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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.

Technological Progress in Food Processing presents scientific achievements and ideas of Polish and international researchers from universities and research institutes, including technical, agricultural, and economical ones.

Czasopismo naukowe, o zasięgu międzynarodowym, promujące postęp w technice branż przetwórstwa spożywczego, zamieszczające prace naukowo-badawcze, badawczo-rozwojowe, wdrożeniowe i przeglądowe z zakresu: inżynierii żywności, organizacji i techniki produkcji, projektowania, konstrukcji, wykonawstwa oraz eksploatacji i energochłonności maszyn spożywczych, a także z zarządzania w przetwórstwie spożywczym.

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ZARZĄDZANIE W PRZETWÓRSTWIE SPOŻYWCZYM

OD REDAKCJI

Przekazujemy do rąk Szanownych Czytelników sześćdziesiąty pierwszy numer „Postępów Techniki Przetwórstwa Spożywczego".

Kończymy trzydziesty pierwszy rok działalności na rynku naukowych wydawnictw periodycznych, promując postęp techniczno- technologiczny w przetwórstwie spożywczym.

Publikujemy jedynie oryginalne, podwójnie recenzowane artykuły naukowo-badawcze, badawczo-rozwojowe i analityczno-przeglądowe. Recenzje w większości zostały uzyskane od specjalistów zagranicznych.

Dotychczas opublikowaliśmy ponad 1220 artykułów.

W bieżącym numerze znajdą Państwo 27 artykułów.

Sygnalizuję tylko niektóre z nich mimo, że wszystkie są interesujące.

Pracownicy Politechniki Opolskiej we współpracy z Uniwersytetem w Brnie (Czechy) prezentują badania dotyczące spożywczego wykorzystania ziół:majeranku i tymianku. Stwierdzili oni, że stosowanie oprysku dolistnego podczas uprawy w/w ziół zwiększa w nich zawartość olejków eterycznych.

Zespół Instytutu Biotechnologii Przemysłu Rolno-Spożywczego- Państwowego Instytutu Badawczego w Warszawie zbadał, że spośród wielu form ryb, znajdujących się na polskim rynku, najbardziej przydatne do obróbki termicznej metodą „sous-vide"(SV) są całe filety świeże. Obróbka mięsa ryb tą metodą(SV) pozwala uzyskać produkt pożądany sensorycznie.

Analiza wyników badań przeprowadzonych w Instytucie Nauk o Żywności SGGW w Warszawie pozwala na stwierdzenie, że wstępną obróbkę osmotyczną oraz suszenie mikrofalowo-próżniowe, przy odpowiednio wysokiej mocy mikrofal, można wykorzystać do wytwarzania suszu z jabłek t.j. żywności trwałej.

Opracowana przez zespól Morskiego Instytutu Rybackiego w Gdyni metoda wytwarzania nowych produktów z mięsa karpi jest innowacyjną koncepcją ich wykorzystania w żywieniu.

Wyprodukowanie w warunkach laboratoryjnych partii burgerów z karpi daje możliwość wdrożenia opracowanej technologii w zakładach przetwórstwa rybnego.

Im wyższa jest zawartość tłuszczu w serze dojrzewającym, tym większa całkowita zawartość witaminy K w tym serze – twierdzą pracownicy Katedry Towaroznawstwa i Badań Żywności Uniwersytetu Warmińsko- Mazurskiego w Olsztynie. Biorąc pod uwagę, że niski poziom witaminy K w organizmie jest jednym z czynników ryzyka chorób sercowo-naczyniowych, sery dojrzewające powinny być traktowane jako ważny składnik diety człowieka.

Kolejne badania w Instytucie Nauk o Żywieniu Człowieka SGGW w Warszawie dotyczą odpadów żywnościowych. Wytłoki jabłkowe zawierają cenne związki, które mogą znaleźć zastosowanie w produktach spożywczych, kosmetycznych oraz farmaceutycznych, ewentualnie mogą być użyte przy produkcji biopaliw.

Racjonalne gospodarowanie bioodpadami zmniejsza zanieczyszczenie środowiska i przyczynia się do redukcji emisji gazów cieplarnianych.

Zachęcam do lektury naszego Czasopisma.

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.

REDAKTOR NACZELNY

A. Denaf

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CONSUMPTION OF MILK AND MILK PRODUCTS IN POLAND IN THE YEARS 2004–2020®

Konsumpcja mleka i jego przetworów w Polsce w latach 2004–2020®

Key words: consumption, milk, milk products, Poland.

