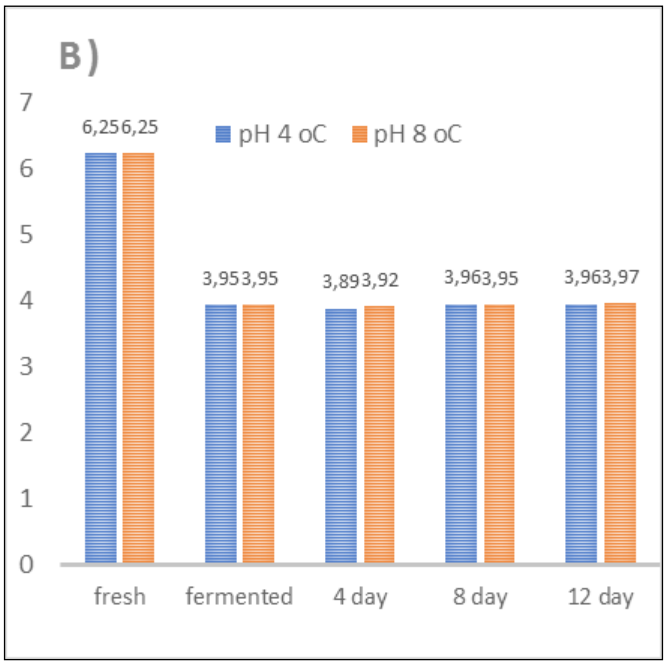


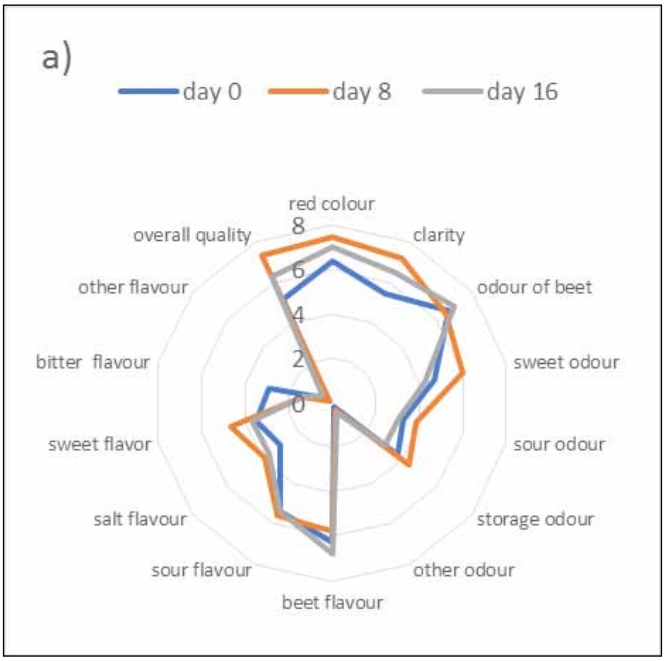
Fig. 2. Mean counts of L. rhamnosus LOCK 900 strains [log cfu/ml] (A) and pH (B) in fermented beet juice with saccharose (2%) added during storage in temperature 4°C and 8°C.

Rys. 2. Średnie wartości liczby bakterii L. rhamnosus LOCK 900 [log jtk/ml] (A) i pH (B) w fermentowanym soku z buraka ćwikłowego z dodatkiem sacharozy (2%) przechowywanego w temperaturze 4°C i 8 °C.

Source: The own study

Źródło: Badania własne

fermentation and during storage in fermented beet juice (Tab. 1). Fruits and fruit juices are particularly rich in putrescine [4,16, 22]. According to some authors, cooking processes and heat treatments can influence polyamine contents [5, 20, 23]. The regulation of European Union Commission 1019/2013 established limits for histamine (20-40 mg/100g) in fishery



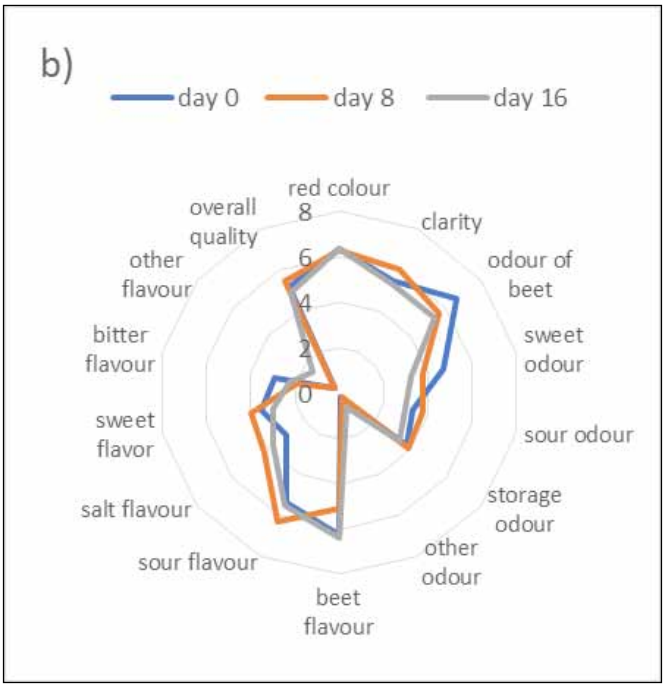


Fig. 3. Evaluation of intensity of sensory attributes of beet juice with 2% saccharose addition after fermentation and during 16 days storage: a) at 4 oC, b) at 8 oC (QDA method, n=16).

Rys. 3. Ocena intensywności wyróżników sensorycznych soku z buraka ćwikłowego z 2% dodatkiem sacharozy po fermentacji oraz podczas 16 dni przechowywania : a) 4 oC, b) 8 oC (metoda QDA, n=16).

Source: The oun study

Źródło: Badania własne

products. The content of putrescine and tyramine in the tested beetroot juice was at a low level after pasteurization and during the entire storage period.

Table 1. Biogenic amine contents in fermented beet juice with saccharose (2%) added [mg/kg]

Tabela 1. Zawartość amin biogennych w fermentowanym soku z buraka ćwikłowego z dodatkiem 2% sacharozy [mg/kg]

Juice/sok		Histamine	Tyramine	Putrescyne
Fresh		n.d.	n.d.	3,17±0,61
Pasteurised		n.d.	1,86±0,23	1,14±0,22
Fermented		n.d.	1,86±0,23	1,18±0,23
Temp.	Days			
4°C	8	n.d.	2,00±0,24	1,63±0,31
	16	n.d.	2,22±0,27	1,45±0,28
8°C	8	n.d.	3,42±0,42	3,27±0,63
	16	n.d.	1,88±0,23	1,88±0,23

LOD=0,5 mg/kg, LOQ=1,0 mg/kg, n.d. – not detected (< LOD)

Source: The oun study

Źródło: Badania własne

CONCLUSIONS

It was found that the storage time and temperature influenced the microbiological quality of the fermented beetroot juice inoculated with *Lacticaseibacillus rhamnosus* LOCK 900 with the addition of 2% sucrose. Better survival of *Lacticaseibacillus* rhamnosus LOCK 900 cells was found during the two-week storage of fermented beetroot juice at 4 than 8 °C. The content of biogenic amines (histamine, tyramine, putrescyne) was low during the production and storage of the fermented beetroot juice. Taking into account the sensory quality, the juice storage time at 4˚C and 8˚C is no longer than 8 days.

It is possible to use the *Lacticaseibacillus rhamnosus* LOCK 900 strain to obtain fermented beetroot juice with the number of bacterial cells in accordance with the FAO/WHO recommendations for probiotic products. Further research is necessary to optimize the parameters of the juice production process and the selection of starter cultures.

WNIOSKI

Stwierdzono, że czas i temperatura przechowywania mają wpływ na jakość mikrobiologiczną fermentowanego soku z buraka ćwikłowego zaszczepionego *Lacticaseibacillus rhamnosus* LOCK 900 z dodatkiem 2% sacharozy. Podczas dwutygodniowego przechowywania fermentowanego soku z buraka ćwikłowego stwierdzono lepszą przeżywalność komórek *Lacticaseibacillus rhamnosus* LOCK 900 w temperaturze 4 niż 8°C. Zawartość amin biogennych (histaminy, tyraminy, putrescyny) była na niskim poziomie podczas produkcji i przechowywania fermentowanego soku z buraka ćwikłowego. Biorąc pod uwagę jakość sensoryczną, czas przechowywania soku w temperaturze 4˚C i 8˚C wynosi nie dłużej niż 8 dni.

Istnieje możliwość zastosowania szczepu *Lacticaseibacillus rhamnosus* LOCK 900 do otrzymania fermentowanego soku z buraka ćwikłowego o liczbie komórek bakterii zgodnej z zaleceniami FAO/WHO dla produktów probiotycznych. Niezbędne są dalsze badania nad optymalizacją parametrów procesu produkcji soku i doborem kultur startowych.

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COMPARISON OF THE CONTENT OF SELECTED BIOACTIVE COMPOUNDS IN INFUSIONS OF DIFFERENT TEAS®

Porównanie zawartości wybranych składników bioaktywnych w naparach herbat®

The purpose of this paper is to compare the content of total extracts, caffeine, tannins and total polyphenolic compounds in infusions of different teas from the same region of cultivation. The antioxidant properties of the infusions prepared from these teas have also been determined. The research material consisted of Chinese leaf teas purchased in a chain of hypermarket stores in Warsaw. They included: green tea, a mixture of green and white tea and black tea. It has been indicated that the type of tea has a significant impact on the content of polyphenols, tannins and caffeine, and the brewing time significantly changes the content of tannins in the infusions. The extract content in tea infusions depends to a large extent on the concentration of the prepared infusions and is the reflection of their strength. For all teas tested, the antioxidant activity of infusions depended on the content of polyphenolic compounds and was significantly higher for green tea infusions and green tea blends.

Key words: tea, bioactive substances, polyphenolic compounds, caffeine, tannins, antioxidant properties.

Celem artykułu jest porównanie zawartości substancji wyciągowych ogółem, kofeiny, garbników oraz związków polifenolowych ogółem w naparach różnych herbat pochodzących z tego samego rejonu upraw. Oznaczono również właściwości przeciwutleniające naparów sporządzonych z tych herbat. Materiał badawczy stanowiły chińskie herbaty liściaste zakupione w sieci hipermarketów w Warszawie. Były to: herbata zielona, mieszanka herbat zielonej z białą oraz herbata czarna. Wykazano, że rodzaj herbaty ma istotny wpływ na zawartość związków polifenolowych, garbników i kofeiny, a czas parzenia istotnie zmienia zawartość garbników w naparach. Zawartość substancji wyciągowych w naparach herbat zależy istotnie od stężenia przygotowanych naparów i jest odzwierciedleniem ich mocy. Dla wszystkich badanych herbat aktywność przeciwutleniająca naparów zależała od zawartości związków polifenolowych i była istotnie wyższa dla naparów z herbaty zielonej i mieszanki herbaty zielonej z białą.

Słowa kluczowe: herbata, substancje bioaktywne, związki polifenolowe, kofeina, garbniki, właściwości przeciwutleniające.

INTRODUCTION

Once reserved only for the elite, tea is today one of the most popular drinks consumed daily by the majority of people in the world. Average tea consumption in Poland per raw material is estimated at approx. 1 kg / person. As a rule, 1–2% infusions are the most acceptable in terms of their sensory content. Tea infusions are widely appreciated for their sensory properties, exceptional aroma, as well as for their characteristic taste with a slight hint of bitterness [34].

Regular consumption of infusions of teas, especially green or red teas, can reduce the development of cardiovascular and nervous system diseases, and it prevents cancer. Scientific research also shows that consuming tea in various forms can regulate body weight and prevent obesity. The high content of various bioactive compounds, which have a beneficial effect on the proper functioning of the organism, contributes to the increased interest in tea infusions [4, 36, 38].

Bioactive substances contained in tea, such as catechins and theaflavins, have a prophylactic effect in the development of atherosclerosis and hypertension by reducing the level of cholesterol and triacylglycerols in the plasma. In addition, numerous polyphenolic compounds are effective in fighting bacteria and viruses, and thus contribute to the prevention and treatment of infectious diseases (flu, colds, diarrhea) and inflammation of the oral cavity.

Green tea infusion stimulates the secretion of gastric juices, so that it stimulates digestive processes, and its alkaline reaction protects the body against acidification. In addition, the high content of fluoride in both green and black tea infusions strengthens the teeth and protects them against caries. This

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effect is additionally enhanced by the antibacterial properties of polyphenols, which prevent bacteria from developing on the surface of the teeth or gums [1, 2, 3, 33].

The aim of this paper was to assess the content of selected bioactive ingredients in infusions made of teas from the same growing region, i.e. total extracts, caffeine, tannins and total polyphenolic compounds. The antioxidant properties of these infusions have also been studied.

MATERIAL AND METHODS

The experimental material consisted of market products from the same producer:

a) green – leaf tea from China,
b) a mixture of green and white tea – leaf tea from China,
c) black – leaf tea from China.

The dry matter content in the leaves was determined by the dryer-weight method in accordance with the requirements of Polish standards [21, 22]. The extracts content was determined in 1% and 2% solutions of the analyzed teas in accordance with the Polish standard [23]. **The content of tannins** in tea infusions was determined by the spectrophotometric method with the use of the Folin-Ciocalteu reagent, described in the Polish Pharmacopoeia VI [7, 14]. **Caffeine content** was determined by spectrophotometric method with prior application of solid phase extraction, i.e. the SPE procedurę [9]. The measurement of absorbance was performed at a wavelength of $\lambda = 280$ nm against distilled water as a blank. To calculate the caffeine content in tea infusions, a regression equation was used, determined on the basis of the previously prepared standard curve. The caffeine content was expressed in mg per 100 ml. **The content of total polyphenolic compounds** was determined with the spectrophotometric method, which involved carrying out a color reaction between polyphenolic compounds and the Folin-Ciocalteu reagent [29]. The content of polyphenols, expressed as GAE (Gallic Acid Equivalent), to. mg of gallic acid based on 1 g of tea. **The antioxidant activity** was determined by spectrophotometric method using the synthetic cation radicals ABTS * + (2,2'-azinobis-(3-ethylbenzothiazoline-6-sulfonate) [24]. **Statistical analysis** was performed using the following computer programs: Excel 2016 and Statgraphic Centurion XVI.

RESULTS AND DISCUSSION

The dry weight of tea leaves

Table 1 presents the minimum, maximum and average ($X_{avg.}$) dry matter content in the tested loose (dry) teas. It ranged from 92.5% (black tea) to 94.4% (green tea).

The results obtained during the study were comparable with the studies of other authors (table 2).

The dry matter content is one of the main factors determining the quality of the raw material. Its relatively large amount has a positive effect on the shelf life of the tea and prevents the dry leaves from absorbing foreign, undesirable odors. The high content of dry matter also confirms the high content of nutritious ingredients that orovide the tea with a specific taste.

Table 1. Average dry matter content in the tested teas (dry)

Tabela 1. Przeciętna zawartość suchej masy w badanych herbatach (suchych)

Type of tea / Rodzaj herbaty	Dry matter content / Zawartość suchej masy (%)	
	Mim – max	$X_{śr.}$ ± SD
Black / Czarna	92,43 – 92,59	92,50 ± 0,09 a*
Green / Zielona	94,3 – 94,56	94,40 ± 0,13 b*
Blend of green with white / Mieszanka zielonej z białą	93,85 – 94,04	93,90 ± 0,10 c*

**/ the same letter designations in the column indicate no significant differences between the compared means / jednakowe oznaczenia literowe w kolumnie wskazują na brak istotnych różnic między porównywanymi średnimi*

Source: The own study

Źródło: Badania własne

Table 2. Comparison of the results of the dry matter content of teas obtained by various authors

Tabela 2. Zestawienie wyników zawartości suchej masy herbat uzyskanych przez różnych autorów

Type of tea / Rodzaj herbaty	Water content / Zawartość wody (%)	Dry matter content / Zawartość suchej masy (%)	Source / Źródło
Tea - requirements / Herbata – wg normy	8	92	[22]
Green / Zielona	7,1 – 8,5	91,5 – 92,9	[17]
	7	93	[8]
Black / Czarna	4,3 – 8,6	91,4 – 95,7	[17]
	7,8	92,2	[8]
Red / Czerwona	7,2 – 9,6	90,4 – 92,8	[17]
	9,2	90,8	[8]
White / Biała	7,4	92,6	[8]
	4 – 8	92 – 96	[20]

Source: Own study

Źródło: Opracowanie własne

Extracts

100 ml of 1% tea infusions tested in this study contained approx. 320-390 mg of extracts, and in 2% solutions almost twice as much, i.e. from 623 to 767 mg / 100 ml (Fig. 1). Both 1% and 2% of green tea infusions contained significantly more extracts than infusions made of black tea or a mixture of green and white tea ($p = 0.018$).

The extracts content of infusions is often called "extract" of infusions and reflects the strength of the infusions. The extracts include, among others: purine alkaloids (caffeine, theophylline, theobromine), tannins, amino acids, pigments, essential oils, vitamins (C, B_1, B_2, PP) and minerals (copper, zinc, cadmium, fluorine, magnesium) [15, 31]. Table 3 shows the results of extracts content in tea infusions obtained by other authors.

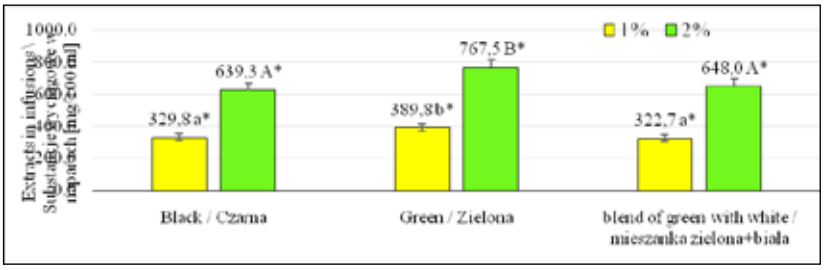

Fig. 1. Comparison of the average content of extracting substances in 1% and 2% of tea infusions.

Rys. 1. Porównanie przeciętnej zawartości substancji wyciągowych w 1 i 2% naparach herbat.

**/ the same letter markings placed next to the values corresponding to individual concentrations indicate no significant differences between the compared means / jednakowe oznaczenia literowe umieszczone przy wartościach odpowiadającym poszczególnym stężeniom wskazują na brak istotnych różnic między porównywanymi średnimi*

Source: The own study

Źródło: Badania własne

Table 3. The content of extracts in tea infusions according to other authors

Tabela 3. Zawartość substancji wyciągowych w naparach herbat wg innych autorów

Type of tea / Rodzaj herbaty	Zawartość (%)	Źródło
Tea – requirements / Herbata – wymagania	32	[23]
Black / Czarna	35,71	[5]

Source: Own study

Źródło: Opracowanie własne

Table 4. Average caffeine content in 1% of the tested teas infusions

Tabela 4. Przeciętna zawartość kofeiny w 1% naparach badanych herbat

Type of tea / Rodzaj herbaty	Caffeine content / Zawartość kofeiny (mg/100 ml)	
	min - max	$X_{śr.}$ ± SD
Black / Czarna	21,47 - 21,95	21,71 ± 0,24 a*
Green / Zielona	10,31 - 10,79	10,55 ± 0,27 b*
Blend of green with white / Mieszanka zielonej z białą	9,94 - 10,42	10,18 ± 0,21 b*

**/ the same letter designations in the column indicate no significant differences between the compared means / jednakowe oznaczenia literowe w kolumnie wskazują na brak istotnych różnic między porównywanymi średnimi*

Source: The own study

Źródło: Badania własne

Caffeine

Black tea infusions contained almost twice as much caffeine (21.71 mg / 100 ml) as green tea or green tea mixed with white tea infusions (10.55 and 10.18 mg / 100 ml, respectively), and these differences were statistically significant (p = 0.001) (table 4).

The caffeine content in tea depends, among other things, on the growing conditions of the bush and on the maturity of the plant during harvest. Young tea leaves, flowers and fruit have the highest caffeine content. The amount of the above alkaloid also largely depends on the process of fermentation of the tea leaves, as a result of which the caffeine content in the dry leaves can increase by up to 85%. Average dry tea leaves contain 2 to 5%. The yield of caffeine (theine) extraction into the brew is about 80%. The amount of theine in the infusion also depends on the degree of leaf fragmentation, the temperature of the water used to prepare the drink and the brewing time [34, 39]. Table 5 shows the results of caffeine content in tea infusions obtained by various authors.

Differences in the values in the presented results may be due to environmental factors of tea cultivation and conditions during its processing, as well as due to the use of different, non-standardized methods of determining these compounds in tea infusions [37].

Tannin

Table 6 contains a summary of the results indicating the content of tannins in 1% infusions of tea brewed for 5 to 20 minutes.

Black tea infusions (62.2 mg / 100 ml) contained the largest amount of tannins, followed by green tea (46.4 mg / 100 ml), while the smallest amount of tannins were found in the mixture of green and white tea (39.5 mg / 100 ml). In 100 ml of tea infusions, brewed for 3 minutes, there was an average of 45.4 mg of tannins, while the infusions brewed for 20 minutes – 59.3 mg of tannins.

Infusions brewed for 3 to 10 minutes were characterized by insignificantly different tannin content, and after 15-20 minutes, for each type of tea tested, a significant increase in the tannin content was observed (p = 0.0001). After 20 minutes of brewing, the infusions contained from 42.4 mg / 100 ml (in case of a mixture of green and white tea) to 77.7 mg / 100 ml (in case of black tea) tannins.

The main representative of catechins in tea is tannin, which constitutes 4–12% of dried tea [30, 32]. Table 7 indicates the results of the tests for tannin content in tea infusions obtained by various authors.

Total polyphenolic compounds

Table 8 indicates the average content of total polyphenolic compounds (expressed as GAE gallic acid content) in 1% infusions from the tested teas. This content ranged from 206.9 to 386.4 mg GAE / 100 ml. Each type of tea was characterized by a significantly different (p = 0.01) content of the said compounds, with black tea infusions having a significantly smallest amount of polyphenolic compounds (209.7 mg / 100 ml), and the biggest amount was found in the mixture of green and white teas (381.5 mg / 100 ml). Green tea infusions and the infusions from green and white tea contained approx. 71–81% more of these compounds than black tea infusions.

Table 5. Comparison of the results of caffeine content in tea infusions obtained by other authors

Tabela 5. Zestawienie wyników zawartości kofeiny w naparach herbat uzyskanych przez innych autorów

Type of tea / Rodzaj herbaty	Concentration tested infusions / Badane stężenie naparów	Caffeine content / Zawartość kofeiny		Result converted to unit / Wynik przeliczony na (mg/100 ml naparu 1%)	Source / Źródło
		Unit of measure / Jednostka	$X_{śr.}$		
Green / Zielona	0,5%	µg/1 ml	120,5	24,1	[28]
	2,5%	mg/1 ml	0,604	24,16	[3]
	1,3%	mg/177 ml	56,1	24,49	[10]
	1,15%	mg/200 ml	33,4	14,52	[12]
Black / Czarna	0,5%	µg/1 ml	149,5	29,9	[28]
	1,4%	mg/177 ml	54,8	22,19	[10]
	1,15%	mg/200 ml	33,5	14,57	[12]
	2,5%	mg/1 ml	0,617	24,68	[3]
White / Biała	0,5%	µg/1 ml	145,5	29,1	[28]
	2,5%	mg/1 ml	0,547	21,68	[3]

Source: Own study

Źródło: Opracowanie własne

Table 6. The average content of tannins in 1% of infusions of the tested teas brewed at various times from 5 to 20 minutes

Tabela 6. Przeciętna zawartość garbników w 1% naparach badanych herbat parzonych w zróżnicowanym czasie od 5 do 20 minut

Type of tea / Rodzaj herbaty	Tannin content / Zawartość garbników (mg/100 ml of 1% infusion / naparu) at different brewing times / w różnym czasie parzenia					On average / Przeciętnie mg/100 ml
	3 min	5 min	10 min	15 min	20 min	
Black / Czarna	56,9a ± 0,02	58,1a ± 0,02	58,6a ± 0,03	59,6b ± 0,02	77,7c ± 0,01	62,2
Green / Zielona	41,4a ± 0,02	43,2a ± 0,03	43,6a ± 0,01	45,7b ± 0,05	57,9c ± 0,02	46,4
Blend of green with white / Mieszanka zielonej z białą	38,0a ± 0,01	38,1a ± 0,02	39,1b ± 0,02	40,2c ± 0,03	42,4d ± 0,01	39,5
On average / Przeciętnie, mg/100 ml	45,4	46,4	47,1	48,5	59,3	

**/ the same letter designations in individual lines indicate no significant differences between the compared means / jednakowe oznaczenia literowe w poszczególnych wierszach wskazują na brak istotnych różnic między porównywanymi średnimi*

Source: The own study

Źródło: Badania własne

Table 7. Comparison of the tannin content in tea infusions obtained by various authors

Tabela 7. Porównanie zawartości garbników w naparach herbat uzyskanych przez różnych autorów

Type of tea / Rodzaj herbaty	Concentration tested infusions / Badane stężenie naparów	Tannin content / Zawartość garbników				Result converted to unit / Wynik przeliczony na (mg/100 ml 1% naparu)	Source / Źródło
		Unit of measure / Jednostka	$X_{śr.}$	Min	Max		
Green / Zielona	2%	g/100 g s.m.	9,81	-	-	24,55	[27]
	b.d.	%	-	0,22	0,31		[32]
Black / Czarna	2%	g/100 g s.m.	-	3,33	9,03	16,65-45,15	[4]
	2%	g/100 g s.m.	-	11,8	25,93	59-129,7	[27]
	b.d.	%	-	0,14	0,31	-	[32]
Red / Czerwona	2%	g/100 g s.m.	17,26	-	-	86,30	[27]
White / Biała	2%	g/100 g s.m.	18,43	-	-	92,15	[27]

Source: Own study

Źródło: Opracowanie własne

Table 8. Average content of total polyphenolic compounds in 1% of the tested teas infusions

Tabela 8. Przeciętna zawartość związków polifenolowych ogółem w 1% naparach badanych herbat

Type of tea / Rodzaj herbaty	The content of total polyphenolic compounds / Zawartość związków polifenolowych ogółem [mg GAE/100 ml]	
	min – max	$X_{śr.}$ ± SD
Black / Czarna	206,9 – 213,3	209,7 ± 3,2 a*
Green / Zielona	354,7 – 367,4	359,7 ± 6,8 b*
Blend of green with white / Mieszanka zielonej z białą	373,7 – 386,4	381,5 ± 6,8 c*

**/ the same letter designations in the column indicate no significant differences between the compared means / jednakowe oznaczenia literowe w kolumnie wskazują na brak istotnych różnic między porównywanymi średnimi*

Source: The own study

Źródło: Badania własne

Polyphenolic compounds together with tannins are found in tea in varying amounts and averaged from 13 to 30% by dry weight. These compounds are the main factors contributing to the bitter taste and the characteristic aroma of tea infusions. They are attributed with antioxidant properties, which manifest themselves by the ability to chelate heavy metal ions, and to inhibit and capture the generation of free radicals. Unfortunately, excessive consumption of these compounds may have an adverse effect on the absorption of iron, calcium and magnesium [16, 27, 34, 39].

Among the polyphenolic compounds, the composition of tea leaves consists mainly of flavonoids, the majority of which are catechins. There are also flavanols (kaempferol, quercetin) and phenolic acids (gallic acid, chlorogenic acid and caffeic acid derivatives) [2, 18, 16].

Table 9 presents the content of total polyphenolic compounds in tea infusions of various concentrations obtained by various authors.

The amount of polyphenolic compounds in infusions depends on many factors, such as: soil and climatic conditions in which the plant was grown, the season when the raw material was harvested, the processing and storage methods [6, 15].

Antioxidant properties

Table 10 shows the antioxidant properties tested with ABTS cation radicals^{*+}. Black tea infusions showed the lowest value (2235.5 µmol of Trolox / 100 ml). Infusions of green teas and teas consisting of a mixture of green and white tea indicated approx. 34-37% higher values, i.e. ranging from 3,061.7 to 2997.6 µmol of Trolox / 100 ml. Green tea was characterized by a 27% greater ability to quench radical cation ABTS^{*+} in comparison to black tea [26].

There wasa fairly strong correlation (r = 0.97) indicated between the content of polyphenolic compounds in tea infusions and their antioxidant activity. These results are

Table 9. Total polyphenolic compounds content according to various literature data

Tabela 9. Zawartość związków polifenolowych ogółem wg różnych danych literaturowych

Type of tea / Rodzaj herbaty	Concentration tested infusions / Badane stężenie naparów	Amount of polyphenols / Ilość związków polifenolowych				Result converted to unit / Wynik przeliczony na jednostkę (mg GAE/100 ml)	Source / Źródło
		Unit of measure [mg GAE]	$X_{śr.}$	Min	Max		
Green / Zielona	1%	w 1g suchej herbaty	150	146	185	146–185	[25]
	1%		–	146	177	146–177	[13]
	2%	w 100 ml naparu	–	111,3	135,3	70	[19]
	1%	w 200 ml naparu	–	96	201	48–101	[16]
	1,5%	w 1 l naparu	2083	–	–	140	[1]
Black / Czarna	1%	w 1 g suchej herbaty	130	112	151	112–151	[25]
	1%		–	152	177	152–177	[13]
	1%	w 100 ml naparu	–	58,2	60,8	60	[36]
	2%		124,2	–	–	62	[19]
	1,5%	w 1 l naparu	1844	–	–	123	[1]
White / Biała	1,5%	w 1 l naparu	2180	–	–	145	[1]
	1%	w 1 g suchej herbaty	140	99	174	99–174	[25]
Red / Czerwona	1,5%	w 1 l naparu	825	–	–	55	[1]

Source: Own study

Źródło: Opracowanie własne

consistent with the analysis of data available in literature provided by various authors (tab. 11).

Table 10. Antioxidant properties of 1% of tea infusions

Tabela 10. Właściwości przeciwutleniające 1% naparów badanych herbat

Type of tea / Rodzaj herbaty	Antioxidant activity / Aktywność przeciwutleniająca $ABTS^{\cdot+}$ [µmol Troloxu/ 100 ml]	
	min – max	$X_{śr.}$ ± SD
Black / Czarna	2209,4 – 2252,1	2235,5 ± 22,9 a*
Green / Zielona	3028,4 – 3099,7	3061,7 ± 35,8 b*
Blend of green with white / Mieszanka zielonej z białą	2964,3 – 3049,8	2997,6 ± 45,8 b*

**/ the same letter designations in the column indicate no significant differences between the compared means / jednakowe oznaczenia literowe w kolumnie wskazują na brak istotnych różnic między porównywanymi średnimi*

Source: The own study

Źródło: Badania własne

The main components of the tea leaves responsible for the antioxidant properties are catechins belonging to the polyphenolic compounds. Catechin derivatives of polyphenols have the greatest influence on the antioxidant properties of tea infusions, mainly: epicatechin (EC), epigallocatechin (EGC), epigallocatechin gallate (EGCG), epicatechin gallate (ECG) [18]. The content of compounds responsible for the antioxidant properties of infusions largely depends on their stability, as well as on other factors, such as the time of harvesting tea leaves or the time of sun exposure of the bush [14].

CONCLUSIONS

1. All the leaf teas tested had a comparable extract ranging from 31 to 39%.
2. The type of tea has a significant impact on the content of polyphenols, tannins and caffeine in infusions.
3. The time of brewing the teas significantly affects the tannin content in the infusions. The content of these compounds in infusions brewed for 3–10 minutes. differs slightly, but the extension of the tea brewing time to 15–20 minutes. it significantly increases the tannin content in the infusions.
4. There is a strong correlation between the total polyphenolic compounds in teas and the antioxidant properties of infusions.

WNIOSKI

1. Wszystkie badane herbaty liściaste charakteryzują się porównywalnym wyciągiem wynoszącym od 31 do 39%.
2. Rodzaj herbaty ma istotny wpływ na zawartość związków polifenolowych, garbników, jak również kofeiny w naparach.
3. Czas parzenia herbat istotnie wpływa na zawartość garbników w naparach. Zawartość tych związków w naparach parzonych przez 3–10 min. różni się nieistotnie, natomiast przedłużenie czasu parzenia herbat do 15–20 min. wpływa na istotny wzrost zawartości garbników w naparach.
4. Istnieje silna korelacja między zawartością związków polifenolowych ogółem w herbatach a właściwościami przeciwutleniającymi naparów.

Table 11. Antioxidant properties of tea infusions according to various literature data

Tabela 11. Właściwości przeciwutleniające naparów herbat wg różnych danych literaturowych

Type of tea / Rodzaj herbaty	Concentration tested infusions / Badane stężenie naparów	Antioxidant activity / Aktywność przeciwutleniająca				Result converted to unit / Wynik przeliczony na (ìmol TEAC/100 ml)	Source / Źródło
		Unit of measure / Jednostka	$X_{śr.}$	Min	Max		
Green / Zielona	1%	µmol TEAC/1g suchej herbaty	1772	1418	2191	1418–2191	[25]
	1%	mmol TEAC/1g suchej herbaty	1,81	–	–	1810	[35]
	2,5%	mmol Trolox eq	–	30	87	–	[3]
Black / Czarna	1%	µmol TEAC/1g suchej herbaty	1328	1149	1703	1149–1703	[25]
	1%	mmol TEAC/1g suchej herbaty	0,78	–	–	780	[35]
	1%	mmol TEAC/ 100 ml	–	0,94	1,05	940–1050	[11]
	2,5%	mmol Trolox eq	–	10	45	–	[3]
White / Biała	1%	µmol TEAC/1g suchej herbaty	1742	1273	2091	1273–2091	[25]
	1%	mmol TEAC/1g suchej herbaty	–	0,5	3,23	500–3230	[20]
	2,5%	mmol Trolox eq	–	20	53	–	[3]
Red / Czerwona	1%	mmol TEAC/1g suchej herbaty	0,58	–	–	580	[35]

Source: Own study

Źródło: Opracowanie własne

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THE INFLUENCE OF TECHNOLOGICAL FACTORS ON THE CONTENT AND COMPOSITION OF SACCHARIDES IN LACTOSE-FREE MILK PRESERVED BY UHT METHOD®

Wpływ czynników technologicznych na zawartość i skład sacharydów w bezlaktozowym mleku utrwalanym metodą UHT®

The article presents the available knowledge about the influence of various factors on the composition and content of saccharides in lactose-free milk, i.e. milk with enzymatically degraded lactose. Various technological solutions applied in lactose-free milk production, in particular the sequence of lactose hydrolysis and heat treatment processes, were identified. The influence of lactose-hydrolyzed milk production procedure on saccharide transformations taking place, such as the process of sugar isomerization and Maillard reaction, was discussed. The relatively high variability in the quality of commercial lactose-free milk samples was pointed out. Special attention was paid to the importance of milk storage conditions on saccharide content changes. Moreover, the need to establish specific quality criteria for this type of milk was stressed.

Key words: lactose-free milk, saccharides, lactulose.

W artykule przedstawiono dostępną wiedzę o wpływie różnych czynników na skład i zawartość sacharydów w mleku bezlaktozowym, tj. z enzymatycznie rozłożoną laktozą. Wskazano na różne rozwiązania technologiczne stosowane w produkcji mleka bez laktozy, w szczególności sekwencyjność procesu hydrolizy laktozy i obróbki cieplnej. Omówiono wpływ procedury produkcji mleka z rozłożoną laktozą na zachodzące przemiany sacharydów, jak np. proces izomeryzacji cukrów oraz reakcje Maillarda. Wskazano na stosunkowo dużą zmienność jakości handlowych próbek mleka bezlaktozowego. Zwrócono uwagę na znaczenie warunków przechowywania mleka na zmiany zawartości sacharydów. Podkreślono konieczność ustalenia określonych kryteriów jakościowych dla tego rodzaju mleka.

Słowa kluczowe: mleko bezlaktozowe, sacharydy, laktuloza.

INTRODUCTION

At present, there is a significant increase in the production of lactose-free milk and milk products. The problem of consumer lactose intolerance is cited in the justification of these technological trends. This is not always justified on medical and health grounds [3].

The interpretation of the necessity to consume lactose-free milk and dairy products was presented in our earlier study [13].

In the evaluation of the quality of lactose-free milk, in particular milk preserved by the UHT method, attention is paid to the analysis of potential changes in the composition of proteins and saccharides in the preserved product, induced by the thermal process.

The composition and content of saccharides of lactose-free milk are determined by factors such as the type and biocatalytic properties of the β-galactosidase preparation used, its form (free or bound), as well as the conditions of lactose hydrolysis process, e.g. temperature, acidity and time [2, 7, 8]. The products of enzymatic reaction of lactose hydrolysis are mainly glucose and galactose. The β-galactosidase preparations used in the production of lactose-free milk also show transgalactosylation activity. This promotes the synthesis of galacto-oligosaccharides (GOS) with prebiotic properties. The scheme of transgalactosylation reactions is presented in Fig. 1 and Fig. 2 [14].

The efficiency of GOS synthesis depends on: type (source) of the enzyme and its activity, as well as on the reaction environment conditions, including mainly lactose concentration and reaction time [7]. The studies of Rodriguez-Colinas et al. [11] show that the kinetics of galacto-oligosaccharide synthesis reaction changes over time. After reaching a certain maximum concentration of galacto-oligosaccharides, there is

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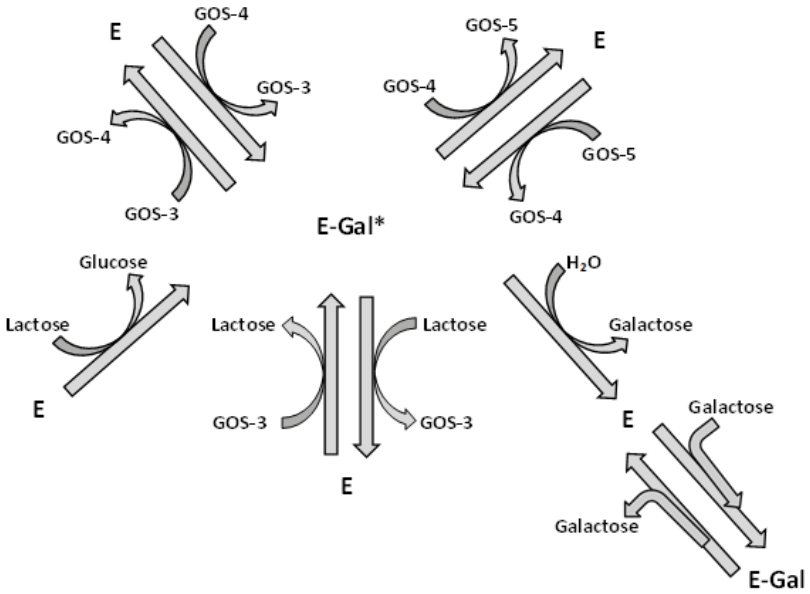

Fig. 1. Mechanism of synthesis of GOS with β-galactosidase from A. oryzae.
Rys. 1. Mechanizm syntezy GOS z udziałem β-galaktozydazy z A. oryzae.

Explanation of abbreviations: E – free enzyme concentration (mmol/kg or mM), E-Gal* – galactosyl-enzyme transition complex concentration (mmol/kg or mM), E-Gal – galactose-enzyme complex concentration (mmol/kg or mM), GOS-3, GOS-4, GOS-5 – galactooligosaccharides composed of three, four or five sugar residues.

Objaśnienie skrótów: E – stężenie wolnego enzymu (mmol/kg or mM), E-Gal* – stężenie kompleksu przejściowego galaktozyl-enzym (mmol/kg or mM), E-Gal – stężenie kompleksu galaktoza-enzym (mmol/kg or mM), GOS-3, GOS-4, GOS-5 – galaktooligosacharydy zbudowane z trzech, czterech lub pięciu reszt cukrowych.

Source: Own study based on [14]

Źródło: Opracowanie własne na podstawie [14]

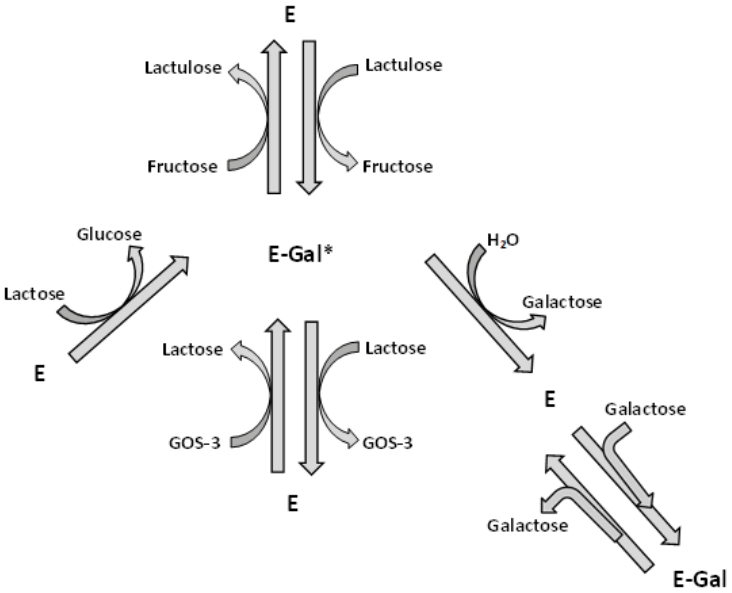

Fig. 2. Mechanism of synthesis of lactulose with β-galactosidase from A. oryzae.
Rys. 2. Mechanizm syntezy laktulozy z udziałem β-galaktozydazy z A. oryzae.

Explanation of abbreviations: E – free enzyme concentration (mmol/kg or mM), E-Gal* – galactosyl-enzyme transition complex concentration (mmol/kg or mM), E-Gal – galactose-enzyme complex concentration (mmol/kg or mM), GOS-3 – galactooligosaccharides composed of three sugar residues.

Objaśnienie skrótów: E – stężenie wolnego enzymu (mmol/kg or mM), E-Gal* – stężenie kompleksu przejściowego galaktozyl-enzym (mmol/kg or mM), E-Gal – stężenie kompleksu galaktoza-enzym (mmol/kg or mM), GOS-3 – galaktooligosacharydy zbudowane z trzech reszt cukrowych.

Source: Own study based on [14]

Źródło: Opracowanie własne na podstawie [14]

a gradual decrease in the amount of GOS due to competition between hydrolysis and transgalactosylation reactions [11].

The biocatalytic specificity of β-galactosidase used and the process management conditions also determine the content and composition of the resulting galacto-oligosaccharides. The transgalactosylation reaction may produce tri-, tetra- or pentasaccharides. Their proportion changes over the course of the process. For example, it is known that the concentration of tri- and tetra-saccharides reaches its maximum after 30 minutes of reaction and then gradually decreases. It follows that in lactose-free milk the composition of galacto-oligosaccharides may be variable [2].

In the production of lactose-free milk preserved by the UHT method, lactulose, i.e. disaccharide composed of fructose and galactose combined with a β-1,4-glycosidic bond, may also be formed. It is synthesized in the reaction of internal transformation of glucose in the lactose molecule to fructose by conversion of the aldose form to the ketose form [2, 4, 9].

Lactulose is not a natural component of milk. However, its presence is found in milk after heat treatment. The heating of milk promotes thermal isomerization of lactose. The presence of lactulose in milk is often assumed as an indicator (marker) of changes in milk caused by the thermal process [10].

Interestingly, lactulose is a saccharide with beneficial functional, including prebiotic, properties [2, 9].

According to the available literature information, monosaccharides, disaccharides and galacto-oligosaccharides may be present in lactose-free milk preserved by the UHT process. Their composition and content largely depends on the technological process conditions [8, 11, 12].

In this article, according to the available literature, a decision was made to confirm the above dependencies.

THE INFLUENCE OF TECHNOLOGICAL PROCESS CONDITIONS ON SACCHARIDE CONTENT AND COMPOSITION

It is known that lactose-free milk has a higher content of reducing sugars compared to conventional UHT-preserved milk. As a result, lactose-free milk is more susceptible to ingredient changes. This is because, inter alia, the monosaccharides, glucose and galactose produced after lactose hydrolysis are more active than lactose in the formation of the Maillard reaction products during thermal preservation as well as during milk storage [6, 12].

There are a number of lactose-free UHT milk production procedures known. The differences concern mainly the sequence of the lactose hydrolysis process and the thermal preservation process. Both pre- and post-UHT lactose hydrolysis is possible. Currently, the production of lactose-free milk is predominantly based on two processes, referred to as batch (lactose hydrolysis prior to thermal treatment) and aseptic (lactose hydrolysis following thermal treatment), both of which use a free-form enzyme. Processes with an immobilized enzyme offer an alternative solution. However, their application in the industrial production of lactose free milk is more difficult to popularize due to problems with final product microbiological stability. Furthermore, the recycling of the immobilized enzyme is limited, which reduces the profitability of this procedure; the product is more vulnerable to quality defects when compared to the product obtained in the process using the free, soluble form of the enzyme [5, 8].

Depending on the procedure used (pre- or post-UHT lactose hydrolysis), lactulose and furosine, which are markers of the intensity of changes in sugars and proteins during the technological process, may appear in various quantities in the finished product. According to the research by Messia et al. [8], the use of UHT treatment prior to lactose hydrolysis induces minor changes in milk, e.g. less loss of lysine, the main substrate of the Maillard reaction [8].

Performance of lactose hydrolysis in heat-treated milk (post-UHT) requires preservation of conditions hindering microbial proliferation. This concerns mainly the technique of aseptic enzyme dosing into milk [12].

In the discussed technological variant, the use of the immobilized form of the enzyme seems to be more advantageous, despite the aforementioned reservations, as by conducting the hydrolysis of lactose with the free form of the enzyme, it may be expected that the enzyme will be active in the finished product, in which it may, for example, hydrolyze the lactulose produced after thermal lactose isomerization. Lactulose hydrolysis may be confirmed by the presence of fructose in lactose-free milk samples [15].

However, fructose and tagatose are sometimes present in lactose-free milk as products of thermal isomerization of glucose and galactose, respectively [12].

The diversity of composition and saccharide content in commercial samples of lactose-free milk is confirmed by the results of the research by Ruiz-Matute et al. [12] presented in Table 1.

Table 1. Saccharide content in seven samples of commercial lactose-free UHT milk

Tabela 1. Zawartość sacharydów w siedmiu próbkach handlowego bezlaktozowego mleka UHT

Saccharides	Content [g/l]		Average content [g/l]
Galactose	17,3	23,5	21,0
Glucose	19,9	25,1	22,8
Fructose	0,076	0,185	0,117
Tagatose	0,036	0,098	0,076
Lactose	0,033	0,291	0,096
Allolactose	0,139	0,841	0,348
β-1-6-Galactobiose	0,166	0,747	0,348
6'-galactosyl-lactose	0,271	1,703	0,825
4'-galactosyl-lactose	0,028	0,254	0,065
Unidentified galactooligosaccharides	0,349	1,020	0,580
Total galactooligosaccharides	0,956	4,350	2,134

Source: Own study based on [12]

Źródło: Opracowanie własne na podstawie [12]

The content of individual saccharides varied in lactose-free milk samples analyzed by the aforementioned authors. Glucose content fluctuated from 19.9 g/l to 25.1 g/l, and galactose content fluctuated from 17.3 g/l to 23.5 g/l. In the tested milk samples, lactose content was between 0.033 and 0.291 g/l. Five out of the seven tested milk samples met the criterion of lactose content in lactose-free milk (below 0.01%) (Table 1). The above-presented glucose and galactose content in the compared samples of lactose-free milk indicates that probably no other lactose removal technique was used apart from its hydrolysis. Glucose and galactose content differences in the tested milk samples indicate that part of the galactose was used in the enzymatic synthesis of galacto-oligosaccharides. The content of galacto-oligosaccharides was significantly different in the analyzed milk samples. This concerns both the identified ones, e.g. 6'-galactosyl-lactose: from 0.271 to 1.703 g/l and 4'-galactosyl-lactose: from 0.028 to 0.254 g/l, and the unidentified ones: from 0.349 to 1.020 g/l (Table 1) [12].

Significant influence on the composition and content of galacto-oligosaccharides (including those given in Table 1) is exerted by factors such as the source and properties of β-galactosidase used and the temperature and time of hydrolysis reaction. This was confirmed by the research by Rodriguez-Colinas et al. [11], which compared the effects of transgalactosylation, including the composition and content of galacto-oligosaccharides after reaction with various β-galactosidase preparations: Biolactase NTL-CONC (β-galactosidase from *Bacillus circulans*), Lactose pure 6500L (β-galactosidase from *Kluyveromyces lactis*) and Lactase F (β-galactosidase from *Aspergillus oryzae*) [11].

The presence of fructose and tagatose in the evaluated UHT lactose-free milk samples confirms that they were formed in the process as products of thermal isomerization of glucose and galactose, respectively. Fructose content oscillated between 0.076 and 0.185 g/l and tagatose content oscillated between 0.036 and 0.098 g/l. The presence of fructose in milk does not depend on the sequence of lactose hydrolysis process (pre- or post-UHT). It may be formed, as mentioned above, after glucose isomerization if the hydrolysis process occurs prior to thermal treatment. If the UHT process precedes enzymatic hydrolysis, part of lactose is converted to lactulose, which is then broken down to fructose and galactose by enzymatic hydrolysis [12].

Demonstration of tagatose in samples of lactose-free UHT milk may indicate that lactose was hydrolyzed prior to the thermal process, as free galactose is present in small amounts (about 0.01%) and tagatose is not present in conventional UHT milk [1, 12].

It is interesting that no lactulose (below 0.01 g/l) was found in the analyzed milk samples, which, as described earlier, is a marker of the range of thermal changes, mainly lactose isomerization. Notably, the analyzed milk samples came from different producers and there is no information about the technological process procedure. From the analysis of saccharide content, e.g. lactulose, it is difficult to indicate unequivocally whether lactose hydrolysis was carried out prior to or after milk heat treatment. This is due to the fact that the absence of lactulose in lactose-free milk is independent of whether the UHT treatment is carried out prior to or after enzymatic hydrolysis. Lactulose is produced by isomerization of lactose during heat treatment of milk, so if UHT treatment is applied after lactose hydrolysis, there is not enough substrate (lactose) to produce lactulose. By means of an alternative procedure, i.e. post-UHT lactose hydrolysis, the lactulose formed from lactose is also hydrolyzed under the influence of β-galactosidase remaining in milk [12].

The results of the research carried out by Messia et al. [8] indicate that the UHT treatment of milk with partially degraded lactose promotes lactulose formation. The experimental technological process of milk production included the following stages: pasteurization (72°C/15 s), lactose hydrolysis in milk at 4°C for 36 h and then UHT treatment with infusion system. After enzymatic hydrolysis, the milk contained lactose and lactulose in the quantities of 6.0 g/l and 0.014 g/l, respectively. After the UHT process, a lactulose content of 0.078 g/l, which was five times higher than in the pre-UHT milk sample, was present in the analyzed milk sample. Such a large increase in lactulose concentration in the examined post-UHT milk sample is probably due to the fact that milk contained a comparatively high concentration of lactose (6.0 g/l), thus a substrate for the lactulose formation reaction [8].

The subject of the research by Messia et al. [8] was also saccharide and furosine analysis in 14 different samples of commercial UHT, lactose-hydrolyzed semi-skimmed milk. The lactose, lactulose and fructose content of the samples of lactose-hydrolyzed UHT milk was within 3.0÷12.0 g/l (mean: 8.0 g/l), 0.0÷0.401 g/l (mean: 0.191 g/l), and 0.047÷0.655 g/l (mean: 0.168 g/l), respectively. The presence of lactulose was demonstrated in almost all of the UHT milk samples. The lowest content of lactose (3.0÷4.0 g/l) and the highest content of galactose (22.0÷25.0 g/l) and glucose (23.0÷25.0 g/l) reported for milk samples no. 11, 12 and 13 may have resulted from the applied technology consisting in aseptic addition of β-galactosidase to milk after UHT treatment, as indicated by producers on the packaging. In the indicated samples, lactulose, fructose and furosine content was in the range of 0.265÷0.401 g/l, 0.052÷0.088 g/l and 0.484÷0.603 g/100 g of protein, respectively. In comparison with other milk samples, the relatively high lactulose and furosine content may indicate that indirect UHT treatment (membrane heat transfer) was applied. Fructose present in the listed samples may have originated from lactulose degradation under the influence of β-galactosidase during enzymatic hydrolysis [8].

In the characteristics of other tested milk samples, the applied technology impact on the composition of saccharides is not readily determinable, as no details of their production are specified. However, based on the content of saccharides and furosine, the authors evaluated the tested samples with an indication of the possible production process. The low content of lactulose (0.018÷0.139 g/l) and furosine (0.162÷0.188 g/100 g protein) and the significant quantity of fructose (0.056÷0.110 g/l) in milk samples nos. 5, 7 and 10 may indicate that a mild UHT treatment (infusion) was performed after hydrolysis. The absence of lactulose and increased levels of fructose (0.391 g/l) and furosine (0.319 g/100 g protein) in milk sample no. 8 may indicate that indirect (membrane) UHT treatment was performed after lactose hydrolysis. The high content of furosine (0.397 g/100 g of protein), lactulose (0.382 g/l) and fructose (0.655 g/l) in milk sample no. 3 may

indicate that thermal treatment was performed both prior to and after lactose hydrolysis [8].