The aim of the research was to present changes in the consumption of milk and its dairy products in Poland. The research covered data for the years 2004-2020. The time interval of the research was determined by the availability of data in the database of the Central Statistical Office. The research material included literature on the subject, which contributed to the characterisation of the issue of consumption and on-going changes in the consumption of dairy products. Based on the literature, the factors that determine changes in the consumption of milk and its dairy products in dynamic terms were identified. The descriptive and cause-and-effect methods were applied in the presentation of research results. Based on the research analyses and the literature review, it was shown that changes in the level of milk consumption were small in relation to changes in prices expressed in current prices, as well as consumer income. In contrast, there were changes in dairy consumption. Between 2004 and 2020, the consumption of highly processed dairy products, i.e. yoghurts, cheeses, cottage cheese, increased, while the consumption of liquid milk decreased and the consumption of fat products, i.e. butter and cream, increased at a lower rate.

Słowa kluczowe: konsumpcja, mleko, przetwory mleczne, Polska.

Celem badań było przedstawienie zmian konsumpcji mleka i jego przetworów mleczarskich w Polsce. Badania obejmowały dane za lata 2004-2020. Przedział czasowy badań był determinowany dostępnością danych w bazie Głównego Urzędu Statystycznego. Materiał do badań obejmował literaturę przedmiotu, która przyczyniła się do scharakteryzowania zagadnienia konsumpcji oraz zachodzących zmian w spożyciu artykułów mleczarskich. W oparciu o literaturę wskazano czynniki, które determinują zmiany spożycia mleka i jego przetworów mleczarskich w ujęciu dynamicznym. Przy prezentacji wyników badań zastosowano metodę opisową oraz przyczynowo-skutkową. W oparciu o przeprowadzone analizy badawcze oraz przegląd literatury wykazano, że zmiany poziomu konsumpcji mleka były niewielkie w odniesieniu do zmian cen wyrażonych w cenach bieżących, a także dochodów konsumentów. Nastąpiły natomiast zmiany w konsumpcji nabiału. W latach 2004-2020 wzrosło spożycie artykułów mleczarskich wysokoprzetworzonych, tj. jogurty, sery, twarogi, przy jednoczesnym spadku konsumpcji mleka płynnego, a także mniejszej dynamice wzrostu spożycia produktów tłuszczowych, czyli masła oraz śmietany.

INTRODUCTION

Demand for the good produced is one of the important factors shaping changes in a given production in a free market economy. The specificity of agricultural production derives from the compulsion to consume and the associated constant demand for food, which is the source of changes in production [10]. According to Rembisz [2008], the magnitude of demand, including its direction of change, is determined by many diverse and interrelated variables [7]. Taking into account the specificity of food products, these can be variables of economic, social, cultural, biological nature [10]. Important economic determinants of food consumption include consumers' incomes, the prices of food items compared to these incomes, and the relationship of these prices to other prices. Economic theory indicates a relationship in that as consumer income increases, an increase in demand for specific products or services is observed [6]. In the case of food products, as income increases, an increase in demand for food is observed, but only up to a certain level. A long-term increase in income does not result in a continuous increase in demand for foodstuffs, which would simultaneously be combined with an increase in food expenditure. Such a phenomenon is referred to in economic theory as Engel's law. In the case of poor societies, an increase in the income of the population can lead to an increase in demand for food. In rich societies, an improvement in citizens' income does not necessarily mean an increase in demand for foodstuffs. Instead, there may be a change in the structure of consumption towards a shift in demand from cheaper products to more expensive and processed products [10]. In addition to the income received by society, the volume

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of demand for foodstuffs is shaped by changes in population. The demand for food in macroeconomic terms is the resultant of the population and the demand per capita [4, 14].

The key food product is milk and dairy products, which is related to their share in agricultural production, their importance for the income of the agricultural population, and their nutritional properties. Milk has about 500 chemical compounds, 240 of which are low molecular weight fatty acids [5]. In addition to this, it should be emphasised that milk protein is a source of essential amino acids. Regular consumption of milk and dairy products contributes to the supply of well-absorbed immune components. Due to its good source of calcium, which is crucial for the proper development of the skeletal system, milk is an essential product used in the nutrition of children [15]. The virtues of milk as a foodstuff contribute to an increase in its demand, which is evident in analyses of food consumption [10].

The aim of this study was to present changes in the consumption of milk and its dairy products in Poland between 2004 and 2020.

MATERIAL AND METHOD

The study took into account data from the years 2004-2020. The time interval used in the analyses was determined by the availability of data on the consumption of milk and its products in the database of the Central Statistical Office (CSO).

The study used materials from published Agricultural Statistical Yearbooks for the years 2005–2020, as well as market analyses of the milk market published by the Institute of Agricultural and Food Economics of the National Research Institute for the years 2001–2021.

The research material included also literature on the subject, which contributed to characterisation of the issue of consumption and indication of factors determining consumption of milk and its products in Poland.

Descriptive and cause-and-effect methods were used to present the results of the study and were supported by graphical and tabular presentation of the results.

RESULTS AND DISCUSSION

Household consumption and balance sheet data are used to assess domestic demand for milk and dairy products [11]. The increase in milk consumption in balance sheet terms between 2004 and 2020 was 40%, from 174 l/capita per year to 244 l/capita per year (Figure 1). Factors stimulating an increase in the consumption of milk and milk products in Poland include [8]:

- an increase in consumer purchasing power, which was strengthened by the progressive economic development taking place after Poland's accession to the EU,
- the convergence of consumption patterns to Western European countries.

It is estimated that the balance consumption of milk, including milk for processing, excluding milk processed into butter, in Poland in the years 2004–2020 increased from 174 l/capita per year to 244 l/capita per year (Figure 1). Total raw milk consumption in Poland in 2020 was indicated at around 11.1 billion litres. This was 22% more than in 2004 [3].

Analysing the CSO data on unit butter consumption, one can observe an increase in butter consumption by 34%, from 4.4 kg/capita per year to 5.9 kg/capita per year between 2004 and 2020 (Figure 2). The highest levels of balance butter consumption in Poland were in 2016 and 2018 (4.7 kg/inhabitant) and 2019 (5.4 kg/inhabitant) and 2020 (5.9 kg/inhabitant) (Figure 2). The reasons for the increase in butter

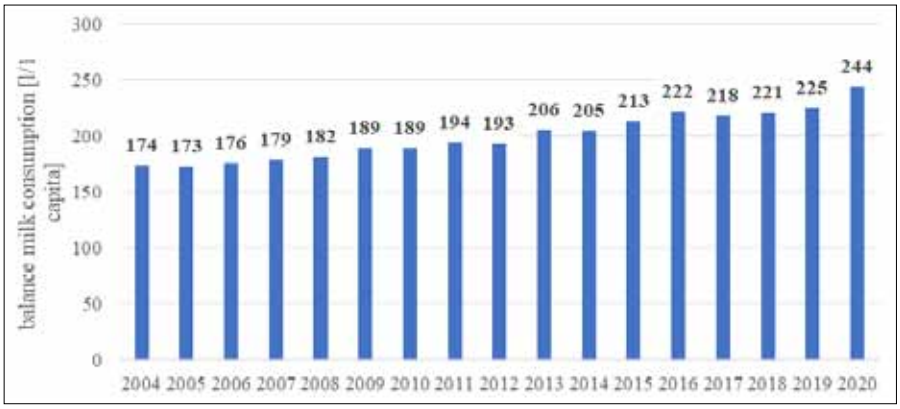

Fig. 1. Balance consumption of milk in Poland in the years 2004-2020 expressed in [l/capita/year].

Rys. 1. Spożycie bilansowe mleka w Polsce w latach 2004-2020 wyrażone w [l/mieszkańca/rok].

Source: Own elaboration based on data from the BDL [2]

Źródło: Opracowanie własne na podstawie danych pochodzących BDL [2]

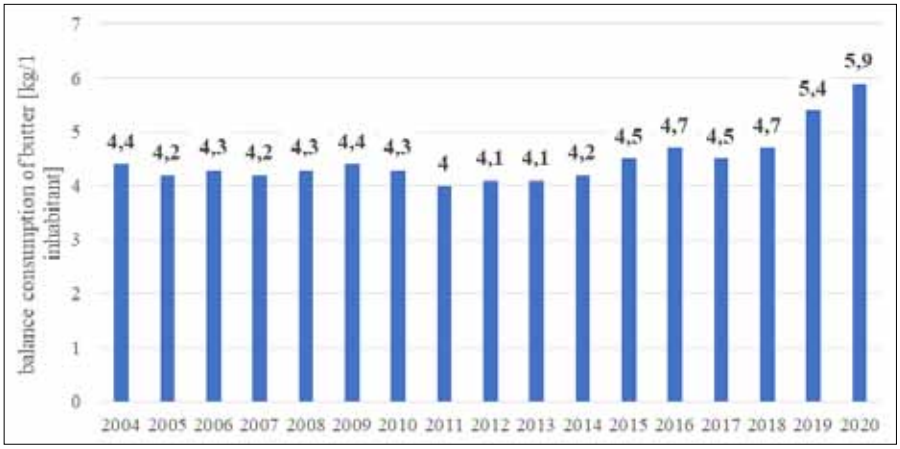

Fig. 2. Balance consumption of butter in Poland in the period 2004-2020 expressed in [kg/capita/year].