The obtained results indicate that the technology of lactose-hydrolyzed milk production (thermal treatment and enzymatic hydrolysis intensity and sequence) has an effect on the composition of saccharides and the intensity of Maillard reaction. The analysis of furosine content and the composition of saccharides, in particular lactulose and fructose, may be helpful in the evaluation of lactose-hydrolyzed milk quality, and indicate the sequence of enzymatic hydrolysis and thermal treatment [8].

The scope of the research by Messia et al. [8] also included the assessment of the influence of storage conditions, i.e. its time (from 1 to 4 months) and temperature (4°C and 20°C), on changes in lactulose and fructose content in lactose-hydrolyzed milk samples differing in technological procedure – lactose hydrolysis sequence (pre- or post-UHT), as well as UHT treatment type (direct and indirect). Milk that was subjected to lactose hydrolysis prior to the thermal process (abbreviated as "A-UHT-HD") was preserved by direct UHT treatment (infusion). Whereas milk that was subjected to lactose hydrolysis after the thermal process (abbreviated as "B-UHT-HD") was preserved by indirect UHT treatment. The content of the above-mentioned saccharides in the control samples, which was traditional UHT milk produced without lactose hydrolysis (marked as "A-UHT" and "B-UHT" respectively), was also analyzed for two variants of UHT treatment, analogous to the production of lactose-hydrolyzed milk. There were significant differences in the content of the aforementioned saccharides in the compared samples. The initial lactulose content in lactose-hydrolyzed milk, in which post-UHT lactose hydrolysis was carried out (B-UHT-HD), was 0.117 g/l, while it was 0.340 g/l in the traditional milk control sample (B-UHT). This confirms that lactulose was hydrolyzed by the continuously active β-galactosidase present in milk. Lower lactulose concentrations were reported for A-UHT-HD lactose-hydrolyzed milk (pre-UHT lactose hydrolysis) and the control sample (A-UHT); 0.0445 g/l and 0.110 g/l, respectively. The lower lactulose content in lactose-hydrolyzed milk (A-UHT-HD) vs. the control sample (A-UHT) may result from the reduced amount of lactose in heat-treated milk [8].

For each of the variants, the initial concentration of fructose in lactose-hydrolyzed milk (0.0912 g/l and 0.0892 g/l) was several times higher than in the control samples (0.0236 g/l and 0.0242 g/l). Depending on the sequence of lactose hydrolysis and UHT treatment processes, this results from the release of fructose by lactulose hydrolysis (for post-UTH lactose hydrolysis milk) or glucose isomerization (for pre-UTH lactose hydrolysis milk) [8].

The results of the aforementioned studies also indicate the significance of the storage temperature of milk samples for changes in lactulose and fructose content. Those changes were more intense in samples stored at 20°C than in samples stored at 4°C. It should be noted that under these conditions (20°C), lactulose content in traditional UHT milk (A-UHT) and lactose-hydrolyzed milk (A-UHT-HD, pre-UHT lactose hydrolysis) increased by about 50% after 4 months of storage. By comparison, the lactulose content of traditional UHT milk (B-UHT) increased by about 10%, and that of lactose-hydrolyzed milk (B-UHT-HD, post-UHT lactose hydrolysis) decreased by about 20% of the initial value after 4 months of storage. The decrease in lactulose concentration in lactose-hydrolyzed milk, in which lactose hydrolysis was carried out after UHT treatment, was caused by β-galactosidase activity in milk during storage. In all milk samples stored at 20°C, a fructose concentration increase was detected, with the highest increase being observed for B-UHT-HD milk (lactose hydrolysis after UHT treatment), which was also marked by a significant lactulose concentration decrease. This confirms the activity of β-galactosidase present in milk even for several months of storage [8].

It is worth noting that the authors of the cited studies also demonstrated the unfavorable effect of higher storage temperature and longer storage time of milk on the increase in the content of furosine, an important marker of thermal changes in proteins [8].

The results confirmed the influence of the milk production procedure on milk saccharide content, as well as on the intensity of the components transformations, e.g. Maillard reaction.

The UHT-induced changes may lead to the emergence of unfavorable taste and smell, and sometimes to the formation of sediment during milk storage. It turns out that these changes may be inhibited by introducing polyphenols into milk, e.g. in the form of green tea extract containing catechins [6].

CONCLUSION

The technology used in the production of lactose-free and lactose-reduced milk, as well as the type of β-galactosidase preparation influence the transformations of milk components (mainly proteins) and saccharide composition. Maillard reaction and saccharide isomerization intensified by heat treatment show different rates by milk composition (the content of the substrates for these reactions) and milk production process, in particular the lactose hydrolysis and heat treatment sequence, heat treatment type, as well as lactose hydrolysis time and degree. Therefore, traditional milk and lactose-hydrolyzed milk are characterized by a different content of saccharides as well as compounds which are markers of changes caused by the thermal process, e.g. furosine and lactulose. Milk with partially hydrolyzed lactose was found to contain about 2-3 times less lactulose compared to the traditional milk control samples. Moreover, no lactulose was found in lactose-free milk (lactose content <0.01%). The content of the aforementioned compounds also shows high variability depending on the technology of lactose-hydrolyzed milk production. The presence of tagatose may, for instance, indicate that lactose hydrolysis was carried out prior to thermal treatment. The analysis of the results of various commercial samples of lactose-hydrolyzed milk indicates a high variability of their quality, which in turn highlights the need to establish specific quality criteria for this type of milk so as to ensure product quality. Detailed analysis of the content of saccharides (e.g. lactose, lactulose, fructose, tagatose) as well as furosine may be instrumental in assessing the effect of the technological process on changes in the composition of saccharides and on the nutritional value of lactose-free milk and milk with partially hydrolyzed lactose preserved by the UHT method.

PODSUMOWANIE

Technologia stosowana w produkcji mleka bezlaktozowego i o obniżonej zawartości laktozy, jak również rodzaj preparatu β-galaktozydazy wpływają na przemiany składników mleka (głównie białek) i skład sacharydów. Reakcje Maillarda i izomeryzacja sacharydów intensyfikowane obróbką cieplną wykazują różne tempo w zależności od składu mleka (zawartości substratów tych reakcji) oraz procesu produkcji mleka, a w szczególności sekwencyjności hydrolizy laktozy i obróbki termicznej, rodzaju obróbki termicznej, a także czasu i stopnia hydrolizy laktozy. W związku z powyższym, mleko tradycyjne oraz z rozłożoną laktozą charakteryzują się różną zawartością sacharydów, a także związków, stanowiących markery zmian wywołanych procesem cieplnym, np. furozyny i laktulozy. Mleko z częściowo rozłożoną laktozą charakteryzowało się około 2-3-krotnie mniejszą zawartością laktulozy w porównaniu do próbek kontrolnych mleka tradycyjnego. Ponadto nie odnotowano obecności laktulozy w mleku bezlaktozowym (zawartość laktozy <0,01%). Zawartość w/w związków wykazuje również dużą zmienność w zależności od technologii produkcji mleka z rozłożoną laktozą. Obecność tagatozy może np. wskazywać, że hydroliza laktozy była przeprowadzona przed obróbką termiczną. Analiza wyników badań różnych handlowych próbek mleka z rozłożoną laktozą wskazuje na dużą zmienność ich jakości, co z kolei podkreśla konieczność ustalenia określonych kryteriów jakościowych dla tego rodzaju mleka w celu zapewnienia jakości produktu. Kompleksowa analiza zawartości sacharydów (np. laktozy, laktulozy, fruktozy, tagatozy), a także furozyny może być pomocna w ocenie wpływu procesu technologicznego na zmiany składu sacharydów oraz na wartość żywieniową mleka bezlaktozowego i z częściowo rozłożoną laktozą utrwalanego metodą UHT.

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THE ROLE OF SELECTED PLANT PRODUCTS IN THE PREVENTION OF CADMIUM-INDUCED TOXICITY®

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Long-term exposure to cadmium (Cd) leads to the development of numerous diseases in human as well as in animals associated with renal and hepatic injury, respiratory, skeletal and cardiovascular disturbances, as well as visual changes, blindness and hearing loss. Cd was classified as human carcinogen (Group 1) by the International Agency for Research on Cancer. The study discusses the effect of selected plant products on reduced toxicity caused by Cd. Animal studies confirmed that the effect of such products as: turmeric, ginger, garlic, onion, black seeds oil, olive oil, blueberry, green tea, hibiscus was efficient in reducing the Cd level in organs and tissues and had positive effect on the urinary tract and cardiovascular, reproductive, nervous, immune and respiratory system. Consumption of these products in occupational and environmental exposure to Cd appears promising.

Key words: cadmium exposure, oxidative stress, turmeric, ginger, garlic, onion, black seeds oil, olive oil, blueberry, green tea, hibiscus.

Długotrwała ekspozycja na kadm (Cd) ludzi jak i zwierząt, prowadzi do rozwoju wielu zmian patologicznych związanych z uszkodzeniem nerek, wątroby, zaburzeniami w układzie oddechowym, kostnym, sercowo-naczyniowym, a ponadto z zaburzeniami widzenia, ślepotą i niedosłuchem. Cd został zaklasyfikowany przez Międzynarodową Agencję Badań nad Rakiem jako substancja rakotwórcza dla człowieka (Grupa 1). W artykule omówiono potencjalnie korzystny wpływ wybranych produktów roślinnych na zmniejszanie toksyczności wywołanej przez Cd. Badania na zwierzętach wykazały, że spożywanie produktów takich jak: kurkuma, imbir, czosnek, cebula, olej z czarnuszki, oliwa z oliwek, borówka amerykańska, zielona herbata, hibiskus było skuteczne w obniżaniu zawartości Cd w narządach i tkankach oraz korzystnie wpływało na układ krwionośny, moczowy, rozrodczy, nerwowy, odpornościowy i oddechowy. Obiecujące wydaje się zalecanie spożywania tych produktów przy zawodowym i środowiskowym narażeniu na Cd.

Słowa kluczowe: ekspozycja na kadm, stres oksydacyjny, kurkuma, imbir, czosnek, cebula, olej z czarnuszki, oliwa z oliwek, borówka amerykańska, zielona herbata, hibiskus.

INTRODUCTION

Cadmium toxicity in humans

Cadmium (Cd) is a heavy metal which occurs naturally in the Earth's crust. Its content in the environment increases as a result of volcano eruption and thermal rock weathering. Environmental pollution with Cd further derives from human activity associated with metal mining, refining, production of phosphorus fertilizers. Cd is used in numerous technological processes, i.a. for the production of batteries, pigments, coatings and platings, stabilizers for plastics. A group of people facing particular exposure to Cd includes workers dealing with welding and electroplating [4]. Apart from professional exposure, tobacco smoking constitutes another source of exposure to Cd [23, 45]. In the non-smoking population, approximately 90% Cd originates from food [18]. According to EFSA main sources of Cd in the diet are the products typically consumed in greater amounts, such as grains and grain products, vegetables and vegetables products and starchy roots and tubers.

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Long-term exposure to Cd leads to the development of numerous diseases associated with renal and hepatic injury, respiratory, skeletal and cardiovascular disturbances, as well as visual changes, blindness, and hearing loss [16, 26, 47, 50]. It has been also demonstrated that Cd has teratogenic and carcinogenic effect [34, 35, 43, 49].

The toxic effect of Cd results from numerous mechanisms, but the most important are the weakening of the antioxidant system and thus related increase of reactive oxygen species concentration. This leads to induced oxidative stress and intensification of lipid peroxidation, protein oxygenation, DNA damage, and as a result of this cell membrane injury and cell death. Another mechanism of toxic effect of Cd stems from homeostasis disturbance (by forming bonds with sulfur, oxygen and hydrogen ions from sulfhydryl, disulfate, carboxyl, imidazole or amine groups of the compounds present in the cells) [15].

Exposure to Cd and its health consequences have provoked the search of efficient means of protection against the unfavorable effects of the element. Antioxidative compounds can play a significant role here. Their potential protective characteristics can be associated with antioxidative enzyme activation and reactive oxygen species scavenging, as well as affecting Cd metabolism (formation of complexes excreted with urine and feces) and interaction at the cellular level [32]. These compounds are contained in numerous plant products, including turmeric, ginger, garlic, onion, black seeds oil, olive oil, blueberry, green tea, hibiscus.

PROTECTIVE EFFECT OF PLANT PRODUCTS ON ANIMALS EXPOSED TO CD

Turmeric

The majority of studies (18) concerned curcumin - the main component of turmeric. In the conducted studies, different doses of curcumin and different time of exposure to Cd were used. Research revealed changes in the level of Cd in the blood, vessels (aorta), organs (heart, kidneys, liver), improved biochemical parameters of the blood, positive impact on liver, muscles, cardiovascular, genitourinary, nervous and immune system. Summary of research results is presented in Table 1.

Two studies in animal models exposed to the effect of Cd demonstrated favorable effect of curcumin on the cardiovascular system, including reduced blood pressure, improvement of vascular responsiveness, reversal of the alterations of the aortas. Protective effect of curcumin was observed, including protein concentration regulation (endothelial nitric oxide synthase and anti-inducible nitric oxide synthase) in aortas, increase of urinary nitrate/nitrite level, restoration of glutathione redox ratio. It was furthermore shown that curcumin reduces lipid and protein peroxidation and in heart, liver and kidneys, which was linked to reduced blood pressure [28, 44].

Alghasham et al. [10] demonstrated that curcumin reduced intensification of inflammation in rats exposed to Cd. Reduced concentration of tumor necrosis factor alpha and interleukin-6 and favorable changes of the activity of superoxide dismutase, glutathione concentration and total antioxidant capacity in plasma were observed.

With exposure to Cd and curcumin supplementation, kidneys were found to inhibit adenosine deaminase activity (ADA), increase of nitric oxide level and functional SH groups as well as reduced Cd accumulation [8]. The favorable effect of curcumin in nephrotoxicity caused by Cd was also revealed in the study conducted by Kim [27]. Curcumin prevented proximal tubular cell damage and it contributed to reducing inflammatory processes and histopathological changes of the kidneys.

The protective effect of curcumin also concerned the animal reproductive system of animals exposed to Cd. A study in mice revealed influence of curcumin on the protection against testicle damage by the activation of Nrf2/ARE signaling pathway. Curcumin also contributed to the improvement of semen quality in mice [51]. Similar effects were obtained in studies on rats. Curcumin improved histological and biochemical testicular fluctuations [1]. On the other hand, the study conducted by Aktas et al. [9] demonstrated that the usage of curcumin resulted in restricted apoptosis in rat testicle tissues and improved histological appearance, as well as increased testosterone level. The study of Oguzturk et al. [37] showed that curcumin limited histopathological changes, reproductive and spermatological damage in rats exposed to Cd. The effect of curcumin on lipid and protein peroxidation and the positive effect on morphometrical parameters in the testis was also observed in studies on mice [31].

Furthermore, curcumin can constitute an agent supporting the treatment of memory dysfunction caused by Cd. Two studies in animal models revealed that curcumin produced AChE (acetylcholinesterase) and ADA activity in cerebral cortex, and restricted lipid peroxidation, which had a positive effect on cognitive functions of the animals [5, 7]. Similar effects were observed in a study conducted on rats. Curcumin reduced lipid peroxidation and modulated the activity of cerebral ectonucleotidases and AChE activities, thus limiting memory disturbances in animals [17]. In a different study, curcumin alleviated the negative effect of Cd by affecting the level of antioxidative enzyme activity as well as hippocampal protein concentration. What is more, restored behavioral changes in Cd-exposed mice was observed [33]. The study of Akinyemi et al. [6] showed neuroprotective effect of curcumin exhibited by inhibiting AChE activity and modulating mRNA expression level in whole cerebral cortex. Other research on animals exposed to Cd provided evidence for the multidirectional effect of curcumin, i.a. changes in social behavior, normalization in blood composition, reproductive hormones and brain AChE [3].

Studies on animal models further revealed the effect of curcumin on the activity of antioxidative enzymes and the concentration of non-enzymatic antioxidants in liver, reduced lipid peroxidation and liver damage [42].

On the other hand, study conducted on carp exposed to Cd showed increased effect of curcumin associated with reduced Cd accumulation in muscle. However, lipid peroxidation reduced by curcumin could not be confirmed [46].

Ginger

Ginger has been another plant product tested for the aspect of reducing Cd induced toxicity. Table 2 presents results of studies in animal models exposed to Cd, which analyzed

the effect of ginger on the urinary, reproductive and nervous system, as well as liver and kidneys.

Protective effect of ginger on urinary system was demonstrated, including reduced DNA damage, histopathological changes and disturbances of renal function of rats exposed to Cd [21]. Another study on rats enabled observation of a positive impact of ginger on urogenital tract. Reduced activity of enzymes (acid phosphatase, prostatic acid phosphatase, alkaline phosphatase) in the serum, improvement of hematological indices and organ weight were observed [39].

In a study on rats subject to the effect of Cd, Akinyemi and Adeniyi [5] observed protective effect of ginger oil on the nervous system. Compounds contained in the essential oil regulated inflammatory cytokine concentration (interleukin-6, interleukin-10) in brain and reduced activity of enzymes (AChE and ADA) in prefrontal-cortex and hippocampus significant in the prevention/treatment of neurodegenerative disorders.

What is more, positive effect of ginger was observed on genetic changes (influence on gene expression) and histopathological changes in liver and kidneys of rabbits exposed to Cd [13].

Garlic

Table 3 presents results of studies with animals exposed to Cd concerning the effect of garlic on liver and urinary and reproductive system.

Research conducted on rats exposed to Cd demonstrated protective effect of garlic in prostate glands. Researchers observed increased activity of enzymes (glutathione S-transferase, catalase, superoxide dismutase, acid phosphatase) in the prostate gland, reduced concentration of glutathione and increased activity of acid phosphatase in the serum [38].

The cytoprotective effect of diallyl tetrasulfide contained in garlic was presented in the study of Ponnusamy and Pari [41]. Administering animals with diallyl tetrasulfide reduced Cd accumulation in testicles and reduced lipid peroxidation and testicle damage.

Study of Nwokocha et al. [36] conducted on rats subject to the effect of Cd showed protective effect of garlic extracts on liver. Garlic extract had positive effect on the body weight and reduced Cd accumulation in liver. On the other hand, the study conducted by Ugwaja et al. [48] revealed positive effect of a spice mix containing garlic, ginger and nutmeg on the parameters of liver function when rats were exposed to Cd. Addition of these spices significantly reduced alanine aminotransferase, aspartate aminotransferase, bilirubin and albumin concentration in blood serum. The spice mix further contributed to improved renal function and cholesterol concentration in blood.

Onion

Table 4 presents results of studies in animal models exposed to Cd, which analyzed the protective effect of onion on the cardiovascular and urinary system and liver.

The study of Alpsoy et al. [11] demonstrated favorable effect of onion extract on the cardiovascular system. It was shown that onion extract reduced histological changes and apoptosis in cardiomyocytes.

What is more, positive effect of onion extract on atherosclerotic changes including improved lipid metabolism parameters in rats exposed to Cd. What is more, onion extract resulted in reduced lipid peroxidation and increased super oxide dismutase activity in liver and kidneys, and improved renal function parameters [24].

Ola-Mudathir and Suru [38] who conducted studies on animals exposed to Cd presented protective effect of onion in prostate glands. They were able to observe increased activity of enzymes (glutathione S-transferase, catalase, superoxide dismutase, acid phosphatase) in the prostate gland, reduced glutathione concentration and increased acid phosphatase concentration in the serum.

Other plant products

Studies on animal models also analyzed the effect of black seeds oil, olive oil, blueberry, hibiscus and green tea in the aspect of reducing Cd induced toxicity. It was observed that these products reduced the unfavorable changes in urinary, respiratory, reproductive and nervous system and in liver (Table 5).

Protective effect of thymoquinone (the main constituent of the essential oil from black seeds) was observed in reducing Cd-induced nephrotoxicity. Thymoquinone, thanks to its antioxidative and anti-apoptotic properties reduced the number of apoptotic cells and expression of nuclear factor-κB in renal tissue. What is more, reduced histopathological changes in renal tissue was demonstrated [20].

Study conducted on rats [19] revealed that the use of black seeds oil in animals exposed to Cd reduced the majority of negative structural changes of the lung parenchyma. The cytoprotective effect was related to the antioxidative and anti-inflammatory properties of the oil.

In the group of animals administered with olive oil and exposed to Cd were found to have restored activity of antioxidative enzymes, alanine transferase and aspartate aminotransferase to normal levels, palliation of changes in the lipid profile and activity of AST, ALT, as well as reduced oxidative stress [12].

Protective effect of DPE (2-(3,4 dihydroxyphenyl)ethanol - phenolic compound present in olive oil) on spleen and testes exposed to Cd was observed in the study conducted by Merra et al. [30]. DPE protected cytosol of spleen in rats exposed to Cd.

Two studies on animals exposed to Cd revealed positive effect of blueberries on ovaries and liver. Izaguirry et al. [25] showed positive effect of blueberries on the level of reactive species in ovaries and δ-aminolevulinate dehydratase activity in mice. Increased number of normal follicles was observed. However, no changes in the activity of 17 β-hydroxysteroid dehydrogenase, glutathione peroxidase and glutathione-S-transferase and in Cd concentration in mice ovaries were observed.

The study on mice exposed to Cd conducted by Gong et al. [22] showed hepatoprotective effect of blueberries via activation of antioxidative enzymes and reduced lipid and protein peroxidation in liver, as well as increased alanine

aminotransferase and aspartate aminotransferase activity in plasma. Furthermore, blueberries limited the DNA damage in hepatic tissue.

Study conducted on mice model [14] revealed that L-theanine (one of the major components in green tea) (at a dose of 50 and 100 mg/day) contributed to reduced Cd concentration in brain and blood of the animals and reduced tau hyperphosphorylation. L-theanine showed protective effect against apoptosis of brain cells, and at higher dose (100 mg/day) it affected brain antioxidative enzyme activation.

In mice exposed to Cd, green tea extract produced increased sperm cell concentration and reduced sperm cell morphological changes. What is more, increased antioxidative enzyme activity and reduced glutathione in animal testes were shown [2]. Positive effect of green tea on reproductive system was also observed in the study conducted by Mahmoudi et al. [29]. Thanks to the antioxidative properties of green tea, reduced lipid peroxidation in testicular tissue was shown. Green tea also had positive impact on the semen quality of animals and reduced spermatogenesis disorders.

The protective effect of hibiscus on reproductive system in rats exposed to the effect of Cd was shown in the study by Oyewopo et al. [40]. Reduced histopathological changes in ovaries and increased level of reproductive hormones was observed.

CONCLUSIONS

Results of studies in animal models revealed positive effect of such plant products as turmeric, ginger, garlic, onion, black seeds oil, blueberry, green tea, hibiscus in the aspect of reducing negative health effects caused by exposure to Cd. The scope of action of these products was very broad and it included improved function of cardiovascular (primarily decreasing blood pressure, reduction changes in blood vessels), nervous (mainly through decreasing activity of acetylcholinesterase in brain and memory improvement), urinary (among others by improvement of creatinine clearance, reduction of creatinine and urea, reduction of degree of kidney damage), reproductive (improvement of sperm quality, increasing testosterone level in serum, reduction of histopathological changes in testes and ovaries) and respiratory system (reduction of changes in lungs), as well as liver (improvement of liver function parameters and reduction Cd accumulation) and muscles (reduction Cd accumulation). What is more, improved biochemical parameters of blood (increase hemoglobin and improvement blood counts) and lipid metabolism of the organism (decrease in total cholesterol, LDL fraction and triglicerydes, increase in HDL cholesterol in the blood) were shown.

Considering the promising results of studies in animal models, it appears valid to promote the consumption of natural plant products cited above in populations exposed to Cd in occupational and environmental terms and conducting research in the aspect of their efficacy rate for the human organism.

WNIOSKI

Wyniki badań na modelach zwierzęcych wykazały korzystny wpływ produktów roślinnych takich jak kurkuma, imbir, czosnek, cebula, olej z czarnuszki, borówka amerykańska, zielona herbata, hibiskus w aspekcie zmniejszania negatywnych skutków zdrowotnych spowodowanych ekspozycją na Cd. Spektrum działania tych produktów było bardzo szerokie i obejmowało poprawę funkcji układu krwionośnego (przede wszystkim obniżenie ciśnienia tętniczego krwi, zmniejszenie zmian w naczyniach krwionośnych), nerwowego (głównie poprzez obniżenie aktywności acetylocholinoestrerazy w mózgu i poprawę pamięci), moczowego (m.in. poprawa klirensu kreatyniny, obniżenie stężenia kreatyniny i mocznika, zmniejszenie stopnia uszkodzenia nerek), rozrodczego (poprzez poprawę jakości spermy, wzrost stężenia testosteronu w surowicy, zmniejszenie zmian histopatologicznych w jądrach i jajnikach), oddechowego (zmniejszenie zmian w płucach), a także wątroby (poprawa parametrów czynności wątroby, obniżenie stężenia Cd) i mięśni (obniżenie stężenia Cd). Wykazano również poprawę parametrów biochemicznych krwi (wzrost stężenia hemoglobiny i elementów morfotycznych krwi) oraz parametrów gospodarki lipidowej organizmu (obniżenie stężenia cholesterolu całkowitego, frakcji LDL i trójglicerydów, wzrost stężenia cholesterolu HDL we krwi).Ze względu na obiecujące wyniki badań prowadzonych na modelach zwierzęcych zasadnym wydaje się promocja spożycia wyżej wymienionych naturalnych produktów roślinnych w populacji osób narażonych zawodowo i środowiskowo na Cd oraz prowadzenie badań w aspekcie skuteczności ich działania na organizm człowieka.

Table 1. Results of studies in animal models with Cd exposure and curcumin treatment

Tabela 1. Wyniki badań przeprowadzonych na zwierzętach indukowanych kadmem i suplementowanych kurkuminą

References	Research model	Study description	Main results
28	Mice, ICR, adult male	CG (n= 8-10) – $CdCl_2$ (100 mg/l orally for 8 weeks) G1 (n= 8-10) – $CdCl_2$ (100 mg/l orally for 8 weeks) and curcumin (100mg/kg bw intragastically for 8 weeks)	G1 vs CG vascular: responsiveness↑, eNOS protein↑, pressure↓ aortic superoxide anion↓ urine: nitrate/nitrite↓ plasma: MDA↓, protein carbonyls↓ blood: GSH↓, Cd↓ aorta, liver, kidneys: Cd↓
44	Mice, ICR, male	CG (n=8-10) – $CdCl_2$ (100mg/l via drinking water, for 8 weeks) G1 (n=8-10) – $CdCl_2$ (100mg/l via drinking water, for 8 weeks) and THU (100 mg/kg bw/day concurently with Cd treatment)	G1 vs CG blood pessure↓, heart rate↔ aortas: eNOS↑, iNOS↓, superoxide anion↓, Cd↓ blood: GSH↑, Cd↓ urine: nitrate/nitrite↓ plasma: MDA↓, protein carbonyl↓ heart: MDA↓, protein carbonyl↓, Cd↓ liver: MDA↓, protein carbonyl↓ kidney: MDA↓, protein carbonyl↓, Cd↓
10	Rats, albino, male	CG (n=10) – $CdCl_2$ (40 mg/L drinking water, for 6 weeks) G1 (n=10) – $CdCl_2$ (40 mg/L drinking water, for 6 weeks) and curcumin (50 mg/kg bw, by gastric tube daily, for 6 weeks)	G1 vs CG body weight↑ plasma: CAT↔, SOD↑, GSH↑, TCA↑, MDA↓, TNF-α↓, IL-6↓
8	Rats, albino, adult male	CG (n=6) – Cd (2.5 mg/kg orally for 7 days) G1 (n=6) – Cd (2.5 mg/kg orally) and curcumin (12,5 mg/kg orally by gavage for 7 days) G2 (n=6) Cd (2.5 mg/kg orally) and curcumin (25 mg/kg orally by gavage for 7 days)	G1 and G2 vs CG kidney: ADA↓, arginase↓, NO↑, urea↓, creatinine↓, Na^+↓, K^+↓, Cl^-↓, MDA↓, TSH↑, NPSH↑, Cd↓
27	Rats, Spraque-Dawley, male	CG (n=6) – $CdCl_2$ (25 mg/kg bw, oral gavage for 7 days) G1(n=6) – $CdCl_2$ (25 mg/kg bw oral for 7 days) and curcumin (50 mg/kg bw pre-treatment, orally)	G1 vs CG weight: body↔, kidney↑, serum: BUN↓, creatinine↓, AST↓, glucose↓, ALT↔, uric acid↔ urine: volume↓, pH↔, creatinine↑, creatinine clearance↑, total protein↑, glucose↓ excretion of Kim-1↓, OPN↓, TIMP-1↓, NGAL↓, netrin-1↓
51	Mice, Kunming, male	CG (n=12) – $CdCl_2$ (2 mg/kg bw, intraperitoneally for 10 day) G1 (n=12) – CdCl2 (2 mg/kg bw, intraperitoneally for 10 day) and curcumin (50 mg/kg bw, co-treatment, for 10 days)	G1 vs CG sperm: motility↑, concentration↑, abnormal↓ serum: testosterone↑ testis: Nrf2 protein↑, GPx↑, GSH↑, T-SOD↑, MDA↓
1	Rats, Sprague Dawley, adult male	CG (n=10) – CdC_2 (1 mg/kg bw, intraperitoneal injection for 3 days) G1 (n=10) – CdC2 (1 mg/kg bw, intraperitoneal injection for 3 days) and after that curcumin (5 mg/kg bw/day, orally for 4 weeks)	G1 vs CG serum: testosterone↑ testis: MDA↓, SOD↑, GSH↑, NO↓, mean number of spermatogenic cells↑
9	Rats, Wistar albino, male	CG (n=10) – Cd (1mg/kg bw, injected for 4 weeks) G1 (n=10) – Cd (1mg/kg bw, injected) and curcumin (100 mg/kg bw by using intra-gastric intubation)	G1 vs CG serum: testosterone↑ testis: MSTD↑, MTBS↑, damage↓, apoptotic index↓, apoptotic index of Leydig cell↓

References	Research model	Study description	Main results
37	Rats, Spraque-Dawley, adult male	CG (n=7) – $CdCl_2$ (1mg/kg intraperitoneally for 3 days) G1 (n=7) – $CdCl_2$ (1mg/kg) and curcumin (100 mg/kg bw orally for 3 days)	G1 vs CG testis: TBARS↓, SOD↑, CAT↔, GPx↑, GSH↑, histopathological changes↓ weight: testis↔, epididymis↔, seminal vesicle↔, prostate↔ sperm: concentration↔, motility↔, abnormal↔
31	Mice, NMRI adult male	CG (n=6) – $CdCl_2$ (5 mg/kg bw, subcutaneously) G1 (n=6) – CdCl2 (5 mg/kg bw, subcutaneously) and curcumin (100 mg/kg bw, single intraperitoneal dose)	G1 vs CG testis: seminiferous tubules diameter↑, seminiferous tubule's lumen diameter↑, serum: MDA↓, TSH↑, CAT↑, SOD↑, GPx↑, GSH↑, H_2O_2↓
7	Rats, albino, adult male	CG (n=6) – Cd (2,5mg/kg by gavage, for 7 days) G1 (n=6) – Cd (2,5 mg/kg by gavage) and curcumin (12,5 mg/kg by gavage, for 7 days) G2 (n=6) – Cd (2,5 mg/kg by gavage) and curcumin (25 mg/kg by gavage for 7 days)	G1 and G2 vs CG cerebral cortex: NOR↑, AChE↓, ADA↓, NO↑, MDA↓, TSH↑, NPSH↑ memory index↑
5	Rats, albino, adult male,	CG (n=10) – Cd (2.5 mg/kg bw orally for 14 days) G1 (n=10) – Cd (2.5 mg/kg bw orally for 14 days) and essential oil from turmenic (50 mg/kg bw orally for 14 day)	G1 vs CG brain: IL-10↑, IL-6↓, TNF-alpha↓, prefronal cortex: AChE↓, ADA↓ hippocampus: AChE↓, ADA↓
17	Rats, Wistar, adult male,	CG (n=15) – Cd (1mg/kg by oral gavage 5 days a week for 3 months) G1(n=15) – Cd (1mg/kg by oral gavage 5 days a week for 3 months) and curcumin (90 mg/kg by oral gavage 5 days a week for 3 months, after Cd)	G1 vs CG cerebral cortex synaptosomes: AChE↓, ATP↔, ADP↔, AMP↑ motor abilities↔, shock sensivity↔ striatum: AChE↓, TBARS↓ cerebral cortex: AChE↓, TBARS↓ hippocampus: AChE↔, TBARS↔ hypothalamus: AChE↔, TBARS↔ cerebellum: AChE↔, TBARS↓ whole blood: AChE↓ lymphocytes: AChE↓
33	Mice, Swiss Albino, young	CG (n=7) – Cd (2.5 mg/kg bw oral for 60 days, pre-treatment) G1 (n=7) – Cd (2.5 mg/kg bw oral for 60 days) and curcumin (160 mg/kg bw oral for 30 days from day 30th to day 60th)	G1 vs CG locomotor activity↑, retention memory↑, recognition memory↑ hippocamp: MDA↓, SOD↑, catalase↑, GSH↑, proteins (BDNF, SynII, DCX, CREB)↑
6	Rats, albino, male	CG (n=10) – Cd (2.5 mg/kg bw by oral gavage for 7 days) G1 (n=10) – Cd (2.5 mg/kg bw by oral gavage for 7 days) and curcumin (25 mg/kg bw by oral gavage for 7 days) G2 (n=10) – Cd (2.5 mg/kg bw by oral gavage for 7 days) and curcumin (50 mg/kg bw by oral gavage for 7 days)	G1 and G2 vs CG cerebral cortex: AChE↓, AChE mRNA↓
3	Mice, Swiss-Webster, male and female	CG (n=10) – Cd (100 mg/kg bw oral administration for 2 weeks) G1 (n=10) – Cd (100 mg/kg bw oral administration for 2 weeks) and curcumin (150 mg/kg bw oral administration for 2 weeks) G2 (n=10) – Cd (100 mg/kg bw oral administration for 2 weeks) and curcumin (300 mg/kg bw oral administration for 2 weeks)	G1 and G2 vs CG blood: hemoglobin↑, packed cell volume↑, WBC↑, platelets↑, testosterone (male)↑, progesterone (female)↑ brain: AChE↓ G1 vs CG blood: RBC↑

References	Research model	Study description	Main results
42	Rats, Wistar, albino, male	CG (n=6) – $CdCl_2$ (5 mg/kg bw/day orally administered for 4 weeks) G1 (n=6) – $CdCl_2$ (5 mg/kg bw/day orall administered for 4 weeks) and THC (80 mg/kg bw/day orally administered for 4 weeks)	G1 vs CG body weight↔, food, water intake↑, hepatic index (liver weight-body weight ratio)↓ serum: AST↓, ALT↓, ALP↓, LDH↓, GGT↓, bilirubin↓, blood: Cd↓ liver: Cd↓, TBARS↓, LHP↓, protein carbonyl↓, SOD↑, CAT↑, GPx↑, GST↑, GR↑,G6PD↑, GSH↑, TSH↑
46	Carps, *Cyprinus carpio*, young	CG (n=4) – Cd (5 mg/kg bw, single intraperitoneal dose) G1 (n=4) – Cd (5 mg/kg bw, single intraperitoneal dose) and curcumin (50mg/kg bw, injected after Cd)	G1 vs CG muscle: Cd↓, SOD↑, CAT↔, GPx↑, GR↔, tGSH↔, GSSG↔, GSH↔, TRABS↔, protein↔

AChE – acetylcholinesterase, ADA – adenoine deaminase, ALP – alkaline phosphatase, ALT – alanine aminotransferase, AST – aspartate aminotransferase, BDNF – brain-derived neurotrophic factor, BUN – blood urea nitrogen, CAT – catalase, Cd – cadmium, CG - Control Group, CREB – cAMP response element binding protein, curcumin- the main component of turmenic, DCX – doublecortin, eNOS - endothelial nitric oxide synthase, G1 - Group 1, G2 – Group 2, G6PD – glucose-6-phosphate dehydrogenase, GGT – gamma glutamyl transferase, GPx – glutathione peroxidase, GR – glutathione disulfide reductase, GSH – reduced glutathione, GSSG – oxidized glutathione, IL-10 – interleukin-10, IL-6- interleukin-6, iNOS – anti-inducible nitric oxide synthase, Kim-1 – kidney injury molecule-1, LDH- lactate dehydrogenase, LHP – lipid hydroperoxides, MDA – malondialdehyde, MSTD – mean seminiferous tubule diameter, MTBS – mean testicular biopsy score, NGAL – neutrophil gelatinase-associated lipocalin, NO – nitric oxide, NOR – novel object recognition, NPSH – non-protein thiol, OPN – osteopontin, RBC – red blood cell, SOD – superoxide dismutase, Syn II – synapsin II, TBARS – thiobarbituric acid reactive substances, TCA – total antioxidant capacity, tGSH – total glutathione, THC – tetrahydrocurcumin, TIMP-1 – tissue inhibitor of metalloproteinases 1, TNF-alpha – tumor necrosis factor alpha, TSH – total thiol, T-SOD – total superoxide dismutase, WBC – white blood cell.

AChE – acetylocholinoesteraza, ADA – deaminaza adenozynowa, ALP – fosfataza alkaliczna, ALT – aminotransferaza alaninowa, AST – aminotransferaza asparaginianowa, BDNF – neurotroficzny czynnik pochodzenia mózgowego, BUN – azot mocznika, CAT – katalaza, Cd – kadm, CG – Grupa Kontrolna, CREB - białko wiążące element odpowiedzi cAMP, kurkumina – główny składnik kurkumy, DCX – doublekortyna, eNOS – śródbłonkowa syntaza tlenku azotu, G1 – Grupa 1, G2 – Grupa 2, G6PD – dehydrogenaza glukozo-6-fosforanowa, GGT – gamma-glutamylotransferaza, GPx – peroksydaza glutationowa, GR – reduktaza glutationu, GSH – glutation zredukowany, GSSG – glutation utleniony, IL-10 – interleukina-10, IL-6 – interleukina-6, iNOS – indukowalna syntaza tlenku azotu, Kim-1 – cząsteczka uszkodzenia nerek-1, LDH – dehydrogenaza mleczanowa, LHP – wodoronadtlenki lipidowe, MDA – dialdehyd malonowy, MSTD – średnia średnica kanalików nasiennych, MTBS – średni wynik z biopsji jąder, NGAL – lipokalina związana z żelatynazą neutrofili, NO – tlenek azotu, NOR – test rozpoznawania nowego obiektu, NPSH – niebiałowy tiol, OPN – osteopontyna, RBC – krwinka czerwona, SOD – dysmutaza ponadtlenkowa, SynII – synapsyna II, TBARS – substancje reagujące z kwasem tiobarbiturowym, TCA – całkowita zdolność antyoksydacyjna, tGSH – glutation całkowity, THC – tetrahydrokurkumina, TIMP-1 – tkankowy inhibitor metaloproteinaz-1, TNF-alpha – czynnik martwicy nowotworów alfa, TSH – całowita zawartość tioli, T-SOD – całowita dysmutaza ponadtlenkowa, WBC – krwinki białe.

Source: Own study

Źródło: Opracowanie własne

Table 2. Results of studies in animal models with Cd exposure and ginger treatment

Tabela 2. Wyniki badań przeprowadzonych na zwierzętach indukowanych kadmem i suplementowanych imbirem

References	Research model	Study description	Main results
21	Rats, Wistar, male, adult	CG (n=10) – $CdCl_2$ (5 mg/kg bw for 30 days) G1 (n=10) – $CdCl_2$ (5 mg/kg bw for 30 days) and ginger extract (100 mg/kg for 30 days) G2 (n=10) – CdCl2 (5 mg/kg bw for 30 days) and ginger extract (200 mg/kg for 30 days)	G1 and G2 vs CG body weight↑ kidney: weight↓, creatinine↓ urea↓, urine albumin↓, creatinine clearance↑, MDA↓, TAC↑, DNA↑
39	Rats, Wistar, albino, adult	CG (n=10) – $CdCl_2$ (3 mg/kg bw orally for 28 days) G1 (n=10) – $CdCl_2$ (3 mg/kg bw orally for 28 days) and ginger supplement (0,5 g/kg bw orally for 28 days)	G1 vs CG testes: MDA↓, weight↑ kidney: MDA↓, weight↑ serum: ACP↓, PAP↓, ALP↓ blood: Hb↑, PCV↑, RBCs↑, WBCs↓
5	Rats, albino, male, adult	CG (n=10) – Cd (2.5 mg/kg bw orally for 14 days) G1 (n=10) – Cd (2.5 mg/kg bw orally for 14 days) and essential oil from ginger (50mg/kg bw orally for 14 day)	G1 vs CG brain: IL-10↑, IL-6↓, TNF-alpha↓ prefronal cortex: AChE↓, ADA↓ hippocampus: AChE↓, ADA↓

References	Research model	Study description	Main results
13	Rabbits, male	CG (n=10) – $CdCl_2$ (200 mg/kg bw orally for 12 weeks) G1 (n=10) – $CdCl_2$ (200 mg/kg bw orally for 12 weeks) and ginger supplement (400 mg/kg bw orally for 12 weeks)	G1 vs CG kidney: caspase 3 expression↓, Bcl2 expression↑, GST expression↑, C-fos↓, MKI67↓ liver: caspase 3 expression↓, Bcl2 expression↑, GST expression↓, C-fos↓, MKI67↓

AChE – acetylcholinesterase, ADA – adenoine deaminase, ALP – alkaline phosphatase, Cd – cadmium, CG – Control Group, DNA – deoxyribonucleic acid, G1 – Group 1, Hb – hemoglobin, IL-10 – interleukin-10, IL-6 – interleukin-6, MDA – malondialdehyde, PAP – prostatic acid phosphatase, PCV – packed cell volume, RBC – red blood cell, TAC – total antioxidant status, TNF-alpha – tumor necrosis factor alpha, WBC – white blood cell.

AChE – acetylcholinoesteraza, ADA – deaminaza adenozynowa, ALP – fosfataza alkaliczna, Cd – kadm, CG – Grupa Kontrolna, DNA – kwas deoksyrybonukleinowy, G1 – Grupa 1, Hb – hemoglobina, IL-10 – interleukina-10, IL-6 – interleukina-6, MDA – dialdehyd malonowy, PAP – kwaśna fosfataza sterczowa, PCV – objętość upakowanych komórek, RBC – krwinka czerwona, TAC – całkowity status antyoksydacyjny, TNF-alpha – czynnik martwicy nowotworów alfa, WBC – krwinka biała.

Source: Own study

Źródło: Opracowanie własne

Table 3. Results of studies in animal models with Cd exposure and garlic treatment

Tabela 3. Wyniki badań przeprowadzonych na zwierzętach indukowanych kadmem i suplementowanych czosnkiem

References	Research model	Study description	Main results
38	Rats, Wistar, male, adult	CG (n=6) – Cd (1.5 mg/100 g bw/ day by gavage for 3 weeks) G1(n=6) – Cd (1.5 mg/100 g bw/ day) and garlic extract (1 ml/100 g bw/day by gavage for 3 weeks)	G1 vs CG prostate glands: MDA↓, GSH↑, CAT↑, SOD↑ GST↓, PAP↑ plasma: ACP↓
41	Rats, Wistar, male,	CG (n=6) – $CdCl_2$ (3 mg/kg bw/day, subcutaneously for 3 weeks) G1 (n=6) – $CdCl_2$ (3 mg/kg bw/day for 3 weeks) and DTS (40 mg/kg bw/day subcutaneously for 3 weeks)	G1 vs CG testis: weight↑, Cd↓, TBARS↓, hydroperoxides↓, protein carbonyls↓, GSH↑, TSH↑, SOD↑, CAT↑, GPx↑, GST↑, GR↑, G6PD↑
36	Rats, Wistar, male	CG (n=15) – $CdCl_2$ (200 ppm in drinking water for 6 weeks) G1(n=15) – $CdCl_2$ (200 ppm in drinking water for 6 weeks) and garlic (7%w/w for 6 weeks)	G1 vs CG weight changes↔ liver: Cd↓
48	Rats, albino, male	CG (n=6) – Cd (25 mg/kg bw/day orally for 4 weeks) G1(n=6) – SM (300 mg/kg bw/day orally for 2 weeks) and after Cd (25 mg/kg bw/day orally for 4 weeks) G2 (n=6) – Cd (25 mg/kg bw/day orally for 4 weeks) and SM (300 mg/kg bw/day orally for 4 weeks) G3 (n=6) – Cd (25 mg/kg bw/day orally for 4 weeks) and after SM (300 mg/kg bw/day orally for 2 weeks)	G1, G2, G3 vs CG urine: creatinine↓ serum: AST↓, ALT↓ G1 vs CG urine: urea↔, uric acid↓, total cholesterol↓ G2 vs CG urine: urea↑, uric acid↑, total cholesterol↑ G3 vs CG urine: urea↓, uric acid↓, total cholesterol↑

CAT – catalase, Cd – cadmium, CG – Control Group, DTS – diallyl tetrasulfide from garlic, G1 – Group 1, G2 – Group 2, G3 – Group 3, G6PD – glucose-6-phosphate dehydrogenase, GPx – glutathione peroxidase, GR – glutathione disulfide reductase, GSH – reduced glutathione, GST – glutathione-S-transferase, MDA – malondialdehyde, PAP – prostatic acid phosphatase, SM – spice mixture (ginger rhizomes, garlic bulbs and nutmeg), SOD – superoxide dismutase, TBARS – thiobarbituric acid reactive substances, TSH – total sulphydryl groups.

CAT – katalaza, Cd – kadm, CG – Grupa kontrolna, DTS – tetrasiarczek diallilu z czosnku, G1 – Grupa 1, G2 – Grupa 2, G3 – Grupa 3, G6PD – dehydrogenaza glukozo-6-fosforanowa, GPx – peroksydaza glutationowa, GR – reduktaza glutationu, GSH – glutation zredukowany, GST – transferaza glutationowa, MDA – dialdehyd malonowy, PAP – kwaśna fosfataza sterczowa, SM – mieszanka przypraw (kłącze imbiru, czosnek i gałka muszkatołowa), SOD – dysmutaza ponadtlenkowa, TBARS – substancje reagujące z kwasem tiobarbiturowym, TSH – wszystkie grupy sulfhudrylowe.

Source: Own study

Źródło: Opracowanie własne

Table 4. Results of studies in animal models with Cd exposure and onion treatment

Tabela 4. Wyniki badań przeprowadzonych na zwierzętach indukowanych kadmem i suplementowanych cebulą

References	Research model	Study description	Main results
11	Rats, Sprague-Dawley, male	CG (n=8) – $CdCl_2$ (2 ml/kg bw injected subcutaneously for 30 days) G1(n=8) – $CdCl_2$ (2 ml/kg bw injected subcutaneously for 30 days) and AcE (1 ml via intragastric intubation for 30 days)	G1 vs CG cardiac tissue: MDA↓, SOD↑, CAT↑, GPx↑, degenerative changes↓
24	Rats, Wistar, male	CG (n=10) – $CdSO_4$ (1.5 ml/kg bw via drinking for 4 weeks) G1 (n=10) – $CdSO_4$ (1.5 ml/kg bw via drinking for 4 weeks) and AcE (1 ml/100 g bw orally for 8 weeks)	G1 vs CG weight: ↑ liver: weight↑, MDA↓, SOD↑ kidney: weight↔, 24-hour urinary volume↑, creatinine clearance↑, urea clearance↑, MDA↓, SOD↑ plasma: cholesterol↓, TG↓, HDL↑, LDL↓, total protein↑, albumin↓, MDA↓, SOD↑
38	Rats, Wistar, male, adult	CG (n=6) – Cd (1.5 mg/100 g bw/ day by gavage for 3 weeks) G1(n=6) – Cd (1.5 mg/100 g bw/ day) and onion extract (1 ml/100 g bw/day by gavage for 3 weeks)	G1 vs CG prostate glands: MDA↓, GSH↑, CAT↑, SOD↑ GST↓, ACP↑ plasma: PAP↓

AcE – onion extract, CAT – catalase, Cd – cadmium, CG – Control Group, G1 – Group 1, GPx – glutathione peroxidase, GSH – reduced glutathione, GST – glutathione- S-transfera, HDL – high density lipoprotein, LDL – low density lipoprotein, MDA – malondialdehyde, PAP – prostatic acid phosphatase, SOD – superoxide dismutase, TG – triglyceride.

AcE – ekstrakt z cebuli, CAT – katalaza, Cd – kadm, CG – Grupa Kontrolna, G1 – Grupa 1, GPx – peroksydaza glutationowa, GSH – glutation zredukowany, GST – transferaza glutationowa, HDL – lipoproteina o dużej gęstości, LDL – lipoproteina o niskiej gęstości, MDA – dialdehyd malonowy, PAP – kwaśna fosfataza sterczowa, SOD – dysmutaza ponadtlenkowa, TG – triglicerydy.

Source: Own study

Źródło: Opracowanie własne

Table 5. Results of studies in animal models with Cd exposure and black seeds oil, olive oil, blueberry, green tea and hibiscus treatment

Tabela 5. Wyniki badań przeprowadzonych na zwierzętach indukowanych kadmem i suplementowanych olejem z czarnuszki, oliwą z oliwek, borówką amerykańską, zieloną herbatą i hibiskusem

References	Research model	Study description	Main results
		Black seeds oil	
20	Rats, Wistar albino	CG (n=8) – $CdCl_2$ (1 mg/kg bw injrcted subcutaneously for 30 days) G1(n=8) – $CdCl_2$ (1 mg/kg bw injrcted subcutaneously for 30 days) and TQ (50 mg/kg bw/day orally)	G1 vs CG renal tissue: injury↓, MDA↓, SOD↑, CAT↑, GPx↑ immunoreactivity NK-κB p65↓, apoptotic cells↓
19	Rats, Wistar, male, adult	CG (n=10) – $CdCl_2$ (2 mg/kg intraperitoneally for 28 days) G1 (n=10) – $CdCl_2$ (2 mg/kg intraperitoneally for 28 days) and NSO (1 ml/kg bw by gastric gavage for 28 days)	G1 vs CG lungs: changes↓
		Olive oil	
12	Rats, Wistar, male	CG (n = 5) – olive oil (contain olive oil of diet 4% for 8 weeks) G1 (n = 5) – Cd (50 mg/l orally - drinking water for 8 weeks) and olive oil (contain olive oil of diet 4% for 8 weeks)	G1 vs CG plasma: total cholesterol↔, HDL↓, LDL↓, VLDL↑, TG↑, CAT↓, SOD↓, MDA↑ protein carbonyls↔ liver: total cholesterol↔, total lipids↔, TG↓, CAT↓, SOD↓, MDA↔, protein carbonyls↔, GSH↓ serum: AST↑, ALT↑
30	Rats, Wistar, male	CG (n=5) – $CdCl_2$ (2.5 mg/kg bw injected i.p.) G1 (n=5) – $CdCl_2$ (2.5 mg/kg bw injected) and DPE (9 mg/kg bw injected i.p.)	G1 vs CG spleen: TBARS↓, CytCAT↑, MitCAT↔, testes: TBARS↔, CytCAT↔, MitCAT↔

References	Research model	Study description	Main results
Blueberry			
25	Mice, Swiss, adult, female	CG (n = 6) – $CdCl_2$ (10 µmol/kg bw, injected subcutaneously for 3 weeks) G1 (n=6) – $CdCl_2$ (10 µmol/kg bw, injected subcutaneously for 3 weeks) and blueberry extract (2,5 mg/kg, orally via gavage for 3 weeks)	G1 vs CG ovaries: reactive species↓, follicle viability↑, Cd↔, δ-ALA-D↑, GPx↔, GST↔, 17-β HSD↔
22	Mice, Kunmig, male	CG (n=7) – $CdCl_2$ (2 mg/kg/day intraperitoneal injections for 14 days) G1 (n=7) – $CdCl_2$ (2 mg/kg/day intraperitoneal injections for 14 days) and Ay (0,3 mg/kg/day, intragastric for 14 days) G2 (n=7) – $CdCl_2$ (2 mg/kg/day intraperitoneal injections for 14 days) and Ay (3 mg/kg/day, intragastric for 14 days) G3 (n=7) – $CdCl_2$ (2 mg/kg/day intraperitoneal injections, for 14 days) and Ay (30 mg/kg/day, intragastric for 14 days)	G1, G2, G3 vs CG plasma: AST↑, ALT↑ liver: MDA↓, protein carbonyl↓, SOD↑, CAT↑, GHS↓, NO↓, DNA fragmentation↓
Green tea			
14	Mice, ICR, male	CG (n=10) – $CdCl_2$ (3.75-6 mg/kg bw orally administered, 30 mg/l in water for 8 weeks) G1 (n=10) – $CdCl_2$ (3.75-6 mg/kg bw orally administered, 30 mg/l in water for 8 weeks) and L-theanine (100 mg/kg bw intraperitoneally injected for 8 weeks) G2 (n=10) – $CdCl_2$ (3.75-6 mg/kg bw orally administered, 30 mg/l in water for 8 weeks) and L-theanine (200 mg/kg bw intraperitoneally injected for 8 weeks)	G1 and G2 vs CG brain: Cd↓, ROS↓, tau hyperphosphorylation↓, apoptotic neuronal cell death↓ plasma: Cd↓ G1 vs CG brain: MDA↔, GSH↔, CAT↔, GPx↔ G2 vs CG brain: MDA↓, GSH↑, CAT↑, GPx↑
2	Rats, Wistar, male	CG (n=9) – $CdCl_2$ (3 mg/kd bw, gavage for 63 days) G1 (n=9) – $CdCl_2$ (3 mg/kd bw, gavage for 63 days) and GTE (70 mg/kg gavage for 63 days)	G1 vs CG weight: body↑, sexual organs↑ sperm: cell concentration↑, viability↔, abnormalities↓ serum: total cholesterol↓ testis: CAT↑, SOD↑, GSH↑
29	Rats, Wistar, male	CG (n=12) – $CdCl_2$ (1,5 mg/kg bw intraperitoneally, single dose) G1 (n=12) – $CdCl_2$ (1,5 mg/kg bw intraperitoneally, single dose) and GT solution (1,5% w/v until the end of the treatment – 49th day)	G1 vs CG sperm motility: fast↑, slow↔, non-motile↔ sperm: morphology↔, count↑ serum: testosterone↑ testis: MDA↓
Hibiscus			
40	Rats, Wistar, female	CG (n=5) – Cd (cadmium sufphate 5 mg/kg bw for 5 days i.p.) G1 (n=5) – Cd (cadmium sufphate 5 mg/kg bw for 5 days i.p.) and hibiscus (100 mg/kg bw orally for 28 days)	G1 vs CG body weight↑ serum: FSH↑, LH↑ ovaries: histopathologiacal changes↓

17-β HSD – 17 β-hydroxysteroid dehydrogenase, ALT – alanine aminotransferase, AST – aspartate aminotransferase, Ay – anthocyanin, CAT – catalase, Cd – cadmium,, CG – Control Group, CytCAT – catalase in cytosol, DNA – deoxyribonucleic acid, DPE – 2-(3,4 dihydroxyphenyl) ethanol (phenolic compound present in olive oil), FSH – follicle stimulating hormone, G1 – Group 1, GPx – glutathione peroxidase, GSH – reduced glutathione, GST – glutathione-S-transferase, GTE – green tea extract, HDL – high density lipoprotein, LDL – low density lipoprotein, LH – luteinizing hormone, LYM – lymphocyte, MDA – malondialdehyde, MitCAT – catalase in mitochondria, NO – nitric oxide, NSO – black seeds oil, SOD – superoxide dismutase, TBARS – thiobarbituric acid reactive substances, TG – triglyceride, TQ – thymoquinone (the main constituent of the essential oil from black seeds), VLDL – very low density lipoprotein, δ-ALA-D - δ-aminolevulinate dehydratase.