Rys. 2. Spożycie bilansowe masła w Polsce w latach 2004-2020 wyrażone w [kg/mieszkańca/rok].

Source: Own elaboration based on data from the BDL [2]

Źródło: Opracowanie własne na podstawie danych pochodzących BDL [2]

consumption over the analysed period are the improvement in the income situation of households, the decrease in retail prices, the decrease in consumption of oils and fats in general, and the change in consumption patterns [1]. The demand for butter on the internal market is determined by the level of household consumption of dairy products, but also by consumption in secondary food processing, which includes food industry companies, including internal turnover in the dairy sector, the feed industry and the HoReCa sector. Butter is both consumed in households and used as a raw material component in the production of processed foods, which increases the demand for this product [12].

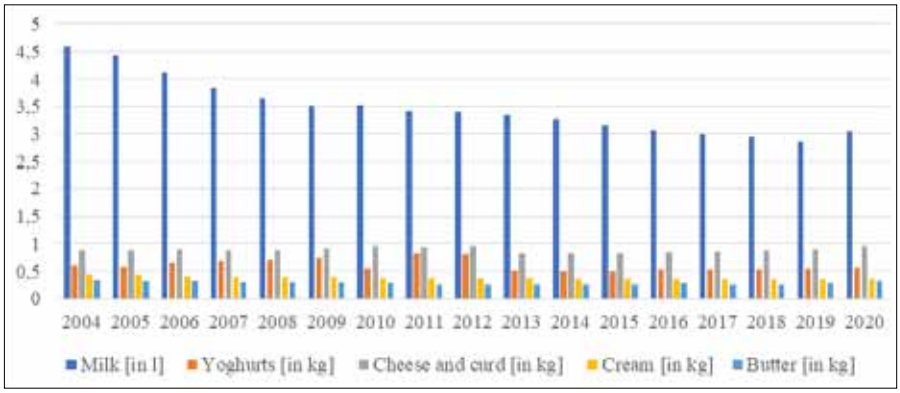

Fig. 3. Average monthly consumption of milk, selected dairy products and butter in Poland in the years 2004–2020 per person per household.

Rys. 3. Przeciętne miesięczne spożycie mleka, wybranych artykułów mleczarskich i masła w Polsce w latach 2004–2020 w przeliczeniu na 1 osobę w gospodarstwie domowym.

Source: Own elaboration based on data from the BDL [2]

Źródło: Opracowanie własne na podstawie danych pochodzących BDL [2]

Changes in the dairy sector since 1990, both in the scale and structure of production of dairy products and in the level of retail prices, were reflected in the volume of consumption of dairy products in Poland. Considering the consumption of milk and milk products and butter in Poland in the years 2004–2020 in monthly terms per 1 person in households, it can be observed (Figure 3):

- a 33% decrease in milk consumption in the analysed years, from 4.60 litres per person in households to 3.06 litres per person in households,
- a decrease in yoghurt consumption in the years under study by 7%, from 0.61 kg per person in households to 0.57 kg per person in households,
- an increase in the volume of cheese and cottage cheese consumption by 9%, from 0.87 kg per 1 person in households to 0.95 kg per 1 person in households,
- a decrease in cream consumption of around 20%, from 0.44 kg per 1 person in households to 0.36 kg per 1 person in households,
- a slight decrease in butter consumption of around 3%, from 0.33 kg per 1 person in households to 0.32 kg per 1 person in households.

The sustained upward trend in the consumption of cheese and cottage cheese in Poland was caused, among other things, by an increase in the supply of dairy products, making the assortment of products more attractive, the improving income situation of society, as well as changes in lifestyle and related eating habits [9]. The continuing downward trend in the consumption of fresh milk in Poland was conditioned by an increase in the price of fresh milk and yoghurt, changing dietary trends and an increasing number of people who eliminate milk from their diet for various reasons [9, 13].

Changes in the average monthly consumption of milk and its products and butter between 2004 and 2020 were mainly due to an increase in consumer awareness of nutrition, which consequently contributed to a decrease in the consumption of milk and cream in favour of fermented milk drinks, including yoghurt. The increase in the income level of Polish society in the analysed years contributed to an increase in the consumption of more processed dairy products, i.e. cheese and cottage cheese. An increase in the retail price of butter and low prices of substitute goods, e.g. margarine, resulted in a decrease in the average monthly consumption of butter in the analysed years.