17-β HSD – dehydrogenaza 17-ß-hydroksy-steroidowa, ALT – aminotransferaza alaninowa, AST – aminotransferaza asparaginianowa, Ay – antocyjany, CAT – katalaza, Cd – kadm CG – Grupa Kontrolna, CytCAT – katalaza cytozolowa, DNA – kwas deoksyrybonukleinowy, DPE 2-(3,4-hydroksyfenylo)etanol (związek fenolowy obecny w oliwie z oliwek), FSH – hormon folikulotropowy, G1 – Grupa 1, GPx – peroksydaza glutationowa, GSH – glutation zredukowany, GST – transferaza glutationowa, GTE – ekstrakt z zielonej herbaty, HDL – lipoproteina o dużej gęstości, LDL – lipoproteina o niskiej gęstości, LH – hormone luteinizujący, LYM – limfocyt, MDA – dialdehyd malonowy, MitCAT – katalaza

mitochondrialna, NO – tlenek azotu, NSO – olej z czarnuszki, SOD – dysmutaza ponadtlenkowa, TBARS – substancje reagujące z kwasem tiobarbiturowym, TG – triglicerydy, TQ – tymochinon (główny składnik olejku eterycznego *z czarnuszki*), VLDL – lipoproteina o bardzo małej gęstości, δ-ALA-D – dehydrataza kwasu delta-aminolewulinowego.

Source: Own study

Źródło: Opracowanie własne

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TRANSFORMATIONS TAKING PLACE IN THE DAIRY SECTOR IN POLAND IN THE YEARS 1995–2020®

Przekształcenia zachodzące w sektorze mleczarskim w Polsce w latach 1995–2020®

The Polish dairy sector is subject to constant adjustment processes due to significant political events that took place in 1989–2020. The first was the systemic transformation, the consequences of which are visible in the entire Polish economy, the second was the accession to the European Union, and the third was the abolition of production quotas in 2015 and the Covid-19 pandemic lasting from March 2020. In the preparation of the article, literature on the subject was used, reports published by the Central Statistical Office in statistical yearbooks of agriculture and industry, as well as reports published by the Institute of Agricultural and Food Economics (IERiGŻ-PIB) in Warsaw, which were used to describe the causes and effects of phenomena occurring in the dairy sector in Poland in the years 1995-2020. The article uses simple descriptive and cause-effect methods. Based on the conducted analyzes, it was found that the integration with the EU resulted in the rebuilding of the institutional environment for agri-food producers and processors. Among all agricultural markets, the most dynamic changes took place in the dairy sector. It was related to extensive intervention mechanisms on the milk market in the EU, which limiting production and applying a wide range of subsidies for farmers.

Key words: dairy sector, market analysis, production concentration, processing concentration, effects of Covid-19, forecast.

Polski sektor mleczarski podlega ciągłym procesom dostosowawczym ze względu na istotne wydarzenia polityczne, które miały miejsce w latach 1989–2020. Pierwszym z nich była transformacja ustrojowa, której konsekwencje są widoczne w całej polskiej gospodarce, drugim akcesja do Unii Europejskiej, zaś trzecim zniesienie kwotowania produkcji w 2015 roku oraz pandemia Covid-19 trwająca od marca 2020 roku. W opracowaniu artykułu wykorzystano literaturę przedmiotu, raporty publikowane przez GUS w rocznikach statystycznych rolnictwa i przemysłu, a także raporty publikowane przez Instytut Ekonomiki Rolnictwa i Gospodarki Żywnościowej (IERiGŻ-PIB) w Warszawie, które posłużyły do opisania przyczyn i skutków zjawisk zachodzących w sektorze mleczarskim w Polsce w latach 1995-2020. W artykule zastosowano proste metody opisowe i przyczynowo-skutkowe. Na podstawie przeprowadzonych analiz stwierdzono, że integracja z UE spowodowała przebudowanie otoczenia instytucjonalnego dla producentów i przetwórców rolno-żywnościowych. Spośród wszystkich rynków rolnych najbardziej dynamiczne zmiany zachodziły w sektorze mleczarskim, było to związane z rozbudowanymi mechanizmami interwencyjnymi na rynku mleka w UE, przejawiającymi się m.in. limitowaniem produkcji oraz stosowaniem szerokiego wachlarza dopłat dla rolników.

Słowa kluczowe: sektor mleczarski, analiza rynku, koncentracja produkcji, koncentracja przetwórstwa, skutki Covid-19, prognoza.

INTRODUCTION

In Poland, both agriculture and the food industry have been subject to constant adjustment processes since 1990, which are related to political events. In the 90s of the twentieth century, it was a systemic transformation that caused a number of effects in the entire Polish economy, including the dairy sector, and the second - accession to the European Union (EU) [2, 16].

Over the last 30 years, the Polish dairy sector has undergone significant transformations, being one of the key sectors of the food industry. This sector was subject to great pressure from structural changes after 1990. The economic transformation of the 90s was of significant importance for the Polish dairy industry, due to such activities as: abolition of subsidies, introduction of a free market, changing the current orientation of the industry from production to demand, and meeting consumer expectations, which not only threatened the development opportunities of the industry, but also caused foundations of the economic existence of many of its entities. Other reasons for the deep crisis that the dairy sector struggled with in 1990–1995 were significant imports of cheap and attractive dairy products, a decline in the use of obsolete production capacities and difficulties in reorienting

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production to meet market demand [20]. The crisis in milk processing was accompanied by a collapse in the level of its production on farms, caused by a very high fragmentation and a rapid deterioration of the economic conditions of production [20].

From May 1, 2004, the history of the Polish dairy industry was created together with other countries of the common market. After European integration, the milk market was covered by a more extensive regulatory system, including milk quotas, mechanisms influencing the maintenance of market equilibrium, intervention prices, mechanisms supporting the increase in demand in the internal market, regulations concerning foreign trade [22, 26]. After accession to the EU, there was a need to adjust the Polish dairy industry to the requirements of the EU Member States [7]. The development of the milk and dairy products market is of great importance to the development of exports with a simultaneous reduction of imports [14]. The adaptation of enterprises to contemporary economic processes is inextricably linked with their activity in initiating and improving activities that may increase their ability to compete. Poland's integration with the European Union meant the necessity to significantly rebuild the institutional environment for agri-food producers and processors. Among all agricultural markets, the most dynamic changes took place in the dairy sector. It was mainly related to extensive intervention mechanisms on the milk market in the EU, manifested, inter alia, in in limiting production and applying a wide range of subsidies for farmers [2, 14]. In the EU, milk quota was introduced in the mid-1980s, and in Poland this mechanism began to function on April 1, 2004. In 2015, milk quotas were abolished, which initially raised objections and concerns from many circles, pointing to the destabilization of milk prices [2]. According to BGŻ BNP Paribas experts, the abolition of milk quotas favors the development of milk production, especially in north-eastern Poland. From April 2017 to March 2018, according to GUS data [2021], almost 11.3 billion liters of milk were purchased in Poland, i.e. 10.9% more than in the last year of the quotas (from April 2014 to March 2015.) [9, 34].

The dairy sector is one of the important sectors of the Polish food economy, which is responsible for generating the production value of the entire industry at the level of about 2.5%, and the production value of the food industry at the level of 15% [26]. Based on the data contained in the EUROSTAT database [3], it was shown that Poland is a key milk producer in the EU, with an 8.3% share in global production. Poland ranks fourth in terms of the volume of milk production among the EU countries, second only to Germany, France and Great Britain [3]. Milk and dairy products are among the key products that are important in the diet of people due to their nutritional, dietary and economic values. The dairy sector is the subject of research by many agricultural economists, including: Nieżurawski [18], Smoleński [29] and others, Sznajder [31], Seremek-Bulge [28], Parzonko [21], Malak-Rawlikowska [15].

According to Falkowski and Kostrowicki [4], in Poland (especially in the central and north-eastern region) there are favorable natural conditions for cattle breeding and production, due to the large share of meadows and pastures, which contributes to the development of production in accordance with the traditional grazing of animals, less susceptible to fluctuations in the supply and prices of fodder 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 [13]. On the other hand, cattle breeding in Poland is limited by the low water resources and relatively low rainfall affecting fodder plants [21, 26].

An important direction of changes in the dairy industry is the progressive concentration of milk production and processing. Processing plants should be a particularly important link of concentration, as they are less efficient compared to their Western competitors. [23, 26]. Without accelerating the concentration in cattle breeding and further consolidation in processing, it will be difficult for the Polish dairy to maintain the competitiveness of its products in the conditions of trade liberalization and the departure of the European Union from subsidizing exports. Concentration in cattle breeding is also necessary due to the growing income challenges of farmers, for whom the possibilities of price increases are exhausted (due to the specificity of flexibility in food markets) [5, 17]. The fastest concentration takes place in regions with high commodity production, natural and economic conditions most favorable to milk production [8]. This applies mainly to the Mazowieckie, Podlaskie and Wielkopolskie voivodships, which have the highest number of cows [19].

The aim of the research was to identify the most important changes that took place in the Polish dairy sector in three research periods: period I covering the years 1995–2003, i.e. during the transformations taking place in connection with the political transformation and preparatory activities related to the intention to join the EU; The second period covering the years 2004–2012, i.e. the time after Poland's accession to the EU, taking into account changes related to the adjustment of the dairy sector to EU requirements; The third period covering the years 2013–2020, i.e. the time associated with the lifting of regulations on the milk market, as well as changes related to the Covid-19 pandemic. Due to the important role of the dairy sector in Poland, it was chosen deliberately.

METHODS AND MATERIALS

The research included data for the years 1995–2020. The time period was selected so that there would be a comparable number of periods both before and after the accession to the EU, as well as the lifting of regulations on the milk market. The work uses material from reports published by the Central Statistical Office in statistical yearbooks of agriculture and industry and from reports published by the Institute of Agricultural and Food Economics (IERiGŻ-PIB) in Warsaw [11]. The research material also included the literature on the subject, which contributed to the description of the causes and effects of the phenomena occurring in the dairy sector in Poland in the years 1995–2020. In order to show changes in the sector, the following issues were examined: the state of the cows population, milk production, milk purchase, milk yield, milk distribution, economic and financial results of enterprises dealing with milk processing and cheese production, and consumption of milk and its products. As part of the study, the

following research problem was identified: Changes taking place in the Polish dairy sector in 1995–2020 related mainly to: the political transformation (1995–2003), accession to the EU (2004–2012), the abolition of milk quotas and the occurrence of the Covid pandemic 19 (2012–2020) had a significant impact on changes in the production, processing and consumption of milk in Poland. The descriptive and cause-effect methods were used to present the research results.

RESULTS AND DISCUSSION

In the 1990s, the economy in Poland changed from centrally planned to free market, which led to a number of changes also in the dairy sector. Activities related to the political transformation resulted in, inter alia, the elimination of state-owned herds on farms, the conversion of dairy cooperatives and the reduction of domestic demand for milk, ripened cheese and butter [14]. The changes taking place in the Polish economy and the dairy sector also contributed to a decrease in the amount of milk supplied for processing, which meant that dairy enterprises could not fully use their processing capacity, which consequently led to a deterioration of their financial situation. Due to the complicated situation on the food market, the Ministry of Agriculture and Food Economy has developed a "Program for the restructuring and modernization of the dairy industry" focusing on:

- achieving long-term profitability of milk production and processing, while maintaining moderate prices and guaranteed product quality,
- modernization of the dairy industry using modern infrastructure, conducting promotional activities and increasing the level of milk processing,
- stabilization of the dairy market with the help of an increase in domestic demand and supply and the creation of opportunities for exporting dairy products,
- increasing the competitive ability of the dispersed capital in order to optimize the use of production factors and resources, adjusting offers to market needs [14].

In order to improve the flow of current assets, most milk processors have set up their own chain of stores. The process of concentration of processing was carried out by extending the existing plants. The reduction of the production scale resulted in the deterioration of the financial situation of many plants and layoffs of employees. There were many small plants on the market that did not cooperate with other dairies. The result is competition between them, especially on the local market. Accelerating the concentration of milk production is the most important condition for meeting competition and taking advantage of the possibilities of the Polish dairy industry in the enlarged Union. Concentration of production continues to be the most important factor in reducing costs and improving the profitability of milk production and processing [14].

CHANGES IN MILK PRODUCTION IN POLAND IN 1995–2020

Domestic production determines the supply of milk in Poland [2]. The quota of milk produced in Poland from 1995 to 2020 reached the value of 11–13 billion liters per year. In the period before Poland's accession to the EU (1995–2003), the average annual volume of milk production in Poland was 11,631 million liters, and after the integration (2004–2012) it increased to 11,873 million liters, and after the removal of regulations on the milk market, production increased to 13 281 million l (Table 1).

Table 1. Average annual volumes of selected data on milk production in Poland in the period before and after accession to the EU (1995–2003) and after (2004–2012) and (2013–2020)

Tabela 1. Średnioroczne wielkości wybranych danych dotyczących produkcji mleka w Polsce w okresie przed akcesją do UE (1995–2003) i po niej (2004–2012) oraz (2013–2020)

	1995–2003	2004–2012	2013–2020 (2019*, 2020**)
Production [mln l]	11 631	11 873	13 281
Purchase [mln l]	6 785	8 684	11 075
Cow population [thous. Pcs.]	3 262	2 729	2 394
Milk yield [l/pcs]	3 569	4 381	5 985

* Estimate of IAFE-NRI for 2019

** IERiGŻ-PIB forecast for 2020

Source: Own study based on [27]

Źródło: Opracowanie własne na podstawie [27]

Intervention mechanisms of the Common Agricultural Policy (CAP), i.e. milk production quotation, as well as intervention prices for dairy products, or instruments stimulating internal demand (e.g. subsidizing milk fat in processing and consumption) and direct subsidies, compensating milk producers for lowering income due to price reductions, they are of key importance for the functioning of the milk market [2, 14]. In the years 2002–2011, over PLN 113 billion was allocated to the agri-food sector and rural areas under financial aid programs [2, 33]. In the dairy sector, one of the CAP regulation mechanisms aimed at limiting milk production was the quota system introduced in Poland in 2004, which indicated what amount of milk a given EU country could market in a quota year without bearing any financial consequences [25]. Based on the IERiGŻ (2008) report: Multiannual Programs 2005–2009, it was found that the national milk quota was increasing from 2004 to 2015, which was related to the activation of restructuring provisions by the European Commission (Fig. 1) [24]. The national milk quota in the quota years 2014/2015 amounted to PLN 10,056 thousand. tonnes and was compared to the quota year 2004/2005 by 676 thous. tons higher (Fig. 1). The purpose of the production quotation was to reduce the growing production surpluses and to stabilize the prices of dairy products. This system was to contribute to reducing the costs associated with the need to conduct extensive market intervention and the costs associated with the storage and management of the emerging stocks. In addition, the reduction in milk production was expected to increase milk prices and thus support producers' income [25]. On the other hand, the disadvantages of the milk quota system were the risk of paying penalties for exceeding milk production by the largest producers, which in consequence meant that producers who, as a result of the investments made, increased the efficiency of cows,

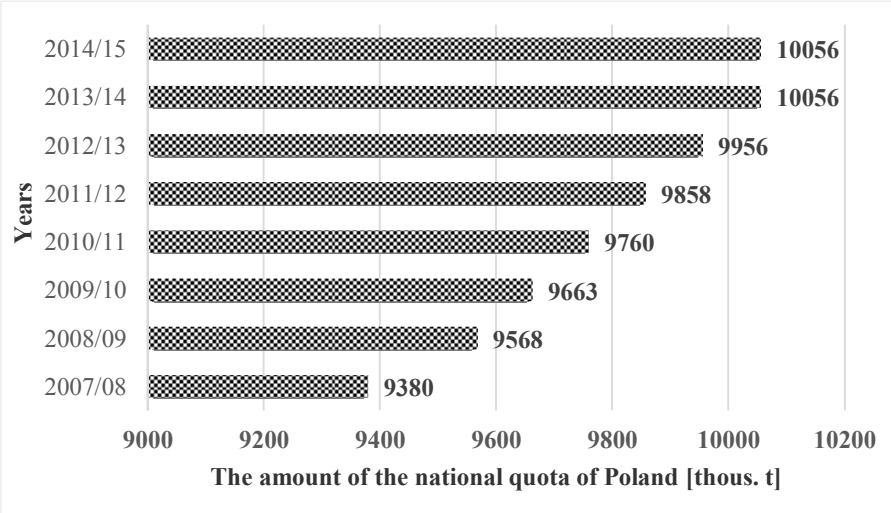

Fig. 1. The amount of the national quota of Poland [thous. t].
Rys. 1. Wielkość kwoty narodowej Polski [tys. t].
Source: Own study based on [27]
Źródło: Opracowanie własne na podstawie [27]

were most exposed to exceeding the limits granted to them. Another drawback of the quota system was that it helped small producers stay in the market. The limits bind small producers with collection points and processing plants and postpone the date of these producers' decisions about choosing other forms of earning money. In addition, the quota system created additional costs for processors and the quota administration. A number of disadvantages of the milk production quota system, as well as the progressive regionalization and concentration of production, and the reduction of the number of milk producers led the European Commission to decide to abolish milk quotas in 2015. According to the European Commission, the abolition of milk quotas will lead to an increase in milk production by about 5–6% and a decrease in its price [25].

Milk production is determined by two main factors: the herd of dairy cows and their productivity. The remaining determinants (eg weather conditions, economic situation) have an indirect impact on production [32]. The shaping of the volume of milk produced in Poland was a consequence of changes in the number of herds and their milk yield. The number of cows in Poland (according to the June data from IAFE) has significantly decreased in the entire period under study, i.e. from 3,579,000 units in 1995 to 2,190 thousand pcs. in 2020 [27], which is caused by the decreasing number of farms keeping cows (in 1996-2008 the number of milk producers decreased from 1.31 million to 0.55 million). In Poland, this phenomenon was accompanied by a slow process of concentration, with a clear fragmentation of production compared to the EU [2, 10]. In the period before the accession to the EU (1995-2003), the annual average number of cows amounted to 3,262 thousand. pcs, while after it (2004-2012) it decreased to 2,729 thous. pcs. and in the period (2013-2020), taking into account the period after the abolition of milk quotas, it decreased to 2,394 thous. pcs (Table 1). On the other hand, the milk yield of cows in the whole period studied increased from 3136 l / head. in 1995 up to 5850 l / unit in 2020 (increase by 53%) [27]. The dynamic improvement of milk production efficiency was caused by technological progress in production, but the factor limiting the improvement of milk yield of cows is the fragmentation of raw milk production, as genetic progress in small herds is small [2, 25]. In the years 1995–2003, the average annual milk yield was 3569 l / animal, while in 2013–2020 it increased to 5985 l / animal. (Table 1).

In the Polish dairy industry, the commodity production of raw milk is systematically increasing, as distribution is increasingly carried out through market channels. The dairy industry plays a decisive role in this respect, as it dynamically increases the purchase and processing of milk. At the same time, the direct sale of milk and milk products from farms is decreasing, as the number of small entities keeping cows is decreasing. The use of milk on farms includes consumption (self-supply) and fodder purposes. The dairy industry shows a great demand for the raw material [25]. In the distribution of domestic milk production from 1995 to 2020, a decrease in the use of milk on the farm, both for fodder and consumption purposes, can be observed (Table 2). Before Poland's accession to the EU, the average annual consumption of milk was 3266 million liters, of which 671 million liters were allocated to fodder, and 2583 million liters to consumption. (Table 2). However, after the accession to the EU and the abolition of milk quotas, a decrease in milk consumption by 1,426 million l was observed (Table 2). The reduction of milk consumption on the farm after the integration with the EU was influenced by the progressive disappearance of small milk production farms from the market, which faced high requirements in terms of milk production standards, animal welfare and formal procedures in connection with participation in the quota process [2, 12]. Due to the decrease in milk consumption on farms, its sale increased significantly. In 1995–2003 it amounted to an average of 8364 million liters, and in the period after accession (2004–2012) it increased by 12% to the level of 9373 million liters, while in the period 2013–2020 it increased by 22% to the level of 11,426 million liters (tab. 2). In the same period, the average annual sales of raw material for the dairy industry increased even more (by 66%). On the other hand, direct sales of milk to small processors decreased significantly (by 78%) (Table 2).

CHANGES IN MILK PROCESSING IN 1995–2020

In the dairy sector, there is a desirable industrialization trend in milk processing. The share of domestic milk processing is decreasing [25]. The economic and financial situation of the Polish dairy industry from 1995 to 2020 has significantly improved, despite the systemic transformation, adjustment measures related to the accession to the EU, the abolition of milk quotas, as well as the recession in the national economy caused by the COVID-19 pandemic and the introduction in March 2020 state of epidemiological emergency. The number

Table 2. Average annual disposals of national milk production in Poland in the period before and after accession to the EU

Tabela 2. Średnioroczne rozdysponowanie krajowej produkcji mleka w Polsce w okresie przed akcesją do UE oraz po niej

Years	Consumption on the farm [mln l]			Purchase/commodity production [mln l]				Total expenditures
	for feed	for consumption	Total	for the dairy industry	to the other processors	Other Purchase	total	
1995–2003	671	2 583	3 266	6 667	124	1574	8 364	11 631
2004–2012	536	1 956	2 491	8 579	105	698	9 373	11 873
2013–2020	566	1 274	1 840	11 041	34	351	11 426	13 266
Change [%]	-16	-51	-44	66	-73	-78	37	14

Source: Own study based on [27]

Źródło: Opracowanie własne na podstawie [27]

Table 3. Economic and financial results of milk processing and cheese production

Tabela 3. Wyniki ekonomiczno-finansowe przetwórstwa mleka i produkcji serów

Description	1995	2004	2010	2015	2018	2019
1. Number of dairies	336	265	205	177	163	156
2. Number of employed persons (thousand people)	56,30	42,20	34,90	32,24	32,89	32,94
3. Sales value (PLN million)	13,6	61,1	23,1	26,92	33,17	34,74
4. Gross profit for dairies (PLN million)	-	404	629	451,0	526,4	621,1
5. Profitability ratios (in% of revenues):						
- Gross profit	0,38	2,91	2,68	1,66	1,57	1,77
- Net profit	-0,29	2,31	2,21	1,31	1,28	1,36
- capital accumulation	3,5	-	4,86	3,57	3,23	3,27
-operating surplus			5,97	4,27	3,84	4,01
6. Financial costs in% of revenues	-	-	0,64	0,35	0,32	0,33
7. Current financial liquidity	1,41	1,32	1,51	1,41	1,62	1,59
8. Investment rate	-	-	1,34	1,35	1,35	1,45
9. Share of profitable companies (%):						
- in the total numer of companies	-	-	80,5	70,6	68,7	68,1
- in the revenues of the sector			93,2	84,5	85,5	90,8
10. Share of direct export in sales value (%)	-	-	10,6	15,2	16,7	18,4
11. The share of dairy in the sales value of the food industry (%)	-	-	13,7	12,3	12,6	12,3

* Data refer to enterprises employing 10 or more people;

Source: Own study based on IAFE-PIB calculations based on unpublished data of the Central Statistical Office

Źródło: Opracowanie własne w oparciu o obliczenia IERiGŻ-PIB na podstawie niepublikowanych danych GUS

of dairy industry entities is systematically decreasing. At the same time, milk processing is concentrated [25]. Currently, there are about 156 entities operating in Poland, in 2004 there were 265 of them, and in 1995 – 336 (Table 3). Along with the decrease in the number of dairy enterprises, there was a decrease in the number of employees in the dairy industry by 23.36 thousand people (41%) (Table 3). From 2004 to 2019, a decrease in the value of sales by PLN 26.36 million was observed (Table 3), while the gross profit of the dairy industry since the accession to the EU has increased by PLN 217.1 million, reaching the level of PLN 621.1 million in 2019 (Table 3). The share of profitable companies in the sales revenues of the dairy industry has a growing tendency since 2015 has increased from 84.5% to 90.8% in 2019 (Table 3) The dairy industry is characterized by safe financial liquidity, which in 2019 amounted to 1.67 and is able to settle current liabilities, in particular, it concerns raw material costs.

The Polish dairy industry continues its restructuring and modernization processes. The improvement in the financial situation contributed to the increase in the investment activity of enterprises. In the first half of 2020, capital expenditure amounted to PLN 359.2 million. The value of investment outlays was 18% higher than the value of depreciation write-offs, which means that enterprises systematically increase the value of fixed capital. The investment structure is dominated by expenditure on machinery and equipment (88.3%), but expenditure on buildings (14.8%) and means of transport (4.5%) also had a significant share. Investments also concerned the storage and logistics base, as well as energy installations and water and sewage management in order

to reduce costs related to environmental protection [27]. A significant investment boom was observed in the years 2002–2006, which was related to the adjustment processes taking place in dairy enterprises. The entities took actions necessary to meet the sanitary and veterinary requirements required to operate on the European market. In 2002–2006, PLN 3.5 billion was invested in dairy companies employing over 9 people. The largest expenditure was incurred in the year of Poland's accession to the EU. The investments made allowed a significant number of enterprises to start operating on the international market. Most dairies made investments related to the modernization of the milk collection system from the producer and improved the transport of milk to the dairy plants. The share of milk collected by dairies directly from agricultural producers increased. These activities significantly contributed to the improvement of the quality of milk produced [25]. One of the sources of financing investments in the dairy sector was the SAPARD program, launched before Poland's accession to the EU. In the years 2002–2006, more than 60% of the SAPARD funds allocated to support the dairy industry were invested in three voivodships: Mazowieckie, Podlaskie and Wielkopolskie. The value of average investments was the highest in the province Podlaskie (PLN 56.6 million) and Mazowieckie (PLN 30.5 million), where the strongest enterprises operated [25].

CHANGES IN MILK CONSUMPTION IN 1995–2020

The range of products manufactured by the food industry has changed since 1995. The range of manufactured products is adapted to the changing market situation. After Poland's accession to the EU, in the conditions of expanded export opportunities, dairy enterprises significantly increased the production of cheese, drinking milk, milk drinks and powdered milk (Fig. 2). The upward trend in cheese production continues, but the growth dynamics is much slower. Production is adjusted to the anticipated demand. The range of manufactured products must be constantly changing in order to meet the needs of consumers [25].

According to the Central Statistical Office (GUS) data, in 2019 the balance consumption of milk, including milk intended for milk products, without milk processed into butter, amounted to 228 l per capita and was 3.2% higher than in the previous year. The increase in consumption took place in the conditions of a relatively good economic situation on the international market and a real cheapening of dairy products in relation to food in general, including in particular meat and its products and fish [27]. The GUS household budget research shows that in 2019 the downward trend in the consumption of potable milk continued. The decrease in consumption was 2.4% compared to 2018. In 2019, the balance consumption of butter in Poland was 5.0 kg per capita and was 6.4% higher than in 2018. The consumption of butter reached the highest level since 1992 The main reason for the increase in consumption was the improvement in the income situation of households, the decrease in retail prices by an average of 4.5% and the change in the consumption model. Domestic consumers increasingly appreciate the taste and health benefits of butter [27].

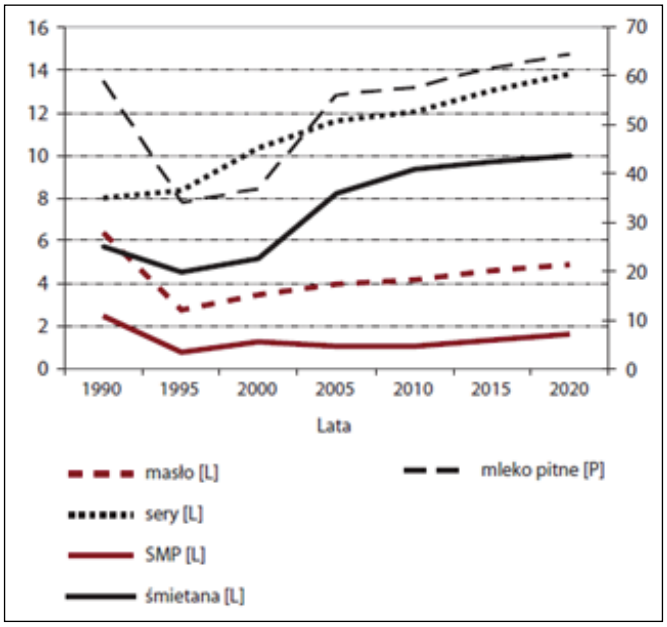

Fig. 2. Consumption of milk and dairy products [kg / person] in Poland in 1990-2005 and forecast until 2020 (L – left axis, P – right axis).

Rys. 2. Spożycie mleka i produktów mleczarskich [kg/ osobę] w Polsce w latach 1990-2005 oraz prognoza do 2020 roku (L – lewa oś, P – prawa oś).

Source: [1]

Źródło: [1]

IMPACT OF THE COVID-19 PANDEMIC ON THE DAIRY SECTOR IN POLAND AND THE RELATED FORECAST FOR 2021

As of March 2020, the entire world has been struggling with the Covid-19 pandemic. Humanity is concerned about the immediate and long-term health effects that Covid-19 could cause. Despite the fact that human health and life are perceived as the highest commodities, the economic consequences of the Covid-19 pandemic also deserve attention [30]. Reliable assessment of these effects, inter alia, for the food industry, including the dairy sector, is currently not fully possible, which is related to the advancement of the pandemic, the scale and directions of its spread, and insufficient knowledge about the value and scope of food market support from both the state and EU institutions. Food producers were less affected by the effects of the Covid-19 pandemic than other branches of industrial processing, as the products produced in this sector are basic products, and therefore have lower income elasticity of demand. Market observations and reports from economic practice confirm that the food industry, including the dairy sector, is doing well during the pandemic. Producers of food products and beverages take a number of steps to ensure food production, along with reducing the obstacles associated with the Covid-19 virus on work efficiency. Processors faced the challenges of reorganizing work, adapting to new legal norms and the additional costs associated with it, in other words minimizing risk, while maintaining business stability in the long term [30]. According to the authors of the report

entitled: Food Foresight: *The impact of COVID-19 on the food sector in Central and Eastern Europe developed by EIT Food at the request of the European Commission* [2020], changes in purchasing habits and the emergence of new consumer trends are changing the structure of demand for food to which they will be food producers forced to adapt. Nowadays, after a period of buying in stock, consumers have entered the phase of purchasing less frequently but in larger quantities. Ecological, traditional and branded products are popular because their health and nutritional values are appreciated to a greater extent. For food safety, packaging is also important - products that are hermetically sealed by the manufacturer and products in collective packaging gain. A chance for the development and production growth of food companies is not only to adjust the structure of supply to the changing structure of domestic demand, but also to acquire and recognize new markets where food shortages have been revealed [6, 30].

The impact of the COVID-19 pandemic may be more or less noticeable and varied depending on the specificity of production and the operating conditions of individual sectors of the food industry. According to Szczepaniak et al. [2020] the possible impact of the Covid-19 pandemic on the dairy sector in Poland in a short period of time may manifest itself, inter alia, in turbulences in the export of milk and its products, egg powdered milk, which cannot always be absorbed by the domestic market; problems with the export of dairy products may increase their supply to the internal market and, as a result, lead to a drop in prices and a temporary reduction in companies' revenues [30]. On the other hand, in the long term, the Covid-19 pandemic in the dairy sector may result in problems with the export of milk and its products, which will result in an increase in their supply to the domestic market and, consequently, cause a drop in prices and a long-term reduction in companies' revenues. Another effect for the dairy sector in the long-term perspective, due to the high connection of the Polish dairy sector with the world market, is a possible decline in the revenues of dairy companies if the prices of milk and its products fell on world markets [30].

According to experts of the Institute of Agricultural and Food Economics, in 2021 the upward trend in balance milk consumption will be halted, which will be a consequence of the Covid-19 pandemic lasting from March 2020, which results in a recession in the national economy, deterioration of the labor market situation, decrease in consumer income and restrictions in the movement of the population. As a consequence, households will reduce their expenses on food, including milk and milk products [35]. According to Śmigielska (2020), in 2021 the milk market in Poland will be affected by the economic recession, and the dairy sector will continue its restructuring processes. Experts forecast that in 2021 the total number of cows will decrease by 1.5% to 2,450,000. heads, and dairy cows by 1.6% to 2,190 thousand. pcs. The average yield of dairy cows will increase to 6540 l per animal. and will compensate for the drop in the stock, which will contribute to the increase in milk production by 0.6% to the level of 14.5 billion liters. Raw material supplies to processing plants will increase by 2.6% and will amount to 12.5 billion liters [32, 35]. The pandemic will not disrupt international trade. Exports of dairy products in milk equivalent will increase to 5.1 million tons, and imports to 2.2 million tons. In terms of value, exports will increase to the level of EUR 2.5 billion. Export will be necessary with the growing milk production and the decline in consumption in Poland. In 2021, the consumption of milk and its products should be at the level of 226 l / person, and of butter – 4.7 kg / person. Next year, the prices of the raw material will mainly depend on the economic situation on the world market. In a situation where the economic recession caused by the pandemic will not last too long, milk prices in Poland should remain at the level of PLN 1.35 / l. However, if the recession continues for an extended period of time, export problems may arise. The increase in production will contribute to the excess supply, which will cause prices to fall to the level of 1.30 – 1.33 PLN / l [32, 35].

SUMMARY

Based on the review of the literature on the subject and the conducted research analyzes in the field of determining the significance of changes taking place in the Polish dairy sector in 1995–2020 in the field of production, processing and consumption of milk in Poland, it was found that:

- In 1995–2020, significant progress was achieved in increasing cow milk yield, increasing production concentration and improving the quality of raw milk production. The improvement of cows' milk yield was achieved through the use of modern cow feeding techniques and breeding methods.
- Integration with the European Union and the introduction of the Common Agricultural Policy stimulated the restructuring of the dairy sector. Restructuring activities were forced by the need to comply with high sanitary and veterinary production standards. Moreover, a significant improvement in the profitability of milk production after the accession resulted in an increased interest in cattle breeding and facilitated the restructuring of farms producing milk.
- In 2004–2015, the volume of milk production was limited by its limitation. The introduced system of limiting milk production did not allow for its increase. This system administratively determines the sales volume and makes it difficult to adapt smoothly to the changing market.
- In milk processing in Poland, the production concentration process took place. The number of dairy industry entities is systematically decreasing. Plants that did not comply with EU requirements had to be closed, others merged or were taken over.
- The Covid-19 pandemic announced by the World Health Organization in March 2020 has a significant impact on changes in the consumption of milk and dairy products. The Covid-19 pandemic has changed consumer attitudes regarding food consumption. Enterprises in the dairy sector have undertaken a number of measures to adapt to functioning in the conditions of a pandemic, which was fostered by the launch of various protective measures by the state. In the long run, dairy companies themselves will have to take care of planning and risk management strategies, investments in digitization and automation, and the integration of production management systems with distribution systems. These activities will help to ensure

the continuity of supply chains in various crisis situations. An appropriate economic policy and the involvement of entrepreneurs may allow the current level of development of the Polish dairy sector to be maintained.

PODSUMOWANIE

W oparciu o przegląd literatury przedmiotu oraz przeprowadzone analizy badawcze dotyczące określenia znaczenia zmian zachodzących w polskim sektorze mleczarskim w latach 1995–2020 w zakresie produkcji, przetwórstwa oraz spożycia mleka w Polsce stwierdzono, że:

- W latach 1995–2020 osiągnięto znaczny postęp w zakresie zwiększenia mleczności krów, zwiększenia koncentracji produkcji i poprawy jakości produkcji mleka surowego. Poprawę mleczności krów osiągnięto w wyniku stosowania nowoczesnych technik żywienia krów i metod hodowlanych.
- Integracja z Unią Europejską i wprowadzenie Wspólnej Polityki Rolnej stymulowało restrukturyzację sektora mleczarskiego. Działania restrukturyzacyjne były wymuszane przez konieczność przestrzegania wysokich standardów sanitarnych i weterynaryjnych produkcji. Znaczna poprawa opłacalności produkcji mleka po akcesji spowodowała ponadto wzrost zainteresowania chowem bydła i ułatwiała restrukturyzację gospodarstw produkujących mleko.
- W latach 2004–2015 wielkość produkcji mleka była ograniczona przez jej limitowanie. Wprowadzony system limitowania produkcji mleka nie pozwalał na jej zwiększenie. System ten, w sposób administracyjny określa wielkość sprzedaży i utrudnia płynne dostosowanie się do zmieniającego się rynku.
- W przetwórstwie mleka w Polsce nastąpił proces koncentracji produkcji. Liczba podmiotów przemysłu mleczarskiego systematycznie maleje. Zakłady, które nie dostosowały się do wymagań unijnych musiały zostać zamknięte, inne połączyły się lub zostały przejęte.
- Na zmiany w konsumpcji mleka i artykułów mleczarskich istotne znaczenie ma pandemia Covid-19 ogłoszona przez Światową Organizacje Zdrowia w marcu 2020 roku. Pandemia Covid-19 przyczyniła się do zmian postaw konsumenckich w zakresie spożywania żywności. Przedsiębiorstwa sektora mleczarskiego podjęły szereg działań dostosowawczych do funkcjonowania w warunkach pandemii, czemu sprzyjało uruchomienie przez państwo różnego rodzaju środków osłonowych. W dłuższej perspektywie przedsiębiorstwa mleczarskie same będą zmuszone zadbać o strategie planowania i zarządzania ryzykiem, inwestycje w cyfryzację i automatyzację oraz integrację systemów zarządzania produkcją z systemami dystrybucyjnymi. Działania te będą sprzyjać zapewnieniu ciągłości łańcuchów dostaw w różnych sytuacjach kryzysowych. Odpowiednia polityka gospodarcza i zaangażowanie przedsiębiorców pozwolą utrzymać dotychczasowy poziom rozwoju polskiego sektora mleczarskiego.

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FOOD ENRICHED WITH DIETARY SUPPLEMENTS®

Żywność wzbogacana w suplementy diety®

The article deals with the subject of fortified foods and dietary supplements. Methods of food enrichment, their forms and doses, examples of fortification and its effects on health were discussed. Then, the subject of dietary supplements was introduced, their basic chemical composition, health risks resulting from inept use of supplementation were presented, and a criterion for the division of dietary supplements was created. Dietary supplements can be divided according to their composition and chemical structure, function and form. An example of a dietary supplement was a drink with green tea extract based on nano-water, which was created in low-temperature plasma.

Key words: dietary supplements, low-temperature plasma, food, nanowater, health risks, functional food.

W artykule zajęto się tematem żywności wzbogacanej oraz suplementów diety. Omówiono metody wzbogacania żywności, ich formy oraz dawki, przykłady fortyfikacji i jej skutki dla zdrowia. Następnie przybliżono temat suplementów diety, przedstawiono ich podstawowy skład chemiczny, zagrożenia zdrowotne będące następstwem nieumiejętnego korzystania z suplementacji oraz stworzono kryterium podziału suplementów diety. Suplementy diety można podzielić ze względu na skład oraz budowę chemiczną, spełnianą funkcję oraz formę. Za przykład suplementu diety posłużył napój z ekstraktem z zielonej herbaty na bazie nanowody, która powstała w niskotemperaturowej plaźmie.

Słowa kluczowe: suplementy diety, niskotemperaturowa plazma, żywność, nanowoda, zagrożenia zdrowotne, żywność funkcjonalna.

ADMISSION

It has been known since ancient times that one of the most important determinants of health is diet. Proper human nutrition is based on the complete coverage of the body's demand for energy and all the ingredients necessary for the development of life and maintaining health. The key to this is a properly varied diet that will provide all the necessary nutrients in the right amounts [7].

Food has undergone a great evolution over the centuries. The translation of technological progress into everyday life is the reason for significant changes in lifestyle, unfortunately, it should be remembered that these are not always only changes beneficial to health. At the same time, this situation is accompanied by a great deal of consumer interest in maintaining health and slowing down the aging processes. People want to live in full health as long as possible, which is why the demand and interest in food with a targeted, desired effect on the body has been growing for many years.

The term functional food began to appear in world literature from the early 90's. The concept of such food comes from the philosophical tradition of the East in which there is no discernible difference between medicines and food. It has been practiced for centuries to add plant extracts to food and drink to improve human health. Functional food is therefore a continuation of this long-chosen direction. Today, thanks to a very in-depth knowledge of the characteristics of human health and the use of the latest technologies of treatment, it is possible to produce additional substances, the production of which will result in further development of this currently "free" activity in the field of pro-health food, as well as its legal regulation [10].

Another way to avoid macro and micronutrient deficiencies is to use dietary supplementation. This is one type of nutrition rationalization strategy. Dietary supplements using the form of pharmaceutical preparations are in the form of tablets, but remember that they are not drugs. In developing countries, they are a tool for the authorities to combat the most common shortages among the population, in developed countries they are a product that fits in the new trend of taking care of health, using prophylaxis, improving well-being, increasing physical performance or maintaining a slim figure. Reaching for

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synthetic substitutes for vitamins and ingredients is not fully safe and known.

PURPOSE AND SCOPE OF WORK

The aim of the work presented in the article was to analyze, characterize and classify dietary supplements and food additives as enrichment ingredients. The paper presents the criteria for the division of these substances, and also discusses one of the dietary supplements available on the market, which is a drink with green tea extract. This drink is a nano-water dietary supplement. It is an example of one of the dietary supplements available.

The scope of work includes:

– literature review (characterization of food enrichment substances, characteristics of dietary supplements, literature division of these substances, chemical composition, organoleptic evaluation, division of food containing enrichment ingredients, dietary supplements available on the market, their advantages and disadvantages.
– research methodology (criteria, conditions for the classification of dietary supplements, enrichment ingredients).

ENHANCING FOOD

The term functional food first appeared in 1984 in Japan, and in 1991 legal regulations and a special procedure were created that allowed for the granting of status to functional food products. In 1996, the FUFOSE (Functional Food Science in Europe) research program was launched, financed by the European Union, the aim of which was to scientifically define the foundations for the concept of functional food in the European Union and to develop criteria, directions and ways of implementing functional food products in Europe.

Many countries have their own interpretations of the concept of functional food, but work on creating a universal definition is ongoing. The most famous definitions are:

- they are specially prepared food products that have a proven beneficial effect on health [2],
- "A food can be considered functional if it has been proven to have a beneficial effect on one or more bodily functions over and above the nutritional effect of improving health and well-being and / or reducing the risk of disease. Functional foods must resemble conventional foods and have beneficial effects in amounts that are expected to be consumed normally with the diet – they are not tablets or capsules, but part of a healthy diet "[5],
- food and drinks that improve the physical and mental quality of life, facilitate the increase of physical performance or the proper development or recovery after suffering severe illnesses, may also improve health or reduce the risk of its risks, thus meeting the expectations of high-awareness consumers health [1].

Food enrichment, also known as fortification (enchrimentfortification), as defined by the FAO / WHO (CodexAlimentarius 1994) is the addition of one or more nutrients to a food, whether normally present in the food or not, in to prevent and correct existing deficiencies of one or more nutrients in entire populations or specific groups of the population [4]. Groups that are at risk of such deficiencies are children, adolescents during intensive growth and development, pregnant and breastfeeding women, elderly people, people exposed to a high stress factor, people practicing sports, people on dieting, people taking drugs with a destructive effect on the body, convalescents, alcoholics, smokers, as well as people with diseases of the digestive system.

There are three basic options for food enrichment depending on the desired goal: intervention enrichment is directly related to the prevention and combating of specific shortages; compensatory enrichment consists in directly increasing the nutritional value of a food product; Improved enrichment consists in imparting properties desired by the consumer to food, often creating new characteristics and significantly improving the health quality of such products.

According to the recipes, you can enrich both products that already contain a certain amount of a given nutrient in their composition, as well as those products that naturally do not contain a given ingredient. In order to choose the right carrier, one should have the necessary information, such as knowledge of the nutritional situation of a given population, knowledge about the amount and type of deficient nutrients. The product intended to be a carrier should be easily available and commonly consumed among consumers in the population at risk. In developing countries, the most vulnerable population is poor villagers whose diets are self-produced. This is related to the fact that industrially manufactured products are not used, which makes it difficult to select the appropriate carrier. In such a situation, salt or sugar is enriched, or specific commercial preparations are distributed for the self-enrichment of meals prepared in households. However, it should be remembered that producers and consumers not threatened with a deficit of a given ingredient should also have access to products that do not contain enriching substances. An example is the inhabitants of coastal areas, where the consumption of iodized salt could lead to thyrotoxicosis.

In the ideology of food enrichment in various countries of the world, products such as flour, rice, long-lasting and confectionery bread, cereal products, pasta, milk and milk drinks are used as a carrier [3].

"Only those micronutrients which are a source of food and which are considered essential for the nutrition of the human body should be added to food products, and at the same time in the form and dose in which they are safe and digestible" [6].

The enrichment substances are most often synthetic compounds, but also concentrates or isolates from natural sources are used. Their important feature should be low price and stability, without losing the bioavailability of a given nutrient.

Food is most often enriched with substances such as: dietary fiber, vitamins A, C, D, E and B vitamins, minerals, lecithin, polyunsaturated fatty acids, amino acids, caffeine. Table 1 shows the most commonly used enrichment substances, and table 2 shows the bioactive ingredients used in food fortification.

Table 1. The most commonly used enrichment substances and their doses [6]

Tabela 1. Najczęściej stosowane substancje wzbogacające i ich dawki [6]

Nutrient (enrichment substance)	Products – carriers	The added amount per 100 g of the product
Amino Acids (Synthetic Amino Acids)	Grain products, soy meat substitutes, preserves for children and babies	0,01 – 0,1 g
Calcium (calcium carbonate, CCM, calcium phosphate, dried whey, calcium lactate)	Wheat flour, corn flour, bread, breakfast cereals, powdered milk	100 – 400 mg
Iron [iron (II) sulfate (VI), iron (III) fumarate, iron (III) citrate, iron (II) gluconate]	Wheat flour, corn flour, bread, breakfast cereals, powdered milk	0,5 – 5,0 mg
Iodine (potassium iodide, potassium iodate)	Salt, butter, and bread	0,5 – 3,0 mg
Vitamin A (retinol, β – carotene, retinyl acetate, retinyl citrate,	Margarines, vegetable oils, milk, flour, cereals, pasta, desserts, drinks, sugar, monosodium glutamate	0,1 – 2,0 mg
Vitamin D (cholecalciferol, ergocalciferol)	Margarines, milk, dairy products, cereal products	1,5 – 10,0 μg
Vitamin E (α – tocopherol acetate, tocopherol concentrate, γ and δ tocopherol)	Vegetable oils, margarines, salad dressings, confectionery fats, lard	5 – 20 mg
Vitamin C (L – ascorbic acid)	Fruit and carbonated drinks, vegetable preserves, powdered milk, dry grain products, powdered drinks, salt	5 – 20 mg
B vitamins	Fruit juices, drinks, flour, cereals, pasta, rice, bread, dairy products	10 – 100 mg np. B1, B2, B6 0,1 – 2,0 mg, PP do 10,0 mg

Table 2. Bioactive natural ingredients used in food fortification

Tabela 2. Bioaktywne składniki naturalne stosowane we wzbogacaniu żywności

Natural bioactive ingredients	Examples	Health benefits
Dietary fiber	betka – glucans, pectins, guar, alginates, resistant starch	reducing blood cholesterol levels, preventing constipation
Amino acids, peptides, proteins	creatine, carnitine, glutamic acid, taurine, tyrosine, protein hydrolysates, protein concentrates and isolates	proper tissue structure, regulation of metabolic processes, easier absorption of minerals
Oligosaccharides (so-called prebiotics)	stachiosis, inulin, raffinose, lactulose, oligofructose	stimulating the development of probiotic intestinal flora, reducing blood cholesterol levels, preventing constipation
Polyols	xylitol, maltitol, lactitol, isomalt, sorbitol	reducing blood glucose levels, inhibiting the development of caries
Polyunsaturated fatty acids	from the omega 3 group: lionolenic acid, ecosapentaenoic acid, docosahexanoic acid	preventing cardiovascular diseases, inhibiting inflammation and allergies, proper development of the nervous system
Vitamins	from group B, D, antioxidant (A, C, E)	regulation of metabolic processes, neutralization of free radicals, stimulation of the immune system
Minerals	calcium, magnesium, iron, zinc, selenium, iodine, manganese	ensuring proper bone mineralization, regulation of metabolic processes, stimulation of the immune system
Choline and lecithin	soybean, rapeseed, egg	improving the functioning of the central nervous system, easier digestion of fats
Lactic fermentation bacteria (so-called probiotics)	Lactobacillusacidophilus, L. plantarum, L. rhamnosus, Bifidobacteriumbifidum	preventing constipation, reducing cholesterol, preventing colon cancer, stimulating the immune system
Phytochemicals	polyphenolic compounds, flavonoids, caffeine, glycosides, phytosterols	different depending on the substance, e.g. counteracting cancer, cardiovascular diseases, general improvement of mood and others.

Source: [1, 5, 6]

Źródło: [1, 5, 6]

EXAMPLES OF FORTIFICATION AND ITS EFFECTS ON HEALTH

The most common salt iodization procedure is in Europe and South America, while in Australia the carrier for iodine is bread, and in South America – butter. The idea of salt iodization was born in 1922 in Switzerland, where there was a problem of iodine deficiency among the inhabitants. Table salt was first enriched with a dose of 3.75 and then it increased to 15 mg KJ / kg, thanks to which over time the problem of iodine deficiency in the Swiss diet was eliminated. In Poland, salt iodization began in 1935, adding 5 mg KJ / kg of the product [3]. Already during the Second World War, due to large calcium deficiencies in Europe and North America, flour was enriched with calcium carbonate. In Poland, calcium carbonate is fortified mainly with flour and cereal products in the amount of up to 3 g / kg of the finished product. Table margarines belong to the most frequently fortified foodstuff. In Poland, when the production of margarines began, they were immediately enriched with vitamins A and D, and recently with vitamin E. „Vitamin preparations in the form of an oil solution are introduced together with other components into the tank where mixing and emulsion production takes place. The addition of vitamins can be carried out by means of a slurry system – or a continuous system – the vitamin solution is dispensed successively by means of a multi-head dosing pump. The latter system ensures a more even distribution of the enrichment additive and reduces fluctuations in the vitamin content of the finished product" [6]. Sugar began to be used as a carrier in Central America since 1970, when several countries in the area experienced large vitamin A deficiencies among the inhabitants. The reason why this carrier was chosen was the fact that sugar was a product commonly consumed also among the poor and rural population. Sugar is enriched by adding 15µg of retinol / g of freshly crystallized sugar, followed by homogenization and drying. As a result, in the group of people at risk (ie preschool and school-age children and nursing mothers) an increase in serum vitamin A level by half and a reduction in the incidence of clinical symptoms of the disease was observed [3].