Between 2000 and 2020, the highest amount of milk was consumed on a monthly basis in farmer households and pensioner households. At the same time, in dynamic terms, these households showed the largest decrease in milk consumption. In the case of farmer households, the decrease in monthly milk consumption over the years under study was 59%, and 49% in pensioner households (Table 1). The least milk was consumed in employee and self-employed households (Table 1).

Between 2000 and 2020, an increase in monthly yoghurt consumption was noticeable in all household types, ranging from 32–207% (Table 1). Monthly yoghurt consumption in 2020 was highest in self-employed households and pensioner households, at around 0.60–0.62 kg per person. In contrast, monthly yoghurt consumption in 2020 was lowest in farmer households at 0.46 kg per person (Table 1). The higher consumption of yoghurt in self-employed households than in other households may be related to this group's receipt of a monthly income that enables them to purchase dairy products such as yoghurt and other fermented milk drinks. In addition to this, other factors determining yoghurt consumption may include a change in consumer food preferences, an increase in consumer awareness of the nutritional value of dairy products, and convenience of consumption.

Between 2000 and 2020, all household types showed an increase in cheese and curd consumption, except for farmer households, where a 9% decrease in cheese and curd was evident. The highest average monthly consumption of cheese and cottage cheese in the years under study was found in pensioner households (1.12 kg of cheese per person per month was consumed in these households in 2020) (Table 1). The higher consumption of cheese and cottage cheese in pensioner households was related to their food preferences and habits.

In the years analysed, a decrease in the average monthly consumption of cream was visible in all household types. The

Table 1. Average monthly consumption of milk and milk products in households from 2000 to 2020 expressed in [l/kg per person]

Tabela 1. Przeciętne miesięczne spożycie mleka i jego przetworów w gospodarstwach domowych w latach 2000–2020 wyrażone w [l/kg na osobę]

	2000				2010				2020			
	employees	farmers	self-employed	pensioners	employees	farmers	self-employed	pensioners	employees	farmers	self-employed	pensioners
Milk [in l]	3,92	8,71	4,27	6,91	3,03	5,3	3,09	4,42	2,90	3,57	2,86	3,50
Yoghurts [in kg]	0,39	0,15	0,47	0,39	0,55	0,35	0,6	0,55	0,57	0,46	0,62	0,60
Cheese and curd [in kg]	0,78	0,79	0,91	0,96	0,91	0,78	1,01	1,08	0,92	0,72	0,97	1,12
Cream [in kg]	0,35	0,69	0,37	0,58	0,33	0,43	0,31	0,54	0,31	0,38	0,30	0,50
Butter [in kg]	0,28	0,29	0,35	0,39	0,23	0,25	0,28	0,38	0,29	0,25	0,33	0,45

Source: Own compilation based on [1]

Źródło: Opracowanie własne na podstawie [1]

highest consumption of cream on a monthly basis in 2020 was recorded in pensioner households and amounted to 0.50 kg per person (Table 1).

On the other hand, in the case of average monthly butter consumption between 2000 and 2020, an increase in butter consumption was observed in pensioner households, with an increase of 15%, and in employee households, with an increase of 4%, while other household types experienced a decrease in consumption of 6–14% (Table 1). The highest consumption of butter on a monthly basis in 2020 was seen in pensioner households at 0.45 kg per person (Table 1). The higher consumption of cream as well as butter in pensioner households was related to their dietary preferences and habits.

One of the factors that determine the consumption of food items, including milk and milk products, is the size of the average monthly disposable income per person in the household [10]. Between 2004 and 2020, the average monthly disposable income per person in households in Poland increased almost 3 times (Figure 4). In 2020, it amounted to approximately PLN 1919.21 in Poland (Figure 4). The upward trend in average monthly disposable income per person in households, which has continued since 2004, may have been one of the reasons for the increase in the consumption of dairy products, i.e. cheese, cottage cheese, yoghurt.

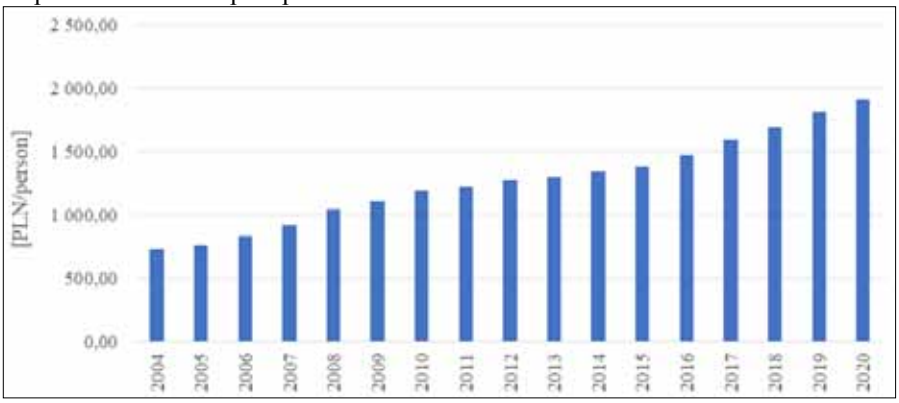

Fig. 4. Average monthly disposable income from 2004 to 2020 per person per household.

Rys. 4. Przeciętny miesięczny dochód rozporządzalny w latach 2004–2020 w przeliczeniu na 1 osobę w gospodarstwie domowym.

Source: Own elaboration based on data from the BDL [2]

Źródło: Opracowanie własne na podstawie danych pochodzących BDL [2]

Another factor identified in the literature that is important in shaping the consumption of dairy products is their share in average monthly household expenditure [10]. Between 2010 and 2020, expenditure on milk and dairy products accounted for 2.7–3.1% in total expenditure, while expenditure on butter accounted for 0.4–0.6% (Table 2). Expenditure on milk and dairy products in expenditure on food and non-alcoholic beverages in the years studied ranged from 10.8–12.2%, while expenditure on butter was 1.7–2.3% (Table 2). It can be seen that as the population's income increased, the share of expenditure on milk and dairy products in total expenditure and food expenditure decreased, which is in line with Engel's law. In contrast, during the years under study, there was an increase in expenditure on butter in total fat expenditure, from 39.1 to 53.3% (Table 2). This was related, among other things, to the increase in society's income, which contributed to a shift in the structure of demand away from margarine and other vegetable fats, which are substitutable goods to butter, towards consuming more butter despite the increase in the retail price.

The volume of consumption of milk, milk products and butter is also determined by retail prices of dairy products. In the years 2004–2020, an increase in retail prices of such products as drinking cow's milk, semi-skimmed cottage cheese, ripened cheese, cream and fresh butter in Poland was noticeable (Figure 5). Between 2004 and 2020,

Table 2. Share of average monthly expenditure on milk and milk products and butter in household expenditure in Poland in 2010–2020 expressed in [%]

Tabela 2. Udział przeciętnych miesięcznych wydatków na mleko i jego przetwory oraz masło w wydatkach gospodarstw domowych w Polsce w latach 2010–2020 wyrażone w [%]

Years	Expenditure on milk and milk products as % of total expenditure	Expenditure on milk and milk products as % of expenditure on food and non-alcoholic beverages	Expenditure on butter as % of total expenditure	Expenditure on butter as % of expenditure on food and non-alcoholic beverages	Expenditure on butter as % of total expenditure on fats
2010	3,0	12,2	0,5	1,8	39,1
2011	3,1	12,2	0,5	1,8	38,7
2012	3,0	12,0	0,4	1,7	36,0
2013	2,9	11,5	0,4	1,8	39,8
2014	2,9	11,7	0,5	1,9	41,8
2015	2,7	11,3	0,4	1,8	43,6
2016	2,7	11,0	0,5	1,9	46,2
2017	2,7	11,0	0,6	2,3	50,7
2018	2,7	11,1	0,6	2,3	53,0
2019	2,7	10,8	0,5	2,1	53,2
2020	**3,1**	**11,3**	**0,6**	**2,1**	**53,3**

Source: Own compilation based on [1]

Źródło: Opracowanie własne na podstawie [1]

an increase in the price of drinking cow's milk by 24% was visible (Figure 5). In the period under study, the increase in the retail price of semi-skimmed cottage cheese in Poland was 58% (Figure 5). In the case of the price of ripened cheese, there was an increase in its price in the analysed period for Poland, at the level of 35% (Figure 5). On the other hand, a noticeable increase in the price of cream in Poland amounted to 54%, while that of butter was 82% (Figure 5).

CONCLUSIONS

Analysing changes in the consumption of milk and milk products in Poland in the period 2004–2020, it can be concluded that:

- changes in the level of milk consumption were small in relation to changes in prices expressed in current prices, as well as consumer income. This confirms low income and price elasticity of consumption of this group of food products,
- changes occurred in the consumption of dairy products. In the years under study, the consumption of highly processed dairy products, i.e. yoghurts, cheeses, cottage cheese, increased, while the consumption of liquid milk decreased, and the consumption of fat products, i.e. butter and cream, increased at a lower rate.