RESEARCH METHODOLOGY

The experimental object discussed in the article is a drink with green tea extract by NANTES LIFE, which is an example of one of the available dietary supplements. Thanks to the treatment of water in a low-temperature plasma reactor, its structure is changed, or more precisely, the structure is ordered, thanks to which the water acquires new properties – no it does not freeze or boil at its usual temperatures, it is highly absorbable (the ability to easily penetrate cells).

Cold plasma formation process.

Plasma is the fourth gas-like state of matter. In order to generate plasma, a certain amount of energy must be supplied, which will allow the first phase to change substances from a solid to a liquid, then into a gas, and finally into a plasma [9,11].

"In plasma technologies, plasma is divided into three types, namely: high-temperature plasma (in the Anglo-Saxon nomenclature it is called high plasma temperature, equilibriumplasma), low-temperature spot (thermalplasma, quasi-equilibriumplasma) and plasma known as non-thermal, cold (non-thermalplasma, non-equilibriumplasma, coldplasma)" [8].

Fig.1. Drink with green tea extract.
Rys. 1. Napój z ekstraktem z zielonej herbaty.
Source: Owen study
Źródło: Opracowanie własne

The energy necessary to convert the neutral gas to plasma depends on the ionization and dissociation of the gas. Plasma, due to the wide range of temperature and pressure within which it can occur, is the state of aggregation that most often occurs in the universe. However, on our planet, the state of plasma is rare, only in the form of aurorae. Plasma generated at low temperatures, known as cold or low-temperature plasma, is a mixture of ionized and non-ionized particles, ground and excited atoms, free radicals and electrons. Currently, scientists have developed a method for producing low-temperature plasma under atmospheric pressure. Many research teams construct low-temperature plasma generators on their own. "The prototype set of devices (Fig. 2) for plasma generation in laboratory conditions under atmospheric pressure consists of a ceramic tube through which an appropriate mixture of gases, an electrode assembly and a high-voltage generator is supplied" [11].

"The tube is surrounded by a copper coaxial electrode connected to a high voltage generator (6.5 – 16 kV, 23 – 38.5 kHz). In turn, the second electrode (earth electrode) is placed at such a distance from the end of the ceramic tube to allow the flow of the generated plasma and create a place for placing the sample. The plasma generated in this way in the vicinity of the air appears as a bright purple cloud, which is called CAP-pen (coldatmosphericplasmapen)" [11].

Basic features of nanowire:

Unlimited penetration properties through any, even damaged cell membrane. The combination of water with preparations, thanks to the maintenance of nanoparticle bonds at the level of individual molecules, increases the penetration and concentration of dissolved active components. Maintaining atomic bonds, preserving the achieved nanostructure,

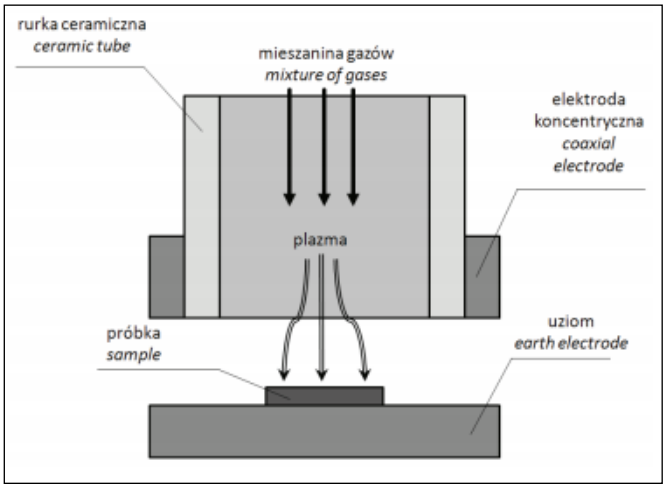

Fig. 2. Diagram of a device for the production of low-temperature plasma CAP – pen [11].
Rys. 2. Schemat urządzenia do wytwarzania niskotemperaturowej plazmy CAP – pen [11].

preventing re-aggregation, up to 60 days. The increased chemical and biological activity of nanowires allows for the dissolution of sparingly soluble organic compounds.

GREEN TEA EXTRACT

Drink with green tea extract

The ingredients transported by water nanoparticles reach the places that require regeneration. Thanks to nanoparticles, polyiefenols and strong antioxidants contained in green tea capture free radicals in the body with double their power. The substances contained in green tea, transported thanks to nanoparticles, can lower the risk of a heart attack and atherosclerosis, and even serve as cancer prophylaxis. The uniform crystal lattice of declustered water in the form of pure or nutrient solutions not only helps to eliminate anomalies, but also stimulates the regeneration processes of tissues and organs affected by the lesion.

SUMMARY

Enriched foods and dietary supplements are becoming more and more popular among consumers. They are commonly available in pharmacies, shops or on websites. All negative aspects of food and everyday diet resulted in the appearance of enriched foods with added chemical compounds that are a source of vitamins and minerals. Products with probiotics such as kefirs and yoghurts are enriched, as well as salt (iodine), flour (folic acid), cereals, margarines, eggs, etc. Consuming fortified products should not reduce efforts to plan a balanced and varied diet. Thanks to the increasing knowledge about a healthy lifestyle, with the simultaneous lack of time for careful diet planning, people turn to vitamin and mineral substitutes. The effect of using supplementation may be an improvement in the functioning of, for example, the immune, digestive and blood systems, concentration or vitality, beauty, vision or increased physical performance and reduction of the negative effects of intense physical effort. The effects of substances used in dietary supplements are not fully understood, and the evidence for the advantages and disadvantages of consumption is unclear. Therefore, the topic requires further work, in particular the development of the role of substances at the cellular level throughout life. When using dietary supplementation, remember to control the amount of vitamins and minerals from food in relation to the amount of synthetic forms of vitamins and minerals.

In the above work, nanowater with green tea extract from Nantes was used as an example of a dietary supplement. The basic element of this dietary supplement is nanowater, which was formed in a low-temperature plasma reactor. Thanks to the declastation process, water acquires new properties, e.g. it permeates through any, even damaged membrane. This feature is the most important in terms of consuming the supplement, because the taken preparation is absorbed with great efficiency, and the final health effects will still have to wait – with further research in this area.

PODSUMOWANIE

Żywność wzbogacona i suplementy diety cieszą się coraz większą popularnością wśród konsumentów. Dostępne są powszechnie w aptekach, sklepach lub na stronach internetowych. Wszelkie negatywne aspekty dotyczące żywności oraz codziennej diety spowodowały, iż pojawiła się żywność wzbogacana do której dodano związki chemiczne które są źródłem witamin i składników mineralnych. Wzbogaca się produkty z probiotykami czyli kefiry, jogurty, a także sól jodowaną, mąkę z kwasem foliowym, produkty zbożowe, margaryny i jaja itd. Spożywanie produktów wzbogacanych nie powinno zmniejszać wysiłków na rzecz planowania zbilansowanej i zróżnicowanej diety. Dzięki zwiększającej się wiedzy o zdrowym trybie życia przy jednoczesnym braku czasu na dokładne układanie diety ludzie sięgają po substytuty witamin i minerałów. Efektem stosowania suplementacji może być poprawa funkcjonowania np. układu immunologicznego, trawiennego, krwionośnego, koncentracji lub witalności, urody, widzenia lub zwiększenia wydajności fizycznej i zmniejszenie negatywnych skutków intensywnego wysiłku fizycznego. Działanie substancji stosowanych w suplementach diety nie jest w pełni poznane a dowody na zalety i wady dotyczące spożywania są niejasne. W związku z tym temat wymaga dalszych prac a w szczególności opracowania roli substancji na poziomie komórkowym na przestrzeni całego okresu życia. Stosując suplementację diety należy pamiętać aby kontrolować ilości dostarczanych witamin i składników mineralnych pochodzących z pożywienia w stosunku do ilości przyjmowanych syntetycznych form witamin i składników mineralnych.

W powyższej pracy za przykład suplementu diety posłużyła nanowoda z ekstraktem z zielonej herbaty firmy Nantes. Zasadniczym elementem tego suplementu diety jest nanowoda, która powstała w reaktorze niskotemperaturowej plazmy. Dzięki procesowi deklastracji woda przyjmuje nowe właściwości np.. przenikanie przez każdą nawet uszkodzoną błonę. Ta cecha jest najbardziej istotna w ujęciu spożywania suplementu, ponieważ przyjmowany preparat wchłania się z dużą skutecznością, a na ostateczne efekty zdrowotne trzeba będzie jeszcze poczekać – prowadząc dalsze badania w tym zakresie.

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THE NUTRITIONAL AND HEALTH VALUE OF FRUIT, VEGETABLE AND FRUIT-VEGETABLE JUICES®

Wartość odżywcza i zdrowotna soków owocowych, warzywnych i owocowo-warzywnych®

Juices are obtained from the edible part of one or more types of fruit, which may be fresh or chilled. They are characterized by the color, aroma and taste typical of a given fruit. The main ingredient of juices is water, which is essential for the proper functioning of the body. Fruit juices, as well as vegetable and fruit-vegetable juices are characterized by relatively high nutritional value and concentration of pro-health compounds, the so-called phytochemicals. These are, for example, carotenoids (α- and β - carotene, lycopene, lutein), vitamins A, C, E and B vitamins, as well as polyphenols that have antioxidant properties and reduce the effects of oxidative stress, thus limiting the development of diseases such as cancer, ischemic heart disease or neurological diseases.

Key words: fruit juices, vegetable juices, fruit-vegetable juices.

Soki pozyskiwane są z części jadalnej jednego lub kilku gatunków owoców, które są w stanie świeżym lub schłodzonym. Charakteryzują się typową dla danego owocu barwą, aromatem i smakiem. Głównym składnikiem soków jest woda, która jest niezbędna do prawidłowego funkcjonowania organizmu. Soki owocowe, jak również warzywne i owocowo-warzywne charakteryzują się stosunkowo dużą wartością odżywczą oraz koncentracją związków o charakterze prozdrowotnym, tzw. fitozwiązków. Są to na przykład karotenoidy (α– i β – karoten, likopen, luteina), witaminy A, C, E i witaminy z grupy B, a także polifenole mające działanie przeciwutleniające oraz zmniejszające skutki stresu oksydacyjnego, przez co ograniczają one rozwój schorzeń, takich jak nowotwory, choroba niedokrwienna serca, czy schorzenia neurologiczne.

Słowa kluczowe: soki owocowe, soki warzywne, soki owocowo-warzywne.

INTRODUCTION

According to the definition provided in Directive 2012/12/EU of the European Parliament and of the Council of April 19, 2012 amending Council Directive 2001/112/EC relating to fruit juices and certain similar products intended for human consumption, fruit juices are unfermented products, but capable of for fermentation. They are obtained from the edible part of one or more types of fruit, which may be fresh or chilled. They are characterized by the color, aroma and taste typical of a given fruit [4]. Fruit juices, as well as vegetable and fruit-vegetable juices are characterized by relatively high nutritional value and concentration of pro-health compounds, the so-called phytochemicals. These are, for example, carotenoids (α- and β - carotene, lycopene, lutein), vitamins A, C, E and B vitamins, as well as polyphenols that have antioxidant properties and reduce the effects of oxidative stress, thus reducing the risk of developing diseases such as such as cancer, ischemic heart disease or neurological diseases. The content of phytochemicals in juices depends on the raw material used in the production [4].

DIVISION OF JUICES

Taking into account the raw material used to produce the juice, the following juices are distinguished: fruit, vegetable and fruit-vegetable. Continuing this division, we can distinguish single-ingredient, two-ingredient and multi-ingredient juices. The second criterion according to which juices can be divided is the type of intermediate from which the juice was made. Juices can be natural, i.e. produced simply by squeezing fruit juice or reconstituted from concentrated juices (concentrates). Another division concerns the method of thermal processing of juices. In this case, juices are divided into juices: unpasteurized, pasteurized at low temperature and pasteurized. Juices that have been pasteurized contain fewer compounds (including antioxidants) that are not resistant to elevated temperatures [33]. During production, the juices are thermally fixed by pasteurization at a temperature of about 100º C. The most common method of preserving juices is the HTST method, i.e. the action of the temperature of 95ºC for 15-30 seconds and is aimed at inactivating enzymes, microbiological stabilization of the juice, starch gluing and protein denaturation [11].

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Juices can also be divided according to their appearance and consistency. Depending on this discriminant, we are talking about the following juices: clarified, naturally cloudy, puree [13,14]. Naturally cloudy and puréed juices, compared to those subjected to clarification processes, contain fiber and contain more substances with antioxidant properties and vitamins [12].

ENERGY AND MACRONUTRIENT CONTENT

The main component of juices is water, which performs many important functions in the body and, above all, is the main component of each emerging cell and tissue, it is an excellent solvent, participates in thermoregulation and plays a protective and moisturizing role. In fresh juices and drinks, its content is in the range of 85-100%, so they can be a source of water in the daily diet [17]. The next nutrient that is found in high levels of juices is carbohydrate. Depending on the type, juices contain from 2.7 g to 15.8 g of carbohydrates in 100 ml of the product, and their calorific value ranges from 18 kcal/100 ml to 67 kcal/100 ml, respectively. Due to the relatively high content of simple sugars in juices, it is recommended to consume no more than one glass of this product per day. Protein and fat are present in a very small amount, while some vegetable and raw juices contain relatively large amounts of dietary fiber [4]. Vegetable juices provide more nutrients, and at the same time are less caloric, because they contain much less carbohydrates, mainly simple sugars, than fruit juices [26]. Juices are a good variety and complement of daily diet. Table 1 shows the energy value and the content of selected macronutrients and dietary fiber in juices [17].

Table 1. Energy value [kcal], content of selected macronutrients [g] and dietary fiber [g] in juices per 100 g of the product

Tabela 1. Wartość energetyczna [kcal], zawartość wybranych makroskładników [g] oraz błonnika pokarmowego [g] w sokach w 100 g produktu

Type of juice	Energy value	Protein	Fat	Carbohydrates	Dietary fiber
Grapefruit	40	0.5	0.1	9.1	0.1
Apple	41	0.1	0.1	10.0	0.0
Carrot	45	0.4	0.1	10.0	1.3
Orange	43	0.6	0.1	9.8	0.1
Tomato	18	0.8	0.2	2.7	1.1
Multi-vegetable	27	1.0	0.3	4.5	1.2

Source: [17]

Źródło: [17]

VITAMINS CONTENT

The vitamin content in freshly squeezed juices is slightly lower than the content of these ingredients in fresh vegetables and fruit, therefore a portion of the juice can be considered a good source of these ingredients in the diet [25].

Some fruit, vegetable or fruit and vegetable juices, especially freshly squeezed, can be a good source of selected vitamins.. Examples include juices rich in vitamin C, such as grapefruit, orange or tomato juice. Grapefruit juice provides 76 mg of vitamin C in 200 g, and the average requirement (EAR) for this vitamin for women over 19 is 60 mg/person/day [15]. Table 2 shows the vitamin C content in 100 g of grapefruit juice. More than half of the requirement, because 33 mg of vitamin C is covered by 200 g of tomato juice, in 100 g it is 16.5 mg (tab. 2) [17]. The recommended amount of vitamin C should be consumed daily, because the human body does not synthesize it at all and is stored to a small extent [15].

Vegetable and fruit-vegetable juices, especially carrot and carrot juices, are rich in vitamin A, or actually vitamin A provitamin, which is defined as carotenoids found in plant raw materials (β-carotene, α-carotene, β-cryptoxanthin) [7, 29]. Vitamin A plays an important role in the proper functioning of the immune system, in the processes of cell division and differentiation, as well as in the process of vision. Moreover, vitamin A, and in particular β-carotene, exhibits strong antioxidant properties [9]. Table 2 presents the content of selected vitamins in juices [17].

MINERALS CONTENT

Many vegetables, and thus the juices made from them, are a good source of potassium. Rich in potassium are, among others tomatoes, red beets, spinach, carrots, kale [17]. Potassium is essential for the proper functioning of the body's cells. Responsible for maintaining the proper water and electrolyte balance of the body by regulating the osmotic pressure of cells, as well as for the proper functioning of the heart.Its deficiency in the daily diet may lead to an increased risk of diseases such as hypertension, stroke, ischemic heart disease. Tomatoes contain 282 mg of potassium per 100 g. This amount of potassium covers only about 8% of the norm on the level of sufficient consumption (AI) of this ingredient [15]. As for the portion of juice (200 g), after conversion, it turns out that it covers a total of approx. 15% of the norm for this ingredient [17].

Magnesium is one of the most important minerals. It participates in the formation of proteins, muscle contractions, and also regulates blood pressure and affects the nervous system. Magnesium is contained in chlorophyll, which is why green vegetables contain more of it and can be a source of it. The average demand (EAR) for magnesium for women aged 19 to 30 is 255 mg / person / day, and for women over 30 years of age, it is 265 mg / person / day [15]. A glass of multi-vegetable juice provides 24 mg of magnesium, which is about 10% of the daily requirement for this ingredient [17].

Juices contain relatively little iron, in addition in a non-haem form, which has low bioavailability, but the high amount of ascorbic acid in the juices increases its absorption [17].

In addition to the above-mentioned minerals, juices also contain calcium, sodium, and phosphorus [21]. Table 3 presents the content of selected minerals in juices [17].

BIOACTIVE COMPOUNDS

Juices are a good source of polyphenols, biologically active compounds with antioxidant properties. They have anti-inflammatory, anti-arthritic, antiallergic and also anti-

Table 2. Content of selected vitamins in juices in 100 g of the product

Tabela 2. Zawartość wybranych witamin w sokach w 100 g produktu

Type of juice	Vit. A [µg]	β-carotene [µg]	Vit. E [mg]	Thiamine [mg]	Riboflavin [mg]	Niacin [mg]	Vit. C [mg]
Grapefruit	1	6	0.19	0.04	0.020	0.20	38.0
Apple	2	12	0.01	0.01	0.006	0.03	2.3
Carrot	580	3478	0.18	0.02	0.019	0.16	1.2
Orange	13	78	0.10	0.06	0.030	0.30	43.1
Tomato	99	591	1.13	0.06	0.039	0.92	16.5
Multi-vegetable	167	1001	0.48	0.04	0.039	0.63	12.0

Source: [17]

Źródło: [17]

Table 3. Content of selected minerals in juices [mg/100 g]

Tabela 3. Zawartość wybranych składników mineralnych w sokach [mg/100 g]

Type of juice	Sód [mg]	Potas [mg]	Wapń [mg]	Fosfor [mg]	Magnez [mg]	Żelazo [mg]
Grapefruit	1	102	11	9	8	0.1
Apple	2	110	9	6	5	0.2
Carrot	29	99	13	11	6	0.2
Orange	2	175	8	14	11	0.4
Tomato	193	260	8	19	9	0.5
Multi-vegetable	312	190	16	20	12	0.5

Source: [17]

Źródło: [17]

cancer properties [19]. Polyphenols can be divided into phenolic acids and flavonoids, which form a whole group of compounds, which include: flavones, flavonols, flavanols, flavanones, isoflavones, anthocyanins. Their main sources in the diet are drinks, including juices and fruit, especially berries. Anthocyanins, in addition to their functions typical of polyphenols, are responsible for the bright red, blue and purple color of fruits and other parts of plants. Thus, the red color of strawberries or dark eggplant skins is due to the presence of anthocyanins. This is confirmed by the research conducted by Człapka-Matyasik et al. [8], which compared dark-colored juices (chokeberry, currant, grape juice) and citrus juices (orange, grapefruit juice). Dark-colored juices were characterized by a higher content of anthocyanins. Oranges are a good source of flavanones. Hand-squeezed orange juice contains 839 mg of phenols per liter. It is estimated that a person consumes daily approximately 1-2 g of polyphenols to the diet if you consume the recommended amount of fruit and vegetables. Flavanones, which are the dominant flavonoids found in citrus juices, have a beneficial effect on health, have hypolipidemic, anti-carcinogenic, anti-inflammatory, analgesic and blood pressure lowering effects [23, 35]. Table 4 shows the content of selected polyphenols in juices [36].

Table 4. Content of selected polyphenols in juices [mg/l]

Tabela 4. Zawartość wybranych polifenoli w sokach [mg/l]

Type of juice	Phenolic acids		Flavonoids			
	Derivatives of benzoic acid	Derivatives of cinnamic acid	Anthocyanins	Flavonols	Flavanols	Flavones
Orange		15-20				215-685
Apple				6-52	8	
Grapefruit		15-24				100-650
Lemon						50-300
From red grapes	79					
From white grapes	110					
Cherry		124				
From black currant			130-400			

Source: [36]

Źródło: [36]

HEALTH ASPECTS OF JUICE CONSUMPTION

A balanced diet must include vegetables and fruits because they are rich in nutrients necessary for the proper functioning of the body. Juices that are their products are characterized by a lower concentration of biologically active compounds and in accordance with Directive 2012/12/EU of the European Parliament and of the Council of April 19, 2012 amending Council Directive 2001/112/EC relating to fruit juices and certain similar products intended for consumption by people, it is allowed to enrich juices with vitamins and minerals. The World Health Organization (WHO) recommends consuming 5 servings of vegetables and fruit per day, of which, according to the Food and Nutrition Institute (IŻŻ), 1 serving may be a glass of juice [15]. Therefore, it will be correct to say that regular consumption of fruit, vegetable and fruit and vegetable juices has a positive effect on health and even reduces the risk of developing civilization diseases e.g.: hypertension, stroke, ischemic heart diseases and cancers [1, 2].

Ingredients that are contained in fruits and vegetables, such as, vitamin C, β-carotene, and flavonoids are beneficial to the cardiovascular system.. Their antioxidant properties reduce the level of LDL-cholesterol oxidation and the level of platelet aggregation [28]. In addition, folic acid, present in green fruits and vegetables, prevents the development of atherosclerosis, because it participates in the transformation of homocysteine in the human body and thus reduces hyperhomocysteinemia, an independent factor in the development of atherosclerosis. Thus, it can be concluded that the consumption of fruit, vegetable and fruit and vegetable juices containing the above-mentioned nutrients may contribute to reducing the risk of metabolic syndrome [20].

Oxidative stress is the cause of the development of many civilization diseases, including arterial hypertension, coronary artery disease, cancer. Due to this, the presence of antioxidants in the daily diet is necessary [6]. Many studies have been carried out to analyze the ability of compounds with antioxidant properties in juices to remove reactive oxygen species and the impact of these compounds on the reduction of oxidative stress after juice consumption. Wasek et al. [34] observed that chokeberry juice has the highest antioxidant potential, followed by cherry and blackcurrant juice, and the lowest is white grape and apple juices. Another study by O'Byrne et al. [24] showed that the consumption of red grape juice has a positive effect on health. Flavonoids present in it are effective antioxidants, counteract the oxidation of lipids. The results of research conducted by Aviram et al. [3] indicate that consuming 50 ml of pomegranate juice daily contributes to the reduction of lipid peroxidation and to an increase in the concentration of antioxidants in the blood serum.

Orange juice also has a proven beneficial effect on health. Studies by Rampersaud et al. [27] have shown that it is a source of well-absorbed vitamin C, the presence of which is essential for the proper functioning of the body. Vitamin C is involved in a number of biological processes, including in the synthesis of collagen, adrenaline and steroid hormones. In addition, it has an antioxidant effect, prevents the development of such diseases as ischemic heart disease, atherosclerosis, heart attack and neoplastic diseases, mainly of the gastrointestinal tract. Moreover, it increases the absorption of iron and calcium in the digestive tract [18].

In some juices, especially fresh juices, relatively higher amounts of fiber support proper digestion. It accelerates the intestinal peristalsis, slows down the absorption of carbohydrates, and is also a substrate for the development of the intestinal microflora. Moreover, it has a positive effect on lowering blood pressure, cancer prevention and reducing blood cholesterol levels [32]. Research shows that increasing the daily intake of fiber reduction of the risk of heart disease and to the reduction of mortality due to coronary heart disease [16, 30].

Some studies have shown that fruit and vegetable juices can play an role in delaying the onset of Alzheimer's disease. In studies conducted in this area, a lower risk of disease was observed in people who consumed juices three times a week than in people who consumed juices less than once a week. The results of the research allowed for the conclusion that the risk of Alzheimer's disease was significantly reduced with increasing frequency of juice consumption [5].

Despite many positive aspects regarding juice consumption, it should be remembered that consumed in too large amounts, especially fruit juices, which are a source of simple sugars, may contribute to overweight and tooth decay, especially in children [22]. Therefore, it would be recommended to eat freshly squeezed juices made mainly of vegetables.

JUICE MARKET AND THE VOLUME OF THEIR CONSUMPTION

The juice market in Poland in 2010–2017 was characterized by continuous development. Juice production, with an average annual growth of 2.9%, increased by 22% in those years, from 544 million liters in 2010 to 665 million liters in 2017. The largest share in the production structure was mixed juices – 42%, then apple juices – 28%, then citrus juices – 21% and juices made from one type of fruit or vegetable – 9%. The production of apple juice in 2010–2017 increased by as much as 80%, and mixed juices by 27%, while the production of citrus fruit juices decreased by 8.5%. The production of juices in 2017 accounted for 6.8% of the total production of all non-alcoholic beverages in Poland [31]. The report prepared by the International Network of Audit and Advisory Firms – KPMG (2016) shows that Poles buy a lot of fruit juices, drinks and nectars. Calculated per person, it is 35 liters per year, only 1 liter / person less than the inhabitants of Germany, who ranks first in Europe in terms of consumption of these products.

The development of the juice market in Poland depends on several factors. The main one is the price, the next ones are the quality of the products, consumer awareness of the health-promoting properties of juices and new products introduced to the market. The price mainly determines the choice of the consumer. The low price increases juice consumption, and when the price rises, consumption decreases. Increasingly, however, consumers pay attention not to the price, but to the quality of the product. The European Quality Control System (EQCS) and the European Fruit Juice Association (AIJN) are responsible for the authenticity and control of juices in Poland and Europe. Since 2000, the AIJN Code of Practice has been in force in Poland, which serves as a model in assessing the

authenticity of juices [26]. It contains precise data on the chemical composition of various types of juices, both fruit and vegetable. Due to the constant and objective control of the quality of juices, a reduction in the level of adulteration of these products, especially imported ones, is observed. This allows for fair competition and affects the development of the entire juice market in Poland. The growing awareness of consumers about the health-promoting effect of juice consumption makes them choose them more and more often, and thus contribute to the development of this market sector. The market development is also influenced by new products, such as smoothies. They are pure fruit and vegetable juices with a thick, creamy consistency. However, in order for them to stay on the market and influence its development, it is important to maintain a balance between their quality and price. Poland is one of many European countries that has managed to do so and the smoothie market has developed a lot in recent years [26].

The statistical data of the Central Statistical Office (GUS) shows that in 2000-2008 the consumption of fruit and vegetable juices was gradually increasing [10]. Their average monthly consumption in 2000 was 0.79 liters per person, and in 2008 it was 1.10 liters per person. The highest, almost 21% increase in juice consumption was recorded in the years 2000–2005. After 2008, a decrease in the consumption of juices in households is visible. In 2008–2013, consumption decreased by 24%. Since 2013, another upward trend in consumption of this group of products has been observed. Juice consumption in 2017 was estimated at 0.97 liters / person / month, which is 11% higher than in 2013 [10].

According to the data of the Central Statistical Office (2015), the consumption of fruit and vegetable juices varies depending on the level of education, place of residence, socio-economic conditions, biological type of the farm and the number of people in the household. Research conducted by the Central Statistical Office of Poland in 2014 shows that more juices are consumed by people with higher education than other study participants [10]. The highest consumption of juices was characterized by workers in non-manual positions, and the lowest by farmers. Place of residence also had a great influence on juice consumption. People from cities consumed more juices than people living in the countryside. The highest average monthly juice consumption was recorded in cities with a population of over 500,000. Along with the increase in the number of people in the household, the consumption of juices per person/month decreased [GUS, 2015].

CONCLUSION

Juices can be a good variety and supplement to your daily diet. They are characterized by the color, aroma and taste typical of a given fruit/vegetable. The main component of juices is water, which is essential for the proper functioning of the body. Fruit juices, as well as vegetable and fruit-vegetable juices are characterized by relatively high nutritional value and concentration of pro-health compounds, the so-called phytochemicals. These are, for example, carotenoids (α– and β – carotene, lycopene, lutein), vitamins A, C, E and B vitamins, as well as polyphenols that have antioxidant properties and reduce the effects of oxidative stress, thus limiting the development of diseases such as cancer, ischemic heart disease or neurological diseases. Juices, especially vegetable and non-clarified juices, contain relatively large amounts of dietary fiber, which can help to support the digestive process. Fruit juices, which are higher in simple sugars, can contribute to excess weight or tooth decay if consumed in too much.

PODSUMOWANIE

Soki mogą być dobrym urozmaiceniem i uzupełnieniem codziennej diety. Charakteryzują się typową dla danego owocu/warzywa: barwą, aromatem i smakiem. Główny składnik soków to woda. Jest ona niezbędna do prawidłowego funkcjonowania organizmu. Soki owocowe, jak również warzywne i owocowo-warzywne charakteryzują się stosunkowo dużą wartością odżywczą oraz zawartością związków o charakterze prozdrowotnym, tzw. fitozwiązków. Są to na przykład karotenoidy (α– i β – karoten, likopen, luteina), witaminy A, C, E i witaminy z grupy B, a także polifenole mające działanie przeciwutleniające oraz zmniejszające skutki stresu oksydacyjnego. Ich spożywanie może ograniczyć rozwój schorzeń, takich jak nowotwory, choroby niedokrwiennej serca, czy schorzeń neurologicznych. Soki, szczególnie warzywne i nie poddane klarowaniu zawierają stosunkowo duże ilości błonnika pokarmowego, wspomagającego procesy trawienia. Soki owocowe, charakteryzujące się większą zawartością cukrów prostych, spożywane w zbyt dużych ilościach mogą przyczynić się do wystąpienia nadwagi lub próchnicy.

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Key words: yeast, flocculation, fermentation, yeast harvest.

Flokulacja drożdży jest odwracalnym, bezpłciowym i zależnym od zawartości wapnia procesem, w którym komórki przylegają, tworząc kłaczki składające się z tysięcy komórek. Po utworzeniu większego konglomeratu komórek, następuje masowe oddzielenie od podłoża przez sedymentację drożdży dolnej fermentacji. Umiejętność flokulacji komórek drożdży ma duże znaczenie dla branży piwowarskiej, ponieważ zapewnia w skuteczny sposób oddzielanie komórkę drożdży z zielonego piwa pod koniec fermentacji – dlatego pożądana jest silna i pełna właściwość flokulacji drożdży piwowarskich. Komórki drożdży nie powinny jednak zbyt szybko flokulować, zanim brzeczka nie będzie całkowicie odfermentowana, gdyż przedwczesna flokulacja powoduje spowolnienie fermentacji, a także może prowadzić do uzyskania niewłaściwych zawartości lotnych komponentów. Idealne drożdże piwne powinny się charakteryzować silną flokulacją pod koniec fermentacji i powinna ona być również stała w kolejnych fermentacjach. ***Zjawisko flokulacji jest procesem złożonym, na które mają wpływ mechanizmy biochemiczne, genetyczne i fizyczne****.*

Słowa kluczowe: drożdże, flokulacja, fermentacja, odbiory drożdży.

INTRODUCTION

The main aim of brewer's wort fermentations are to consistently metabolise wort into ethanol, carbon dioxide, glycerol, and other fermentation products, many of which contribute to beer flavour in order to produce it with satisfactory quality, drinkability, and stability of beer. Another very important fermentation objective is to produce yeast crops that can be harvested, stored, and subsequently re-pitched into a later brew. The most important features of yeast should be:

- yeast tolerance to stress factors such as: heat, osmotic pressure, temperature, ethanol, mechanical tension,
- wort gravity,
- wort dissolved oxygen concentration at pitching and during fermentation,
- flocculation, adhesion, sedimentation, and harvesting characteristics,
- culture characteristics during storage between fermentations and its subsequent re-pitching into wort [8].

In the article, will be underline very important issue of flocculation of brewery yeast. Flocculation is a complex phenomenon that is affected by genetic, physiological, and environmental factors. Within the two brewer's yeast species - Saccharomyces cerevisiae (ale) and Saccharomyces pastorianus (lager) there are both flocculent and non-flocculent strains. Flocculation is an import ant characteristic in an environment with limited nutrients because the death and autolysis of the cells inside flocs can provide further nutrients to cells in the surrounding environment. Flocculation may enhance the survival of yeast cells during adverse conditions.

Genetic studies on yeast flocculation began over 70 years ago. The first publication on this subject was by Pomper and Burkholder, who reported crossing a haploid culture that possessed a "dispersed" character (non-flocculent) with a haploid culture that possessed a non-dispersed charakter (flocculent). The "dispersed" character was reported to be dominant over the non-dispersed character. In the early 1950s, Gilliland (working in the Guinness laboratory in Dublin) and Thorne (working in the Alfred Jorgensen laboratory in

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Copenhagen) independently carried out extensive studies on the genetics of yeast flocculation. Gilliland studied two non-brewing strains of S. cerevisiae which differed only in their flocculation properties. It was proposed that a single gene was responsible for the flocculent phenotype. Thorne confirmed Gilliland's studies and demonstrated that yeast flocculence was an inherited characteristic and that the flocculence phenotype was dominant over the non-flocculent characteristic. These studies were also confirmed by Guo et al. [8].

FLOCCULATION OF YEAST

Flocculation of yeast cells is usually observed at the end of beer fermentation and is of great importance in brewery. It happened, when wort is almost attenuated and process of fermentation is finished (Fig.1).

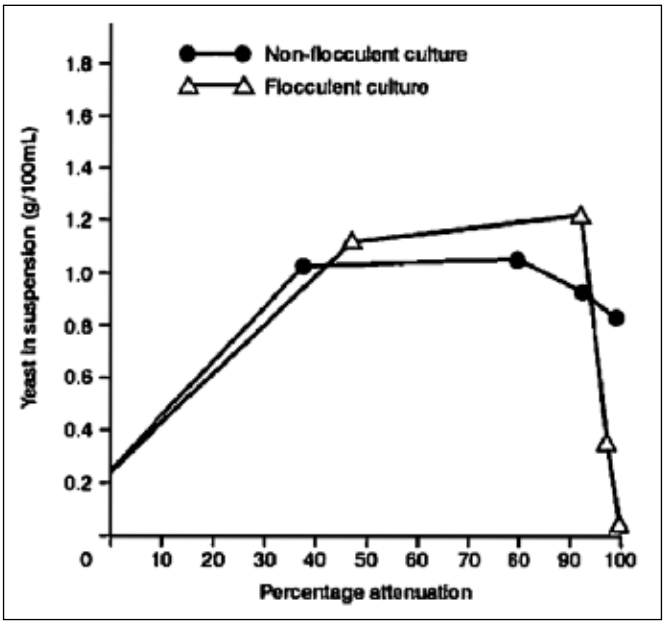

Fig. 1. Static fermentation flocculation characteristics.
Rys. 1. Charakterystyka flokulacji po zakończeniu fermentacji.

Source: Lekkas i in. 2007 [2]

Źródło: Lekkas i in. 2007 [2]

Its mechanism is not yet completely understood and is still the subject of much controversy. It is a very complex process which depends on numerous factors: the yeast strain especially genetics, the composition of the wort, and the culture conditions [4].

It has been shown that some highly flocculent cultures lost their flocculation characteristic during the early stages of growth, in the presence of nutrients, and recovered it towards the end of the exponential growth phase coinciding with nutrient depletion [8].

The issues for, and advantages of, yeast flocculation (particularly, but not only, during the brewing process) have been extensively studied and deliberated. Flocculation may enhance the survival of yeast cells during adverse (starvation and autolysy) conditions. Flocculation is an important characteristic in an environment with limited nutrients because the death and autolysis of the cells inside flocs can provide further nutrients to cells in the surrounding environment to beer. It has been shown that some highly flocculent cultures lost their flocculation characteristic during the early stages of growth, in the presence of nutrients, and recovered it towards the end of the exponential growth phase coinciding with nutrient depletion [1, 3, 6].

As with many aspects of brewer's yeast metabolism, yeast flocculation is rather primarily strain-dependent. During the later stages of fermentation, the following conditions are favourable for culture sedimentation:

- the carbon dioxide production rate is slow,
- wort attenuation is approaching completion—most of the fermentable sugars in wort have been consumed by the yeast culture, including glucose, fructose, sucrose, maltose, and finally maltotriose,
- flocculation ability is high but not too much,
- yeast concentration in suspension is maximal.

There are several factors that influence the rate of floc sedimentation out of the wort:

- The way that yeast cells are packed into flocs,
- the floc size, shape, and concentration (density),
- nurture factors that include wort properties and encompasses: concentration (gravity), viscosity, density, and natural convection in fermentor,
- higher gravity worts, following fermentation, results in "green" (immature) beers with a higher viscosity and density. Both these factors will retard yeast sedimentation and lead to increased osmotic pressure and ethanol prior to dilution to the fermented wort's sales gravity and alcohol concentration. The floc size often decreases as settling proceeds because the concentration of yeast cells in the suspension continues to decrease and smaller flocs form which will slowly settle out of the suspension [7, 8].

A few factors can affect yeast flocculation. They are very important in area of yeast management, especially for yeast flocculation (Fig. 2).

The first factor is the genetic background of a strain. Flocculin proteins are encoded by members of the FLO group of genes. The genetic background (nature effects) with regard to FLO genes varies greatly amongst various types of brewer's yeast (ale or lager) and other strains. Strains contain a variety of FLO gene combinations, resulting in a spectrum of flocculation characteristics.

Second, flocculation is caused by the physiological environment. This includes the pH, availability of appropriate metal ions, and nutrients during the growth phase. The pH will influence the cell surface charge which will have an effect on the flocculation phenotype because the environment is sensed by cells leading to the expression of FLO, their translation to Flo proteins, and their location into the cell wall, which is influenced by a number of environmental factors. Changes in pH may also modify the ionisation of functional groups in flocculin proteins, which will modify their conformation.

Flocculation of yeast cells involves lectin-like proteins – so-called flocculins – that stick out of the cell walls of flocculent cells and selectively bind mannose residues present in the cell walls of adjacent yeast cells (Fig. 3). Calcium ions in the medium are needed in order to activate the flocculins [11].

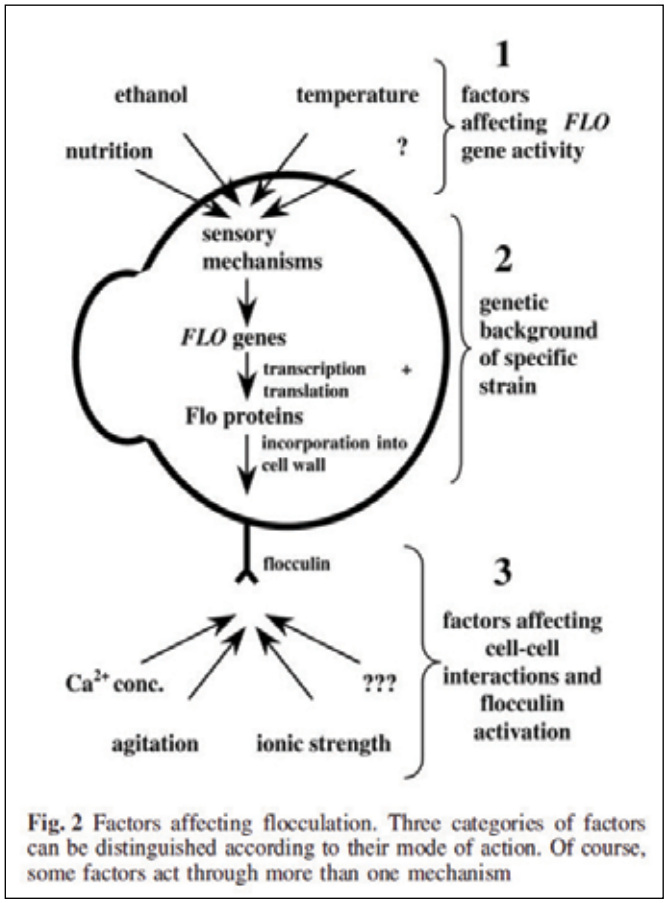

Fig. 2 Factors affecting flocculation. Three categories of factors can be distinguished according to their mode of action. Of course, some factors act through more than one mechanism

Fig. 2. Factors affecting flocculation.
Rys. 2. Czynniki wpływające na flokulację.
Source: Verstrepen i in. 2003 [11]
Źródło: Verstrepen i in. 2003 [11]

Finally thirdly, the physical environment affects flocculation. The hydrodynamic (relevant to liquids in motion) conditions must be favourable and promote collision rates between cells. However, natural convection in fermentor must not be sufficiently violent to cause flocs to disperse. In addition, there must be sufficient cells in suspension in order to result in cell collisions to form floks [5, 8, 9, 10].

Brewer's yeast flocculation is an off-cost process which does not require significant energy input. However, cooling at the end of fermentation does facilitate yeast separation and this normally requires some energy. It is considered that flocculation increases process efficiency and reduces the energy consumption [8].

CONCLUSION

The yeast flocculation process is a very important phenomenon in brewing. After fermentation, the lager yeast should naturally sediment to the bottom of the fermentation tank. The process should be timely - neither too early nor too late. Premature flocculation interrupts fermentation, while too long sedimentation deteriorates yeast harvest from the fermenter, which results in a low concentration of collected yeast, and those cells that remain in the beer contribute to the unfavorable autolysis phenomenon. The phenomenon of yeast flocculation is influenced by three factors, of which genetics are the most important. Only in the case of the content of metal ions, and in particular the amount of calcium, can its content in the fermenting wort be adjusted in any way.

PODSUMOWANIE

Proces flokulacji drożdży jest bardzo istotnym zjawiskiem w piwowarstwie. Drożdże dolnej fermentacji po zakończonej fermentacji w sposób naturalny powinny sedymentować na dno zbiornika fermentacyjnego. Proces ten powinien przebiegać we właściwym momencie – ani za wczesnie ani za późno. Przedwczesne kłaczkowanie powoduje przerwanie fermentacji, natomiast zbyt długie sedymentowanie wpływa na pogorszenie odbiorów drożdży z fermentora, co powoduje niską koncentrację zebranych drożdży a te komórki drożdży które pozostają w piwie, przyczyniają się do niekorzystnego zjawiska autolizy. Na zjawisko flokulacji drożdży mają wpływ trzy uwarunkowania, z których najbardziej istotnym są uwarunkowania genetyczne. Jedynie w przypadku zawartości jonów metali, a zwłaszcza wapnia, można w dowolny sposób regulować jego zawartość w fermentującej brzeczce.

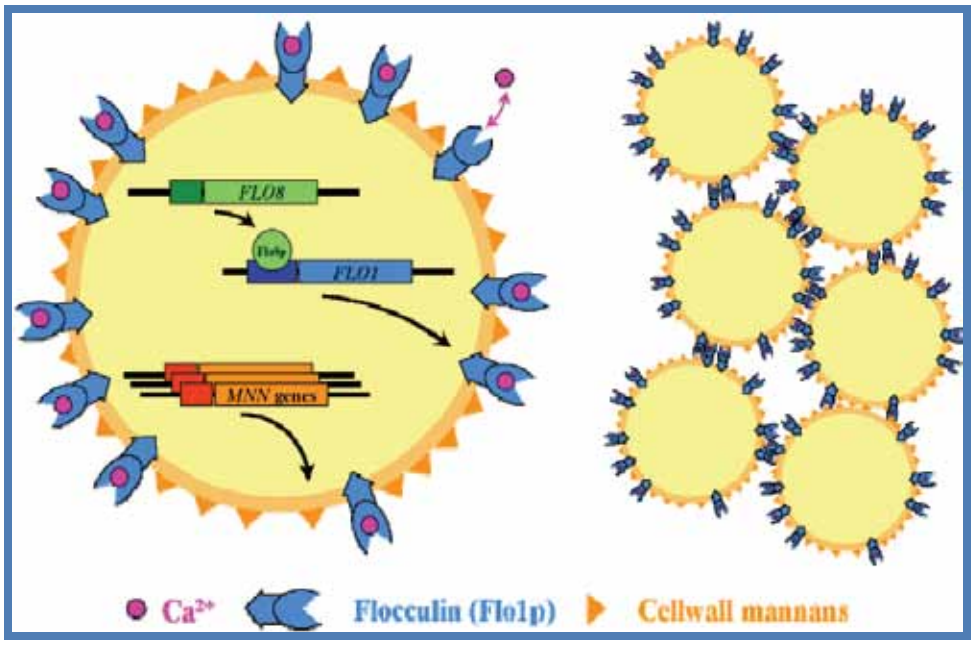

Fig. 3. Simplified lectin-theory of yeast flocculation.
Rys. 3. Uproszczona teoria wpływu lektyn na flokulację drożdży.
Source: Voetz M. 2008 [12]
Źródło: Voetz M. 2008 [12]

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APPLICATION OF THE OAK WOOD CHIPS IN BREWING®

Zastosowanie płatków dębowych w browarnictwie®

Oak chips are finely shredded oak fragments, which were toasted under strictly controlled conditions. They are produced in various grammages and degrees of toasting. Chips can be divided into natural, light, medium and heavily toasted. Their size affects how quickly ingredients are being released from them. The aim of the article is to present issues related to the application of oak chips in brewing, as an alternative to the oak barrels usage. The description presents information regarding the influence of the oak chips addition on the final profile of the drink and also characterizes the processes that take place during aging.

Key words: oak chips, oak, barrel, beer, aging.

Płatki dębowe to drobno poszatkowane szczapy dębowe, które zostały upieczone w ściśle kontrolowanych warunkach. Produkowane są w różnej gramaturze i stopniu opieczenia. Wyróżnia się płatki naturalne, lekko, średnio i mocno opiekane. Rozmiar zrębków wpływa na szybkość wydobywania się z nich składników. Celem artykułu jest przybliżenie zagadnień związanych z zastosowaniem płatków dębowych w piwowarstwie, jako alternatywy dla wykorzystania beczek dębowych. W opisie przedstawiono informacje dotyczące wpływu dodatku zrębków dębowych na końcowy profil napoju, scharakteryzowano również procesy zachodzące podczas leżakowania piwa.

Słowa kluczowe: płatki dębowe, dąb, beczki, piwo, leżakowanie.

INTRODUCTION

Beer has accompanied mankind since antiquity. Its traces can be found all over the world, from Europe, through the Middle East up to China. The production of this beverage became a part of the culture and tradition in many countries, such as the Czech Republic, the United States of America, Germany, Great Britain, Japan, and Poland. Before the advent of stainless steel, barrels were a typical vessel used for storage and transportation for nearly all liquids. The most common tree species, from which wood was obtained for their production was oak. Nowadays, wood barrels are generally made from French and American oak varieties. They gained recognition due to their hardness, durability, and waterproofness. Barrels filled with beer often traveled many kilometers, for example with the Vikings (since about 800 AD) or the British East India Company [7, 16]. Some styles of beer often had to be aged for about 6 – 12 months in wooden tanks, in order to soften their harsh taste. This was the case with the *porter* style. It was invented in England in the 18th century. It quickly gained widespread popularity not only in the originating country but was also a favorite style in the early days of the United States [8].

Wood aging is an old tradition that currently attracts the attention of brewers, looking for new, innovative products. Barrels are frequently used in an attempt to reproduce the original versions of the beers [16, 17]. Although this method is mainly used to obtain a broad range of flavors and aromas from wood, during barrel aging, the compounds extracted from wood also have an impact on color, they improve the properties of the drink and accelerate the maturation of beer. However, the production of these tanks is very expensive, and aging requires long periods of time. A more accessible and cost-effective alternative to the usage of oak barrels is to use fragments of oak wood, commonly known as flakes, shavings, silvers, or chips. Their additional benefit is the usefulness of the entire wood surface, not only 40% of the area inside a barrel [3, 4, 14, 20, 23].

The aim of the article is to present issues related to the application of oak chips in brewing, as an alternative to oak barrels usage. The description presents information regarding the influence of oak chips application on the final sensory profile of beverage, moreover, the processes that take place during the aging were also addressed.

OAK WOOD CHIPS AS BEER ADDITIVES

Oaktree (*Quercus sp.*) is by far the most commonly used wood variety for the production of barrels suited to the aging of wines and spirits. The aging process changes the color and taste of the maturing beverage, as well as reduces

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both its volume and alcohol content. The time required for the aging of alcoholic beverages varies depending on the characteristics of raw distillate, the origin of wood, size and treatment of the barrel, and the environment. Taste and aroma are affected by modifications in the composition and concentration of the chemical compounds. Such changes can be caused by direct extraction of the wood compounds, breakdown of the macromolecules, reactions between its ingredients and molecules of the beverage, as well as by oxidation, esterification, Maillard reactions, polymerization, or condensation.

However, the production of barrels is very expensive, and aging requires long periods of time. A more economical alternative to using oak barrels is to use pieces of oak wood, commonly known as chips. This practice has been approved and passed by the European Community (EC 2165/2005 and EC 1507/2006), although it is also utilized in some non-European countries, such as Australia and South Africa. The composition of the final product is mainly influenced by the botanical and geographical origin of oak used. During the aging process, parameters such as the size of an oak piece, amount of wood used, and degree of toasting (low, medium, and heavily toasted) are also important [4, 14, 21, 22].

Application of oak chips, especially charred or roasted, accelerates the aging process, and their use is also the easiest method of adding wood-derived compounds. They are more and more often used for the aging of strong liquors, such as Brandy. The utilization of oak chips is a part of the traditional good brewing practices, is legally permitted and prevalent in commercial winemaking. A new technique was introduced in this field - insertion of wood pieces (oak shavings or staves) into the tanks. This offers some distinct and previously unavailable flavor advantages, and also wine modification possibilities. Oak chips in various sizes are available in the market and are used to compensate for a low level of extractable ingredients in the old barrels. They provide an environment resembling one found in the barrel. As wood is put into the wine and not the other way around, the entire surface is usable, not only 40% of the area inside a barrel [2–4, 14].

In the case of higher-quality spirit beverages, the aging process often takes place slowly over several decades. Prolonged periods of aging, along with high prices of the barrels and the need for their maintenance or replacement make the product more expensive. In order to accelerate the changes that undergo in a barrel, alternative systems have been proposed, that mainly rely on rapid aging by addition of oak fragments or extracts into the beverages. It has been found that when using extracts or oak chips, amounts of wood-derived compounds in beverages are very abundant, to the point they are even higher than in cases when distillates are aged in the barrels. Particularly, there is a significant amount of phenol and furan compounds. However, the aging process conducted by the addition of oak chips can be considered incomplete, since oxygen that penetrates through the barrel's staves during long periods of maturation has a significant influence, in sensory and chemical terms. Oak products, such as shavings, cubes, powders, or immersed staves are useful when an alternative to obtaining the flavor and aromas from a barrel is desired. They have become popular in the winemaking industry, thanks to their ability to be used not only in stainless steel tanks but also in barrels, which after repeated use, have a minuscule or no impact at all on the taste of liquor. Alternative oak products could be cost-effective and readily available for most of breweries [4, 14, 16, 20].

CHARACTERISTICS OF THE OAK BARRELS

Oak is a hard, strong, durable, and waterproof timber. There are hundreds of oak species, which can be divided into two broad categories: red and white. Red varieties are porous and rarely used for barrel production. Nearly all wooden containers used for wine, beer, and spirit beverages are made from white oak. The ones used for wine are typically crafted from French (*Quercus robur*, *Quercus petraea*) or American (*Quercus alba*) oak, although oak wood from Eastern Europe is also used. Barrels are a modern era invention, and they were unknown in ancient times. At that time, clay amphoras were used to store and transport wine. The main stages of barrel production are selection and cutting oaks from the forest, splitting logs into staves, seasoning wood thanks to which it is possible to reduce its high moisture content, and finally assembling the barrels from staves. This last stage involves bending and toasting operations, during which various chemical reactions take place, which leads to the formation of aromatic compounds from neutral wood biopolymers. The aim of the aging process is not only to enhance the organoleptic properties of alcoholic beverages but also to develop other attractive attributes, such as increasing their antioxidant capacity. A number of drinks such as cognacs, whiskey, brandy, vinegar, mescal, and wine increased their antioxidant capacity after they had contact with wood. Prior to the stainless steel, oak barrels were a typical vessel for storing and transporting almost any fluid. Water, beer, wine, olive oil, rum, chili sauces – all traveled the world in wood. Initially, there wasn't a particular intention that it would impart a sensory characteristic to a liquid [2, 16, 20, 22].