WNIOSKI

Analizując zmiany w spożyciu mleka oraz jego przetworów w Polsce w latach 2004–2020 można wywnioskować, że:

- zmiany poziomu konsumpcji mleka były niewielkie w odniesieniu do zmian cen wyrażonych w cenach bieżących, a także dochodów konsumentów. Jest to potwierdzenie niskiej dochodowej oraz cenowej elastyczności spożycia tej grupy artykułów żywnościowych,
- zmiany nastąpiły w konsumpcji nabiału. W badanym latach wzrosło spożycie artykułów mleczarskich wysokoprzetworzonych, tj. jogurty, sery, twarogi, przy jednoczesnym spadku konsumpcji mleka płynnego, a także mniejszej dynamice wzrostu spożycia produktów tłuszczowych, czyli masła oraz śmietany.

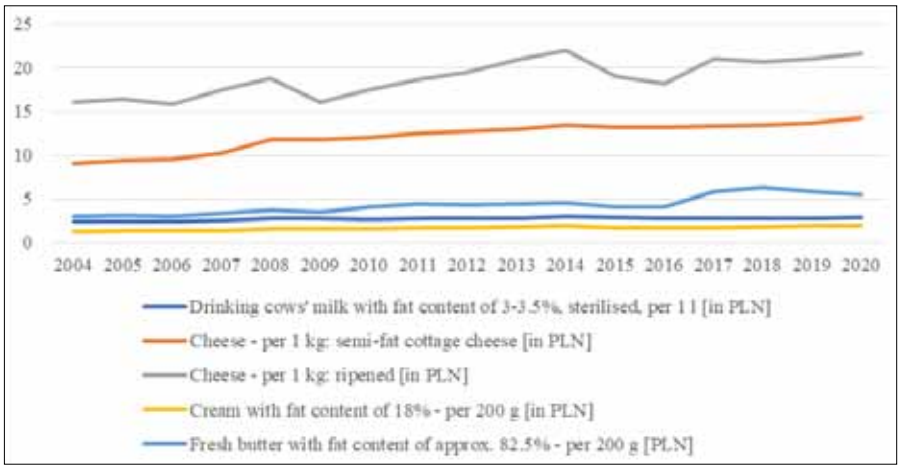

Fig. 5. Retail prices of milk and dairy products in Poland 2004–2020 (current prices).

Rys. 5. Ceny detaliczne mleka i artykułów mleczarskich w Polsce w latach 2004–2020 (ceny bieżące).

Source: Own elaboration based on data from the BDL [2]

Źródło: Opracowanie własne na podstawie danych pochodzących BDL [2]

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APPLICATION OF IMPACT HAMMER CRUSHER FOR ROCK SALT PURIFICATION®

Zastosowanie udarowej kruszarki młotkowej do rozdrabniania i oczyszczania soli kamiennej®

Key words: Food salt, crushing, hammer crusher, salt purification.

The article presents the results of research on crushing rock salt. At the Department of Machinery Engineering and Transport, AGH University of Science and Technology in Kraków, an attempt was made to crush salt with a grain size of up to 5 mm. The aim of the research was to obtain a product with a grain size of up to 2 mm with the smallest possible fraction of less than 0.5 mm, which will allow obtaining a product that meets the requirements of customers. The technological system should allow for a minimum efficiency of 20 Mg/h of product. The tests were carried out on two types of crushers: a vibratory jaw crusher and a hammer crusher with a variable grate size. Based on the analysis of the research results, the use of a hammer crusher was proposed. Using this type of crusher with an adequately selected grate allowed to obtain satisfactory results. It was also proposed to modify the crusher's functional elements (hammers), which should increase the efficiency of the process.

Słowa kluczowe: sól spożywcza, kruszenie, kruszarki młotkowe, oczyszczanie soli.

W artykule przedstawiono wyniki badań, dotyczących kruszenia soli kamiennej. W Katedrze Inżynierii Maszyn i Transportu Akademii Górniczo-Hutniczej w Krakowie podjęto próbę kruszenia soli o uziarnieniu do 5 mm. Celem badań było uzyskanie produktu o uziarnieniu do 2 mm z jak najmniejszym odziałem frakcji poniżej 0,5 mm co pozwoli na uzyskanie produktu spełniającego wymagania odbiorców. Układ technologiczny powinien pozwolić na uzyskanie wydajności wynoszącej minimalnie 20 Mg/h produktu. Badania przeprowadzono na dwóch typach kruszarek: szczękowej kruszarki wibracyjnej i kruszarce młotkowej ze zmiennym rusztem. Na podstawie analizy wyników badań zaproponowano zastosowanie kruszarki młotkowej. Zastosowanie tego typu kruszarki z odpowiednio dobranym rusztem pozwoliło na uzyskanie zadawalających efektów. Zaproponowano również modyfikację elementów roboczych kruszarki co powinno pozwolić na zwiększenie efektywności procesu.