Until the 20th century, most of the beers were delivered to the bars in wooden barrels. Since the 19th century, brewers have worked really hard to elude wood-derived aromas in beer. To accomplish that, new barrels, usually made from oak, were successively filled with portions of boiling water and hydrochloric acid. German, and later American brewers smeared them with tar, minimizing both wood ingredients transfer and possible leakage. Over time, stainless steel containers took over the beer industry. Nowadays, craft brewers, especially in the United States, have once again introduced wooden barrels and their derivatives to the brewery, but this time the goals are completely different. The barrel is no longer an ordinary vessel. A modern brewer ages a beer in wood so that it influences its taste and aroma. We are talking here primarily about oak varieties, however, other tree species are also used. Chestnut, ash, poplar, cedar, acacia, cypress, redwood, cherry, pine, and even eucalyptus have been used with varying degrees of success. When heated and steamed, oak easily bends into barrel staves, and the structure of the wood makes it water-resistant. Oak wood, despite this distinctive attribute, is also porous and has a complex range of flavors that can be brought into beer. In the United States, where oak aging has become common among craft breweries,

the most commonly used barrels are one in which bourbon matured. According to the United States law, whiskey labeled as "Bourbon" must be aged for at least 2 years in new barrels made from American white oak. This implies that barrels can be used only once to mature an authentic Bourbon whiskey, turning an already used one into surplus at the distillery. A common practice in cooperage, considered to be the most important technological step, is oak wood toasting. High temperatures modify wood's physical structure, which is crucial to facilitate the shaping of the staves. What's more important, oak's chemical composition undergoes significant amendment due to thermal degradation of the polymers. Each distillery uses its own blend of oak and degree of charring, which leads to a significant difference in types of flavors, which breweries use to impart desired characteristics to their beers. Whilst most of these barrels are used for the aging of everything, from Scotch whiskey to high-grade tequila to Tabasco sauce, more and more of them end up in the hands of the American craft breweries [2–4, 16, 20].

Oak itself brings many flavors, which differ vastly depending on the species, area of cultivation, and the way the wood was processed. The compounds within oak wood contribute to the improvement of aroma, taste, and color, as well as enhance the "palate fullness". Oak barrels are commonly used for wine aging because they improve quality, increase color stability, induce spontaneous clarification, modify its composition due to the compounds obtained from wood, and are responsible for a more complex aroma. Oak wood consists mainly of three large insoluble polymers – cellulose, hemicellulose, and lignin. It also contains other compounds characterized by a lower molecular weight, such as volatile and non-volatile acids, sugars, steroids, terpenes, volatile phenols, and lactones. Many compounds called lactones derived from lipids are responsible for a considerable number of aromas and flavors which are associated with oak. In lower concentrations, lactones are simply perceived as "oaky" and pleasantly herbal, at a higher level their aroma can become rose-like, and in the highest, they give a strong coconut impression. A secondary perceivable trait is the vanilla flavor, derived from a mixture of vanillin and syringaldehyde, which may be pleasant at a lower concentration, but can easily dominate other tastes and aromas. The mild heat applied to the barrels during their toasting promotes the conversion of lignin compounds into vanillin and syringaldehyde [10, 20, 21]. Hemicelluloses, polymers composed of several simple sugars, are another component of the wood structure. When heated, they break down into constituent sugars, which subsequently caramelize into furfural, maltol, and cyclotene, which bestow flavors ranging from bitter almonds to sweet caramel and burnt sugar. Maltol, which has caramelized flavor, reminiscent of freshly baked bread is also a flavor enhancer and may intensify the perception of sweetness in a beer. Furfural contributes to imparting it a character of dried fruits, and in contact with yeast, it can be converted from the taste of roasted almond into a smoky and leathery, which is desirable in some aging beers. In addition, volatile phenols, such as eugenol (clove) and 4-vinylguaiacol (cinnamon-like) along with flowery, fruity terpenes are present [11, 15, 20]. Oak also contains tannins, which in beer undergo hydrolysis and get broken down into other compounds. They may impart tartness, however, this is prevented by their decomposition during toasting of the barrels, mostly during charring. Tannins are also a potent antioxidant. Oak wood is the only known source of roburins. Their main source in a human diet comes from the consumption of wine and spirits (cognac and whiskey), traditionally matured and stored in oak barrels [3, 12, 15, 16, 18, 19, 21]. Since craft breweries became more popular, especially in the United States, many of them were looking for new and unique methods to improve the flavor of their beers. They soon found out that using spent oak barrels, that once kept bourbon, whiskey, wine, or to a lesser degree brandy, sherry or port could produce a distinct flavor. Bourbon and whiskey barrels are most commonly used for beer types such as a stout or barley wine. Barrel type and maturation time are the two variables, equally important for the quality of the final product. Both of those aging parameters in whiskey and cognac production are defined according to the international or local legislation regarding product name. According to the European countries tradition, brandies are stored for at least two years (sometimes for several decades), in different wooden barrels. New, unused barrels can also be used for beer aging, however, they are unpopular due to the high cost. Flavors, which a new oak can contribute are wooden, vanilla, dill, or toast. After acquiring used bourbon or whiskey barrels, breweries can rinse them or pour beer directly into the remaining liquid. Rinsing or cleaning the barrel leads to attaining softer, more subtle flavors. However brewers often pour beer directly into the barrel, disregarding cleaning, and even if there is still a liter or two of the previous liquor, it comes with sanitary benefits, especially if the previous product was a whiskey. Since barrels contain a finite pool of extractable material, the amount of volatile compounds available for extraction decreases over time. As a result, most of the barrels are withdrawn from operation after 5 or 6 years [4, 6, 12, 16, 20].

Breweries utilizing wine barrels often use them in combination with "wild" *Brettanomyces* yeasts and bacteria, such as *Lactobacillus* and *Pediococcus*. In some cases, brewers might want to extract from wood the remaining small amount of oak taste and tannins. There is also a possibility of trying to obtain any remaining qualities of wine and other liquors, which may remain in the wood. Finally, brewers use wooden barrels as a place to store microflora, such as *Brettanomyces*, *Lactobacillus,* and *Pediococcus*. Even though they are considered as the bane by the majority of brewers and winemakers, they are essential in creating many styles of sour beers, inspired by the Belgian tradition. Beer without the aforementioned yeasts and bacteria is more vulnerable to oxidation because secondary fermentation which ensures a protective barrier of carbon dioxide in the barrel does not take place. Micro-oxygenation is a slow and steady penetration of oxygen into beer through porous wood in the barrels and has many advantages. Brewers as well as winemakers can choose barrels from French or American oak. French varieties are more porous than American ones, which allows for greater diffusion of oxygen through the wood itself. Micro-oxygenation of beer has an immediate effect on acetic bacteria growth (*Acetobacter)* in sour beers. *Acetobacter* requires oxygen for its growth, and the more of this chemical element means the more acetic (vinegar-like) nature of the drink is, which may or may not be desired. Barrels, which are not full (leaving the empty space) may also lend a vinegar feel to the beer. Aging

alcohols using oak chips can be considered incomplete. When added, oak chips start to soak up and release oxygen adhered to their surface. It isn't considered as oxygen originating from wood, as it is not trapped in its porosity. When the liquid starts to fill the empty spaces inside the barrel's wood structure (wood porosity), the air contained in it can begin to seep into the liquid [1, 9, 13, 14, 16].

Similarly to winemakers, brewers also have to take into the consideration size of the barrel. Most of them regard barrel capacity of 219–227 liters to be the standard size. Smaller barrels may provide a larger oak surface area to contact beer. This results in more abundant flavor, but can also lead to excessive diffusion of oxygen. Large oak containers provide a smaller oak area, and may potentially protect the beer from too much oxidation. However, most brewers decide to use more standard-sized barrels, to provide more mixing capabilities. Standard-sized barrels are also easier to acquire [6, 16].

TYPES OF OAK CHIPS

Oak chips are finely shredded oak fragments, which were toasted under strictly controlled conditions. They are produced in various grammages and degrees of toasting. Chips can be divided into natural, light, medium and heavily toasted. Their size affects how quickly the ingredients are being released from them. Much faster extraction of aromas in smaller chips allows for their usage as early as in the beverage fermentation process. Bigger chunks work well in the aging process of beers/wines. Different degrees of toasting affect the nature of aromas released.

American oak chips

American oak imparts the liquids with a strong flavor, which is additionally emphasized by the usage of charring inside the barrel. In America, *Quercus alba* oak is widely used, the wood of which is richer in lactones than European varieties. It is intensely aromatized, hence it's sparingly used in wine production as it can overwhelm the aroma of the beverage itself. Nevertheless, it's one of the most popular types of wood. Lactones tend to impart a coconut flavor, which is particularly noticeable in this variety. Aging the wine spirits in contact with this oak variety improves the quality of alcohol [4, 5, 16, 20, 21].

French oak chips

In Europe and France, *Quercus petraea* (known as sessile) and *Quercus robur* (also known as pedunculate) oak varieties are used. French oak is famous for its delicate mellow character and is preferred by many wine producers, as its contribution to flavor appears to be very refined and balanced. This wood is dense, and as a result, it is also much more expensive as compared to an American oak. In Belgium, breweries that produce *lambic* beers have always bought used French wine barrels for beer aging. Furthermore, oak wood, especially from the French Limousin region (mainly *Quercus robur* L.) is traditionally used to age wine spirits, including those most recognizable in the world: cognac and armagnac [2, 4, 5, 16, 20, 21].

CONCLUSION

Wood aging is an old tradition, which currently attracts the interest of brewers looking for new, innovative products. This method is mainly used in order to acquire a broad spectrum of flavors and aromas from wood. During barrel aging, compounds extracted from wood also influence color, improve beverage characteristics and accelerate beer maturation. However, the manufacturing of these containers is very expensive, and aging requires long periods of time. A more accessible and cost-effective alternative to the usage of oak barrels is to use fragments of oak wood, commonly known as chips. They are made from two main species of oak, but even within a given species, there is a wide variety regarding the properties of wood. Additionally, mixing shavings allows achieving a rich, complex flavor effect that cannot be obtained in a barrel, even after many months of aging. A definitive advantage of oak chips, in comparison to barrels, is the utilization of their entire surface, which is directly related to a shorter time needed for permeating flavors into the beverage. On top of that, they are more convenient to use than barrels, ecological, and low-priced.

PODSUMOWANIE

Leżakowanie w drewnie to stara tradycja, która aktualnie cieszy się zainteresowaniem piwowarów poszukujących nowych, innowacyjnych produktów. Metodę tą stosuje się głównie w celu uzyskania szerokiego spektrum smaków i aromatów z drewna. W trakcie dojrzewania w beczce, ekstrahowane z drewna związki wpływają na kolor, poprawę właściwości napoju oraz przyspieszają starzenie się piwa. Produkcja tych zbiorników jest jednak bardzo kosztowna, a leżakowanie wymaga długich okresów. Łatwiej dostępną i bardziej ekonomiczną alternatywą dla stosowania beczek dębowych jest używanie fragmentów drewna dębowego, zwanych potocznie płatkami. Wykonuje się je z dwóch głównych gatunków dębów, ale nawet w obrębie danego gatunku, występuje duże zróżnicowanie pod względem właściwości drewna. Dodatkowo, mieszanie wiórów pozwala na uzyskanie głębokiego, złożonego efektu smakowego, jakiego w beczce uzyskać się nie da, nawet po wielu miesiącach leżakowania. Zdecydowaną zaletą płatków dębowych, w przeciwieństwie do beczek, jest wykorzystanie całej ich powierzchni, co wiąże się bezpośrednio z krótszym czasem potrzebnym do przenikania substancji smakowych do napoju z drewna. Oprócz tego, że są one wygodniejsze w użyciu niż beczki, są również ekologiczne i tanie.

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NUTRITIONAL VALUE OF EDIBLE INSECTS IN RELATION TO CONSUMER ACCEPTANCE®

Wartość odżywcza owadów jadalnych wobec akceptacji konsumentów®

Due to the fact that the world population is constantly growing, it is necessary to provide adequate amount of food. Research is ongoing to find new food sources. The following articles provide an overview of the current literature data on edible insects as an alternative source of ingredients with high nutritional value. The forms of processing insects were analyzed in terms of their safe consumption, consumer acceptance and legal requirements.

Key words: unconventional food sources, insect breeding, processing methods, safe consumption.

Liczba ludności na świecie stale rośnie, istnieje więc konieczność zapewnienia odpowiedniej ilości pożywienia. Badane są nowe źródła żywności. W artykule przedstawiono przegląd aktualnych danych literaturowych dotyczących owadów jadalnych jako alternatywnego źródła składników o wysokiej wartości odżywczej. Analizowano formy przetwarzania owadów pod względem bezpieczeństwa ich spożywania i akceptacji konsumentów oraz wymogów prawnych.

Słowa kluczowe: niekonwencjonalne źródła żywności, hodowla owadów, metody przetwarzania, bezpieczeństwo spożywania.

INTRODUCTION

Taking into consideration many factors like the growing need for increasing the production of food, and at the same time searching for and creating new products because of the cost of production of livestock and their determinants, in the related pollution of the environment, the limited resources of fresh water, and changes in climate, need is the search for new sources of food [5, 50, 55]. Currently, in this regard, unicellular organisms (yeasts), marine organisms and edible insects [55] are of great interest. Edible insects are of the greatest importance and are considered a traditional food in over 100 countries in Asia, Africa and South America. They are a source of protein, fat, vitamins and minerals in amounts comparable to traditional animal raw materials [3]. There are many aspects to their wider use. Edible insects can be a source of physical, chemical and microbiological hazards and allergens. They may contain pesticides and heavy metal residues. Another aspect is the approach to ideas related to their breeding or harvesting, production technology and the global establishment of legal principles. Socio-economic and ethical issues are also important. The issues of using edible insects as food and feed are present in many regulatory institutions, which in relation to food production and breeding of insects should ensure the quality and safety from the products made of them, and take into account environmental factors and animal welfare [50]. Consumer acceptance of insect products is likely to be associated with the development of an appropriate processing strategy as well as appropriate marketing and incentives.

The aim of the article is to review the available literature on alternative sources of protein, in particular edible insects, their nutritional value and their use in human nutrition.

YEASTS, MOLDS AND ALGAE AS A SOURCE OF FOOD?

Yeasts, algae and molds are a valuable source of lysine, protein, B vitamins and minerals such as phosphorus, zinc and magnesium [1, 8]. Saccharomyces cerevisiae are also a source of probiotic bacteria [32]. The content of nucleic acids (2–18% of dry weight) present in the biomass of unicellular organisms makes it impossible to use them as a potential source of protein in human nutrition. Uric acid deposition in the kidneys or joints may lead to gout [8, 55]. Moreover, some proteins of unicellular organisms, causing allergies, adversely affect the immune system [33].

Sea algae can be an alternative source of protein in human nutrition. *Chlorella sp.* and *Spirulina sp.* algae, which contain about 60-70% protein in dry matter, are used on a large scale for production. *Chlorella sp.* it is also a valuable source of vitamins A, B12, folic acid and minerals, mainly iron, it also has an antioxidant effect. *Spirulina sp.* is characterized by high protein digestibility (90%) and favorable health properties, especially in the prevention of cardiovascular diseases, cancer and hypercholesterolemia. Due to technical difficulties in developing new products with an acceptable taste and high production costs, the use of algae protein in the food industry is not of much interest [9, 55].

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Various species of insects occurring all over the world have the greatest importance as a potential source of human food and feed for animals. Numerous studies have shown that insects are consumed by about 2 billion people in some countries of Asia, Africa and Latin America [9, 12, 48], with over 2,100 species already cataloged as edible. For consumption purposes, almost all groups of insects in the form of adults, pupae and eggs are used. Fried, boiled, baked or dried, as well as raw, the world's main food eaters are crickets, beetles, locusts and termites [3, 9].

CHARACTERISTICS OF POPULAR SPECIES OF EDIBLE INSECTS

Insects are the most numerous and widespread group of animals in the world. The small size, the presence of wings and trachea, the ability to transform, high fertility and the ability to protect against harmful pathogens, predators and parasites make these organisms quite common. They have the ability to quickly assimilate to the prevailing environmental conditions [25]. There are two types of insects, the so-called transformations as complete and incomplete. In the case of incomplete transformation, the pupal stage is skipped and the larva immediately turns into an adult (imago). The type of transformation and the stage of development of an insect determine the possibility of its consumption [48]. Butterflies belonging to the order Lepidoptera are the most numerous group of insects in the world. Their larvae (caterpillars) are often eaten by gourmets of this type of food. The larvae of these insects reach European countries, e.g. Belgium or France, previously dried in the sun. In South Africa and Botswana, butterfly caterpillars are most commonly produced in cans [58].

Termites (order *Isoptera*) are another species of edible insects popular in African countries. These insects are high in fat, so they are often eaten fried or in the form of a dried snack [58].

Crickets and locusts (of the order *Orthoptera*), grasshoppers, are among the most consumed insects. Before thermal treatment, their legs and wings are removed. They are mainly eaten fried or baked. Chitin and chitosan present in the shells of crickets prevent the development of harmful microflora in the human intestine [30, 58].

Beetles (of the order of *Coleoptera*) can be eaten at all stages of development, except in the adult form, due to their hard, chitinous shells. The mealworm of millers belongs to this group of animals, a popular pest of cereal products, as food for humans on a large scale is used in Asia and many European countries [17, 58].

Adult bees and wasps (*Hymenoptera* order) are not eaten due to the presence of a hard, chitinous shell, and thus low taste. The larvae and pupae of these insects are eaten most often in Japan and southern China [58].

ACQUISITION AND METHODS OF BREEDING INSECTS

Over 90% of edible insects are collected in the wild, and they are specially bred only in small numbers. The safety of collected insects is more difficult to guarantee, and wild species may become extinct, moreover, not every type of insect can be bred in artificial conditions, especially when a pathogen appears [3]. Harvesting edible insects can be of benefit, especially when grown organically.

Baiano [3] presented two methods of breeding edible insects as raw material for human food and animal feed; by full domestication and captive breeding, or partial captivity (semi-cultivation), modifying the habitat of insects, but without separating them from the wild population. Domesticated insects include mealworms, cockroaches and some beetles. Locusts, wasps, bamboo caterpillars, palm weevil larvae, and dragonflies belong to the second category. Activities related to semicultivation contribute both to the protection of the habitats of edible insects and to food security [50]. Mealworms and cockroaches work well in home and industrial breeding, because their breeding conditions are well known. Insect breeding is rare in Western countries, while the practice of insect breeding has been around in China for over 5,000 years [7]. It is possible to conduct cultures under controlled conditions in suspension in a closed bioreactor, which ensures consistent quality with a low risk of contamination and the possibility of breeding insects in various environments [7]. The aspect of sustainably breeding is important, especially in the transition to an industrial scale [39]. According to Veldkamp et al. [51], insects such as the soldier's black fly (Hermetica illucens), housefly (Musca domestica) and yellow mealworm (Tenebrio molitor) can process 1.3 billion tonnes of biowaste annually. Large list of already tested wastes like spent grain and brewer's yeast; leftovers of bread and pastries; potato steam peelings, egg waste, wheat bran; plant waste can be used as food for insects [3].

Zielińska et al. [59] demonstrated the ability of insects to digest polystyrene. It was found that the use and degradation of polystyrene did not affect the health status of the tested insect species *Tenebrio molitor* and *Zophobas morio*, but further studies were needed to confirm the nontoxicity of the insects that degrade polystyrene. This way of using the potential of edible insects is promising, both for the breeding of insects used in human or animal nutrition, their use in many other areas of life, and the management of waste products.

PROCESSING OF EDIBLE INSECTS

Edible insects, due to their valuable source of protein with a favorable composition of amino acids, vitamins, mono- and polyunsaturated fatty acids and minerals (iron, zinc), can be used as a component of conventional foods to increase the nutritional value of products [42, 55]. They can be eaten whole (raw, boiled, boiled and dried, fried, baked) [2, 3]. Another direction is the processing of insects into an unrecognizable form by peeling, drying, grinding into powders, pastes or using more complex technologies aimed at obtaining proteins. Insect flour can be used to enrich food, such as crisps, bread, pasta, confectionery, and even beverages [3, 28]. These publications present many conventional and innovative methods used in the processing of insects, incl. bed drying, microwave, vacuum and conventional drying. Traditional and novel techniques for protein, fat and chitin extraction using water, organic solvents and enzymes as well as techniques using ultrasound and supercritical CO2 extraction as well as cold plasma were also tested. The costs of some processes are currently too high to

be applied industrially, but research in various research centers is ongoing. In the studies of Zhao et al. [57], the freeze-dried yellow mealworm larvae contained approximately 33% fat, 51% crude protein and 43% true protein on a dry weight basis. The article analyzed the simultaneous effect of four variables during the extraction of yellow mealworm larvae proteins with NaOH, i.e. the concentration of 0.1 M to 0.5 M and the ratio of NaOH to defatted larvae (from 6: 1 ml / g to 20: 1 ml). / g) at a temperature of 20 and 80° C for 30 to 120 minutes. The actual protein content of the protein extract was about 75% with an extraction yield of 70% (extraction in 0.25 M NaOH, NaOH: lean larvae ratio 15: 1 ml / g, 40° C, time 60 min). The lowest solubility of protein in distilled water was obtained between pH 4 and 5, but increased at pH above or below this range. Lower solubility was observed in the samples treated with 0.5 NaCl solution. This proves that the performance properties of mealworm larvae can be modified in the food industry depending on different applications. Processing activities aimed at the production of protein hydrolysates, especially bioactive peptides, are important. Protein hydrolysates are proteins broken down into smaller fragments, peptides and amino acids. These peptide fragments may contain 2–20 amino acids, inactive in the sequence of the primary protein, which can be released by enzymatic hydrolysis, solvent extraction and microbial fermentation [12, 35].

The available scientific publications analyzed the possibility of using a cricket meal, widely available in some European markets. Research by Montowska et al. [30] showed that in terms of dry weight, cricket meal is a rich source of protein (42.0–45.8%), fat (23.6–29.1%), fiber and minerals, therefore it can become a valuable ingredient in traditional food products. Bread containing 10 and 30% (in relation to wheat flour) of cricket flour addition showed higher nutritional value than the control bread. Baked goods with the addition of cricket flour were characterized by a more favorable profile of fatty acids and a higher content of proteins, including essential amino acids. However, microbiological analysis revealed the presence of sporulating bacteria in the bread with the addition of cricket flour, which poses a risk to consumer safety. Therefore, when processing insect flour as a food component, preventive measures are recommended, eg microwave drying or high-pressure treatment [37]. A relatively small addition of flour (at the level of 5%) to products such as pasta or muffins increased their consumer appeal. Moreover, the color of pasta and muffins with the addition of insects was similar to the color of whole grain products considered "healthier" [15, 40, 55]. In studies by González et al. [18], three different insects (*Hermetia illucens*, *Acheta domestica* and *Tenebrio molitor*) were ground and up to 5% replaced with wheat flour in cakes and breads. The addition of insect flour influenced the rheological properties, mainly the absorbability and stability of the dough during mixing, which is characterized by lower water adsorption. Breads containing *Acheta domestica* flour showed similar volume and texture parameters to wheat bread, but had a higher protein and fiber content. Da Rosa Machado and Thys [11] showed that in combination with hydrocolloids and / or enzymes, cricket powder (*Gryllus assimilis*) can be used as an alternative protein source for gluten-free bread. The product was characterized by acceptable technological properties and a high content of protein and lipids. Similarly, gluten-free sourdough bread enriched with the addition of cricket flour increased the content of wholesome protein and improved the antioxidant properties of baking [34]. Insects are also used to obtain edible oils using Soxhlet or Folch extraction or supercritical CO_2 extraction [12].

Baiano [3] showed that work is underway to extract and restructure insect proteins into a variety of food components, such as soluble protein powders for beverages and textured insect proteins for meat analogs, and substitutes for eggs or dairy products in bakery and food applications [46]. A form of innovative technology that has been proposed for the development of the edible insect market is 3D printing, as it can change both the aesthetics and texture of food [27].

EDIBLE INSECTS IN HUMAN NUTRITION

The history of the use of edible insects in human nutrition was extensively presented by Baiano [3], dating to ancient times, and even millions of years. Starting from the 70s of the previous century, the interest of researchers in edible insects was significant, as evidenced by the large number of scientific publications (637) from this period (1975–2020) compiled by Baiano [3], with about 90% of publications written after 2010.

Edible insects are characterized by high nutritional value, being a source of wholesome protein and all essential amino acids, fats (high content of unsaturated fatty acids), B vitamins, and minerals (including iron, zinc). Most edible insects are fairly low in carbohydrates. According to da Silva Lukas [12], these insects have a balanced nutritional profile and amino acids useful in human diets. The nutritional value of insects depends on the species, stage of development, method of killing, habitat, and even the method of preparing the dish and the type of culinary treatment used before consumption [3, 6, 48].

The protein content in edible insects is 5–77 g per 100 g. The highest protein content in dry matter (over 60%) was recorded in locusts and crickets. The protein content alone does not reflect its usefulness in human nutrition. Its digestibility is also important. In the case of edible insects, the digestibility of the protein is higher compared to many proteins of vegetable origin and is similar to that of egg white (77–98%). Moreover, the nutritional value of insect protein is comparable to that of milk protein and beef protein [9, 29, 48].

Lipids are the second largest fraction in the food composition of edible insects. Their content is higher in the larval phase of the life of insects. Depending on the insect species, the fat content in dry matter ranges from 13 (*Orhopter's order*) to 67% (beetle larvae or *Rhynchophorus phoenicts*) [29, 44, 56]. Fats mainly consist of triacylglycerols (about 80%), and among others present in smaller amounts, there are phospholipids (up to 20%), cholesterol, glycerides, free fatty acids and wax esters [12]. Triacylglycerols serve as an energy deposit during periods of high energy demand, phospholipids play an important role in the construction of the cell membrane. Essential fatty acids are linoleic (18: 2n-6) and α-linolenic (18: 3n-3), which are not synthesized by mammalian cells and therefore should be consumed with food [12]. In terms of the degree of unsaturation, the composition of fatty acids in edible insects is comparable to that of fish and poultry [55]. These fatty acids are present in greater

amounts compared to other sources and are essential for the maintenance of cell membranes, brain function and the transmission of nerve impulses.

Insects are characterized by a low carbohydrate content (0.1–5.3% in dry matter). Most of them are chitin, which has a healing effect. Chitin has been shown to lower blood cholesterol, act as a hemostatic agent for tissue repair, promote wound healing, and as an anticoagulant. In addition, it soothes allergies and has antiparasite properties. Chitin may also play a role as a dietary fiber in the human diet. In most insects, chitin, which is part of their outer shell, constitutes 5–20% of their dry mass [8, 29, 58].

In terms of minerals, insects are characterized by a high content of iron and zinc, and slightly less copper, magnesium, manganese and calcium. For example, caterpillars *(Imbrasia belina*) contain 31–77 mg iron per 100 g dry weight, while beef has an iron content of only 6 mg per 100 g dry weight. Edible insects are also a good source of most B vitamins, including thiamine, riboflavin and cobalamin [8, 58].

Anaduaka et al. [2] examined the nutritional value of *Oryctes rhinoceros* and *Zonocerus variegatus*. Both insects showed approximately 34.8 and 30.7% protein, 10.5 and 5.4% carbohydrate, and both approximately 20% fat, respectively. Both insects contained vitamins B12, B1, B2 and B6; in *Oryctes rhinoceros* 70.4, 5.9, 27.2 and 0.8 mg / 100 g, respectively, and in *Zonocerus variegatus* 276.1, 45.4, 11.1 and 4.4 mg / 100 g. Both also showed vitamin A (0.17 and 0.8 mg / 100 g), vitamin C (0.5–0.6 mg / 100 g), vitamin D (21.4–24.1 mg / 100 g), and in *Oryctes rhinoceros* also vitamin K (7.4 mg / 100 g). Among the minerals, significant amounts of potassium and sodium were found in both insects, i.e. around 1905 and 1656 mg / 100 g in *Zonocerus variegatus* and 1070 and 931 mg / 100 g in *Oryctes rhinoceros*, and a comparable calcium content (368 mg / 100 g). Lower amounts of magnesium (39 and 182 mg / 100 g) and iron (1.2–2.3 mg / 100 g) were found.The antinutritional factors present in some insects can be toxic, discouraging their use. In both insects, the content of antinutritional components (mainly oxalate) was within acceptable limits, so they were not life-threatening.

POTENTIAL NUTRITIONAL COMPONENTS OF EDIBLE INSECTS

Many authors emphasize that insect proteins can serve as functional ingredients in food preparation. Edible insects and foods enriched with them, especially in the form of hydrolyzed proteins (peptides), show antioxidant, antimicrobial and antidiabetic properties [12, 13, 58]. Gravel and Doyen [19] reviewed the articles in detail in terms of insect flour production methods as well as insect-derived ingredients such as protein concentrates and isolates. To increase the functionality of the protein from crickets, Hall at al. [20], whole insects (Gryl-lodes sigillatus) were hydrolyzed with alkase at the concentration of 0.5, 1.5 and 3.0% for 30, 60 and 90 minutes. This treatment increased the solubility of proteins by more than 30% at pH 3 and 7 and by 50-90% at alkaline pH, compared to the control. The emulsion activity index varies from 7 to 32 m^2 / g, and the foam ability from 100 to 155% for all hydrolysates.

Del Hierro et al. [14] obtained extracts from edible insects *Acheta domesticus* and *Te-nebrio molitor* by means of ultrasound-assisted extraction and pressurized liquid extraction with the use of ethanol or ethanol and water. All extracts showed antioxidant activity which correlated with the values of total phenolic compounds. All showed lipase inhibitory activity, although those from *Tenebrio molitor* and obtained by pressurized liquid extraction were the most effective. Therefore, bioactive insect extracts can be selectively obtained by advanced extraction methods.

FOOD SAFETY WITH ADDITIONAL INSECTS

Studies on the safe consumption of edible insects confirm the presence of endogenous and exogenous microbiological, allergenic and toxic substances in them [8, 13, 55]. Insects also have a specific wealth of animal viral pathogens, but do not pose a threat to humans [3]. The presence of viruses introduced into the culture by arthropods (arboviruses), which can cause diseases (eg, West Nile disease, haemorrhagic fever) or other viruses through the medium cannot be excluded [3, 6]. Microbial contamination can be dangerous, but if insects are properly fed, processed and stored, they can be considered safe [3]. Insects can be responsible for mycotoxin contamination when stored under suboptimal conditions. De Castro et al. [13] provided a detailed review of articles on microbial testing in fresh and heat-treated insects. Some studies have shown high microbial content in certain commercial insect species. In fresh insects, i.a. Enterobacteriaceae and spore bacteria, but no pathogenic species were detected. Boiling the insects for 5 min adequate to eliminate Enterobacteriaceae, but had no effect on bacterial spores. The attention was paid to tropical diseases transmitted by insects of the Reduviidae family. Parasites may also be present in edible insects. The relationship of insects with crustaceans and the presence of proteins in their composition may contribute to the fact that some insects and foods with their addition become a potential source of allergens [24, 55]. Therefore, the consumption of edible insects may pose a potential threat to human health. Studies have confirmed that the consumption of edible insects may cause allergic reactions [8, 44]. Moreover, insects have defense mechanisms by producing carbonic acids, alcohols, aldehydes and phenols, which may be irritants, and in the case of alkaloids, steroids, cyanogenic glucosides, (benzo) quinones and alkenes, they are capable of exerting a negative systemic effect [6].

The safety of insect consumption is also determined by external factors. Due to the documented cases of botulism, food poisoning and parasitic diseases, the conditions for the preparation of dishes with the addition of insects, i.e. temperature, time and place of preparation, are important. For this reason, it is essential to maintain the maximum microbiological purity of products with the addition of insects [8]. To ensure the safe consumption of edible insects, it is required to develop and apply specific HACCP procedures [43].

ACCEPTANCE OF EDIBLE INSECTS IN THE OPINION OF CONSUMERS

According to the Codex Alimentarius, which is responsible for international food safety, insects are not treated as food, but as contaminants. In the European Union, edible insects are considered "novel foods" [Regulation 2283/2015]. Insects and products based on them must be authorized before being placed on the market, and the procedure takes at least 17 months. There is also a simplified procedure (5 months) for the authorization of novel foods as long as the traditional food is safe (consumption for more than 25 years in the diet of a significant number of people in at least one third country) and that there are no safety concerns reported by EU Member States or EFSA [3].

Insects are a promising alternative to existing food sources, especially protein, but the literature has shown that insects are not accepted as food by many consumers [54]. Due to cultural barriers, Europeans are reluctant to consume insects. At present, despite the many advantages of edible insects as potential food, even among societies in countries that have traditionally eaten insects or food supplemented with them, there are doubts about the legitimacy of their consumption. Low acceptance in these countries may result, among others, from from the perception of insects as a primitive food, intended for people with low social status and unattractive sensory features of insects eaten as a whole [8, 38]. It is worth emphasizing, however, that dietary stereotypes are constantly changing. Currently available literature sources concern consumer behavior in terms of factors determining the acceptance of edible insects as food [10, 45].

Edible insects are a product still unknown in most societies. Food neophobia, the fear of trying something new or unknown to the consumer, is one of the key determinants of rejecting insects as food [41]. Neophobia largely results from the native culture of a given society. A different approach can be observed among the inhabitants of Northern Europe, who constitute a society more open to the possibility of trying new foods, including edible insects, compared to the inhabitants of Central Europe. The low social acceptance of insect eating is the main obstacle to their introduction to the food market. Consumers in European countries often react with disgust to the possibility of eating insects, which are commonly perceived as pests and not as food. Awareness of the benefits of consuming edible insects, constant awareness of consumers by informing them about the properties of previously unknown products, as well as increasing direct taste contact with new products increases consumers' readiness to eat insects [8, 41, 45, 48, 53].

Many studies have emphasized that the inclusion of edible insects in traditional food, and thus reducing the degree of their visibility in the product or products based on insects, may contribute to increasing their acceptance among consumers [26]. According to a study by Tan et al. [49], the inclusion of mealworm larvae, whether visible or not, as part of well-known dishes, e.g. beef stew, does not achieve high product acceptability. Products with the addition of mealworm, visually identical to the carrier product, in the opinion of consumers, were less attractive. Similarly, Barsics et al. [4], they gave samples of the bread to a group of tasters, falsely telling them that an insect meal had been added to its production. As a consequence, the assessment of the taste of the bread was very low.

Research conducted among German consumers indicated that paying more attention to the processed form of insects and adding it to products will reduce their visibility in ready meals. This is a promising prospect of entomophage implementation in Western countries [36]. According to House [21], creating products with the addition of insects with an acceptable taste, product form, and also, at an affordable price can increase the regular consumption of insects by consumers and their inclusion in their diet.

Other studies have suggested that distinguishing insects by species, rather than aggregating them as a whole, may promote greater consumer acceptance of edible insects, since acceptance of edible insects is often tied to a specific insect species. Insect species vary widely and consumers have different experiences with some, some more accepted than others [45]. For example, among Czech consumers, cockroaches are more accepted than crickets. On the other hand, the Chinese distinguish between crickets and silkworms known in their culture, the Germans do not have such a custom [16].

It should be emphasized that the acceptance of edible insects is related to their sensory quality [3]. The taste of insects depends on the environment in which they live, their food and the method of preparation, as insects lose their taste when cooked. The color of the insect changes from original, e.g. blue / green / gray to red (when cooking), gold / brown / black (when drying). The texture of insects can also be related to the cooking method, but also to the stage of development. The exoskeleton of most adult insects makes them crunchy.

When analyzing the acceptance of edible insects by consumers, it is also worth mentioning their readiness to replace traditionally consumed meat and accept insects as its substitute, i.e. consumers' attachment to eating meat. Opinions are divided on this point. People who consider the production of environmentally friendly food, which cannot be attributed to meat production, will be more favorable to the use of edible insects as a meat substitute. The inverse relationship is easy to notice in the case of people with a positive attitude towards the health and taste of meat [10, 45]. Research conducted by Verbeke [52] shows that an increase by one unit of the belief that meat is healthy, nutritious and tasty causes a decrease in the acceptance of insects as a meat substitute by 64 and 61%, respectively. Moreover, men show a higher propensity than women to introduce edible insects in their diets as a meat substitute. This is probably due to the greater openness of men towards trying new, previously unknown products. The study by Tan et al. [49] prove that younger consumers are more willing to consume insects [45, 47, 52].

Bartkowicz [5] conducted research on the potential consumption of insects among nearly 800 Polish consumers. It was found that men, more than women, would be inclined to eat traditional food with added insects to increase the content of nutrients (proteins, vitamins, minerals). Many people are interested in consuming edible insects as an alternative form of food. House [22] described many factors that made it possible to develop a Dutch commercial network of edible insects. It showed a disconnect between edible (basically) and routine consumption (in practice), so products can be positioned as "edible," but that does not mean people will eat them. Hwang and Choe [23] described the low interest of consumers in insect dishes and the reluctance to visit restaurants offering

dishes with insects. They felt it was important to study the risks and dangers of consuming such products. They found 21 perceived risk items, which they grouped into seven factors such as quality, psychological, health, financial, environmental, time, and social risk. Five sub-dimensions of perceived risk had a negative impact on the image, except for financial and environmental risk.

PROFITABILITY OF EDIBLE INSECTS CULTIVATION AND ENVIRONMENTAL IMPACT

Animal breeding poses real threats to the natural environment, e.g. excessive emission of greenhouse gases (methane and ammonia) to the atmosphere, increased consumption of water resources. The breeding of edible insects is environmentally friendly [24, 31]. From the environmental and economic point of view, important is the issue of using insect faeces as fertilizer in agriculture [8], low requirements for the breeding area, as well as low financial outlays for breeding, which are associated with lower consumption of drinking water resources and economy in using agricultural land and forage. Insects are cold-blooded animals, therefore they more effectively use plant biomass to increase body weight compared to warm-blooded animals. Literature data show that crickets use feed very efficiently, turning it into„meat"; compared to poultry – 2 times more efficient, pigs - 4 times more efficient and cattle – 12 times more efficient. Considerably lower costs of breeding insects compared to livestock allow the introduction of edible insects to the diets of poor societies [5, 24, 48].

Insect breeding significantly reduces the use of plant protection products, which reduces the negative impact on the natural environment and the possible presence of pesticides in food. The consumption of edible insects, which are also pests, such as bearberry, will limit the use of pesticides in agriculture, which will consequently reduce their residues in food of plant origin [24].

Edible insects are becoming increasingly popular not only because of their high nutritional value and the ability to reduce the negative impact on the environment, but also because of the profitability of their production and sales [55]. The practice of using insects in Europe is still under development and is regulated by separate provisions of European Union law [10, 47].

CONCLUSIONS

Edible insects are a source of protein, fat, vitamins, minerals and dietary fiber. They have already become a popular food in many countries. It is also a cheaper way to provide food to starving people. There is a growing interest among consumers looking for new flavors, as well as producers, due to their easy production without negative environmental effects. A significant problem is the lack of acceptance of edible insects as a form of food among consumers of European countries. This makes it difficult to bring insects to the market. Future research should address the aspect of entomophagy to pass the barrier of disgust and treat the insects on the plates as a delicacy in the future. It is also a cheaper way to provide food to starving people. Based on the current literature, there is a clear need for detailed research to overcome food safety concerns throughout the food chain based on edible insects, including collections of wild insects. The use of edible insects on a large scale must be regulated in terms of the safety of their consumption on a global scale, therefore it is very important to continue research on the possibilities of their use in human nutrition.

WNIOSKI

Jadalne owady stanowią źródło białka, tłuszczu, witamin, związków mineralnych oraz błonnika po-karmowego. W wielu krajach stały się już popularnym pożywieniem. Jest to też tańszy sposób zapewnienia żywności ludziom głodującym. Rośnie zainteresowanie konsumentów poszukujących nowych smaków, a także producentów, ze względu na łatwość ich wytwarzania bez negatywnego wpływu na środowisko. Istotnym problemem jest brak akceptacji owadów jadalnych jako formy pożywienia wśród konsumentów krajów europejskich. Powoduje to trudności we wprowadzaniu owadów na rynek. Przyszłe badania powinny być powiązane z entomofagią, aby przejść przez barierę braku akceptacji do owadów jako żywności i w przyszłości mogły gościć na talerzach jako przysmak. Opierając się na aktualnej literaturze, istnieje wyraźna potrzeba przeprowadzenia szczegółowych badań by wykluczyć obawy związane z bezpieczeństwem żywności w całym łańcuchu żywności na bazie owadów jadalnych, w tym zbiorów dzikich owadów. Stosowanie owadów jadalnych na dużą skalę musi być uregulowane pod względem bezpieczeństwa ich spożycia w skali globalnej, dlatego bardzo ważne jest kontynuowanie badań nad możliwościami ich wykorzystania w żywieniu człowieka.

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STEVIA REBAUDIANA BERTONI – HEALTH BENEFITS AND TECHNOLOGY APPLICATIONS IN FOOD PRODUCTION. A REVIEW®

Stevia rebaudiana Bertoni – przegląd korzyści zdrowotnych oraz technologicznych zastosowań w produkcji żywności®

Stevia (Stevia rebaudiana Bertoni), a shrub of the Compositae family, is cultivated in many regions of the world for its sweet taste. The sweetness of this plant is a result of steviol glycosides containment, which are 100-300 times sweeter than sucrose. Steviol glycosides have been used as a sweetener and sugar substitute in the food industry. Scientific studies indicate that the regular consumption of steviol glycosides can have a positive effect on health and the human body. Among others they lower blood glucose levels, lower blood pressure and cholesterol, as well as have a protective effect on the pancreas and kidneys. Due to their technological properties, they are used, among others, in the production of beverages and confectionery. Steviol glycosides have the potential to become an important sweetener in the natural food market due to their functional and sensory properties. In combination with other ingredients, they are used to create functional food products with beneficial health properties. ***The aim of the article was is to present the properties of stevia and the steviol glycosides isolated therefrom, highlighting the health and technological benefits and possible applications in the food industry.***

Key words: *Stevia Rebaudiana Bertoni*, steviol glycosides, health benefits, technological process.

Stewia (Stevia rebaudiana Bertoni), krzew z rodziny Compositae, uprawiany jest w wielu regionach świata ze względu na swój słodki smak. Słodycz, roślina ta zawdzięcza obecności glikozydów stewiolowych, 100–300 razy bardziej słodkich niż sacharoza. Glikozydy stewiolowe znalazły zastosowanie jako substancja słodząca, substytut cukru w przemyśle spożywczym. Ze względu na swój bogaty profil odżywczy glikozydy stewiolowe wykazują właściwości biologiczne. Badania naukowe wskazują, że regularne ich spożycie może mieć pozytywny wpływ na zdrowie i organizm człowieka poprzez m.in. obniżenie poziomu glukozy we krwi, obniżenie ciśnienia i cholesterolu, ochronne działanie na trzustkę i nerki. Ze względu na właściwości technologiczne stosowane są między innymi w produkcji napojów i wyrobów cukierniczych. Glikozydy stewiolowe mają potencjał aby stać się ważną substancją słodzącą na rynku żywności naturalnej ze względu na właściwości funkcjonalne i sensoryczne. W połączeniu z innymi składnikami wykorzystywane są do wytworzenia funkcjonalnych produktów spożywczych o korzystnych właściwościach zdrowotnych. ***Celem artykułu jest przedstawienie właściwości stewii i izolowanych z niej glikozydów stewiolowych, z podkreśleniem korzyści zdrowotnych i technologicznych oraz możliwego zastosowania w przemyśle spożywczym.***

Słowa kluczowe: *Stevia Rebaudiana Bertoni,* Glikozydy stewiolowe, korzyści zdrowotne, proces technologiczny.

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INTRODUCTION

Sugar is a commonly used sweetener. It plays an important role in food technology. It is used not only to add a sweet taste, and to reduce a bitter and sour taste, but also to emphasize the intensity of the aroma, to obtain the right texture of different products, the structure, and brown colors of baking products. Sugar also plays a preservative role in jams, marmalades, preserves, and candied fruit. In a temperate climate, it is obtained from sugar beets, while in subtropical countries it is obtained from sugar cane. The composition of beet sugar does not differ from that of a cane sugar. It contains over 99.5% of sucrose and is a source of readily available energy [83].

Taking into account pure and processed sugar, the consumption in Poland in the 1950s was 21–27.9 kg per capita per year. In the 1960s it has increased to 30.6–38.9 kg and subsequently gradually increased to 44.4 kg per capita in 1990. In the last two decades (2000–2019), the total sugar consumption ranged between 38.4–44.5 kg per capita per year. In 2019, a slight decrease in sugar consumption was stated, which amounted to 42.1 kg per capita per year [75].

High average annual sugar consumption is recorded worldwide. In 2017–2019, it was 22.5 kg per capita per year and varied between continents. In Europe, it amounted to nearly 40 kg; in North America about 50 kg; in Latin America 45 kg; in Asia, less than 20 kg; and in Africa about 18 kg per capita per year [64].

The excessive consumption of sugar with various processed products has led the consumers to reduce the amount of sugar in their diets by giving up sweetening their drinks and choosing low-sugar foods. People with higher education more often decide to substitute sugar with sweeteners, including steviol glycosides [68].

Many countries, including Poland (from January 2021) have introducing the so-called sugar tax. In order to meet the expectations of consumers, producers are trying to transform traditional recipes while maintaining the original sensory features. The main criterion for choosing the use of a sweetener is, first of all, the lack of negative impact on human health, the intensity of the sensation of sweet taste, physicochemical properties, such as solubility, stability, availability, and low production costs [44, 82]. Currently, the goal is to replace sucrose in food products with non-nutritive sweeteners from natural sources [53, 56, 70].

Steviol glycosides, due to their functional and sensory properties as well as their beneficial effect on human health, are considered a new, natural sweetener. They have found use, alone or in combination with other sweeteners, in the manufacturing of food products with functional properties. The aim of this review is to present the properties of stevia and the steviol glycosides isolated therefrom, taking into account the health and technological benefits and applicability in the food industry.

DATA COLLECTION

All data presented in this review were summarized from the references, including scientific journals and book chapters. These references were systematically searched against databases: PubMed, Web of Science, Scopus and Google Scholar with a keywords: *Stevia Rebaudiana Bertoni*, steviol glycosides, health benefits, technological process. To search for maximum relative references, the keyword was set as "steviol glycosides and technological process", and restricted to 2000–2020 years.

CHARACTERISTICS OF STEVIA REBAUDIANA BERTONI

Table 1. Comparison of the properties of steviol glycosides and sucrose

Tabela 1. Porównanie cech sacharozy i glikozydów stewiolowych

Sucrose	Steviol glycosides
It gives a sweet taste	They give products a sweet taste but leave a bitter aftertaste
It shapes the color, e.g. in confectionery products	The color does not change during baking
It creates structure, create texture and consistency	No structure-forming properties
It disrupts the hormonal balance	They reduce the symptoms of liver and kidney diseases
Leads to obesity by providing "empty calories"	Calorie-free sweeteners
It contributes to the development of fungi and yeasts	They have antibacterial properties
It promotes the formation of caries	They have anti-caries properties
Extends durability and has a preservative role	They inhibit the growth of mold
It has a low price	High prices of highly purified stevia preparations

Source: Own elaboration based on literature [33, 48]

Źródło: Opracowanie własne na podstawie [33, 48]

Among natural sweeteners, steviol glycosides seem to be a good choice, meeting basically all criteria of a good sugar substitute (Table 1). They are obtained by extraction from the *Stevia rebaudiana Bertoni* plant, which is one of the 154 herbs of the genus Stevia. This one of the two genus of Stevia that produces sweet glycosides, which have much greater sweetening properties than sucrose. On average, they are about 300 times sweeter than sucrose. In terms of sweetening properties and exhibited biochemical properties, *Stevia rebaudiana Bertoni* was considered the most valuable [91]. This plant belongs to the Compositae species, which grows wild in South America and is now cultivated in many regions of the world, including Asia, Europe, and North America [48].

In many countries, stevia is widely used as a sugar substitute in food, drinks, and medicine [1]. Stevia leaves extracts to have better functional and sensory properties than other high-potency sweeteners and have the potential to become the main sweetener in the natural food market [34]. In addition to technological applications, many research results have indicated that regular consumption of steviol glycosides can have beneficial effects on health [1, 77].

Safety of use of steviol glycosides

Due to the sweet taste of the *Stevia rebaudiana Bertoni* plant, its leaves have been used for centuries by the Guarani Indians to sweeten herbal infusions. In countries with traditions of its use, including Paraguay and Japan, no negative effects of its consumption have been documented [10, 86]. The safety of using steviol glycosides has been discussed in the literature, analyzed and considered by numerous regulatory agencies and research organizations. Based on the results of scientific research, in 2008 the European Food Safety Authority established the Acceptable Daily Intake (ADI) of steviol glycosides at the level of 0–4 mg/ kg body weight expressed as steviol equivalent. In 2011 year, steviol glycosides were approved for use in food with the designation E 960 [25].

High-purity stevia leaf extracts have been approved for use in food and beverages in over 150 countries and regions, including the European Union, United States, Middle East, New Zealand, Australia, China, Canada, Japan, Korea, India, Malaysia, Mexico, Brazil, Paraguay, Egypt, Chile, Argentina, Ghana, Kenya, South Africa and many other countries in Asia, Africa, Europe and Latin America [78]. National and international food safety agencies have concluded that steviol glycosides, including the commonly used stevioside and rebaudioside A, are not genotoxic. In recent years, it has been suspected that steviol glycosides may be mutagenic. However, this opinion was based on a limited number of studies [58, 66]. It has been suggested that further in vivo genotoxicity studies are needed to complete the safety profiles of steviol glycosides. Current knowledge regarding *in vivo* and *in vitro* testing of steviol glycosides does not indicate genotoxicity of stevioside or rebaudioside A. In connection with the lack of evidence of cancer development in rat bioassays, the safety of all steviol glycosides with respect to their genotoxicity and carcinogenicity has been established [90]. Abbas Momtazi-Borojeni et al. [1] conducted an extensive meta-analysis of the collected studies, confirming that steviol glycosides are not mutagenic, teratogenic or carcinogenic and do not cause toxicity. The safety of stevia is also largely due to the fact that steviol glycosides are poorly absorbed by both humans and rats in the stomach and the upper intestine [57].

Health properties of steviol glycosides

Steviol glycosides exhibit biological properties. It has been proven that their regular consumption can have a positive effect on health and the human body, as indicated by many authors (Table 2).

Steviol glycosides as a non-caloric sweetener may have an effect on weight loss and thus on obesity. In studies conducted on rats, it was shown a significant decrease in body weight, total cholesterol, triglycerides and low-density lipoproteins, and an increase in high-density lipoproteins in rats that consumed stevia in their diet compared to control rats exposed in diet to sucrose [24]. In a more recent study, diabetic rats given an aqueous extract of stevia leaves for 8 weeks reduced body weight because they reduced their feed and water consumption compared to a control group [3].

Scientists are still working to determine the effects and benefits of human consumption of stevia. Many randomized controlled studies have failed to describe the change in body weight between stevia users and a control group consuming sucrose [51]. However, some authors report a beneficial effect of steviol glycosides in this aspect. In people who consumed stevia and products with their contain, a reduction in the feeling of hunger and the desire to eat was observed compared to the control group [5, 26]. It seems that it is important for diabetics to lower blood glucose levels under the influence of steviol glycosides. This effect is possible due to the inhibition of the activity of α-amylase and α-glucosidase, important enzymes involved in the digestion of carbohydrates [16, 96]. The administration of 500 mg/ kg steviol glycoside extract with diet to diabetic rats resulted in a decrease in their body weight and blood glucose levels. Histopathological examinations also confirmed the protective effect on the pancreas, showing a slight regeneration of structural damage [22]. The meta-analysis also showed that steviol glycosides significantly decreased systolic blood pressure compared to the control group, but no significant effect on diastolic blood pressure [14]. It is also worth emphasizing that steviol, obtained from stevia, has a significant anti-cancer effect against human cancer cells of the digestive tract [20].

Table 2. Health-promoting properties of steviol glycosides

Tabela 2. Właściwości prozdrowotne glikozydów stewiolowych

Effect on health	Source
Lowering blood pressure	[39]
Can be consumed by people suffering from phenylketonuria	[12]
No adverse effects on fertility and reproduction	[1, 12]
Lowering blood glucose levels	[1, 55, 77]
Lowering blood cholesterol	[55]
Inhibition of the growth of cancer cells	[55]
Strengthening blood vessels	[55]
Choleretic action	[48]
Anti-inflammatory acction	[48]
Prevention of ulceration in the digestive tract	[48]
Alleviating damage to the pancreas, kidneys and liver in diabetes	[22, 81]
Anti-caries action	[81]
Most studies indicate positive aspects of steviol glycoside consumption in the diet.	[16, 76, 89, 90]
They show high antioxidant activity	[1, 40, 67, 77]
They limit the growth of many bacteria and infectious organisms, also demonstrating the effect on microorganisms: *Salmonella typhi*, *Aeromonas hydrophila*, *Vibrio cholerae*, *Bacillus subtilis*, *Staphylococcus aureus*	[1, 2, 40,77]
They exhibit antirrotaviral activity by inhibiting the replication of all HRV serotypes and blocking their attachment to the cell.	[54]

Source: Own elaboration based on literature

Źródło: Opracowanie własne na podstawie literatury

Sensory profile of steviol glycosides

The steviol glycosides are responsible for the flavor of the *Stevia Rebaudiana* plant. The main glycosides include stevioside, which constitutes about 65%, and rebiaudoside A constitutes about 25%. The sweetening potential of individual steviol glycosides in relation to sucrose is presented in Table 3.

Table 3. Sweetening potential of steviol glycosides relative to sucrose

Tabela 3. Potencjał słodzący glikozydów stewiolowych w stosunku do sacharozy

Relationship	Sweetening potential		
Stewiol	210–300	–	
Stewiolbiozyd	114	100–125	90
Stewiozyd	200–450	200–450	150–250
Rebaudiozyd A	150–350	150–450	200–300
Rebaudiozyd B	30–120	30–350	150
Rebaudiozyd C	221–450	50–450	30
Rebaudiozyd D	150–300	150–450	221
Rebaudiozyd E	200	150–300	-
Rebaudiozyd F	30–120	30–120	-
Dulkozyd A	90–125	50–125	30
Source	[82]	[19, 29, 37]	[62]

Source: Own elaboration based on literature

Źródło: Opracowanie własne na podstawie literatury

Stevioside is responsible for a bitter and licorice aftertaste that is weaker with rebaudioside A. Rebaudioside A is the most stable in the technological process. At the same time, it shows the best sensory values, has the least bitterness and sour taste than other steviol glycosides. It also has the most desirable sensory profile of all glycosides, as well as greater sweetening power with a lower level of undesirable off-flavors. It is also more thermally stable and more soluble in water compared to stevioside [18, 48, 71, 85]. Solutions of rebaudioside A, compared to solutions of aspartame and sugar (with the same sweetening power), are characterized by the most intense sweet aftertaste. An important feature of steviol glycosides is the persistence of a sweet aftertaste in the mouth for a long time after consumption, despite the feeling of bitterness. This sensation is much longer and is more intense than that of sucrose [48]. In practice, the lowest possible levels of addition of steviol glycosides are used because of the possible potential for undesirable off-flavors. The use of substances such as rice maltodextrin, vegetable glycerin, erythritol, fructo-oligosaccharin, the addition of citric acid and pectin allows to mask the bitter aftertaste and increases the possibilities addition of steviol glycosides [30, 69]. Chranioti et al. [21] found that the bitterness of steviol glycosides also decreased after encapsulation with maltodextrin and inulin if using the spray drying technique. One of the commonly used flavor improvement strategies for stevioside due to enhance the sweetness power is glycosylation which can be carried out using α-amylase from *Aspergillus oryzae* or *Bacillus amyloliquefaciens*, in the presence of soluble starch [92, 93], glucosyltransferase cyclodextrification [94], dextransucrase [43] and alternansachraza [61]. The enzymatic transglycosylation of rebaudioside A by the enzyme glucansachrase from *Lactobacillus reuteri* 180 was also successfully performed, using sucrose as a glucosyl donor [23, 31, 60, 87]. The third most common steviol glycoside found in stevia leaves is Rebaudioside C. It has limited use in the food industry due to its persistent bitterness and low sweetness compared to other glycosides.

The taste profile of steviol glycosides is influenced by the degree of purification and the quantitative proportions between individual glycosides. The undesirable aftertaste of steviol glycosides is related to the impurities left over from the extraction and purification process. Therefore, thanks to the use of the latest traditional and non-genetically modified breeding techniques, new varieties of stevia are created that contain the desired steviol glycosides, such as Rebaudioside M and D, at a level 20 times higher than in the well-known varieties of stevia [72, 73, 78].

Selected technological properties of steviol glycosides

In Japan, stevia has been used by food producers for over 40 years. Salty snacks are the main group of food products in which steviol glycosides have been used. Due to the fact that the combination of stevioside and sodium chloride gives the dish softness, steviol glycosides are used in the production of pickled vegetables, dried seafood, soy sauces and miso [19, 34, 84, 88], and jams [11, 17, 45, 69].

The use of steviol glycosides in beverages

Steviol glycosides are used in the production of beverages due to their sweetening properties and storage stability (Table 4). It was found that in highly acidic products, at elevated temperatures, gradual hydrolysis of steviol glycosides to steviol may take place. However, this does not affect the loss of sweetness, because the resulting steviol is also characterized by strong sweetening properties. It was also found that 160 mg/ l of stevioside successfully replaces 34 g/ l of sucrose in peach juice without negative affecting the sensory properties of the product, while reducing the energy value by 25% [4, 65]. Stevia can be used as a replacement for sucrose in apple and cherry drinks, as it does not affect the sensory experience [9]. The use of steviol glycosides in peach juice sweetened with a combination of sucrose (56 g/ l) and stevia (160 mg/ l) to replace sucrose (34 g/ l), reduced the energy value by 25% without affecting the sensory aspects of the product compared to the sample containing 90 g/ l sucrose. Fruit juices sweetened with steviol glycosides showed a bitter taste as well as a metallic aftertaste [74]. However, it has been shown that the addition of lime flavor effectively masks negative sensory taste [59]. In mango nectar with no added sugar, the use of 3% stevia and 6% inulin allowed to obtain the best mango nectar with the desired value, without undesirable changes in organoleptic and physicochemical properties [8].

Table 4. Application of steviol glycosides in various food groups

Tabela 4. Zastosowanie glikozydów stewiolowych w różnych grupach żywności

Food group	Source
Beverages: – peach juice – apple and cherry drinks – mango nectar – chokeberry juice – cola drinks – ice tea	[4, 8, 9, 38, 65, 72, 79]
Bakery and confectionery products: – muffins – oatmeal cookies – sweet bread – breakfast cereals – cereal bars	[6, 13, 28, 35, 95]
Functional food: – whipped cream with no added sugar – functional fruit juices – high-protein functional cookies – functional wheat bread	[7, 15, 42, 47, 77]
Nutraceuticals: – chlorophylls – phytosterols – polyphenols – carotenoids – tannins	[46, 63]
Dairy: – yoghurts – chocolate milk – frozen milk dessert (kulfi) – rice pudding (kheer) – milk desserts	[32, 36, 41, 49, 50]

Source: Own elaboration based on literature

Źródło: Opracowanie własne na podstawie literatury

Stevia leaves can also increase the nutritional value of beverages, as has been shown with chokeberry juice. Chokeberry juice with the addition of steviol glycosides had a better nutritional composition (high content of vitamin C, carotenoids, total content of chlorophylls and polyphenols) compared to the juice made with the addition of sucrose [79]. Among the carbonated soft drinks on the food market, Coca-Cola Co. and Pepsi Co Inc. have decided to introduce stevia-sweetened beverages, thus reducing the energy value of the drinks [38]. Fruit functional apple and carrot juices with stevia extract showed better sensory values and phenolic profile [42]. The addition of steviol glycosides to strawberry juice increased the content of phenolic compounds, including the total content of phenols, flavonoids and antioxidant capacity. In addition, the authors report [79] that the addition of stevia together with the use of ultrasonic treatment techniques can be an effective strategy for preserving strawberry juices, while increasing their sweetness and antioxidant properties of the resulting beverages. Study results encourage the use of stevia as a replacement for traditional sugar in fruit juices, which may not only lower the energy value and sugar content, but also provide better physicochemical properties and higher nutritional value, positively influencing the effects of fruit juices [15, 80].

The use of steviol glycosides in bakery products and cookies

Stevia can also be successfully introduced as a sucrose substitute in bakery products (Table 4). Replacing sucrose with stevioside on the level of 50 and 100% in bread did not affect the physicochemical and sensory characteristics of the product compared to the traditional composition (100% sucrose) [95]. In other studies, it was found that replacing more than 50% of sucrose with steviol glycosides negatively affected the sensory profile of bakery products, in particular the undesirable aftertaste [53].

Similarly, replacing up to 50% of sucrose in muffins did not affect the texture deterioration, but lowered the glycemic index. In order to improve the sensory features, the addition of cocoa and vanilla turned out to be necessary. However, muffins with 100% sucrose substitution with steviol glycosides showed high notes of bitter aftertaste, were characterized by a hard consistency and dryness, which resulted in the lack of consumer acceptance [28].

Similar relationships were found in oatmeal cookies. Substitution of sucrose with steviol glycosides on the level of 25, 33, 50 and 66% in cookies did not affect their sensory quality. While the addition of 100% stevia contributed to low sensory ratings in terms of taste, color, appearance, texture and overall acceptability [13, 35].

Stevia, as a sucrose replacement, is also used with other sweetening ingredients to produce functional foods (Table 4). A functional whipping cream with improved physical and sensory properties, with no added sugar, was produced. Isomalt and Rebaudioside A, as well as isomalt were used as a sucrose substitute, and maltodextrin is used for improving texture [7]. Low-calorie and high-protein functional cookies, prepared by replacing sucrose at the level of 20% with stevia leaf powder and wheat flour with soy flour, showed high sensory quality [47]. The innovative use of stevia due to its antioxidant properties was to functional wheat bread [77].

The use of steviol glycosides in dairy products

Stevia can be used to produce functional foods as well as nutraceuticals due to contain of extractable biologically active ingredients such as polyphenols, chlorophylls, carotenoids and tannins [46]. Polysaccharides, i.e. fructans, that have been isolated from stevia roots, have also found application in functional and prebiotic foods [52]. Due to the fact that the addition of stevia and food additives does not negative affect the yoghurt-making process, steviol glycosides have been used as sweeteners in the production of yoghurt [36]. The resulting consistency and creaminess are comparable to products with sugar. In yoghurt sample with the addition of only stevia, an unfavorable aftertaste was noticeable, which was masked by the addition of a thickener. According to Lisak et al. [50] natural and flavored yoghurts, sweetened with the addition of stevia, sucrose, and equal proportions of stevia and sucrose in three different concentrations, showed the same apparent viscosity. On the other hand, yoghurts with the addition of 4.5 g/ 100g of equal amounts of stevia and

sucrose obtained the best sensory scores. Likewise, chocolate milk partially sweetened with monk fruit and stevia reduced the content of traditional sugar without affecting consumer acceptance [49]. Other authors report the possibility of using stevia in milk drinks and desserts, e.g. Indian kulfi (a frozen product resembling ice cream) or rice pudding (kheer). The sucrose content reduced by stevia in kulfi and kheer was 75 and 67%, which also reduced the energy value [32, 41].

CONCLUSIONS

1. Steviol glycosides have special biological properties, and their regular consumption may have a positive effect on human health and body, for example cause lowering blood glucose levels, lowering blood pressure and cholesterol, and have protective effect on the pancreas and kidneys.
2. Studies confirm that steviol glycosides are not mutagenic, teratogenic or carcinogenic and do not cause toxicity and can be consumed at the acceptable doses.
3. Stevia shows better functional and sensory properties than other high-potency sweeteners and has the potential to become the main sweetener on the natural food market.
4. The use of substances such as: rice maltodextrin, vegetable glycerin, erythritol, fructooligosaccharide, addition of citric acid and pectin allows masking the bitter aftertaste and give the possibility of increasing the addition of steviol glycosides in the designed bakery products, cakes and beverages.
5. Steviol glycosides, according to their sweetening properties and stability during storage, are used in the production of beverages, and also improving their health benefits.
6. Stevia can be a substitute for sucrose in bakery products in amounts not greater than 50% of sucrose, due to its unfavorable effect on the sensory profile of the products.
7. Stevia, as a sucrose replacement, is also used with other ingredients to obtain functional food products with beneficial health properties.

WNIOSKI

1. Glikozydy stewiolowe wykazują właściwości biologiczne, zaś regularne ich spożywanie może mieć pozytywny wpływ na zdrowie i organizm człowieka tj. obniżenie poziomu glukozy we krwi, obniżenie ciśnienia i cholesterolu, ochronne działanie na trzustkę czy nerki.
2. Badania potwierdzają, że glikozydy stewiolowe nie są mutagenne, teratogenne ani rakotwórcze i nie powodują toksyczności oraz mogą być spożywane w określonych dawkach.
3. Stewia wykazuje lepsze właściwości funkcjonalne i sensoryczne od innych substancji słodzących o dużej mocy oraz posiadaja potencjał aby stać się główną substancją słodzącą na rynku żywności naturalnej.
4. Stosowanie substancji, takich jak: maltodekstryna ryżowa, roślinna gliceryna, erytrol, fruktooligosacharyna, dodatek kwas cytrynowego oraz pektyny pozwala na zamaskowanie gorzkiego posmaku i możliwość zwiększenia dodatku glikozydami stewiolowymi w projektowanych wyrobach piekarniczych, ciastach, napojach.
5. Glikozydy stewiolowe dzięki swoim właściwościom słodzącym oraz stabilności podczas przechowywania, stosowane są w produkcji napojów, jednocześnie wpływając na poprawę korzyści zdrowotnych.
6. Stewia może być substytutem sacharozy w wyrobach piekarniczych w ilościach nie większych niż 50% sacharozy, ze względu na niekorzystny wpływ na profil sensoryczny produktów.
7. Stewia, jako zamiennik sacharozy, wykorzystywana jest również z innymi składnikami, aby uzyskać funkcjonalne produkty spożywcze o korzystnych właściwościach zdrowotnych.

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WYTŁOKI OWOCOWE – CHARAKTERYSTYKA I MOŻLIWOŚCI ZAGOSPODAROWANIA®

Fruit pomace – characteristics and possibilities of recycling®

W ostatnim czasie obserwuje się wzrost spożycia owoców i warzyw, jak również soków, przecierów, smoothie, których produkcja związana jest z powstawaniem wytłoków. Zagospodarowanie tych produktów odpadowych stanowi istotny problem w przetwórstwie spożywczym. Liczne badania dowodzą, iż wytłoki owocowe stanowią cenne źródło wielu wartościowych substancji odżywczych. Ze względu na swoje właściwości rośnie popularność ich zastosowania w wielu gałęziach przemysłu, m.in. w produkcji pasz, herbat owocowych, wyrobów piekarniczych i wielu innych. ***W artykule omówiono owoce i ich przetwory, nowoczesne metody technologiczne w przetwarzaniu owoców, powstawanie wytłoków owocowych oraz możliwości ich zagospodarowania.***

Słowa kluczowe: owoce, przetwarzanie owoców, wytłoki owocowe, zagospodarowanie.

Recently, there has been an increase in the consumption of fruit and vegetables, as well as juices, purees, and smoothies, the production of which is associated with the formation of pomace. The recycling of these waste products is a significant problem in food processing. Numerous studies prove that fruit pomace is a valuable source of many nutrients. Due to their beneficial properties, the popularity of their use in many industries is growing, including in the production of fodder, fruit teas, bakery products, and many more. ***The article discusses fruit and their products, innovative methods of fruit processing, the formation of fruit pomace, and the possibilities of their management.***

Key words: fruits, fruit processing, fruit pomace, recycling.

WPROWADZENIE

Owoce są cennym źródłem wielu witamin i związków mineralnych, dlatego stanowią kluczowy element w diecie człowieka. Składnikiem owoców zasługującym na szczególną uwagę jest błonnik. Włókno pokarmowe, ze względu na swoje właściwości prozdrowotne, powinno stanowić element zrównoważonej diety każdego człowieka. Dodatkowo właściwości funkcjonalne błonnika sprawiają, że cieszy się dużym zainteresowaniem w technologii żywności. Rosnąca popularność przetworów owocowych m.in. soków, przecierów czy smoothie skutkuje wzrostem ilości odpadów produkcyjnych, którymi są wytłoki [8]. Utylizacja niewykorzystanych części surowca jest istotnym problemem dla przemysłu owocowego. Liczne badania wskazują na możliwość zagospodarowania wytłoków owocowych w rożnych gałęziach przemysłu. Produkty odpadowe znajdują zastosowanie m.in. w przemyśle spożywczym jako składniki herbat owocowych, dodatek do wyrobów cukierniczych i piekarniczych. W przemyśle kosmetycznym ekstrakty pozyskane z wytłoków są składnikami kosmetyków, natomiast w przemyśle tekstylnym wytłoki stanowią surowiec do produkcji alternatywy dla skóry zwierzęcej. Wytłoki znajdują szerokie zastosowanie ze względu na zawartość wielu cennych związków, których obecność oraz ilość zależy od pochodzenia wytłoków. **Celem artykułu jest charakterystyka owoców i ich przetworów, omówienie nowoczesnych metod technologicznych w ich przetwarzaniu oraz powstawanie wytłoków owocowych i możliwości ich zagospodarowania.**

OWOCE I ICH PRZETWORY

Owoce posiadają odpowiednią kombinację cukrów, kwasów oraz związków aromatycznych kształtujących się w procesie dojrzewania. Produkty te są bogatym źródłem witamin, w szczególności A i C, minerałów oraz związków bioaktywnych [5]. WHO zaleca spożywanie co najmniej 400 g owoców i warzyw dziennie w celu zmniejszenia ryzyka chorób sercowo-naczyniowych, otyłości, cukrzycy oraz raka jelita grubego i żołądka. Około 2,8% zgonów na świecie wynika ze zbyt niskiego spożycia owoców i warzyw [18]. Czynniki takie jak sezonowość, wahania w wielkości plonów, niska trwałość wpływają na konieczność przetwarzania i utrwalania owoców. Do produktów otrzymanych na bazie owoców należą przeciery, pulpy, konserwy, dżemy, powidła, marmolady, soki, napoje oraz nektary. Najważniejszym celem obróbki jest inaktywacja drobnoustrojów, co pozwala na zwiększenie trwałości przetworów owocowych. W wyniku przerobu

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surowców zmniejszony zostaje dostęp tlenu oraz zanika zdolność enzymów do rozkładu, dzięki czemu chemiczne części składowe ulegają utrwaleniu. Ma to istotne znaczenie żywieniowe, ponieważ zostają zachowane cukry, białka a przede wszystkim witaminy, błonnik i barwniki. Wiele procesów technologicznych wpływa na zwiększenie przyswajalności określonych związków np. karetonoidów. Niektóre cechy sensoryczne i fizykochemiczne mogą ulec pogorszeniu podczas procesu otrzymywania lub przechowywania. Przetwory pozwalają na pominięcie obróbki wstępnej, co pozwala na usprawnienie czynności kulinarnych. Przetworzone owoce są również łatwiejsze do przechowywania [15, 49]. Soki i nektary owocowe należą do największego i najprężniej rozwijającego się sektora w polskim przemyśle spożywczym. Pierwsze z nich stanowią najlepszą alternatywę dla surowych owoców, ponieważ zawierają mniej węglowodanów [15]. Soki są bogate w witaminy, błonnik pokarmowy, minerały i flawonoidy, co wpływa na ich prozdrowotne odziaływanie na organizm. Produkty te są istotnym elementem diety osób zmagających się ze schorzeniami związanymi z układem pokarmowym [49]. Habanova i wsp. [16] przeprowadzili badania, które dowiodły, iż spożywanie soku z jabłek i jagód powoduje spadek poziomu cholesterolu LDL oraz zmniejsza ryzyko chorób sercowo-naczyniowych. W ostatnich latach wzrasta popularność soków nieklarowanych, które cechują się wyższą zawartością przeciwutleniaczy oraz błonnika ograniczającego wchłanianie cukrów, co skutkuje obniżeniem indeksu glikemicznego. Proces produkcji tego typu soków przebiega z pominięciem obróbki enzymatycznej i filtracji, dzięki czemu aktywność biologiczna jest zbliżona do świeżych owoców [15]. Podział soków wynika ze sposobu ich otrzymania – z koncentratu lub nie z koncentratu. Soki odtworzone z koncentratu wymagają wzbogacenia w witaminy i związki aromatyczne, które uległy degradacji w wyniku przetwarzania owoców [17]. Dodatek barwników, substancji konserwujących czy aromatów innych niż pochodzące z surowców, z których sok został otrzymany jest niedozwolony [35]. W odróżnieniu od soków nektary mogą zawierać cukier, miód, słodziki oraz regulatory kwasowości [17, 32]. W ostatnich latach rośnie zainteresowanie gęstymi sokami przecierowymi – smoothie. Skład tych produktów stanowi mieszanina soków owocowych lub warzywnych, przecier, kawałki owoców, mleko, jogurt, nasiona lub orzechy. Popularnym dodatkiem do tego typu przetworów są nasiona chia, które wzbogacają produkt w kwasy tłuszczowe omega-3 i omega-6. Dodatkowo w porównaniu do soków i nektarów charakteryzują się większą zawartością błonnika oraz witaminy C [15, 11].

Dżemy, powidła oraz marmolady należą do produktów o wysokim stopniu przetworzenia. Przetwory te są utrwalane przez obróbkę termiczną, wysoką koncentrację cukru i kwasów oraz ewentualny dodatek konserwantów [42]. Pomimo tego, iż dżemy są popularnym przetworem w Polsce, ich wybór nie jest tak zróżnicowany jak w innych krajach, w których znajdziemy dżemy imbirowe, bananowe, kokosowe, z liczi lub z guawy [13]. Wysokoprzetworzone produkty charakteryzują się mniejszą zawartością polifenoli i niższą aktywnością przeciwutleniającą niż owoce świeże. Mirończuk -Chodakowska i wsp. [33] oznaczyli zawartość polifenoli w produktach owocowych o znacznym stopniu przetworzenia. W badanych dżemach jagodowych zawartość polifenoli wynosiła 323 mg/100 g natomiast w świeżych owocach była ona niemal dwa razy wyższa – 614 mg/100 g. Podobną zależność zaobserwowano między niskosłodzonym dżemem morelowym (57 mg/100 g) a świeżymi morelami (148 mg/100 g). Niska aktywność antyoksydacyjna wynika z destrukcyjnego wpływu procesu technologicznego na polifenole oraz witaminę C. Powodem znacznych różnic w zawartości polifenoli między świeżymi owocami a przetworami może być skład recepturowy dżemów, w których znajduje się często jedynie 35% owoców. Przeprowadzone badania dowiodły również, iż zawartość polifenoli ogółem w dżemach wysokosłodzonych jest wyższa niż w niskosłodzonych wyprodukowanych z tych samych gatunków owoców, co może wynikać ze zwiększonej trwałości antocyjanów w wysokich stężeniach sacharozy. Zmiany zawartości witaminy C, antocyjanów i polifenoli badali również Martinsen i wsp. [31]. Badacze wykazali, że wysoka temperatura niezbędna w procesie technologicznym powoduje zmniejszenie zawartości wyżej wymienionych związków w dżemie truskawkowym, natomiast nie ma istotnego wpływu na dżem z malin. Dowiedziono również, że im wyższa temperatura tym większe następują straty związków.

NOWOCZESNE METODY TECHNOLOGICZNE W PRZETWARZANIU OWOCÓW

Termiczne metody przetwarzania

Suszenie jest jedną z najstarszych metod utrwalania owoców. Celem tego procesu jest zmniejszenie zawartości wody do poziomu, który pozwala na zahamowanie zmian enzymatycznych oraz uniemożliwi wzrost i rozwój drobnoustrojów [28]. Susze owocowe są wykorzystywane do produkcji mieszanek owocowych, musli, kisieli oraz herbat [10]. Suszenie próżniowo – mikrofalowe jest procesem przebiegającym przy obniżonym ciśnieniu z jednoczesnym nagrzewaniem mikrofalowym. Obniżenie ciśnienia powoduje obniżenie temperatury wrzenia wody, co pozwala na zredukowanie niekorzystnego działania wysokiej temperatury na poddawany suszeniu produkt. Zastosowanie mikrofal jako źródła ciepła pozwala na ogrzanie całej objętości materiału w bardzo krótkim czasie. Dzięki odpowiedniemu kształtowaniu rozkładu temperatur wewnątrz suszonego materiału możliwe jest ograniczenie a nawet wyeliminowanie miejscowego przegrzewania produktu. Suszenie próżniowo – mikrofalowe pozwala na uzyskanie produktu o odpowiedniej teksturze, strukturze i dobrych cechach organoleptycznych [20].

Liofilizacja jest procesem polegającym na zamrożeniu materiału, z którego następnie usuwana jest wilgoć na drodze sublimacji lodu. Suszenie sublimacyjne przebiega z pominięciem stanu ciekłego. Proces ten przeprowadza się najczęściej pod obniżonym ciśnieniem, które wynosi od 15 do 150 Pa. Pierwszym etapem liofilizacji jest zamrożenie materiału w temperaturze od –20°C do –40°C. Kolejny etap procesu polega na suszeniu produktu w komorze liofilizatora [56]. Suszenie sublimacyjne uważane jest za najlepszą metodę suszenia. Produkty otrzymane na drodze liofilizacji cechują się bardzo dobrą jakością. Suszenie sublimacyjne pozwala na zachowanie większej ilości witamin w porównaniu do innych metod suszenia. Straty witamin w liofilizatach wynoszą kilka procent, podczas gdy w suszach otrzymanych innymi metodami kształtują się na poziomie 20-80% w zależności od

rodzaju surowca. Susze sublimacyjne charakteryzują się również lepszą zdolnością do rehydratacji. Proces liofilizacji pozwala na zachowanie atrakcyjnej barwy produktu w porównaniu do suszy otrzymanych metodą konwekcyjną, w czasie której straty barwinków wynoszą nawet 70%. Suszenie sublimacyjne wpływa na zmniejszenie start aromatu, który jest uzależniony od zmian strukturalnych. Podczas suszenia sublimacyjnego skurcz materiału wynosi 5–15%, natomiast podczas suszenia konwekcyjnego osiąga 80% [57].

Nietermiczne metody przetwarzania

Pulsacyjne pole elektryczne PEF jest jedną z nietermicznych metod utrwalania żywności. Działanie PEF polega na inaktywacji drobnoustrojów znajdujących się w płynie przez wysokonapięciowe impulsy. Ciecz poddawana utrwalaniu musi znajdować się pomiędzy dwoma elektrodami. Pulsacyjne pole elektryczne niszczy wegetatywne formy drobnoustrojów natomiast nie jest skuteczne w stosunku do form przetrwalnikujących. PEF w porównaniu do termicznych metod utrwalania pozwala na zachowanie odpowiednich cech sensorycznych, chemicznych oraz fizycznych. Dodatkowo charakteryzuje się niską energochłonnością procesów technologicznych [38]. Pulsacyjne pole elektryczne może również wspomagać ekstrakcję polifenoli czy pektyny z wytłoków jabłkowych [52]. Zastosowanie pulsacyjnego pola elektrycznego w produkcji wina przyczynia się do poprawy wydobycia anocyjanów, co powoduje zwiększenie zawartości tych prozdrowotnych związków o 5% w porównaniu do wina, otrzymanego bez użycia PEF [23]. Ultradźwięki są falą mechaniczną mieszczącą się w zakresie częstotliwości od 18 kHz do 100 MHz. Mechanizm działania ultradźwięków polega na wywoływaniu zmian w komórkach biologicznych poprzez kawitację, która powoduje powstanie, wzrost i gwałtowne znikanie pęcherzyków gazu tworzących się, gdy propagowane są ultradźwięki o odpowiedniej mocy. Innym rezultatem oddziaływania ultradźwięków jest szybkie, naprzemienne ściskanie oraz rozprężanie materiału wywołane przechodzeniem fali akustycznej przez materiał stały oraz efektami związanymi z kawitacją na granicy ciało stałe – ciecz. Zmiany te nazywane są efektem gąbki [58]. Barros i wsp. [3] zastosowali ultradźwięki do intensyfikacji procesu suszenia papai. Badacze dowiedli, iż obróbka ultradźwiękowa przyśpieszyła suszenie owocu oraz zmniejszyła straty związków bioaktywnych. Badania przeprowadzone przez Rojasa i wsp. [45] potwierdziły, iż zastosowanie ultradźwięków pozwoliło na zachowanie większej ilości fenoli w suszonych konwekcyjnie jabłkach w porównaniu do próbek niepoddanych działaniu ultradźwięków. Bozkir i wsp. [7] zbadali wpływ obróbki ultradźwiękowej i odwadniania osmotycznego na owoce persymony. Uzyskane wyniki pozwoliły na stwierdzenie, iż procesy te spowodowały skrócenie czasu suszenia a także wpłynęły na lepsze zachowanie cech jakościowych w porównaniu do próbek owoców niepoddanych obróbce. Kolejną nietermiczną metodą utrwalania wykorzystywaną w przemyśle owocowym jest wysokie ciśnienie hydrostatyczne – HPP. Metoda ta jest stosowana do przedłużenia trwałości soków, dżemów, smoothies, przecierów oraz galaretek. Inaktywacja form wegetatywnych zachodzi przy ciśnieniu około 200 MPa, drożdży i pleśni przy ciśnieniu około 400 MPa. Najwyższego ciśnienia wymaga inaktywacja przetrwalników, około 600-800 MPa, dodatkowo wspomagana przez podwyższoną temperaturę [30]. Badania przeprowadzone przez Raghubeer i wsp. [44] dowiodły, iż poddanie działaniu HPP wody kokosowej pozwala na uzyskanie produktu stabilnego mikrobiologicznie. Próbki utrwalone przy pomocy wysokiego ciśnienia hydrostatycznego podczas przechowywania przez 120 dni w 4°C charakteryzowały się smakiem zbliżonym do świeżego soku oraz nie posiadały nieprzyjemnego zapachu. Próbki wody kokosowej niepoddane działaniu HPP po dwóch tygodniach przechowywania w tej samej temperaturze miały podwyższoną liczbę drobnoustrojów a także odnotowano wytwarzanie gazu, zmętnienie i nieprzyjemny zapach. Zastosowanie zimnej plazmy jest kolejną nietermiczną metodą obróbki owoców i ich przetworów. Zjonizowany gaz, taki jak tlen, argon czy azot jest czynnikiem inaktywującym drobnoustroje. Zjonizowany gaz otrzymywany jest poprzez doprowadzenie do niego znacznej ilości energii, która pozwala na rozpad cząstek na elektrony i dodatnio naładowane jony. Wysoka energia oraz reaktywność cząstek plazmy eliminuje drobnoustroje bez zmian cieplnych w utrwalanym produkcie. Składniki plazmy są nietrwałe, w wyniku czego nie będą one obecne w produkcie gotowym [48]. Li i wsp. [27] zastosowali zimną plazmę w celu utrwalenia świeżych, pokrojonych owoców pitaji, co pozwoliło na zahamowanie wzrostu liczby bakterii tlenowych. Dodatkowo zimna plazma spowodowała akumulację fenoli oraz zwiększenie aktywności przeciwutleniającej owoców.

OTRZYMYWANIE WYTŁOKÓW OWOCOWYCH

W przetwórstwie owocowo-warzywnym istotny problem stanowi zagospodarowanie lub utylizacja produktów odpadowych – części niewykorzystanych w procesie technologicznym. Jest to ilość w granicach 10–35% masy przetworzonego surowca [50]. W ich skład wchodzą skórki, nasiona oraz wytłoki. Produkty uboczne w przetwórstwie owocowym powstają podczas produkcji soków, pulp czy dżemów. W procesie produkcji soków masa wytłoków jest uzależniona od wydajności tłoczenia. Podczas tradycyjnego tłoczenia udział wytłoków wynosi 20–25% masy surowca. Zastosowanie preparatów enzymatycznych, które upłynniają miazgę oraz ługowanie wytłoków wodą, pozwala na zmniejszenie udziału wytłoków do około 12% masy owoców [8].

Wzrost populacji oraz zmiany żywieniowe przyczyniają się do większego spożycia owoców i warzyw, co powoduje wzrost ilości odpadów związanych z ich przetwarzaniem [25]. W Europie produkty uboczne powstające w wyniku przetwarzania owoców stanowią 8% wszystkich odpadów z sektora spożywczego. Branża ta jest piątym największym producentem odpadów. Sytuacja jest znacznie gorsza w krajach rozwijających się, gdzie produkty uboczne przetwórstwa owocowego są traktowane jako nieistotne i zbędne w porównaniu do przetworzonych owoców [37]. Według danych GUS w Polsce w sezonie 2018/2019 na produkcję soku zagęszczonego przeznaczono 3150 tys. ton jabłek [41]. Przyjmując, że wytłoki, które powstają podczas produkcji soków, stanowią 20% zużytego surowca, w sezonie tym powstało aż 630 tys. ton wytłoków.

ZAGOSPODAROWANIE WYTŁOKÓW OWOCOWYCH

Wytłoki są materiałem charakteryzującym się niską trwałością i stabilnością. Wytłoki owocowe z uwagi na dużą zawartość wody, która w jabłkowych stanowi nawet do 73%, są narażone na szybki wzrost zanieczyszczeń mikrobiologicznych. Do najpopularniejszych metod utrwalania wytłoków należy suszenie oraz kiszenie hamujące niekorzystne zmiany prowadzące do obniżenia jakości. Dzięki tym zabiegom nadają się one do dalszego zastosowania [50].

Table 1. Chemical composition of chockeberry, black currant and cherry pomaces

Tabela 1. Skład chemiczny wytłoków z aronii, czarnej porzeczki i wiśni

skład chemiczny	wytłoki		
	z aronii	z czarnej porzeczki	z wiśni
błonnik (g/100g s.s.)	42,0	59,7	70,9
węglowodany (g/100g s.s.) glukoza (g/100g s.s.) fruktoza (g/100g s.s.) sacharoza (g/100g s.s.)	45,1 6,3 7,49 -	16,0 0,6 1,0 0,6	11,3 1,5 1,4 0,5
białko (g/100g s.s.)	6,4	17,4	12,6
antocyjany (mg /100 g s.s.)	10,0	1,5	0,8

Source: Own study based on [54, 55]

Źródło: Opracowanie własne na podstawie [54, 55]

W skład wytłoków zależnie od odmiany i sposobu przetwarzania, wchodzą skórki, nasiona oraz resztki miąższu. Ze względu na ich skład oraz zawartość wielu prozdrowotnych składników, w ostatnich latach można dostrzec wzrost zainteresowania możliwościami ponownego wykorzystania tych produktów ubocznych [39]. Skład chemiczny wybranych wytłoków owocowych przedstawiono w tabeli 1. Wytłoki są bogate we włókno roślinne. W zależności od pochodzenia wytłoki różnią się zawartością poszczególnych frakcji błonnika (rys. 1). Kwaśniewska i Nawirska [36] oznaczyły skład poszczególnych frakcji błonnika w wytłokach z czarnych porzeczek, aronii, jabłek, wiśni i gruszek. Przeprowadzone badania wykazały, iż wytłoki jabłkowe na tle pozostałych analizowanych odpadów wywierają najkorzystniejszy wpływ na nasze zdrowie, dzięki znacznej zawartości pektyn posiadających zdolność wiązania jonów metali ciężkich oraz celulozy mającej pozytywy wpływ na perystaltykę jelit. Zdolność do wiązania jonów metali ciężkich przez wytłoki owocowe została również zaobserwowana przez Król i Nawirską [26]. Badaniom zostały poddane wytłoki z jabłek, wiśni i czarnych porzeczek oraz ich kombinacje w celu usuwania jonów ołowiu, miedzi, cynku i kadmu z roztworów wodnych w układach dynamicznych. Wytłoki z wiśni zatrzymały najwięcej jonów kadmu i ołowiu, natomiast mieszanka wytłoków jabłkowych z wiśniowymi pozwoliła na zatrzymanie największej ilość jonów cynku i miedzi. Najmniej skuteczne okazały się w tym zestawieniu wytłoki z czarnych porzeczek. Właściwości adsorpcyjne wytłoczyn owocowych badali Dudczak i wsp. [9]. Badaniom poddano wytłoki z agrestu do usuwania jonów miedzi w układach modelowych. Przeprowadzony eksperyment wykazał, że suszone wytłoki agrestu przy pH 4-5 są w stanie zaadsorbować około 58% jonów miedzi obecnych w roztworze wodnym. Na podstawie otrzymanych wyników badacze stwierdzają, iż wytłoki mogą służyć jako materiał sorpcyjny do usuwania jonów metali ze ścieków (nowy kierunek zagospodarowania odpadów owocowych).

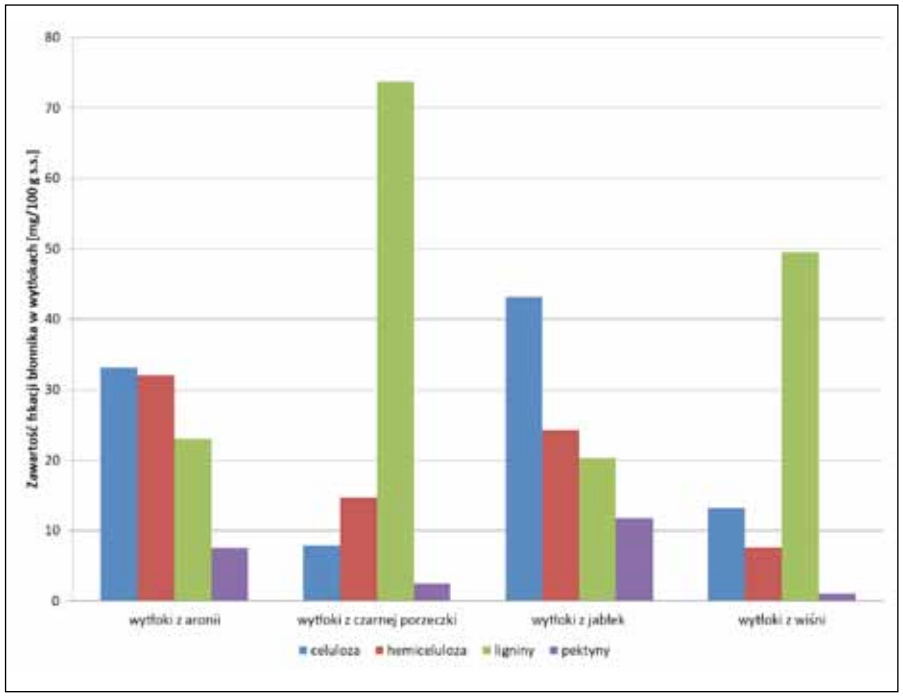

Fig. 1. Fibre fraction content in selected fruit pomaces.

Rys. 1. Zawartość frakcji błonnika w wybranych wytłokach owocowych.

Source: Own study based on [36]

Źródło: Opracowanie własne na podstawie [36]

Pektyny, których najlepszym źródłem są owoce cytrusowe i jabłkowe, poza zdolnością wiązania jonów, charakteryzują się także właściwościami żelującymi, zagęszczającymi i stabilizującymi. Dzięki temu znajdują zastosowanie w przemyśle jako hydrokoloidy [24]. Wysoka zawartość błonnika sprzyja także przeciwdziałaniu otyłości, cukrzycy, chorobom serca, miażdżycy i niektórym rodzajom raka [50]. Pektyna z owoców cytrusowych modyfikowana metodami termicznymi, chemicznymi lub enzymatycznymi jest zarejestrowana w Stanach Zjednoczonych jako suplement diety. Badania kliniczne potwierdziły antynowotworowy potencjał modyfikowanej pektyny, która przeciwdziała progresji guzów i hamuje przerzuty. Pektyna cytrusowa wpływa również na komórki układu odpornościowego w celu regulacji odpowiedzi zapalnej [4].

Wytłoki stanowią ponadto źródło wielu innych wartościowych składników odżywczych takich jak: związki mineralne,

sacharydy, białka, kwasy organiczne, lipidy, witaminy, aldehydy czy alkohole. Są również bogate w substancje aromatyczne oraz barwniki, do których zaliczają się antocyjany potrafiące nadać barwę od żółtej do niebieskiej. Wysoką zawartością związków barwiących charakteryzują się wytłoki z owoców jagodowych. Umożliwia to wydobycie z wytłoków tych związków i produkcję barwników. Związki fenolowe poza nadawaniem barwy wykazują silne właściwości prozdrowotne. Wraz z tokoferolami należą do przeciwutleniaczy, odpowiedzialnych za ochronę przed szkodliwym działaniem wolnych rodników, co w konsekwencji pozwala na zapobieganie chorobom serca, zaćmie, nowotworom oraz powstrzymywanie procesów starzenia [50].

Wytłoki są bogatym źródłem biopolimerów, białek oraz węglowodanów, które mogą być odzyskiwane, koncentrowane, przekształcane w prekursory a następnie zastosowane w przemyśle kosmetycznym, farmaceutycznym czy spożywczym. Badacze podjęli próby, które pozwoliły na uzyskanie z wytłoków owoców tropikalnych enzymów, oligosacharydów, biosurfaktantów, kwasu mlekowego oraz furfuralu [37]. Wytłoki mogą być również zastosowane do wzrostu mikroorganizmów, co pozwala na uzyskanie enzymów pektynolitycznych z wytłoków ananasa, pomarańczy lub cytryny, amylaz z mango lub bananów czy lipaz ze skórki cytryny. Wytłoki stanowią alternatywne źródło węgla dla powszechnie używanych w hodowli mikroorganizmów glukozy i sacharozy. Pozwala to na znaczne obniżenie kosztów produkcji i uzyskanie cennych w przemyśle polisacharydów takich jak guma ksantanowa, pullulan czy kurdlan. Mohsin [34] za pomocą wytłoków z pomarańczy zsyntezował kurdlan, który dzięki swoim właściwościom żelującym znajduje szerokie zastosowanie w różnych gałęziach przemysłu. Należący do β-glukanów polisacharyd jest komponentem biodegradowalnych folii, produktów funkcjonalnych np. jogurtów a także może stanowić zamiennik tłuszczu w produktach mięsnych obniżając ich kaloryczność. Kurdlan charakteryzuje się również właściwościami immunostymulacyjnymi, co powoduje wzrost zainteresowania tym związkiem w medycynie. Fermentacja alkoholowa, w której źródło węgla stanowią wytłoki, pozwala również na uzyskanie biopaliwa. Najwydajniejszym substratem są wytłoki z jabłek, które pozwalają na uzyskanie 190 g etanolu z 1 kg odpadów [12]. Piwowarek i wsp. [40] zastosował wytłoki jabłkowe jako podłoże mikrobiologiczne w procesie fermentacji propionowo-octowej. Wykorzystanie wytłoków z jabłek jako źródła węgla umożliwiło hodowlę dzikiego szczepu bakterii *Propionibacterium freudenreichii* T82 i uzyskanie kwasu octowego i propionowego.

Skórki jabłek charakteryzują się wysoką zawartością fenoli co oznacza większe skoncentrowanie tych związków bioaktywnych w wytłokach niż w całych owocach. Związki fenolowe posiadają silne właściwości przeciwdrobnoustrojowe, przeciwzapalne i antyoksydacyjne. Wyizolowanie tych substancji pozwala na wprowadzenie wytłoków do preparatów kosmetycznych [2], gdzie znalazły również zastosowanie pestki owoców bogate w cenne oleje. Powszechnie stosowanym w tym przemyśle jest olej z pestek malin doceniany ze względu na zawartość związków mineralnych, prowitaminy A, witaminy B_2, C oraz kwasów organicznych m.in. salicylowego i jabłkowego. Skład chemiczny omawianego oleju sprawia, że może on stanowić komponent preparatów przeciwsłonecznych, kremów lub past do zębów [21].

Obecnie najpopularniejszym kierunkiem zagospodarowania wytłoków jest zastosowanie ich jako paszy, co pozwala na znaczne obniżenie kosztów żywienia zwierząt. Zawierają one ponadto istotne składniki takie jak: kwasy organiczne, cukry, substancje tłuszczowe, związki bezazotowe i witaminy. Zawartość tych ostatnich w wytłokach po procesie tłoczenia soków może wynosić nawet 2 g/kg suchej masy. Wartość ta jest uzależniona od warunków prowadzenia procesu [50].

Wytłoki mogą również służyć jako składnik do herbat owocowych wpływający na poprawę walorów organoleptycznych [53]. Bober i Oszmiański [6] wskazali na możliwość zastosowania wytłoczyn z aronii jako zamiennika owoców w produkcji herbat owocowych. Porównano wyciągi wodne otrzymane z owoców i wytłoków suszonych różnymi metodami. W naparach otrzymanych z wytłoków aronii suszonych owiewowo uzyskano 2-krotne zmniejszenie zawartości glukozy, sorbitolu i fruktozy w porównaniu do naparów z owoców suszonych tą samą metodą. Odnotowano natomiast 11,5-krotne zwiększenie monomerów antocyjanów. Niezależnie od metody suszenia napary z wytłoków posiadały bardziej czerwoną i nasyconą barwę niż te z owoców. Dodatkowym atutem herbat na bazie wytłoczyn była ich aktywność przeciwrodnikowa. W wyciągu wodnym z liofilizowanych wytłoków aronii zaobserwowano największą zdolność do pochłaniania wolnych rodników (8383 mg/L). Dla porównania wyciąg wodny z liofilizowanych owoców aronii usunął około 600 mg/L wolnych rodników.

Oceny sensoryczne przeprowadzone przez Baranowskiego i wsp. [1] wykazały możliwość zastosowania zagęszczonych ekstraktów z wytłoków z aronii i czarnej porzeczki do herbat owocowych typu „ice", kisieli oraz galaretek. Dodatek ekstraktu z wytłoków z czarnej porzeczki sprawił, że galaretki z syntetycznym aromatem opisywanego owocu zostały lepiej ocenione pod względem smaku i zapachu. Wzbogacone w ekstrakty produkty posiadały specyficzny, lekko kwaskowaty smak oraz bardziej intensywną, czerwoną barwę, która jest pożądana dla tego typu produktów.

Odpady przemysłu owocowego mogą z powodzeniem być stosowane w niektórych wyrobach cukierniczych i piekarniczych. Kidoń i wsp. [22] zmodyfikowali recepturę wafli suchych zastępując mąkę suszonymi wytłokami jabłkowymi w ilości 10 i 12,5%. Na podstawie przeprowadzonych badań stwierdzono, iż 10% dodatek wytłoków pozwolił na uzyskanie produktu ze zwiększoną zawartością składników prozdrowotnych przy minimalnych zmianach cech sensorycznych. Dodatek suszonych odpadów owocowych spowodował znaczny wzrost związków polifenolowych. Uzyskane wafle posiadały ciemniejszą barwę, natomiast ocena sensoryczna wykazała różnice w teksturze. Siemianowska i wsp. [47] użyli wytłoków z truskawek, jabłek, czarnych porzeczek i malin do wypieku kruchych ciastek. Badania wykazały, że 30% udział wytłoków pozwolił na zachowanie odpowiednich cech sensorycznych jednocześnie nie pogorszając parametrów teksturalnych i przechowalniczych. Dodatkowo oznaczona została aktywność antyoksydacyjna wszystkich rodzajów ciastek, wynosiła ona 52,2–66,5%. Podobne badania przeprowadzili Maner i wsp. [29], zastępując w ciastkach część mąki pszennej wysuszonymi wytłokami winogronowymi. Wyniki badania, tak jak w poprzednich przytoczonych, pozwoliły na stwierdzenie, iż dodatek wytłoków pozwolił na wzbogacenie

produktów w substancje o charakterze prozdrowotnym przy jednoczesnym zachowaniu lub nadaniu odpowiednich cech sensorycznych. Salehia i Aghajanzadeh [46] także opisali wpływ wysuszonych i sproszkowanych owoców i warzyw na jakość ciasta. Obecność wyżej wymienionego proszku spowodowała zwiększenie absorpcji wody w wyniku czego ciasto charakteryzowało się większą wilgotnością. Zmniejszenie ilości glutenu przyczyniło się do zmniejszenia objętości i poprawy jędrności. Dodatek proszku pozwolił na zwiększenie wartości odżywczej. Ciasto biszkoptowe, w którym część mąki pszennej zastąpiono sproszkowanymi skórkami i pulpą z mango w proszku zawierało więcej błonnika oraz mniej tłuszczu i kalorii a ponadto zostało wzbogacone w cenne żywieniowo polifenole i karetonoidy. Wytłoki owocowe znajdują zastosowanie w produkcji pieczywa bezglutenowego. Wzbogacenie receptury chleba z mąki ryżowej i skrobi ziemniaczanej w wytłoki z pomarańczy pozwoliło na otrzymanie produktu o właściwościach sensorycznych zbliżonych do próby kontrolnej [43].

Grasso [14] w swoim przeglądzie przestawiła możliwość zastosowania wytłoków do produkcji ekstrudowanych przekąsek. Produkty te mogą stanowić alternatywę dla przekąsek zbożowych obecnych na rynku, charakteryzujących się najczęściej niską wartością odżywczą, zbyt dużą zawartością soli, cukru oraz tłuszczu. Przykładem tego typu produktu jest przekąska, w której skład wchodzi kukurydza, mąka z sorgo oraz wytłoki z jabłek. W celu zwiększenia zawartości oraz zrekompensowania strat związków fenolowych i przeciwutleniaczy poniesionych w procesie ekstruzji przeprowadzono wcześniej fermentację i kawitację hydrodynamiczną, co zwiększyło zawartość błonnika w finalnym produkcie. Autorka przeglądu przytoczyła także badania, które dowiodły, iż do produkcji przekąsek z powodzeniem można zastosować wytłoki z wiśni, czarnej porzeczki, ananasa czy borówki.

Wytłoki mogą również znaleźć zastosowanie w utrwalaniu żywności. Liczne badania dowiodły, iż ekstrakty pozyskane z wytłoków mają wpływ na przedłużenie trwałości produktów. Przeprowadzono badania polegające na dodaniu do kotletów z jagnięciny ekstraktów z wytłoków z winogron, oliwek, pomidorów i granatu. Po 7 dniach przechowywania w warunkach chłodniczych zakonserwowany w ten sposób produkt posiadał 10-21% mniej bakterii mezofilnych w porównaniu do próby bez dodatków. Wytłoki z pomidorów i granatu przyczyniły się do zmniejszenia liczby psychrofili oraz bakterii z rodziny *Enterobacteriaceae.* Działanie przeciwbakteryjne odnotowano także przez wzbogacenie produktów z wołowiny w skórki granatu oraz zanurzanie krewetek w roztworze zawierającym wytłoki. Wytłoki mają także pozytywny wpływ na produkty mleczne. Badanom został poddany ser, który zanurzono w roztworze ze skórkami z granatu. Po 28 dniach przechowywania w temperaturze 4°C odnotowano mniejszą liczbę mikroorganizmów wpływających na obniżenie jakości produktu w porównaniu do próby kontrolnej. Wzbogacenie jogurtu w sproszkowaną skórkę z ananasa przyczyniło się natomiast do zwiększenia jego probiotyczności [51].

W przemyśle skrobia powszechnie pozyskiwana jest z bulw i zbóż. Alternatywę dla tych surowców mogą stanowić wytłoki niektórych owoców o wysokiej zawartości tego polisacharydu. Dodatkowo skrobia otrzymana z wytłoków posiada inne właściwości funkcjonalne, co zwiększa zakres jej zastosowań w przemyśle. Kringel i wsp. [25] wskazali na możliwość pozyskania skrobi m.in. z wytłoków z ananasa, jabłek, mango, liczi, awokado czy owocu drzewa bochenkowego. Pestki ostatniego z wymienionych stanowią najlepsze źródło omawianego polisacharydu (60-80%). Unikalnymi właściwościami charakteryzuje się skrobia pozyskana z wytłoków z mango, ponieważ posiada niski indeks glikemiczny dzięki czemu znajduje zastosowanie w produktach o obniżonej kaloryczności.

Nowatorskim kierunkiem zastosowania wytłoków jest produkcja tekstyliów. Bio2materials jest polską marką, która zajmuje się tworzeniem alternatywny dla skóry zwierzęcej i syntetycznej z wytłoków z jabłek. Produkt jest całkowicie biodegradowalny oraz pozbawiony szkodliwych dla zdrowia substancji [19].

PODSUMOWANIE

Owoce będące źródłem wielu cennych związków stanowią ważny element zrównoważonej diety. Sezonowość, wahania w wielkości plonów oraz niska trwałość są czynnikami wpływającymi na konieczność utrwalania i przetwarzania owoców. Najpopularniejsze przetwory owocowe to soki, nektary, smoothies, dżemy, przeciery, powidła oraz marmolady. Ważnym aspektem przetwarzania owoców jest zachowanie jak największej ilości cennych z punktu żywieniowego związków oraz zmniejszenie strat smaku, zapachu oraz barwy. Wymagania te powodują konieczność opracowywania nowych metod przetwarzania owoców. W ostatnich latach popularność zyskują nietermiczne metody, do których zalicza się m.in. pole pulsacyjne, wysokie ciśnienie hydrostatyczne, ultradźwięki czy zimną plazmę. Zastosowanie wyżej wymienionych sposobów utrwalania pozwala na wyeliminowanie niekorzystnego działania wysokiej temperatury. Zasługującym na szczególną uwagę składnikiem owoców jest błonnik, który ze względu na właściwości prozdrowotne oraz funkcjonalne cieszy się dużym zainteresowaniem. Bogatym źródłem włókna pokarmowego są wytłoki, które stanowią produkt uboczny w procesie produkcji soków, dżemów czy pulp. Skład i właściwości wytłoków wskazują na możliwość ich zagospodarowania, dzięki czemu produkt odpadowy staje się surowcem w innych gałęziach przemysłu spożywczego.

SUMMARY

Fruits, which are the source of many valuable compounds, are an important part of a balanced diet. Seasonality, fluctuations in yields and low shelf life are factors influencing the necessity of preserving and processing the fruit. The most popular fruit preserves are juices, nectars, smoothies, jams, purées, plum jam and marmalades. An important aspect of fruit processing is to preserve as many nutrients as possible and reduce the loss of taste, smell and colour. These requirements cause the development of new methods of fruit processing. In recent years, nonthermal methods have been gaining popularity, including pulse field, high hydrostatic pressure, ultrasounds or cold plasma. The use of the above-mentioned methods of fixing makes it possible to eliminate the unfavorable effects of high temperature. The fruit component that deserves special attention is fibre, which, due to its health-promoting and functional properties, is very popular. A rich source of dietary

fiber is pomace, which is a by-product in the production of juices, jams and pulp. The composition and properties of pomace indicate the possibility of their management, thanks to which the waste product becomes a raw material in other branches of the food industry.

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THE USE OF THE ARTIFICIAL DIGESTIVE TRACT MODEL IN NUTRITIONAL SCIENCES®

Wykorzystanie modelu sztucznego przewodu pokarmowego w naukach żywieniowych®

The human microbiome, especially the gut microflora, has been a research topic for many years and its influence on human health has caught a particular interest. Thus, any abnormalities are linked to the prevalence of many diseases and conditions. Due to the rapid technological development, microbiome research is often undertaken using an artificial model of the digestive tract or gastrointestinal tract, these technological developments are of significant support to the basic research performed on the microbiome. The structure of the human gut is very complicated as well as its function, thus, it is extremely difficult to build such machinery that would function correctly. This review is based on available literature about the SHIME® artificial human gut model (patented technology by the University of Ghent and the ProDigest company that act as the owner).
Thanks to the project "Food and Nutrition Center – modernization of the SGGW campus in order to create the Food and Nutrition Research and Development Center (CŻiŻ)" co-financed by the European Union from the European Regional Development Fund under the Regional Operational Program of the Mazowieckie Voivodeship for 2014-2020 [RPMA project no. 01.01.00-14-8276 / 17] The Institute of Human Nutrition Sciences has acquired the SHIME® technology artificial digestive tract.

Key words: microbiome, artificial gut, artificial gastrointestinal system, small intestine, large intestine.

Mikrobiom człowieka, w tym szczególnie mikrobiota jelitowa od wielu lat jest przedmiotem badań w aspekcie jej wpływu na zdrowie. Z kolei, zaburzenia składu mikrobioty powiązane są z ryzykiem występowania wielu chorób. Do badań nad mikrobiomem coraz częściej wykorzystuje się modele sztucznego przewodu pokarmowego, które stanowią istotne wsparcie badań podstawowych w naukach żywieniowych. Ze względu na skomplikowaną budowę i funkcjonowanie przewodu pokarmowego człowieka bardzo trudno jest skontruować taki model, który by w pełni odpowiadał wszystkim uwarunkowaniom naturalnego przewodu pokarmowego.
Niniejsze opracowanie powstało na bazie dostępnych artykułów naukowych dotyczących w szczególności działania i zastosowania sztucznego modelu przewodu pokarmowego SHIME®, (opatentowanej technologii, której twórcą i właścicielem jest konsorcjum Uniwersytetu w Gandawie i firma ProDigest).
Dzięki projektowi pt. „Centrum żywności i żywienia - modernizacja kampusu SGGW w celu stworzenia Centrum Badawczo-Rozwojowego Żywności i Żywienia (CŻiŻ)" współfinansowanego przez Unię Europejską ze środków Europejskiego Funduszu Rozwoju Regionalnego w ramach Regionalnego Programu Operacyjnego Województwa Mazowieckiego na lata 2014-2020 [Nr projektu RPMA.01.01.00-14-8276/17] Instytut Nauk o Żywieniu Człowieka wzbogacił się o sztuczny przewód pokarmowy w technologii SHIME.

Słowa kluczowe: sztuczny przewód pokarmowy, mikrobiom, jelito cienkie, jelito grube.

INTRODUCTION

The human microbiome, especially the gut microflora, has been a subject of interest to many scientists around the world for many years. Its impact on human is of high significance and the currently available scientific literature confirms that microbiome quality influences immune system, namely the formation of immunity [15, 25], it supports the digestion processes which have an impact on formation of metabolites like vitamins and hormones, [7] but also neurotransmitters like serotonin [3, 19]. Furthermore, there is a constant influx of new information and research about the abnormalities of the microbiota, usually defined as dysbiosis. Dysbiosis is a known cause of obesity, inflammation and even psychological disorders [3, 25]. Gut microbiota consists of very large numbers of microbes, approximately 0.9 x10^{11} microbes/g of faeces. It is estimated that the proportion of microbes to the entire amount of cells in the human organism is 1,3:1 [14, 25].

The existing models of the artificial gastrointestinal tract, described in the scientific literature, such as Dynamic Gastric Model (DGM), Human Gastric Simulator (HGS),

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TNO Gastro-Intestinal Model (TIM), DIDGI System, IViDiS [4, 10, 17, 18, 23] are considered as an important support for nutritional research. However, due to the complicated structure and function of the digestive tract, both in humans and other mammals it is nearly impossible to replace one hundred per cent of studies carried out *in vivo* models (i.e. studies carried out with the use of animal models) using these newly developed technologies. The problem that the creators of such systems had to face was often the reconciliation of the complexity of that system, reflecting the conditions that naturally prevail in the gastrointestinal tract as faithfully as possible, with its universal use for research on digestion or other physiological processes.

The SHIME®2 system consists of sections corresponding to the digestive system organs, i.e. stomach, small intestine and colon (ascending, transverse and descending) (Fig. 1, 2 and 3). The device is made of glass reactors placed in a double water jacket. This enables continuous and constant heating by a software-controlled water bath. Because of this configuration, it is possible to maintain a constant temperature of 37°C in the whole model. The motor functions are ensured by a number of peristaltic pumps, which are responsible for both the intestinal passage and the supply of an appropriate volume of solutions containing digestive enzymes and other necessary components. These regulate digestive functions and ensure the stability of the entire system. The system also requires feeding using the medium that ensures the optimal supply of macro-and micronutrients [5, 11]. The pumps support the process of expelling products produced in the "intestines". In order to the digestion process run smoothly at the same time maintaining the appropriate pH, the fluid in each section of the digestive tract is mixed with magnetic stirrers. This solution allows establishing a specific pH profile for each section of the gastrointestinal tract. As during normal physiological process, during digestion in SHIME® the pH in the small intestine fluctuates around the neutral pH – slightly alkaline, while in the ascending colon the pH fluctuates around 5.6 to 5.9 in the transverse part of the large intestine – in between 6.1 and 6.4, reaching a range between 6.6 and 6.9 in the descending part [8]. An important feature of the system is keeping it in an oxygen-free atmosphere. This is achieved by providing an inert gas (Nitrogen N2).

The SHIME® system has been designed to study the human gut microbiota. The quality, microbial profile and conditions of which have a fundamental effect on the human body. The research involves regulating the absorption of nutrients and other compounds formed during digestion or fermentation [25]. The system is inhabited by natural human microbiota. The *in vivo* microbiological composition of faeces differs from that of the colon. The colon has a high specificity, it acts as a bioreactor in which the transformation of the intestinal microbiota takes place. Therefore, starting an experiment using an artificial model requires time to adapt the faecal microbiome in different parts of the system. Assuming that the adult intestinal transit time is about 48 hours, the time to colonise the entire system under these conditions will oscillate in the range of 10-20 days. During this period, the inoculated faecal microbiome will adapt to the conditions in the bioreactors [13, 23]. The adaptation period is adjusted to the composition of the microbiome used, but can also be

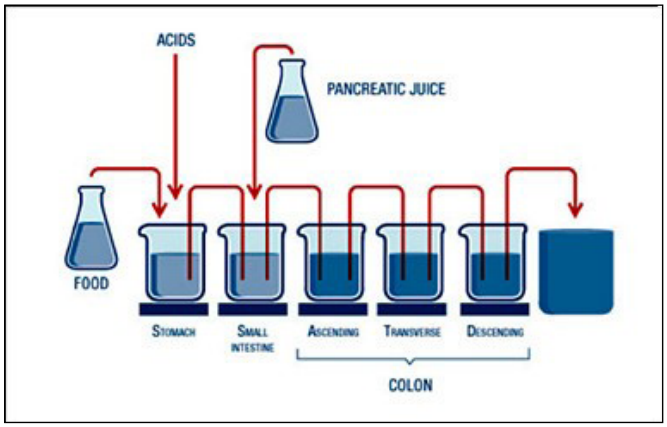

Fig. 1. The diagram of the reactors system. Source: Pro-Digest Gastrointestinal expertise
Rys. 1. Schemat układu reaktorów. Źródło: ProDigest Gastrointestinal Expertise

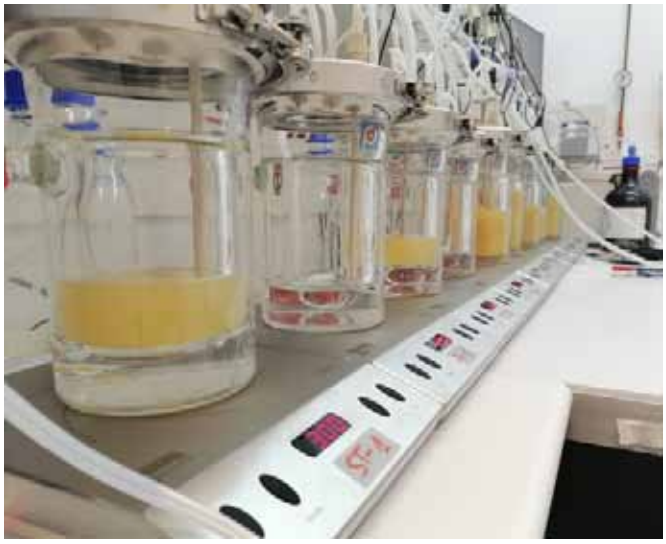

Fig. 2&3. System of reactors. Photograph provided. Source: Own study
Rys. 2 i 3. System reaktorów. Źródło: Opracowanie własne

controlled by the scientist depending on the research needs. As mentioned, the system is inhabited by the faecal microbiome collected from one person. This solution causes a very high convergence of natural conditions with those prevailing in the model conditions, which has been confirmed by other studies [1, 22]. The results indicate that the metabolism of microorganisms in the intestines e.g. selected polyphenolic compounds (isoxanthohumol, daidzein, catechins, etc.) is dependent on a microbial makeup of a person. Therefore, there is no pooling of samples from multiple individuals. This helps to maintain the microbiological phenotype of the person from whom the biological material was collected and allows for long-term research in the metabolism of specific polyphenols [2, 12].

Studies optimising the operation of the SHIME® system [20] have found that the selection of a specific inoculum enables the proper colonisation of the large intestine mucosa. The mucosa microbiome is that part of the gut microbial ecosystem that is able to colonise the mucus covering the intestinal epithelium [8]. Due to the proximity of host epithelial cells, it is believed that the mucosal microbiome has a greater intrinsic power to modulate intestinal health as well as human health overall [21]. Additionally, it is known that the mucosal microbiome differs significantly from the intestinal microbiome in composition. Interestingly, the presence of important mucosal colonizers, such as *Faecalibacterium prausnitzii*, seems to be negatively correlated with the occurrence [24] and postoperative recurrence of Lesnikowski-Crohn's disease in the ileum [16]. Given the difficult access to the mucosal environment, the development of gut simulators that closely mimic mucosal microbial colonisation is considered a strong asset in gaining a better understanding of host-microbial interactions. An artificial model of the gastrointestinal tract such as SHIME® is a highly standardised system. The scientist uses software to control many parameters of the processes that are running in this system, this creates the possibility of obtaining highly reproducible results [5, 23]. It is a significant and important element of experiments that allows comparison between different products such as new probiotics, prebiotics, new plant extracts or potential drug ingredients [8].

OPERATION

According to the assumptions of ProDigest, a typical SHIME® simulator experiment involves four stages:

- stabilization period (2 weeks) – allowing the inoculated faecal microorganisms to adapt to the environmental conditions in the relevant regions of the colon;
- basic period (2 weeks) – during which the parameters in the reactors are equalised, this enables the basic parameters (output - control) to be measured in the experiment
- the period of the experiment (2–4 weeks) – the effect of the substances used on the community of microorganisms in the gastrointestinal and gas-intestinal tract is examined;
- a wash period (2 weeks) – to determine how long the changes caused by the test substance can be measured in the absence of the substance itself.

The scheme of action adopted in this way makes it possible to study the activity and stability of probiotics and prebiotics during gastrointestinal transport, bacterial conversion of bioactive food ingredients (e.g. phytoestrogens), metabolism of pharmaceutical ingredients, the effectiveness of delivery systems targeted to the colon, and the conversion and biological (in) activation of food and/or ingested environmental pollutants [23].

Due to the modularity of the SHIME® system, short-term experiments are also possible. One-week long experiments can be performed, especially in the context of monitoring the initial stages of microbial colonisation on the mucosal surface.

USES

The experiment carried out by [20] confirmed the possibility of colonisation within 5 days of the intestinal mucosa, excluding the luminal microbiome. The modular configuration of the system also allows for placebo-controlled studies, e.g. when comparing different prebiotics and probiotics [6] or when the microbiome phenotype producing a bioactive metabolite is compared with a non-producing phenotype [12]. Furthermore, it is possible to study the interindividual variability in the microbiome profile by dividing the system into several parallel sections of the colon, each of which is inoculated with faecal microbiota from different donors.

The application of the SHIME® artificial gastrointestinal model is an *in vitro* model that integrates the entire gastrointestinal transit into a single system makes it possible to study the digestibility of prebiotic substrates and their subsequent fermentation in the colon. Additionally, measuring the survival of pathogens or probiotics in the upper gastrointestinal tract before they reach the colon environment is possible. Thanks to the modularity of the system, to conduct both short-term experiments appropriately, e.g. the colonisation capacity of microorganisms, and long-term experiments gives the possibility of responding to the adaptation of the microbial ecosystem to the changing environmental conditions specified by the system operator. Another interesting application, which is a strong advantage of the SHIME® system, is the possibility of extending it to M-SHIME – enabling the assessment of mucosal microbiota [20, 23].

By using the SHIME® model, the production of SCFA or ammonia can be preliminarily assessed on the basis of the amount of NaOH or HCl, which are supplemented by pH regulators to maintain appropriate pH values in the corresponding vessels of the colon. This system also allows the microbiome composition to be assessed in the relevant vessels in the colon. For further determinations, DGGE (Denaturing Gradient Gel Electrophoresis) is usually used, which can be supplemented by quantitative analysis by q-PCR or high-throughput analysis at the phylogenetic level with next-generation sequencing [9].

SUMMARY

The artificial digestive tract SHIME® technology (by ProDigest) will allow the Institute of Human Nutrition Sciences to expand its research activities with the new scientific directions concerning microbiota. It can also contribute to the development and creation of new products or the improvement of existing formulations and the protection of the gastrointestinal tract, which play a vital role in the human body and impacts human health greatly.

PODSUMOWANIE

Podsumowując, sztuczny przewód pokarmowy w technologii SHIME® (firmy ProDigest) pozwoli Instytutowi Nauk o Żywieniu Człowieka rozszerzyć swoją działalność badawczą o nowe kierunki badań dotyczące, przede wszystkim mikrobioty. Może również przyczynić się do opracowywania nowych produktów lub ulepszania istniejących receptur oraz ochrony przewodu pokarmowego – tak ważnej części ciała odpowiedzialnej za zdrowie i prawidłowe funkcjonowanie organizmu ludzkiego.

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MICROBIOLOGICAL SAFETY OF FRUIT AND VEGETABLES AT THE PRIMARY PRODUCTION STAGE®

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Consumers are increasingly interested in healthy lifestyles, leading to increased consumption of fresh produce. This may contribute to their exposure to an increased risk of foodborne illness. Before consumption, fresh produce does not undergo processing steps each time that ensure effective removal or inactivation of pathogenic microorganisms. This problem has resulted in a significant increase in reports of disease outbreaks associated with ready-to-eat fruits and vegetables in recent years. In addition, the nature and sources of microbial contamination of these products is critical to the development of appropriate countermeasures with the potential for implementation by food manufacturers. The objective of this review was to characterize the foods most susceptible to microbial contamination and the microorganisms responsible for outbreaks based on information available in scientific publications. Pathogenic strains of Escherichia coli and Salmonella and norovirus accounted for the majority of cases. There is a need for standardized data sets on all aspects of outbreaks. Providing knowledge to food entrepreneurs will allow them to implement better strategies to improve safety of fresh produce.

Key words: fresh vegetables and fruit, microbial contamination, produce outbreaks.

Konsumenci są coraz bardziej zainteresowani zdrowym stylem życia, co prowadzi do zwiększonego spożycia świeżych produktów. Może to przyczynić się do narażenia na zwiększone ryzyko chorób przenoszonych drogą pokarmową. Przed spożyciem świeże produkty nie są za każdym razem poddawane etapom przetwarzania, zapewniającym skuteczne usunięcie lub inaktywację mikroorganizmów chorobotwórczych. Spowodowało to w ostatnich latach znaczny wzrost liczby zgłoszeń ognisk chorób związanych z owocami i warzywami gotowymi do spożycia. Charakter i źródła mikrobiologicznego zanieczyszczenia tych produktów są kluczowe dla opracowania odpowiednich środków zaradczych, które mogą być wdrożone przez producentów żywności. Celem tego przeglądu jest omówienie żywności najbardziej podatnej na zanieczyszczenia mikrobiologiczne oraz mikroorganizmów odpowiedzialnych za powstawanie ognisk chorób w oparciu o informacje dostępne w publikacjach naukowych. Większość przypadków stanowiły patogenne szczepy Escherichia coli i Salmonella oraz norowirusy. Istnieje potrzeba standaryzacji zestawów danych dotyczących wszystkich aspektów ognisk chorobowych. Dostarczenie wiedzy przedsiębiorcom branży spożywczej pozwoli na wdrożenie lepszych strategii w celu poprawy bezpieczeństwa świeżych produktów.

Słowa kluczowe: świeże warzywa i owoce, zanieczyszczenie mikrobiologiczne, ogniska chorób.

INTRODUCTION

Unsafe food has been a health problem for centuries, and many food safety issues are not new. Although governments around the world are making every effort to improve the safety of the food supply, the incidence of foodborne illnesses remains a major health problem in both developed and developing countries. An estimated 1.8 million people die each year from diarrheal diseases, and most of these cases can be attributed to contaminated water or food. Proper food preparation can prevent most foodborne illnesses [40, 60]. In many cases, fresh fruits and vegetables are ready-to-eat (RTE) commodities [37]. Consumers often do not subject these foods to any processing step before consumption (lack of effective removal or inactivation of contaminants). Their increased consumption, combined with globalization and large-scale production of RTE foods [45], has resulted in longer distribution times and increased distribution distances [32]. In particular, product-related disease outbreaks have increased in recent years [26, 45]. Reports from the European Food Safety Authority (EFSA) and the European Centre for Disease Prevention and Control (ECDC) have indicated an increase in the trend in the contribution of non-animal foods to the total burden of foodborne illness in Europe [13, 14, 15]. The same trend has been observed in reports from the US Centers for Disease Control and Prevention (CDC) regarding foodborne illness outbreaks [5].

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GROUPS OF MICROORGANISMS INVOLVED IN FOOD CONTAMINATION

The increase in world population has resulted in an increased demand for food [5, 39]. However, food security problems in different regions of the world arise due to food spoilage [37, 39]. Food spoilage occurs when the quality of food deteriorates from its original organoleptic properties found during processing. Food spoilage causes huge economic losses to both producers (farmers) and consumers [39]. Food spoilage rates are influenced by factors such as storage temperature, water availability, pH, initial microbial load (total viable count-TVC), processing and the most all presence of spoilage-causing microorganisms including bacteria and fungi [4, 38, 39, 41, 43]. A report prepared by the United Nations Food and Agriculture Organization states that one-third of the food produced for human consumption is either spoiled or wasted [23]. Food spoilage is defined as a change in the quality of food that makes it undesirable and unfit for consumption by both humans and animals (unpleasant odor and changes in texture and appearance) [2, 34; 42]. This is a complex process resulting from underlying causes that can be broadly grouped as microbiological, chemical, or physical [48]. In addition to the problems of food insecurity and economic losses [29], spoiled food also contributes to food waste, which is another global environmental problem [24]. Colonization of food by spoilage-causing microorganisms occurs in different ways depending on the type of food. There are countless types of microorganisms that may be involved in food spoilage. A few of these are listed below [11, 39, 47, 49, 57]:

- Mold fungi. These are capable of growing over a wide range of temperatures. Representative types of molds that cause food spoilage include *Rhizopus, Penicillium, Aspergillus, Geotrichum*, *Fusarium*, *Mucor*, *Alternaria, Cladosporium*, *Eurotium,* and *Byssochlamys;*.
- Yeasts. Food spoilage microorganisms may act on perishable foods, indicating that the food has been stored for an extended period of time after synthesis or harvest. a. Fermentation yeasts. Representative genera include *Saccharomyces* and *Zygosaccharomyces*. b. Oxidative yeasts. Representative genera include *Saccharomyces* and *Zygosaccharomyces*. b. Oxidative yeasts. Representative genera include *Mycoderma*, *Candida*, *Pichia*, and *Debaryomyces*. They are involved in food spoilage, which is defined as having oxidative damage;
- *Enterobacteriaceae.* These Gram-negative mycobacteria are facultatively anaerobic, fermentative, mesophilic, non-spore forming, and lack oxidase and catalase. Representative types of these bacteria include *Escherichia*, *Erwinia*, *Enterobacter*, *Citrobacter, Serratia*, and *Proteus*. These bacteria are usually involved in spoilage of fresh vegetables, meat poultry, fish, and eggs;
- *Pseudomonadaceae.*Representative types of this family of bacteria include *Xanthomonas* and *Pseudomonas.* These non-spore-forming Gram-negative mycobacteria are inherently psychrophilic, aerobic and oxidase-positive. Pseudomonads are well known major microorganisms causing spoilage of seafood, fresh meat, poultry and eggs;
- Lactic-acid bacteria. Representative genera are *Lactobacillus*, *Leuconostoc*, *Streptococci*, *Lactococcus*, *Enterococci*, and others. The growth of these bacteria in the same fresh foods, such as meats, vegetable salads, fluid milk, and so forth constitutes spoilage.
- *Neisseriaceae.* Representative genera of this family include *Acinetobacter* (oxidase negative) and *Moraxella* (oxidase positive). Some strains of *Acinetobacter* are psychrophilic. They also infect food, as do pseudomonas;
- *Micrococcaceae.* The two main genera representative of this genus are *Micrococcus* and *Staphylococcus.* They are commonly involved in spoilage of fresh produce and processed meat and poultry [39].

In 2019 by comprehensive review the researchers at Teagasc and National University of Ireland Galway identified the main aetiological agents for foodborne disease outbreaks associated with fruit and vegetables. In this review *Listeria monocytogenes*, followed by *Escherichia coli* and *Salmonella*, were associated with the most deaths [37]. RTE foodstuffs, and particularly fresh fruits and vegetables, are notably vulnerable to contamination by microbial pathogens, and play a key role in pathogen transmission [5]. Also the number of produce related disease outbreaks is increasing worldwide, as is, which has a serious socioeconomic impact. Based on the reviewed scientific literature, the most common foodstuffs associated with outbreaks can be divided into three major groups: leafy green vegetables, sprouted seeds, and fruits (particularly soft fruits and fruit juices) [37]. Understanding the mechanisms of food spoilage is paramount in developing robust food spoilage and waste prevention technologies [43, 44].

SOURCES OF CONTAMINATION

Human pathogen contamination of fresh fruit and vegetables can occur at any number of stages in the production and distribution chain (Figure 1). During cultivation, crop contamination can occur from the soil (e.g. from the use of organic fertilisers). Plants can also be contaminated by animal manure or bird droppings [5]. The application of water is also an important consideration (used for irrigation purposes, for pesticide application and cooling). Contamination can also occur during harvest. Pathogens can be transferred to produce either from the handlers or contaminated equipment (as knives, crates or belts) [37]. During transport, maintenance of the cold chain plays an important role in preventing the proliferation of microorganism, contributing to both product quality and safety [5]. Extreme rain can lead to flooding of terrains or run off events that can result in contamination of crops. On the other hand, extreme drought conditions can lead to the utilization of water of lower microbiological quality, due to the lack of potable water, increasing the chances of contamination (37, 62]. The survival of microorganisms in produce may be dependent on factors such as air temperature, solar radiation, or humidity [37]. Handling of contaminated soil or produce can result in transference of pathogenic microorganisms to workers' hands. Additionally, the survival of microbial pathogens such as *E. coli* O157 and *Salmonella* on nitrile and latex gloves after transfer from contaminated produce has been demonstrated [12], which may increase the probability of further contamination of foodstuffs. Cross contamination may occur due to the transport of microorganisms via washing water, particles present in the water (that is, soil and small plant fragments), or plant to plant contact [22, 37].

Fig 1. Potential routes of microbial contamination in crop production.
Rys. 1. Potencjalne drogi skażenia mikrobiologicznego w produkcji roślinnej.

Source: Own elaboration based on source Machado-Moreira et al. [37]

Źródło: Opracowanie własne na podstawie Machado-Moreira et al. [37]

ENSURING PRODUCE SAFETY

Countries also have different criteria regarding acceptable parameters for water and produce quality [5]. Sprouted seeds are a particular source of risk, given the potential of contaminated seeds to cause contamination of the product, leading to microbial disease outbreaks. In Europe, there is no standardized approach in terms of microbial decontamination of seeds (each member state determining and authorizing specific treatments) [37]. Seeds should be treated in order to ensure their microbiological quality. Different treatment options are available [56] e.g. high chlorine dosages, the use of organic acids, different chlorine-based chemical compounds, electrolyzed water, ozone, and more recently, atmospheric cold plasma discharges or plasma-activated water [7, 30, 53]. Physical approaches, such as thermal inactivation of microorganisms, irradiation, high pressure, or UV treatments, can also be employed or biological alternatives, such as the usage of bacteriophages, bacteriocins, or protective cultures, have also been suggested as seed treatment alternatives [37, 51, 56]. The maintenance of cold storage conditions throughout processing, shipping, storing, and retail of fresh produce is of crucial importance, as low temperatures will hinder the proliferation of bacterial pathogens during these steps [8]. One challenge to selecting suitable treatments is the ease with which some products (soft fruits) can be damaged. Another factor is that a demonstration of lab – based efficacy is no guarantee of success in real world scenarios, as numerous additional interfering factorswill also be at play in th field. The regulatory landscape also need to be acknowledged and can vary globally [5].

COVID-19 AND FRESH FOOD SAFETY

It is unlikely that people can contract COVID-19 from food or food packaging. COVID-19 is a respiratory illness and the primary transmission route is through person-toperson contact and through direct contact with respiratory droplets generated when an infected person coughs or sneezes [6, 9, 17, 27, 33, 35, 46, 61]. There is no evidence to date of viruses that cause respiratory illnesses being transmitted via food or food packaging. Coronaviruses cannot multiply in food; they need an animal or human host to multiply [17]. Despite this, some consumers perceive there is a risk of COVID-19 infection resulting from open food displays. It is important to maintain good hygiene practices around open food displays, such as salad bars, fresh produce displays, and bakery products. Consumers should always be advised to wash fruit and vegetables with potable water before consumption. Both customers and staff should strictly observe good personal hygiene practices at all times around open food areas [17]. Resent research evaluated the survival of the COVID-19 virus on different surfaces and reported that the virus can remain viable for up to 72 hours on plastic and stainless steel, up to 4 hours on copper, and up to 24 hours on cardboard [59]. This research was conducted under laboratory conditions (controlled relative humidity and temperature) and should be interpreted with caution in the real-life environment [5]. It is imperative for the food industry to reinforce personal hygiene measures and provide refresher training on food hygiene principles to eliminate or reduce the risk of food surfaces and food packaging materials becoming contaminated with the virus from food workers [10]. Personal protective equipment (PPE) can be effective in reducing the spread of viruses and disease within the food industry, but only if used properly [37]. The food industry is strongly advised to introduce physical distancing and stringent hygiene and sanitation measures and promote frequent and effective handwashing and sanitation at each stage of food processing, manufacture and marketing [17].

OUTBREAKS

Bacteria, virus, and parasites have all been implicated in RTE produce–related disease outbreaks (Table 1) [37]. Norovirus and Hepatitis A (HAV) are responsible for a significant number of reported cases of foodborne infection [1, 20, 23, 28, 50]. Norovirus (excreted in high number in human feces, and transmitted via the fecal–oral route) is linked to the majority of reported outbreaks (304 outbreaks, 53.2% of total) and infections (27,495 cases, 37.7% of total reported). They are present in several groundwater sources [3, 19]. HAV has been shown to be internalized by green onions and spinach, in static hydroponic culture and nutrient film technique culture [51]. In Machado-Moreira et al. [37] study, leafy green vegetables, responsible for 34.8% of cases and 72.4% of outbreaks [16, 55], and soft fruits (55.7% of cases) [1, 50] are the main foodstuffs implicated in the transmission of norovirus. *Escherichia coli* is responsible for a high number of reported cases, accounting for 16 416 infections. Nonpathogenic strains of *E. coli* are common inhabitants of the gastrointestinal tract of humans and animals, but some strains are virulent and capable of causing disease to the gastrointestinal, nervous and urinary systems (such as *E. coli* O157:H7, *E. coli* O96, *E. coli* O104 and *E. coli* O121). *Salmonella* is responsible for over 20% of all reported cases in this study. *Shigella*, *Campylobacter*, *Bacillus*, and *Listeria* are the other bacterial genera identified as relevant to RTE food–related outbreaks. Of the pathogens analysed in Machado-Moreira et al. [37] study, *Listeria monocytogenes* had the highest mortality rate (19%); [18, 25, 36, 54, 58]. It was responsible for the outbreak with the second highest mortality count (33 deaths out of 147 disease cases) included in this study, which resulted from the consumption of contaminated cantaloupes in the United States in 2011 [36]. Outbreaks whose setting was known were mainly associatedwith commercial food services (canteens, restaurants, market stalls, catered events, hotels, or cruise ships) and private consumption of contaminated foodstuffs or supermarket distribution. It is worth noting that based on the analyzed scientific publications no setting information was available for the majority of considered occurrences (64.6%, 369 out of 571 outbreaks) [37].

FUTURE PREVENTION

Implementing strategies to prevent or minimize microbial contamination of RTE foods controls the burden of disease caused by foodborne microorganisms. Several interventions have been extensively reviewed in the scientific literature [21, 31]. Food producers and processors play a key role in minimizing contamination events and/or implementing strategies to mitigate this issue across the farm-to-fork chain. It is crucial that producers and processors are provided with relevant data regarding fresh produce–related microbial disease outbreaks, covering aspects including the causative

Table 1. Relevant microorganisms implicated in RTE produce related outbreaks in developed countries, as identified in scientific publications*

Tabela 1. Istotne mikroorganizmy zidentyfikowane w publikacjach naukowych, które wystąpiły w ogniskach związanych z produktami gotowymi do spożycia w krajach rozwiniętych*

Cases	Outbreaks	Deaths
Norovirus (27 495)	Noravirus (304)	*L.monocytogenes* (83)
E.coli (16 416)	*Salmonella* (128)	*E.coli* (60)
Salmonella (15 137)	*E.coli* (41)	*Salmonella* (24)
Cyclospora (5 235)	Hepatitis A (23)	Hepatitis A (5)
Hepatitis A (4 804)	*Cyclospora* (22)	*Yersinia* (1)
Shigella (1 139)	*L. monocytogenes* (13)	
Yersinia (686)	*Shigella* (12)	
Cryptosporidium (640)	*Yersinia* (6)	
L. monocytogenes (436)	*Giardia* (6)	
Campylobacter (360)	*Cryptosporidium* (5)	

*Data obtained from 1980-2016 *Dane uzyskane w latach 1980-2016

Source: [37]

Źródło: [37]

microbial pathogen and the vehicle of contamination. Information regarding produce-related outbreaks is available from a number of sources (health protection agencies, such as CDC, EFSA and HPSC and PHE) [37, 52]. Gil et al. [21] and Julien-Javaux et al. [31] have compiled very comprehensive lists of measures to mitigate microbial contamination of crops (primary production). Researchers highlighted aspects such as previous land usage, proximity to livestock producing facilities or industrial activities, and terrain characteristics (potential for water and soil runoff) as key aspects to be taken into account from a food safety perspective [21, 37]. The importance of different water sources and irrigation methods and their associated microbial risks is also taken into consideration [5, 37]. In addition to microbial contamination, horticultural crops are also at potential risk of chemical contamination. It can be observed a drive to minimise the use of chlorine, owing to potential health implications of chlorine by products such as chlorates, environmental concerns, the implementation of maximum residue limits, and consumer concerns about the use of chemicals in the food supply chain [5, 37]. A careful balance is therefore required to provide assurance of microbial safety in horticultural production. A multidisciplinary approach is needed to address produce safety, for example through projects such as the HortAssure project funded by the Irish Department of Agriculture, Food and the Marine (DAFM) [5] that will help to facilitate the safe consumption of fresh vegetables and fruit as part of healthly diet.

CONCLUSION

As consumer demand for fresh food increases, so does the need to ensure its quality and safety. Microorganisms that cause food spoilage, including bacteria, fungi, and molds, play an important role in this process regardless of its source [5, 37, 62]. Storage temperature, processing procedures, and transportation in the supply chain also contribute to adverse changes in food. While bacteria are more prevalent in meat spoilage, fungi and molds cause spoilage in fruits and vegetables. To prevent this, effective strategies, policies, and technology that can be applied at the processing and storage stages should be developed and used to reduce the growth of microorganisms [5]. Early detection of microorganisms that cause food spoilage should be pursued (metabolomics and metagenomics, including next generation sequencing and whole genome sequencing) [5, 37]. It is also suggested to use hurdle technology, which can extend the lag phase of microorganisms, and predictive microbiology to predict the growth rate of food spoilage-causing microorganisms.

PODSUMOWANIE

Wraz ze wzrostem zapotrzebowania konsumentów na świeżą żywność, pojawia się potrzeba zapewnienia jej jakości i bezpieczeństwa. Mikroorganizmy powodujące psucie się żywności, w tym bakterie, grzyby i pleśnie, odgrywają istotną rolę w tym procesie niezależnie od jej źródła pochodzenia [5, 37, 62]. Temperatura przechowywania, procedury przetwarzania i transport w łańcuchu dostaw również przyczyniają się do niekorzystnych zmian w żywności. Podczas, gdy bakterie są bardziej rozpowszechnione w psuciu się mięsa, grzyby i pleśnie powodują psucie się owoców i warzyw. Aby temu zapobiec należy opracować i wykorzystać skuteczne strategie, politykę i technologię, które mogą być stosowane na etapie przetwarzania i przechowywania, w celu ograniczenia wzrostu mikroorganizmów [5]. Należy dążyć do wczesnego wykrywania mikroorganizmów powodujących psucie się żywności (metabolomika i metagenomika, obejmująca sekwencjonowanie następnej generacji i sekwencjonowanie całego genomu) [5, 37]. Sugeruje się również wykorzystanie technologii płotków, które mogą przedłużyć fazę opóźnienia drobnoustrojów oraz mikrobiologii predykcyjnej do przewidywania tempa rozwoju mikroorganizmów powodujących psucie się żywności.

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SWEETENERS AS SUGAR SUBSTITUTES IN FOOD INDUSTRY – CONDITIONS OF USE AND CONSUMER SAFETY®

Substancje słodzące jako substytuty cukru w przemyśle spożywczym – warunki stosowania oraz bezpieczeństwo konsumenta®

Sweeteners, notably non-nutritive sweeteners (NNS) used in the production of food and flavoured beverages give sweet taste with low or no energy and have a much higher sweetening power compared to sugar. Each one of the different sweeteners has a unique physical and chemical properties and sweet taste. Reduction in the intake of sugar-sweetened beverages and foods is advised around the world as part of healthier dietary patterns to help reduce energy intakes, obesity risk and obesity-related disorders. Replacing added sugars with sweeteners is one approach to reduce added sugars. Due to the popularity of such product reformulation, the safety of increased dietary intake of sweeteners should be considered. This review describes types of sugar substitutes and sweeteners available and the European Union regulations applicable to sweeteners based on well-established risk-assessment procedures. Currently, eleven non-nutritive sweeteners (NNS) are permitted in foods and beverages in the European Union. Each sweetener has undergone a safety assessment and most have a numerical Acceptable Daily Intake (ADI). This is the amount of a substance that can be ingested daily over a lifetime with no appreciable health risk. It is important to monitor the use of NNS by the food industry as well as the dietary intake to ensure ADI is not exceeded. It is also key to identify potentially sensitive consumers of each sweetener. Further innovations in the food industry could arise from using naturally occurring sweetening compounds and/or improvements to the substances that are already permitted to be used in food.

Key words: sugar substitutes, non-nutritive sweeteners, low-calorie sweeteners, food additives, acceptable daily intake, ADI, safety evaluation.

Substancje słodzące, w szczególności intensywne nieodżywcze substancje słodzące, stosowane w produkcji żywności i aromatyzowanych napojów celem nadania słodkiego smaku, przy niewielkiej lub prawie zerowej wartości energetycznej, mają wyjątkowe właściwości fizyko-chemiczne oraz znacznie większą słodkość w porównaniu z cukrem. Na całym świecie zalecane jest ograniczanie spożycia napojów i produktów słodzonych cukrem (część prozdrowotnych wzorów żywieniowych), aby obniżać ryzyko wystąpienia otyłości i zaburzeń zdrowotnych. Zastąpienie cukru substancjami słodzącymi to jeden ze sposobów na obniżenie w produkcie zawartości cukrów dodanych. W niniejszym przeglądzie przedstawiono substancje słodzące będące substytutami cukru oraz regulacje prawne EU dotyczące stosowania substancji słodzących, a także procedurę ich dopuszczenia w ramach oceny ryzyka. Obecnie w UE dozwolonych jest jedenaście intensywnych substancji słodzących jako dodatki do żywności. Dla każdej substancji przeprowadzono ocenę bezpieczeństwa, większość z nich ma ustaloną wielkość dopuszczalnego dziennego spożycia (ADI). Jest to ilość substancji, którą można spożywać codziennie przez całe życie bez ryzyka dla zdrowia. W ocenie bezpieczeństwa jest ważne, aby stosowanie substancji przez przemysł, a także ich spożycie w diecie było monitorowane, w celu zapewnienia nieprzekraczania ADI. Kluczowe jest również zidentyfikowanie potencjalnie wrażliwych grup konsumentów. Innowacje w przemyśle spożywczym mogą wynikać ze stosowania naturalnie występujących substancji słodzących i/lub ulepszenia dotychczasowych, które są już dopuszczone do stosowania w żywności.

Słowa kluczowe: substytuty cukru, nieodżywcze substancje słodzące, niskokaloryczne substancje słodzące, substancje dodatkowe, dopuszczalne dzienne pobranie, ADI, ocena bezpieczeństwa.

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INTRODUCTION

Reduction in intake of sugar-sweetened beverages and foods is advised around the world as part of healthier dietary patterns to help reduce energy intakes, obesity risk and obesity-related disorders [4, 5, 26, 34, 38]. Replacing added sugars with non-nutritive sweeteners (NNS) is one approach to reduce added sugars [1, 2, 3, 23, 26, 28, 29, 31, 37].

The World Health Organisation (WHO) in 2015 issued sugar guidelines, recommending that adults and children should limit their added sugar intake to less than 10% of total energy intake per day [44]. In 2020, the WHO published an updated draft guideline confirming this recommendation and suggesting that there are additional benefits of a further reduction to below 5% [45]. Evidence from prospective and randomized controlled trials indicates that a large share of sugar is introduced in the diet as high-fructose sweetening syrups, used widely, but not exclusively, in sugar-sweetened beverages [26, 34, 36]. Added sugars, mainly consumed through the intake of sugary drinks, lead to a high dietary energy intake. Sugars, if taken in excess, are an important risk factor for the development of obesity, cardiometabolic diseases, including metabolic syndrome and type 2 diabetes [5, 27, 31, 44, 45]. In consideration of the importance of prevention, both at the individual level and at the level of public health concern, achieving a reduction of sugar intake requires implementation of a range of strategies [26, 36, 38]; utilising sweeteners is one of the strategies which can be used by the food industry [1, 2, 4, 15].

Sweeteners, especially intense sweeteners, that are added to foods to replace the sweetness provided by sugars, may be a useful tool for reducing sugar intake which can help in the reduction of total energy intake, with increased odds of achieving current dietary guidelines on sugars intake [1, 23, 26, 31, 37]. Due to the popularity of such product reformulation, the safety of increased dietary intake of NNS should be considered [2, 10, 15, 28, 30].

The objective of this review is to introduce on the EU legal framework on the use of sweeteners and the approval processes, to highlight the most important criteria of evaluation of the safety based on well-established risk-assessment procedures and emphasize future directions and technological challenges for food industry.

TYPES OF SUGAR SUBSTITUTES AND SWEETENERS AVAILABLE

This review follows a widely used classification of sweeteners into two groups: non-nutritive sweeteners NNS (also called non-calorie sweeteners, intense sweeteners, synthetic sweeteners) that provide no/negligible amounts of energy, and nutritive sweeteners (also called caloric sweeteners) [3, 15, 26, 32, 43]. NNS's, which are hundreds to thousands of times sweeter than sucrose, can be classified into chemically synthesized sweeteners, including e.g. aspartame, saccharin, and sucralose [15, 26]; and sweeteners extracted from natural plants, such as steviol glycosides (from leaves *Stevia rebaudiana* Bertoni) and thaumatin (from katemfe fruit, *Thaumatococcus daniellii* Benth) [29, 32, 39, 43].

The use of NNS in most of the cases is authorised in beverage or food categories for the production of energy-reduced food (with a reduction of at least 30% of energy) or food with no added sugars, which are used by the food industry in the production of "light" food and drinks [15, 18, 26, 43]. The nutritive sweeteners include polyols (sugar alcohols), which are used as bulking agents, are usually slightly less sweet than sucrose and are therefore used in similar volume to sugars for achieving a similar sweetness level and texture of the food [24, 25].

Sweeteners with a high sweetening power can be used to reduce the sugar and energy content of beverages and some foods whilst maintaining a similar sensory profile. Many sweeteners show a synergistic effect when used in mixtures; then the taste intensity of the mixture is higher than the sum of the intensities of the single components. This is of practical importance, since it offers several advantages [27]. The use of blends of intensive sweeteners helps in approaching the optimal sucrose taste, which can be mimicked by varying the components' concentrations in order to achieve the desired intensity profile of the mixture (e.g. saccharin and cyclamate; acesulfame K, aspartame and cyclamate; saccharin and neotame). Sweetener mixtures can also result in a lower daily consumption of the individual sweeteners with food [3, 16, 32, 43].

The potential for sugar reduction is more limited in foods than in beverages and depends on the options for reformulation and what is used to replace the bulk of sugar. The NNS can only to a certain extent be incorporated into candies, biscuits or cakes, chocolate, ice-cream and dessert, thus potentially limiting the opportunities for food reformulation. Non-nutritive sweeteners with improved taste performance are a partial solution, but a greater challenge is the replacement of the bulking, browning and other properties that sucrose provides in many solid food products [3, 16, 32, 43].

SWEETENERS IN THE LEGAL FRAMEWORK

EU defines "sweeteners" as food additive substances used to impart a sweet taste to foods or in table-top sweeteners [15, 26]. In the European Union (EU), sweeteners are regulated as food additives under a comprehensive set of regulations for foodstuffs which perform specific technological objectives but are not ingested as a food product itself. Under EU legislation, sweeteners are only permitted if used to replace sugars for the production of energy-reduced food (i.e. with 30% less energy) or food with no added sugars. All sweeteners are regulated substances which are subject to safety evaluation prior to market authorization (Table 1).

Regulation (EC) No. 1331/2008 [17] sets out a common authorisation procedure, while Regulation (EC) No. 1333/2008 [18] on food additives and Regulation (EC) No. 1129/2011 [21] include the principles for sweeteners. Annex II of the Regulation (EC) No. 1333/2008 [20] contains food categories and a positive list of sweeteners permitted in the EU including the maximum quantities and their conditions of use. Regulation (EU) No. 231/2012 lays down the specifications for food additives listed in Annex II, including origin, and describes the acceptable criteria of purity [22].

Table 1. Sweeteners regulations in the EU - a review of current provisions

Tabela 1. Regulacje prawne dotyczące substancji słodzących w UE – przegląd obowiązujących przepisów

Authorisation procedure	Regulation (EU) 1331/2008
List of approved sweeteners and their conditions of use in foods and permitted levels.	Regulation (EU) No. 1333/2008 and Regulation (EC) No. 1129/2011 amending Annex II to Regulation (EC) No. 1333/2008
Purity and specifications	Regulation (EU) No. 231/2012
Labelling	Regulation (EU) No. 1169/2012 and Regulation (EU) No. 1333/2008
Setting up a programme for the re-evaluation of approved food additives	Regulation (EU) No. 257/2010

Source: Own study based on: [17-22]

Źródło: Opracowanie własne na podstawie: [17-22]

APPROVAL PROCESSES

Prior to approval for use, all sweeteners undergo a comprehensive safety evaluation [7, 10, 17, 19, 30]; the responsibility for these evaluations lies with the regulator i.e. the European Food Safety Authority (EFSA). Figure 1 shows the main stages and actors of the approval process in the EU. The EFSA is responsible for the risk assessment and the EC is responsible for risk management through the committee procedure involving the representatives of the member states.

An application to authorise a new sweetener is sent to the European Commission (EC) which asks EFSA to carry out a risk assessment. The EC can also act on its own initiative, requesting a review of approved sweeteners. To modify the intended use and conditions of use of an approved additive or to remove it from the list of approved sweeteners, the same procedure is followed. At EFSA, the Panel on Food Additives and Flavourings (FAF), made up of scientists from expert organisations in the EU member states, evaluates the safety of the sweeteners or new proposed uses as a food additive.

EFSA sends its opinion to the EC and the member states and publishes the opinion to the public. The opinion includes the identity and characterisation of the sweetener, the assessment of the biological and toxicological data, a dietary exposure assessment for the European population taking into account other possible sources of dietary exposure and an overall risk assessment establishing an acceptable daily intake (ADI) value. A sweetener may be approved if there are no safety concerns at the proposed legal-use level, a technological need is considered justified, there are advantages and benefits for the consumer, and the consumer is not misled. In that case, the EC submits a draft regulation, taking account of EFSA's opinion, to the Standing Committee on Plants, Animals Food and Feed.

Upon approval, the sweetener is entered into the list in Annex II of the food additive regulation and a unique identifier, the E number, is assigned for it. The list also specifies the name of the sweetener, the foods to which the additive may be added, the conditions under which the food additive may be used. If concerns about safety arise after long-term consumption, the sweetener may be re-evaluated by EFSA.

AUTHORISED SWEETENERS, LABELLING AND USE OF FOODSTUFFS

Like all food additives, sweeteners are subject to an authorisation procedure harmonised at the EU level. All sweeteners are regulated substances which are subject to safety evaluation prior to market authorization. Only the additives on this list can be added to foodstuffs. The authorised sweeteners in the EU and their major dietary sources are listed in Table 2.

At present, a total of 19 sweeteners are approved within the EU for use in accordance with the EU Regulation 1333/2008 on food additives [15, 18, 20, 26]. All sweeteners are included in the ingredient lists on product labels which must identify both the function of the food additive in the finished food, and the specific substance used either by referring to their full name and/or their specific identity number (E-number).

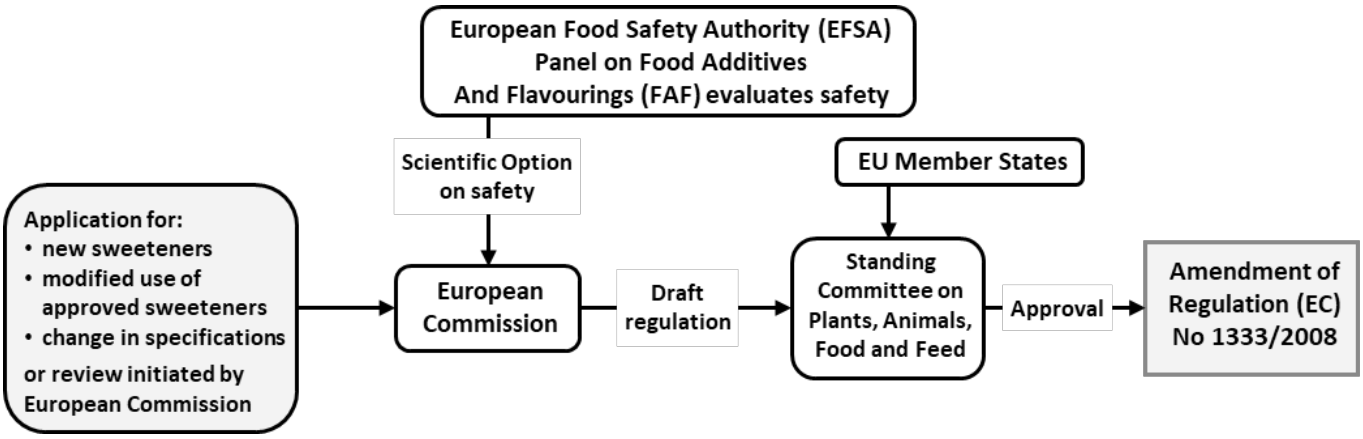

Fig. 1. The approval processes of sweeteners.

Rys. 1. Proces zatwierdzania substancji słodzących.

Source: Own study based on: [7, 10, 15, 17-22, 26]

Źródło: Opracowanie własne na podstawie [7, 10, 15, 17-22, 26]

Table 2. Sweeteners approved for use under Regulation (EC) No 1331/2008, including subsequent amendments, and their major sources

Tabela 2. Substancje słodzące zatwierdzone do stosowania zgodnie z Rozporządzeniem (WE) nr 1331/2008 z późniejszymi zmianami oraz ich główne źródła w żywności

E-number	Non-nutritive sweeteners	E-number	Polyols
E 950	Acesulfame K	E 420	Sorbitols
E 951	Aspartame	E 421	Mannitol
E 952	Cyclamic acid and its Na and Ca salts	E 953	Isomalt
E 954	Saccharin and its Na, K and Ca salts	E 964	Polyglycitol syrup
E 955	Sucralose	E 965	Maltitols
E 957	Thaumatin	E 966	Lactitol
E 959	Neohesperidine dihydrochalcone	E 967	Xylitol
E 960	Steviol glycosides	E 968	Erythritol
E 961	Neotame		
E 962	Salt of aspartame-acesulfame		
E 969	Advantame		
Use in foodstuffs and major sources			
✧ Replacing sugar in a variety of processed foods and beverages, such as flavoured carbonated and non-carbonated drinks/soft drinks, confectionery, desserts, jams, chewing gums. ✧ Table-top sweeteners.		✧ Replacing sugar in a variety of processed foods, such as confectionery, cakes, biscuits, ice-cream, desserts, jams, chewing gum. ✧ Table-top sweeteners.	

Source: Own study based on: [6, 8, 9, 11, 15, 18, 20, 26]

Źródło: Opracowanie własne na podstawie: [6, 8, 9, 11, 15, 18, 20, 26]

To keep the intake of non-nutritive sweeteners at safe use level, regulations define in which foods their use is permitted and where appropriate also set maximum limits for their content. In the EU, the use of each individual sweetener is limited to defined food categories and the addition of sweeteners to unprocessed food, and, for example, unflavoured milk, natural mineral water, coffee and coffee extracts, unflavored leaf tea, is not permitted at all. Polyols, listed as group IV additives in the regulation, are authorised in food categories at *quantum satis*, meaning no maximum level is specified. These sweeteners which are mostly of natural origin, are to be used in accordance with good manufacturing practice, at a level not higher than necessary to achieve the intended purpose [18, 20].

Under EU legislation, food products containing a sweetener or sweeteners must include the statement 'with sweeteners' or 'with sugar(s) and sweetener(s)' on the label accompanying the name of the food product. If aspartame is listed in the ingredients by its E number, E 951 or E 962, then the label must also include the statement 'contains aspartame (a source of phenylalanine)'so that people who have the inherited disease phenylketonuria can avoid consuming these products. Foods containing more than 10% added polyols are required to state on the label that 'excessive consumption may produce laxative effects' [18, 20, 21].

Food industry operators are legally responsible for the safety of their products as well as applying the correct labelling. EU member states are responsible for maintaining systems to monitor and verify the fulfilment of the relevant requirements covering all stages of production, as well as monitoring the consumption and use of sweeteners. Official controls must use a risk-based approach [7, 10, 15, 19, 26, 30].

SAFETY EVALUATION OF SWEETENERS

The EFSA bases its approval of a sweetener on risk assessment in line with international good practice laid down by the FAO/WHO Joint Expert Committee on Food Additives (JEFCA) and requires a large amount of health outcomes to enable evaluation of the safety of a sweetener additive and to define the necessary risk-management measures. These information requirements are laid down in the regulations and in more detail in the EFSA guidance documents for applicants [7, 17] and include detailed descriptions of the identity and properties of the substance and the manufacturing process, proposed foods or food categories, expected use levels and exposure assessment, supported by documented studies and data. The safety evaluation is based on toxicological data and set minimum test requirements, complemented with more specific and elaborate testing depending on the properties of the substance. Where evidence was previously evaluated by other authorities, such as the JECFA and the US Food and Drug Administration [30, 41], that is also taken into account in the EFSA assessment.

As part of its safety evaluations of food sweeteners, when sufficient information is available, EFSA seeks to establish an Acceptable Daily Intake (ADI) for each substance. When re-evaluating previously authorised sweeteners, EFSA may either confirm or amend an existing ADI following a review of all available evidence (see Table 3). The ADI is typically specified following the application of large safety factors (often a factor of 100 times lower than the 'no observed adverse effect level' (NOAEL) to give a large margin of safety for even the most susceptible and sensitive individuals in the population. An ADI that is determined for NNS maintains a sufficient safety margin and indicates the amount of food additive that can be consumed daily, over a lifetime, without presenting an appreciable risk to health. ADIs are usually expressed in mg per kg of body weight per day (mg/kg bw/day) [7, 17, 19, 28, 30].

However, for polyols that are present in the body or are regular components of the diet or that did not indicate adverse effects in animal studies, there is no need to set an ADI, instead, it should be technologically efficacious and should be used at the lowest level necessary to achieve its effect [7, 10, 15, 30]. It should be noted that, in the future, the benchmark dose will be the preferred approach for establishing a reference point [25].

For each substance, a safety assessment is performed in four steps: hazard identification, hazard characterization, exposure assessment, and risk characterization, in accordance with the risk assessment guideline. In an assessment, estimated daily intake is compared with ADIs to investigate the likelihood of potentially hazardous effects in humans. Overall, the Panel needs to conclude that, using data provided by the food industry and a member state, the reported uses and use levels of a substance would not be of safety concern at the estimated exposure [7, 10, 15, 17, 19]. The reports (opinions) of EFSA from recent years are available on the internet, similarly to the earlier work of the EU Scientific Committee on Food (SCF) [30].

The EFSA's expert Panel on Food Additives and Flavourings assesses the safety of sweeteners and also re-evaluates all sweeteners permitted for use in the EU before 20 January 2009 [19]. The order of priorities is set in the Regulation EU 257/2010 re-evaluation programme, which shall be completed by the end of 2020. As part of the exercise, a technical report was published which presents the outcome of the public consultation on a draft protocol for assessing exposure to sweeteners as part of their safety assessment under the food additives re-evaluation programme [13]. The works on the re-evaluation programme have not yet been completed [14].

FUTURE DIRECTIONS AND TECHNOLOGICAL CHALLENGES

The reduction of sugar and energy values in the diet has been a long-standing challenge for the food industry, not only to support consumers seeking to limit their sugar intake but also as a response to public health policy initiatives, such as sugar taxes for the food industry and government reformulation programmes [4, 23, 26, 36]. Future sweetener use will be driven by the needs of an increasingly overweight society. There is currently great interest in reducing the sugar content of foods to control dietary intake [1, 4, 26, 31, 37].

NNS with improved taste performance are a partial solution, but a greater challenge is the replacement of the bulking, browning and other properties that sucrose provides in many solid food products. Reformulation of beverages, where sugar is simply substituted by NNS, is relatively straightforward when compared to reformulation of products where sugars are present in the food matrix [5, 16, 32, 43].

In recent years, responding to this challenge has become more difficult for food manufacturers, as consumers are increasingly seeking products formulated using a limited range of natural, clean – label ingredients. Naturally occurring sugar substitutes have recently emerged as an alternative category of sweeteners. Therefore, the food/beverage industry has focused on the use of natural sweeteners, which may be a better alternative to sugar than synthetic sweeteners [2, 5, 29, 39, 40].

Polyols are gaining popularity as a sugar replacer and are used in a wide range of sugar-free diets. Theyare saccharide derivatives which occur naturally in fruit, vegetables and some fermented foods, and can be chemically manufactured by hydrogenation of mono- or disaccharides. Compared with sugars, polyols (e.g., sorbitol, xylitol) are poorly absorbed and provide fewer calories and lower glycaemic responses. These sweeteners are often used in combination with NNS, but polyols have a relatively lower sweetness index, which enables them to be used in larger quantities as a bulk sweetener. Due to their poor gastrointestinal tolerance, they have laxative effect when consumed in higher doses [15, 24, 26, 35].

Hhigh – potency sweeteners that are currently most popular and are widely distributed throughout the world are steviol glycosides, extracted from the leaves of the *Stevia rebaudiana* Bertoni. Stevioside and rebaudioside A are the main glycosides found in the *Stevia rebaudiana* plant and are each approximately 250-300 times sweeter than sucrose. Stevioside, in its pure form, has a prolonged aftertaste with some bitterness [27, 33, 39]. EFSA authorised the use of steviol glycosides as a sweetener in food with the number 'E 960' [6].

Siraitia grosvenorii Swingle (commonly known as Luo Han Guo or monk fruit) contains varying levels of mogrosides – triterpene glycosides which are sweetening constituents of the fruit primarily responsible for the characteristic. The sweetening power depends on the mogroside content which is reported to be 250-560 times sweeter than sucrose. However, its sweetness profile is characterized by a lower peak sweetness, additional off-tastes, and longer lasting sweetness when compared to sucrose. Further work exploring different blends of monk fruit and natural sweeteners with fewer side tastes is in progress [27, 39]. Unfortunately, the use of mogrosides is still limited due to their lack of authorization for use in food products in the EU [12] despite being recognized as safe (GRAS) in the US [41].

A number of natural sweeteners are becoming popular food ingredients for consumers, e.g. carob molasses, maple syrup, agave nectar, coconut syrup and sugar, and although they contribute to dietary energy intake, these sweeteners tend to have lower glycaemic potency than refined sugars. Despite

Table 3. Available ADI values and characteristics of certain sweeteners approved in the EU

Tabela 3. Wartości ADI oraz charakterystyka substancji słodzących zatwierdzonych w UE

Sweeteners		ADI*	Comments
E 950	Acesulfame K	0 – 9	Can be used for cooking and baking, Bitter taste, 130-200 times sweeter than sucrose, Safety evaluation by SCF in 2000
E 951	Aspartame	0 – 40	Suitable for table use, It is not heat-stable and loses its sweetness when heated, so usually it is not used in baked goods, Source of phenylalanine, 200 times sweeter than sucrose, Safety re-evaluation by EFSA in 2013 (due to the publication of new scientific data)
E 952	Cyclamate	0 – 7	To improve palatability cyclamate is often blended with saccharin, 30-50 times sweeter than sucrose, Safety evaluation by SCF in 2000
E 954	Saccharin	0 – 5	Suitable for cooking or table use, 300-500 times sweeter than sucrose, Safety evaluation by SCF in 1995
E 955	Sucralose	0 – 15	Heat-stable, 600-650 times sweeter than sucrose, Safety evaluation by SCF in 2000
E 957	Thaumatin	ADI not specified	Used according to GMP, flavour enhancer, 2000-3000 times sweeter than sucrose, Safety evaluation by EFSA in 2015
E 959	Neohesperidine DC	0 – 5	Bitter taste, flavour enhancer, 1500-1800 times sweeter than sucrose, Safety evaluation by SCF in 1988
E 960	Steviol glycosides	0 – 4	Can be used for cooking and baking, 200-300 times sweeter than sucrose, Safety evaluation by EFSA in 2010
E 961	Neotame	0 – 2	Heat-stable, flavour enhancer, 800 times sweeter than sucrose, Safety evaluation by EFSA in 2007
E 962	Salt of aspartame-acesulfame	As for aspartame and Ace-K	350 times sweeter than sugar, Produced by mixing 64% aspartame and 36% acesulfame, Safety evaluation by SCF in 2000
E 969	Advantame	0 – 5	Heat-stable, flavour enhancer, 20000-37000 times sweeter than sucrose, Safety evaluation by EFSA in 2013

*ADI: Acceptable Daily Intake (mg/kg body weight/day)

Source: Own study based on: [6, 8, 9, 11, 15, 26]

Źródło: Opracowanie własne na podstawie: [6, 8, 9, 11, 15, 26]

their many valuable nutritional and health-promoting properties, these substitutes are still sugars added to products and should be used in limited quantities as a substitute for sucrose [2, 5, 29, 31, 39, 40].

More recently, the potential use of rare sugars as low-calorie sweeteners in the food industry was also highlighted [29, 42]. Naturally occurring mono- and disaccharides have emerged as an alternative category of sweeteners. A number of beneficial properties have been attributed to this saccharides, including antioxidative effects. Especially allulose has a wide range of health effects [42]. It is noteworthy that compared to intense sweeteners and polyols, the metabolic effects of rare sugars have not been as extensively studied [27].

Rare sugars and their derivatives are found in nature in small quantities and are low on calories. This category includes e.g. D-allulose, D-tagatose and D-allose. The D-allulose is an epimer of D-fructose that has 70% of the sweetness of sucrose and because of its high solubility and antioxidant activity it is a good additive for food processing. On the other hand, D-Tagatose is also structurally similar to d-fructose and has good palatability and 92% of the sweetness of sucrose and good bulk properties. Furthermore, D-Allose is a sweetener that is mass produced from D-allulose that has 70% of the sweetness compared to sucrose. Long-term human trials are needed to determine the clinical benefits of using rare sugars to reduce added sugars [42].

SUMMARY

Sweeteners have changed since they were invented and widely used over the past years. Their role is becoming more and more important with the increase in obesity rates and new guidelines, policies and taxes are being introduced at government level to encourage the reduction of added sugars in the diet. Non-nutritive sweeteners undergo an extensive safety evaluation process by international and UE regulatory food safety authorities both before and after their approval for use in the market. Furthermore, there is an ongoing review process to ensure that any new information on safety is evaluated by the EFSA with the works are still ongoing. Non-nutritive sweeteners and polyols can be used to reduce the added sugars and/or replace total or partial content of sugar and energy content of beverages and some foods whilst maintaining a similar sensory profile, and can be used synergistically in blends to achieve the desired sensory profile

at lower levels of use in foodstuffs. For some consumers and food industry, naturally occurring sweetening compounds can serve as an alternative to synthetic sweeteners or refined sugars. Such compounds seem to be of great relevance to what constitutes a healthy diet, and further studies of their dietary properties are warranted. The use of sweeteners as well as low-energy product development and reformulation may help in achieving the current recommendations of restricting sugar consumption.

PODSUMOWANIE

Substancje słodzące od czasu ich powstania i stosowania zmieniły się w ostatnich latach. Znaczenie i ich rola w diecie staje się coraz ważniejsza w związku ze wzrostem wskaźników występowania otyłości. Nowe wytyczne i regulacje prawne, w tym podatkowe na szczeblu rządowym są wprowadzane aby zachęcić producentów i konsumentów do zmniejszenia zawartości cukrów w produktach oraz w całodziennej diecie. Substancje słodzące przechodzą szeroki proces oceny bezpieczeństwa przez międzynarodowe i unijne instytucje ds. bezpieczeństwa żywności, zarówno przed, jak i po ich dopuszczeniu do użytku na rynku. Obecnie trwa ponowny przegląd i ocena tych substancji przez EFSA, w celu, uwzględnienia wszelkich nowych badań dotyczących bezpieczeństwa stosowania substancji słodzących. Intensywne substancje słodzące oraz poliole mogą być stosowane w celu zmniejszenia ilości dodawanych cukrów i/ lub zastąpienia go całkowicie oraz zmniejszenia wartości energetycznej w napojach i niektórych produktach spożywczych, przy zachowaniu podobnego profilu sensorycznego. Mogą być one stosowane synergistycznie w mieszankach, aby osiągnąć pożądany profil smakowy przy niższych poziomach ich stosowania w produktach spożywczych. Dla konsumentów oraz przemysłu spożywczego, naturalnie występujące związki słodzące mogą służyć jako alternatywa dla syntetycznych słodzików. Wydaje się, że produkty zawierające takie substancje mają obecnie duże znaczenie i mogą stanowić jeden z elementów zbilansowanej diety. Dalsze badania dotyczące oceny ich właściwości żywieniowych są uzasadnione. Stosowanie substancji słodzących, a także zmiana składu i opracowywanie produktów niskoenergetycznych mogą być pomocne w osiągnięciu przez konsumenta obecnych zaleceń dotyczących ograniczenia spożycia cukru.

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FOREIGN TRADE IN AGRI-FOOD PRODUCTS AND THE DOMESTIC RESOURCE BASE®

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The turnover in Polish foreign agri-food trade is constantly growing, and the sale balance is positive. The gradual yearly increase in the value of Polish agri-food exports not only comes from its price competitiveness, but also from its quality. The dynamics of the increase in the volume of agricultural production as well as agri-food imports is greater than the increase in national agricultural production. Moreover, growing exports stimulate import growth more than the domestic agricultural raw resources. Further excessive growth of agri-food imports and an increase of the share in value of export, i.e. an increase in the import intensity of exports, will result in reduced effectiveness of foreign trade of agri-food goods, which results in reduced export and domestic agriculture. Therefore, activities in the field of production activation of farms and reconstruction of the agricultural market are necessary, in order to support smooth and profitable sales of products. This would allow production to be rebuilt, especially in those branches of Polish agriculture that collapsed during the transformation period after 1989 and after Poland's accession to the EU in 2004.

Key words: foreign trade, agri-food products, sustainable development, food processing, agricultural policy, European Union.

Obroty w polskim handlu zagranicznym produktami rolno-żywnościowymi stale rosną, a saldo tego handlu jest dodatnie. Stopniowy od wielu lat wzrost wartości polskiego eksportu rolno-żywnościowego wynika nie tylko z jego konkurencyjności cenowej, ale też jakościowej. Dynamika wzrostu wartości zarówno eksportu, jak również importu rolno-żywnościowego jest większa niż wzrost krajowej produkcji rolniczej. Ponadto, rosnący eksport bardziej stymuluje wzrost importu niż krajowej bazy surowców rolniczych. Nadmierny dalszy wzrost importu rolno-żywnościowego oraz wzrost jego udziału w wartości eksportu, czyli wzrost importochłonności eksportu, będzie powodował zmniejszenie efektywności handlu zagranicznego towarami rolno-żywnościowymi, a w efekcie następować będzie kurczenie się eksportu i krajowego rolnictwa. Zatem, niezbędne są działania w zakresie aktywizacji produkcyjnej gospodarstw rolnych oraz odbudowa rynku rolnego, w celu zagwarantowania płynnego i opłacalnego zbytu produktów rolnych. Pozwoliłoby to na odbudowanie produkcji, zwłaszcza w tych gałęziach polskiego rolnictwa, które uległy załamaniu w okresie transformacji ustrojowej po 1989 roku oraz po akcesji Polski do UE w 2004 roku.

Słowa kluczowe: handel zagraniczny, produkty rolno-żywnościowe, rozwój zrównoważony, przetwórstwo spożywcze, polityka rolna, Unia Europejska.

INTRODUCTION

The aim of the article is a synthetic analysis of Polish foreign trade of agri-food products (products of agriculture and agri-food industry) over the last dozen or so years and to justify the need for the development of the domestic resource base in order to ensure further effective and relatively low import-intensive development of exports of these goods, and increasing the share of domestic production in the internal market [11].

Turnover in Polish-foreign agricultural goods and food products trade (products of agriculture and agri-food industry), included in the CN (Combined Nomenclature) codes from 01 to 24, have a constant upward trend, with a positive foreign trade balance. This means that the export of agri-food products from Poland is greater than their import. In 2019, the export value of these goods amounted to 31,766 million EUR, which means that it was higher than in the previous year by 6.9%. At the same time, imports amounted to 21,270 million EUR and were higher than in the previous year by 6.2%, so import grows almost parallel to the increase in exports. The balance of foreign trade in these products was positive in 2019 and amounted to 10,496 million EUR. In 2019, agri-food exports accounted for 13.3% of the value of all Polish exports. The

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total balance in Polish exports, although positive, amounted to only 1.2 billion EUR [14].

Thus, the constantly growing Polish agri-food exports affects significantly the effectiveness of all Polish exports. It would be beneficial if its constant upward trend would continue, while maintaining a positive foreign trade balance for agricultural products and the agri-food industry. It is possible with faster than before development of the domestic agricultural raw material base and thus limiting the growth of imports of products and semi-finished products for agri-food processing. This would limit a further increase in import intensity of exports.

Errors and omissions made in the development and growth of the domestic production of agri-food raw materials significantly limit the development of many areas of Polish agriculture, as well as the entire agri-food sector. The limitations of this development result both from the erroneous assumptions of the systemic transformation, which resulted, inter alia, in the sale of agri-food processing plants and the liquidation of cooperative market institutions, including purchasing institutions, as well as the conditions for the accession of the Polish agri-food sector to the European Union economy. [9, 17].

The condition and effect of Poland's accession to the EU was to limit the potential and production in the area of the Polish sugar industry and the starch industry, as well as to limit the number of livestock and to limit the production of many agricultural raw materials, including: milk, tobacco, hops and flax.

On the other hand, the reconstruction and further growth and development of the domestic agricultural resource base are possible through the full and egalitarian use of the production potential of Polish farms in accordance with the idea of the Green Deal, currently created in the Common Agricultural Policy of the EU.

ANALYSIS OF THE BASE OF AGRICULTURAL RAW MATERIALS AND FOREIGN AGRI-FOOD GOODS TRADE

The increase in the value of agricultural production in Poland (the value of raw materials and agri-food products), between 2006 and 2018, in current prices (GUS data on agriculture) was as follows [2, 3, 4, 5, 6]:

- Global production increased by approx. 74% (from 65.08 billion PLN to 113.15 billion PLN);
- Final production (global production minus the so-called internal turnover, e.g. feed, seed from own production) increased by approx. 82% (from 51.56 billion PLN to 93.73 billion PLN), where:
  - plant production increased by approx. 71% (from 20.68 billion PLN to 35.37 billion PLN),
  - livestock production increased by approx. 89% (from 30.88 billion PLN to 58.36 billion PLN), which is favorable as it contains a greater percentage of added value than plant production.

Foreign trade in agri-food products manufactured in agriculture and then slightly processed (e.g. flour, meat – CN 01–14), between 2006 and 2018, was in current prices (GUS data on foreign trade) as follows [2, 3, 4, 5, 6]:

- The total value of exports (CN 01–14) increased by 226% (from 18.29 billion PLN to 59.72 billion PLN), and the value of imports (CN 01–14) increased by 251% (from 13.19 billion PLN to 46,27 billion PLN). At the same time, the trade balance was positive both in 2006, when it amounted to +5.10 billion PLN, and in 2018, when it amounted to +13.49 billion PLN;
- The value of exports of animal products (CN 01–05) increased by 231% (from 12.27 billion PLN to 40.68 billion PLN), and the value of imports (CN 01–05) increased by 339% (from 5.5 billion PLN up to 24.2 billion PLN);
- The value of exports of plant-based products (CN 06–14) increased by 216% (from 6.01 billion PLN to 19.04 billion PLN), and the value of imports (CN 06–14) increased by 187% (from 7.768 billion PLN to 22.08 billion PLN);
- The balance of trade in animal products was positive, both in 2006 (+6.77 billion PLN) and in 2018 (+16.52 billion PLN);
- The balance of trade in plant-based products was negative, both in 2006 (–1.66 billion PLN) and in 2018 (–3.03 billion PLN).

In the analyzed period, it was shown that Polish exports of processed food products, semi-finished products (e.g. fats and oils, sugar) and final food products (CN 15–24: fats and oils and food preparations) increased by **331%** between 2006 and 2018 year (from 15.25 billion PLN to 65.76 billion PLN) [2, 3, 4, 5, 6]. **This proves the high competitiveness of the Polish agri-food industry.**

Furthermore, during this period, the import of the above products to Poland increased by **58%** (from 24.56 billion PLN to 38.98 billion PLN). The balance of this trade was positive for processed food, both in 2006 (+3.11 billion PLN) and in 2018 (27.78 billion PLN). However, the balance for fats and oils (CN 15), both in 2006 (–0.71 billion PLN) and in 2018 (–2.16 billion PLN) was negative [2, 3, 4, 5, 6].

When analyzing the relations between the value of Polish exports and imports of agri-food products produced in agriculture (CN 01–14), in relation to the value of various categories of agricultural production in percentage terms (calculated on the basis of the Central Statistical Office data on foreign trade), it should be noted that they constituted :

- In 2006, the value of agri-food exports (CN 01–14) accounted for 27.9% of global production and 35.3% of final production. The value of exports of products falling within CN codes 06–14 accounted for 29.0% of final plant production, and products falling within CN codes 01–05 accounted for 39.5% of final animal production;
- In 2018, the value of total exports (CN 01–14) accounted for 52.8% of global production and 63.7% of final production. The value of exports of products of plant origin (CN 06–14) accounted for 53.7% of final plant production, and the value of exports of products of animal origin (CN 01 - 05) accounted for 65.4% of final livestock production.

In the analyzed period, a significant increase in the value of exports to the value of all categories of agricultural production is visible.

The analysis of Polish agri-food imports shows that:

- In 2006, the value of agri-food imports (CN 01–14) accounted for 20.2% of global production and 25.6% of final production. The value of import of products of plant origin (CN 06–14) accounted for 37.1% of final plant production, and the value of import of products of animal origin (CN 01–05) accounted for 17.8% of final livestock production;
- In 2018, the value of agri-food imports (CN 01–14) accounted for 40.9% of global production and 49.3% of final production. The value of import of products of plant origin (CN 06–14) amounted to 62.5% of final plant production, and the value of products of animal origin (CN 01–05) accounted for 41.4% of final livestock production. Relatively high rates of the share of the imports value in relation to the value of final production, both plant and livestock, in 2018 indicate the unused production capacity of Polish agriculture, which is desirable in view of the growing agri-food exports.

An interesting issue is also the analysis of the relationship between Polish imports and agri-food exports (CN 01 - 14), i.e. the assessment of the average import intensity of exports in the analyzed period as a percentage share of the value of imports in the value of exports.

Import intensity of agricultural products exports (CN 01–14) amounted to (calculated on the basis of GUS data on foreign trade) [2, 3, 4, 5, 6]:

- Overall: 72.1% in 2006 and 86.1% in 2018;
- Vegetable products (CN 06–14): 127.7% in 2006 and 116.0% in 2018;
- Animal products (CN 01–05): 44.8% in 2006 and 59.4% in 2018, including:
  - live animals (CN 01): 25.2% in 2006 and 440.0% in 2018;
  - meat and offal (CN 02): 30.5% in 2006 and 30.1% in 2018;
  - dairy products (CN 04): 17.4% in 2006 and 41.2% in 2018.

Additionally, the value of Polish agri-food imports (CN 01–14), expressed in current prices, although lower than exports, increased by 251% during the period considered (by 339% in the case of products of animal origin – CN 06–14), thus at a slightly higher pace than exports. If such a tendency intensifies, Polish agri-food exports may be stopped, and at the same time the balance of foreign trade in agri-food products will deteriorate.

Increase in the value of agricultural production (in current prices) in the analyzed period, was slower than agri-food exports and imports and amounted to: 74% for global production and 82% for final production (71% for plant production and 89% for livestock production). The low rate of growth dynamics for plant production proves a relatively low use of the production potential of agricultural land.

In the analyzed period, the increase in the total import intensity of agricultural products by 14 percentage points is noticeable. Particularly high is the import intensity of exports of live animals, mainly livestock. These data clearly prove the incomplete use of the production potential of Polish agriculture and the increase in disagrarisation of agriculture and the Polish countryside.

RESULTS OF ANALYSIS OF THE BASE OF AGRICULTURAL RAW MATERIALS AND OF FOREIGN TRADE IN AGRI-FOOD GOODS

The analysis presented in the preceding part of the article authorizes the formulation of the following conclusions.

The value of Polish agri-food exports (expressed in current prices) increased significantly in the analyzed period (2006–2018): by 226% for products of animal and vegetable origin (CN 01–14) and by 331% for products of the agri-food industry (CN 15–24), for which imports increased by 58%. The trade balance in the analyzed period was positive for both product groups (CN 01–24) [2, 3, 4, 5, 6].

Both the increase in the value of the entire Polish agri-food exports (CN 01–24), the relatively low growth dynamics of the import of agri-food products (CN 15–24), and the increase in the positive trade balance result from the high competitiveness of the agri-food industry.

However, it is worth noting that the trade balance for plant-based products was negative (both in 2006 and in 2018). This proves the weakness of the raw material base of plant products. It is disturbing that for several years a negative trade balance has been recorded in trade in live animals. In 2018, the value of exports of these animals was small and amounted to 549.2 million PLN, while the trade balance was – 2.41 billion PLN. This proves that there is an excessive import of livestock (mainly pigs) to our market. The reason for this is the restriction of pig farming in Poland due to African swine fever (ASF). The instability of profitability of breeding these animals and problems on the market, dominated by imports, are also important. Livestock imports come mainly from countries whose capital was taken over by Polish meat processing plants. It is therefore necessary to urgently reorganize the market and repolonize the meat industry.

Reorganization of the market and repolonization of the meat industry is important, not only because of the benefits of reducing the import intensity of Polish agri-food exports and the possibility of extending the scope of use of the domestic raw material base, but also because of the risk of a situation in which some of the markets would be lost. exports (due to the COVID-19 pandemic or other reasons), which would result in the need to locate these products on the internal market.

Repolonization of meat plants (as well as production units from other industries) is a costly and difficult task, because foreign capital bought these plants, not only in order to gain profits, but also as an outlet for its raw material (including livestock for slaughter) and other products. Hence, their repurchase is unlikely. It should be emphasized that a similar situation occurs in other sectors of agri-food production.

An example is one of the largest sugar producers in Germany – Südzucker AG. In this unit, the interests of sugar beet growers are closely related to the production of sugar as well as its processing. The growers bought all the shares of the sugar mill, agreeing to deduct 7 pfennigs from each ton of beet from the amounts received for the delivered sugar beet. The buyout of the shares took 40 years. Currently, the Südzucker AG concern, in addition to German sugar factories, includes sugar factories purchased in the privatization process, including from: Austria, France, Belgium, Czech Republic, Slovakia, Poland and Romania. In 2013, due to the surplus of sugar on the European market, the management of Südzucker AG decided to process 1 million tonnes of sugar into ethanol [7].

A method that could help to partially slow down the import of raw materials to agri-food processing plants currently owned by foreign capital could be market reorganization. One of the most effective solutions could be to organize a multi-industry conglomerate like the South Korean cheebola. Such a solution aimed at activating small and medium-sized farms was proposed in 2018 by the Minister of Agriculture and Rural Development – Jan Krzysztof Ardanowski [8, 10, 16].

Activation of small and medium-sized farms involved in crop and livestock production would be economically justified in the case of guaranteed sales at attractive prices [18].

At the same time, it would be necessary to present farmers activating in agricultural production with a long-term and permanent job offer, as well as a safe level of employment based on an indefinite employment contract. Additional employment for farmers activating their farms may refer not only to areas directly related to agriculture and food processing, but also to areas not related to agriculture and rural areas, but consistent with the interests and qualifications of farmers. This is especially important in view of the rapidly growing online work.

Adaptation to the modern market economy of small and medium-sized farms with the possibility of producing high-quality food, with the simultaneous creation of additional income opportunities for farmers and their families in enterprises belonging to the conglomerate, both in food processing and non-agricultural activities, may be the basic factor inhibiting the outflow of young power work to cities and economic emigration.

A multi-industry conglomerate covering the production and processing of agricultural products and the agri-food industry, enterprises supplying production means for the above-mentioned units and public sector units, eg. hospitals, universities or research institutes, has a strong market position [8].

The basic principle of a conglomerate should be to cover the largest possible number of producers and customers, however, these do not have to be entities belonging to the conglomerate, but only entities related to the conglomerate by civil law agreements. **The main task of the conglomerate is to maximize net exports of agricultural products and the agri-food industry.**

Moreover, an important argument in favor of the use of multi-industry conglomerates in international trade is the possibility of effective purchase of technologies used in the production of import substitute products.

Another advantage of the conglomerate is obtaining from the banking system and financial institutions, such as the National Development Fund or the National Fund for Environmental Protection and Water Management, much better offers than those which would be obtained if each entity negotiated the loan terms separately.

A strong economic entity, such as a conglomerate, can obtain much more favorable conditions in negotiations for the processing of agricultural products. An example of this may be the action where, in return for placing an order with a processing company owned by foreign capital, a condition is imposed that 50% of the raw material used will be of domestic origin. Moreover, when negotiating with supermarkets, there is considerable scope for negotiating better conditions for those within a conglomerate or working directly with it. However, the multi-industry conglomerate has not been launched so far.

In this situation, it remains to be implemented not only to launch traditional methods of purchasing agricultural products and apply minimum prices, but also to use the initiatives of establishments for purchases for their employees and the possible use of the food voucher system for families with incomes below the subsistence minimum, in order to increase the share of Polish food on the internal market.

In Polska Grupa Górnicza (Polish Mining Group), significant savings were achieved in the area of thorough modernization of the system, in which the company compensates many thousands of underground workers for the cost of regenerative meals due to their underground effort [15].

So far, the so-called the "flaps" were carried out traditionally: tens of thousands of employees were given vouchers with which miners would go to selected stores, buying food. Over two years ago, electronic cards were introduced in cooperation with PKO BP. The solution turned out to be very convenient for PGG and its employees.

From the point of view of modifying relations on the internal market by the Ministry of Agriculture and Rural Development, it is possible to apply minimum prices, higher than the equilibrium prices. At the same time, the difference would be compensated by coal, which would have the double effect of reducing both the import of agricultural raw materials and coal.

Another solution could be the introduction, similar to the solutions popular in the USA, of Food Stamps for people below the social minimum [7]. The purpose of using Food Stamps is to improve the conditions of the lowest earners (especially in terms of improving nutrition) while increasing the demand for food without spoiling the market and reducing the costs of subsidizing farms policy by applying minimum prices for agricultural products (reducing the costs of food storage). In Polish conditions, apart from all the above-mentioned function, food stamps could be used to increase the demand for Polish agricultural products and products of the agri-food industry [12, 13].

It should be noted that the US Food Stamp Act was adopted as early as 1964. Until 1979, households meeting certain conditions, including income, could be allocated in food stamps. For example, in January 1975, a family of four

could receive the maximum allocation in 153$ vouchers. The price of these vouchers depended on household income. A family of four with a monthly income of 300$ paid 83$ for a full monthly allocation of vouchers. However, if the family had a monthly income of 100$, the cost of a full monthly allowance was only 25$ [1].

SUMMARY

As shown by the analysis, the percentage relationships of the value of agri-food exports and imports in relation to various categories of agricultural production increased significantly between 2006 and 2018. This proves that the domestic resource base is increasingly linked with agri-food exports, and at the same time that it is less and less competitive in relation to growing imports.

Between 2006 and 2018, the import intensity of agri-food exports (CN 01–14) significantly increased, especially in the case of live animals (CN 01), to the level of 440%. Regarding products of plant origin (CN 06–14), the import intensity slightly decreased but remained at a very high level of 116%. This proves not only the relatively low use of the domestic agricultural potential, but also the increasing dependence of agri-food exports on the import of agricultural raw materials. This is particularly worrying in view of the need to further develop agri-food exports, and this is possible provided that their competitiveness is maintained.

Relatively high competitiveness (both in terms of price and quality) can only be guaranteed by the ecological national resource base, based to a greater extent than at present on the potential of small and medium-sized farms. It is also in line with the concept of the Green Deal in the EU.

According to the authors, the high ecological quality of Polish agri-food exports will worsen along with the increase in import intensity of exports. According to some opinions, the quality of agri-food products imported to Poland is much lower than that of domestic products. Perhaps it is conditioned by the lack of rigorous quality control of imported products, both raw materials of agricultural origin and processed food products, often overly schematic.

It would be advisable not only to increase the volumes and value of agricultural production with its current structure, but also to rebuild some of its industries before Poland's accession to the EU. Therefore, state intervention is necessary in the field of productive activation of farms, their revitalization, but above all in the field of reconstruction of the agricultural market, in order to enable a smooth and profitable sale of agricultural products. Otherwise, in view of the low and fluctuating profitability of agricultural production, Polish agriculture will begin to gradually die out, and both small-scale farms and those with a larger area will start to fall out of production. Moreover, further growth of agri-food imports will inhibit the development of both exports and many agricultural industries.

Thus, there is an urgent need for market reorganization and re-Polonization of agri-food industry enterprises.

PODSUMOWANIE

Jak wynika z przeprowadzonej analizy, wyrażone procentowo relacje wartości eksportu i importu rolno-żywnościowego w odniesieniu do różnych kategorii produkcji rolniczej znacząco wzrosły pomiędzy 2006 a 2018 rokiem. Świadczy to o coraz większym powiązaniu krajowej bazy surowcowej z eksportem rolno-żywnościowym, a jednocześnie o jej coraz mniejszej konkurencyjności w stosunku do rosnącego importu.

Pomiędzy 2006 a 2018 rokiem znacząco wzrosła importochłonność eksportu rolno-żywnościowego (CN 01–14), zwłaszcza w przypadku zwierząt żywych (CN 01) do poziomu 440%. W odniesieniu do produktów pochodzenia roślinnego (CN 06–14) importochłonność nieco obniżyła się, ale pozostała na bardzo wysokim poziomie wynoszącym 116%. Świadczy to nie tylko o relatywnie niskim wykorzystaniu krajowego potencjału rolnictwa, ale również o coraz większym uzależnianiu się eksportu rolno-żywnościowego od importu surowców rolniczych. Jest to szczególnie niepokojące wobec potrzeby dalszego rozwijania eksportu rolno-żywnościowego, a to jest możliwe pod warunkiem utrzymania jego konkurencyjności.

Względnie wysoką konkurencyjność (zarówno cenową, jak i jakościową) może zagwarantować jedynie ekologiczna krajowa baza surowcowa, oparta w większym, niż obecnie, stopniu na potencjale mało- i średnioobszarowych gospodarstw rolnych. Jest to też zgodne z koncepcją Zielonego Ładu w UE.

Zdaniem autorów, wysoka jakość ekologiczna polskiego eksportu rolno-żywnościowego będzie się pogarszała wraz ze wzrostem importochłonności eksportu. Według niektórych opinii, jakość produktów rolno-żywnościowych importowanych do Polski jest znacznie niższa niż produktów krajowych. Być może, jest to uwarunkowane brakiem rygorystycznej kontroli jakościowej importowanych produktów, zarówno surowców pochodzenia rolniczego, jak i produktów żywnościowych przetworzonych, często nadmiernie schemizowanych.

Celowe byłoby nie tylko zwiększenie wolumenów i wartości produkcji rolniczej przy jej obecnej strukturze, ale również odbudowanie niektórych jej branż sprzed akcesji Polski do UE. Zatem, niezbędna jest interwencja państwa w zakresie aktywizacji produkcyjnej gospodarstw rolnych, ich rewitalizacji, ale przede wszystkim w zakresie odbudowy rynku rolnego, w celu umożliwienia płynnego i opłacalnego zbytu produktów rolnych. W przeciwnym razie, wobec niskiej i wahającej się opłacalności produkcji rolnej, polskie rolnictwo zacznie stopniowo zamierać, jak również zaczną wypadać z produkcji zarówno gospodarstwa małoobszarowe, jak również te o większym obszarze. Ponadto, dalszy wzrost importu rolno-żywnościowego będzie hamować rozwój, zarówno eksportu, jak i wielu branż rolnictwa.

Zatem, występuje pilna potrzeba reorganizacji rynku oraz repolonizacji przedsiębiorstw sektora przemysłu rolno-spożywczego.

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GOOD MANUFACTURING PRACTICE IN AGRICULTURAL RETAIL®

Dobra praktyka produkcyjna w rolniczym handlu detalicznym®

Food, regardless of the entity that produces it, must be safe for the health of the consumer. Good Manufacturing Practice is a system based on production and control procedures, the aim of which is to ensure quality, which guarantees that the food meets specific as well as quality assurance, which guarantees that the manufactured products meet specific quality requirements. This activity aims to ensure the repeatability and homogeneity of products by closely supervising the production process, from the stage of sourcing raw materials, through their storage, production, packaging and labelling, to the stage of storing and distributing finished products. Ensuring safe food must be achieved through the joint efforts of all participants in the food chain. Farmers engaged in agricultural retail trade are also obliged to use methods and systems that guarantee the production of safe food that meets the safety levels set out in food law.

Key words: agricultural retail trade, food production, good manufacturing practice.

Żywność bez względu na podmiot, który ją produkuje musi być bezpieczna dla zdrowia konsumenta. Dobra Praktyka Produkcyjna jest systemem opartym na procedurach produkcyjnych, kontrolnych, których celem jest zapewnienie jakości, która gwarantuje, że żywność oraz wytworzone produkty spełniają określone wymagania jakościowe. Działanie to ma na celu zapewnienie powtarzalności oraz jednorodności wyrobów poprzez ścisły nadzór nad procesem produkcji, od etapu zaopatrzenia w surowce, poprzez ich magazynowanie, produkcję, pakowanie oraz znakowanie, aż do momentu składowania i dystrybucji gotowych wyrobów. Zapewnienie bezpiecznej żywności musi być osiągnięte wspólnym wysiłkiem wszystkich uczestników łańcucha żywnościowego. Rolnicy prowadzący rolniczy handel detaliczny także zobowiązani są do zastosowania metod i systemów gwarantujących produkcję żywności bezpiecznej zdrowotnie, która spełnia poziomy bezpieczeństwa określone przepisami prawa żywnościowego.

Słowa kluczowe: rolniczy handel detaliczny, produkcja żywności, dobra praktyka produkcyjna.

INTRODUCTION

By laying down orders and prohibitions of behaviour, the legislator decides which goods are to be protected and to what extent. In the Community food law, the following goods are considered to be protected: human life and health, consumers' economic interest, fairness of commercial transactions, animal health and living conditions and plant health. The goods protected by law are of a diverse nature and value and therefore form a hierarchy. The protection or enjoyment of one good may adversely affect another good, which may cause conflicts, so both the goods and the hierarchy between them are protected [10]. The duty of the state is to protect the goods and to mitigate conflicts arising from the enjoyment of these different goods. The state is to prevent threats to the life and health of citizens, protect them from unfair practices and is obliged to guarantee security and order to its citizens. This duty of the state is particularly important in relation to the production and marketing of food. State protection is manifested in appropriate legal regulations, which regulate the necessary requirements for the production and marketing of food. Food producers are obliged to respect the requirements set out in the legislation in order to produce safe food that meets consumers' expectations regarding its quality[5].

This article presents the Good Manufacturing Practice as a safety management system in food production in the framework of agricultural retail trade.

GOOD MANUFACTURING PRACTICES

EU food law refers to the FAO/WHO Codex Alimentarius -Codex Alimentarius, which was developed by the Codex Alimentarius Commission, set up by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) Fundamental to food law is Regulation (EC) No 178 of the European Parliament and of the Council of 28 January 2002 [7]: "laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety". This regulation imposed an obligation on Member States to implement a system for traceability of food and its ingredients. In Article 3(15) of that Regulation, traceability

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was defined as the ability to trace and follow food, feed, food-producing animals or substances intended to be, or expected to be, incorporated into food or feed, through all stages of production, processing and distribution. However, in order to ensure food safety, it was necessary to consider all aspects of the food chain, i.e. "from farm to fork". This concept was introduced in 1970 and is to be extended under the European New Green Deal [1]. The food chain is defined as a sequence of stages and processes taking place in production, i.e. starting from primary production, through processing, transport, distribution, storage and handling of food and its ingredients, and ending with consumption. Such an approach results in the fact that at each stage of production until consumption, specific product safety and quality management systems must be fulfilled. In the food chain, it is important to analyse and manage risk factors at all stages of the chain and ensure a higher level of safety [2].

Good Manufacturing Practice is the actions that must be taken and the conditions that must be met in order for the production of food and food contact materials and articles to be carried out in a manner that ensures the appropriate health quality for the intended use. Good Manufacturing Practice refers to the basic areas of food production activities that must be maintained to a certain level in order to produce food of adequate health quality. In the USA, the principles of Good Manufacturing Practice were first developed and adopted as mandatory in 1973 [11].

The application of Good Manufacturing Practice standards in food production guarantees consumers a higher level of comfort and confidence in the quality of the manufactured product. The principle of Good Manufacturing Practice is to exclude any accidental activities from the production process and to ensure that the process is carried out in accordance with the requirements found in, among others, instructions and procedures. Good Manufacturing Practice requires that every element of food production is defined and that all inputs are provided in the right quantity, at the right place and at the right time and are used for their intended purpose [4]. This means the development of written procedures and instructions for the entire production process, as well as requirements for the basis of the production process, i.e. personnel, training, sourcing of raw materials, buildings and the production environment, machinery and equipment, storage, transport, distribution, cleaning and disinfection, and pest control. These records should be included in the Production Books. It is commonly believed that what is not written has never been done, and what is not written does not exist. Maintaining Production Log Books makes it possible to properly control the technical and sanitary system of premises, as well as production and control equipment, it is possible to continuously analyse technological parameters, environmental conditions, which may contribute to the reconstruction of the entire production process. It is also important that the book enables identification of persons responsible for execution, supervision and control of individual stages of production [12].

Good Manufacturing Practice requires that all activities both in the production and marketing of foodstuffs be carried out under conditions that ensure foodstuffs of proper health quality. Therefore, it is so important to comply with the principles related to the basic factors of maintaining hygienic conditions of the environment, ensuring adequate space for the arrangement of production and storage equipment and appropriate ventilation. It is equally important to ensure appropriate conditions for storing equipment, food products and chemical substances, to maintain machinery and equipment in a proper technical condition, proper lighting, maintenance of cleaning and disinfection procedures, ensuring proper water and sewage management. It is very important for employees to follow hygiene rules [3].

AGRICULTURAL RETAIL TRADE

Agricultural retail trade was introduced into the Polish legal order by the Act of 16 November 2016 on amending certain acts to facilitate food sales by farmers and the Regulation of the Minister of Agriculture and Rural Development of 16 December 2016 on the maximum quantity of food sold within the framework of agricultural retail trade and the scope and manner of its documentation. From 1 January 2019, the provisions of the Act of 9 November 2018 on amending certain laws to facilitate the sale of food by farmers to shops and restaurants which contains further legislative solutions to facilitate food production and its marketing by entities operating in the so-called "short supply chains", including agricultural retail trade, also apply to agricultural retail trade. Within the framework of such trade, it is possible, inter alia, to process and sell produced food to final consumers to establishments conducting retail trade intended for final consumers, including shops, restaurants, canteens and other establishments with similar characteristics, located in a limited area. This area includes the province in which the production of food in the framework of agricultural retail trade takes place, as well as counties or towns which are the seat of the provincial governor or provincial assembly, adjacent to this province. The condition is that such food must come wholly or partially from own cultivation, breeding or rearing, and the sale is conducted in compliance with the limits specified in the above-mentioned regulation on the maximum quantity of food sold within the framework of agricultural retail trade and the scope and manner of its documentation, as well as the limit of revenue from such sales to the amount of PLN 40,000, if the manufacturer wishes to benefit from tax preferences. Agricultural retail trade is retail trade within the meaning of Article 3(7) of Regulation 178/2002, consisting in the sale to the final consumer referred to in Article 3(18) of that Regulation or (from 1 January 2019) to retail establishments for the final consumer of food coming "in whole or in part from the food business operator's own cultivation, rearing or breeding."

Retail trade is defined in the literature, inter alia, as the uninterrupted and simultaneous making available in small quantities to a large number of purchasers at a convenient selection, quantity, place and time of goods from a wide variety of sources.

As stated in Article 3(7) of Regulation 178/2002, retail trade means the handling or processing of food and its storage at the point of sale or delivery to the final consumer. The term includes distribution terminals, catering operations, factory canteens, institutional catering, restaurants and similar food service operations, shops, supermarket distribution centres and wholesale outlets.

In accordance with Article 44a(1) of the Act of 25 August 2006 on the safety of food and nutrition, the production and sale of food within the framework of agricultural retail trade may be carried out in quantities adapted to consumer needs, and may not pose a threat to food safety or adversely affect the protection of public health and is subject to supervision by the authorities of the State Sanitary Inspectorate or Veterinary Inspectorate respectively [13].

It is permitted to sell foodstuffs (within certain limits) raw materials of non-animal origin, food of non-animal origin other than raw materials and food containing at the same time foodstuffs of non-animal origin and products of animal origin, raw materials of animal origin, products of animal origin other than raw materials [9]. Disposal of food within the framework of agricultural retail trade: to establishments conducting retail trade for the final consumer takes place if these establishments are located on the territory of the province in which production of such food within the framework of agricultural retail trade takes place, or on the territory of districts or towns constituting the seat of the voivode or voivodship assembly, adjacent to this province; is documented in a manner enabling determination of the quantity of food sold; may not be performed with the participation of an intermediary, with the exception of the sale of such food during exhibitions, festivals, fairs or fairs organized for the purpose of food promotion, if the intermediary sells food produced by that intermediary in the course of agricultural retail trade or produced by another operator of agricultural retail trade in the county in which that intermediary produces food in the course of agricultural retail trade or in a county adjacent to that county [14].

In order to register agricultural retail trade in products of animal origin, an application for entry of an establishment in the register of establishments must be submitted in writing to the relevant district veterinarian at least 30 days before the date of commencement of the planned activity. In the case of agricultural retail trade in products of plant origin, an application for entry of an establishment in the register of establishments subject to official control by the authorities of the State Sanitary Inspectorate must be submitted to the competent district sanitary inspector within 14 days before the commencement of the activity. The specimen of the application for registration of agricultural retail trade in products of plant origin, to be submitted to the competent district or border sanitary and epidemiological station, is specified in Appendix No. 2 of the Ordinance of the Minister of Health of 29 May 2007 on specimens of documents concerning registration and approval of establishments producing or marketing food subject to official control of the State Sanitary Inspection.

The place of sale of food to the final consumer by the operator of agricultural retail trade, including through a broker, shall bear, in a manner which is clearly visible to the consumer, the words ‚agricultural retail trade', indicating the name and address of the operator of agricultural retail trade, the place of production of the food, and the agricultural retail operator's veterinary approval number, if any [6].

An operator producing food within the framework of agricultural retail trade is obliged to keep records concerning the principles of good manufacturing practice, and in particular procedures for cleaning and disinfection, protection against pests, waste disposal, supervision of employee hygiene, procedures for handling raw materials, semi-finished products, finished products, food additives used, packaging, marking of finished products, transport. This documentation should be proportionate to the nature and volume of production. The area of production rooms and their equipment should be adapted to the type and size of production, and activities must be carried out in a hygienic manner, according to established procedures in order to minimise the risk of contamination of raw materials and manufactured products.

It is worth noting that an operator in the agricultural retail trade is obliged to have the results of tests carried out on the finished product as part of owner supervision. The lack of appropriate documents violates the provisions of Commission Regulation (EU) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs, which stipulates that food business operators are required to ensure that foodstuffs comply with relevant microbiological criteria, and their owners are obliged to conduct tests to confirm compliance with microbiological criteria throughout the shelf-life period [8].

An agricultural retail trader shall keep and maintain records enabling the quantity of food disposed of annually in the course of such trade to be determined for each calendar year, showing the number of the successive entry; the date of disposal of the food and the quantity and type of food disposed of. An agricultural retail broker disposing of food produced by another trader at an exhibition, fair, market or fairs shall keep records enabling the quantity of food so disposed of to be determined separately for each trader and shall forward those records to the trader whose food he disposed of immediately after the exhibition, fair, market or fairs have ended. Such documentation shall include the number of the successive entry, the date of disposal of the food and the quantity and type of food disposed of, the place of disposal of the food and the name, surname and address or the name, registered office and address of the broker who disposed of the food at the exhibition, fair, market or bazaar. Such records are kept for 2 years, counting from the end of the calendar year for which they were drawn up.

SUMMARY

In food production, it is essential to implement and develop food safety management systems, the primary objective of which is to ensure the safety of the health and life of the consumer. At all stages of the food chain, it is important to eliminate hazards. The system of good manufacturing practice is widespread. It ensures that the production process is manufactured and controlled in accordance with the requirements contained in their specifications and documents. The system covers all aspects of production from the main assumptions concerning the facility (construction, technical and technological), through the requirements for raw materials, machinery, personnel, to the production process itself (procedures and methods), and then to the storage and distribution of the manufactured product. Good Manufacturing Practice is aimed primarily at ensuring the repeatability and quality of the product with regard to its safety, purity and effectiveness, preventing the mixing of intermediate products, products and materials, thereby preventing contamination of one product or raw material with another.

Obtaining an appropriate level of product quality is also becoming extremely important for agricultural retailers, not only because of the legislation in force, but also because of increased competitiveness. Guaranteed and good quality of products and services becomes the basis for their development.

PODSUMOWANIE

W produkcji żywności istotne jest wdrażanie i rozwijanie systemów zarządzania bezpieczeństwem żywności, których nadrzędnym celem jest zapewnienie bezpieczeństwa zdrowia i życia konsumenta. Na wszystkich etapach łańcucha żywnościowego, istotne jest eliminowanie zagrożeń. System dobrej praktyki produkcyjnej jest rozpowszechniony. Gwarantuje wytwarzanie i kontrolowanie procesu produkcji zgodnie z wymaganiami zawartymi w ich specyfikacjach oraz dokumentach. System ten obejmuje wszystkie aspekty produkcji począwszy od głównych założeń dotyczących obiektu (budowlanych, technicznych oraz technologicznych), poprzez wymagania w stosunku do surowców, maszyn, personelu, aż do samego procesu produkcji (procedur i metod), a następnie magazynowania i dystrybucji wytwarzanego produktu. Dobra Praktyka Produkcyjna ma na celu przede wszystkim zapewnienie powtarzalności i jakości produktu z uwzględnieniem jego bezpieczeństwa, czystości i efektowności, zapobieganie pomieszaniu się półproduktów, produktów i materiałów, tym samym zapobieganie zanieczyszczeniom jednego produktu lub surowca innym.

Uzyskanie odpowiedniego poziomu jakości produktów staje się niezwykle istotne również dla podmiotów prowadzących rolniczy handel detaliczny, nie tylko z powodu obowiązujących przepisów prawnych, lecz także w związku ze wzrostem konkurencyjności. Gwarantowana oraz dobra jakość produktów i usług, staje się bowiem podstawą do ich rozwoju.

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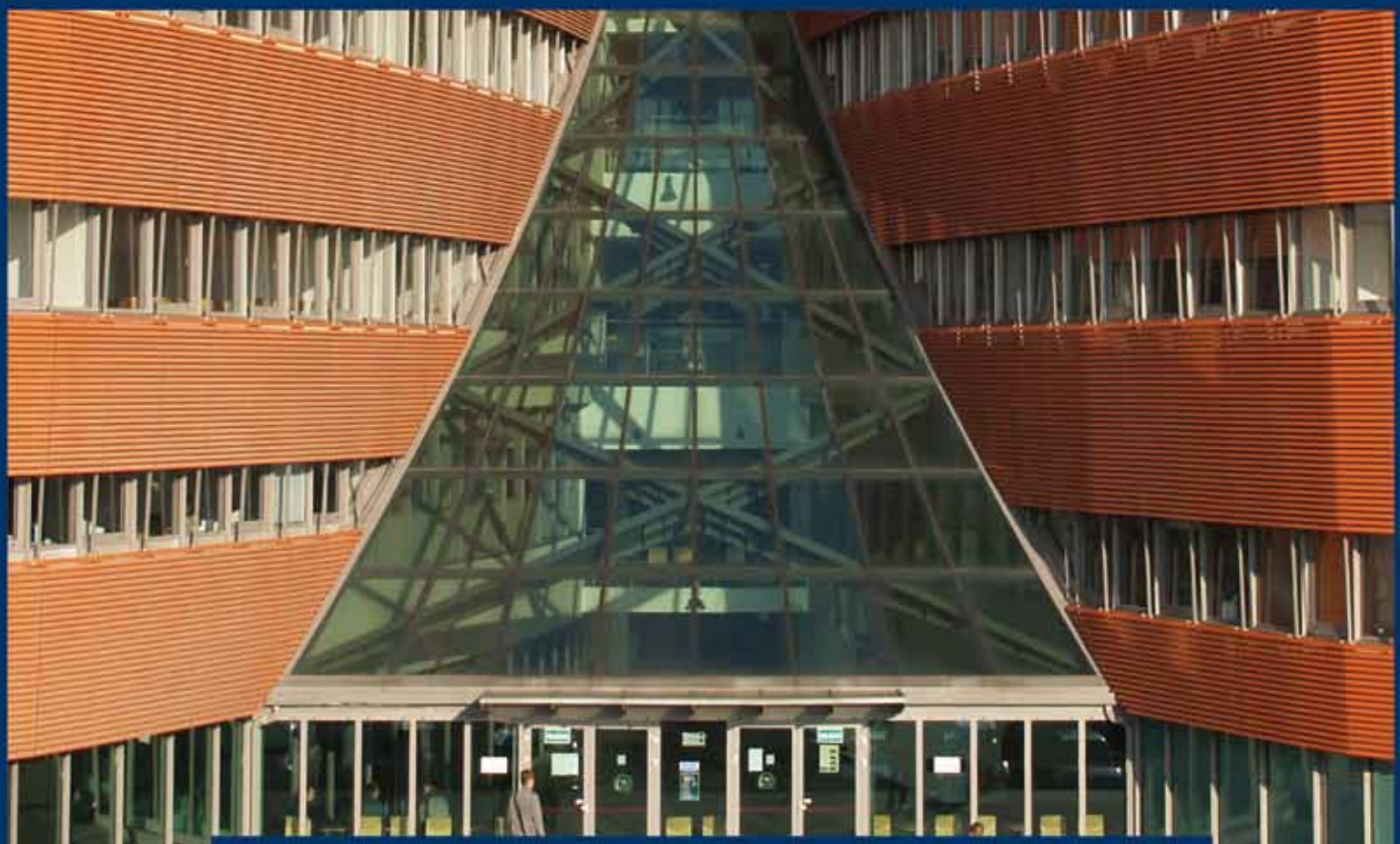

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