INTRODUCTION

Rock salt (halite) is a sedimentary rock, usually colourless. It can also be white or bluish, formed by halite (NaCl) precipitation during water evaporation from seas or salt lakes. It belongs to the group of chemical rocks. Rock salt deposits occur in the form of domes in sediments of various ages, most often Permian and Tertiary, and they also arise today (e.g. the Caspian Sea). The largest rock salt deposits are in Russia, the USA, Germany, France and China. In Poland, large rock salt deposits are found in the northwest and central part of the country, in Kłodawa and Inowrocław. These deposits come from the Upper Permian - Zechstein. They are mined using the brine flushing method (Inowrocław) and the underground method (Kłodawa). In the vicinity of Bochnia and Wieliczka, small rock salt deposits come from the Tertiary - Miocene period. These are currently unexploited. Rock salt is used both in the food industry (table salt, evaporated salt) and in the chemical industry (for producing paints and soap). It is used as an agent for defrosting and combating winter slipperiness (road salt). The aim of this study is presented in the article.

Salt rocks are usually inconsistent with the surrounding rocks. There is water, brine, gas and sometimes even traces of oil on the contact surfaces. Protective pillars are therefore intended to protect the boundaries of the deposit that cannot be disturbed by mining excavations. The greatest danger in salt mines is the water hazard. A slight leakage of water or brine may result in the flushing of large channels and cavities, posing a threat of flooding the mine.

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Fig. 1. Food salt and road salt [1].
Rys. 1. Sól spożywcza i sól drogowa [1].

The exploitation of rock salt is divided into two methods [1]:

- dry method – breaking out,
- wet method – based on leaching or dissolving with water.

When using the dry method of rock salt extraction, metallic impurities result from the extraction technology, which necessitates their separation [2, 5].

One of the processes related to the production of rock salt is comminution, consisting in dividing individual grains of the material into smaller parts using: crushing, shearing, abrasion, hitting or breaking [8]. Machines called crushers and mills are used to reduce grain size. When designing or selecting an appropriate crusher or mill, parameters such as the hardness of the crushed material, efficiency, regularity of grain dimensions, plasticity, humidity and many others should be considered. There are crushers and mills operating continuously (e.g. roller crushers, ball mills, impact crushers) and cyclically (jaw crushers) [8]. The use of impact crushers [3, 4]for crushing salt, especially working in closed circuits (with return) [6, 7], is becoming increasingly popular.

STONE SALT AND QUALITY REQUIREMENTS

The raw materials used for mechanical processing are: white rock salt, pink rock salt and potassium-magnesium salt. The product of mechanical processing is rock salt, meeting the requirements of the applicable PN-C-84081-2 standard. Edible salt should meet the parameters required by the standard given in Table 1.

For the crushing tests, the salt was obtained in the grain size range of up to 5 mm. Table 2 and Figure 2 show the grain size distribution of the salt sample provided for testing.

Table 2. Sieve analysis results of all the salt supplied for testing

Tabela 2. Wyniki analizy sitowej całości soli dostarczonej do badań

Screen mesh size d [mm]	Through F [%]	Through sum ΣF [%]
0,8	54,0	54,0
1,0	8,5	62,5
1,6	16,0	78,5
2,0	8,6	87,1
4,0	12,0	99,1
5,0	0,9	100

Source: Own study
Źródło: Badania własne

Table 1. Required parameters of food salt

Tabela 1. Wymagane parametry soli spożywczej

Parameter	Value or requirement
Color	White or white with a natural shade of gray or pink
Smell	No foreign/unpleasant smell
Taste	Salty without any foreign taste, especially bitter
Appearance	Crystalline product
Mechanical contaminations [%]	None
pH of a 1% water solution [-]	6-8
Water H2O at most [%]	0,5
Substances insoluble in H20 at most [%]	1,5
Sodium chloride NaCl at least [%]	97,0
Heavy metals content	The current order of the Minister of Health and Social Welfare on the list of additional substances
Iodine content	The current order of the Minister of Health and Social Welfare on the list of additional substances

Source: Own study based on [1]
Źródło: Opracowanie własne na podstawie [1]

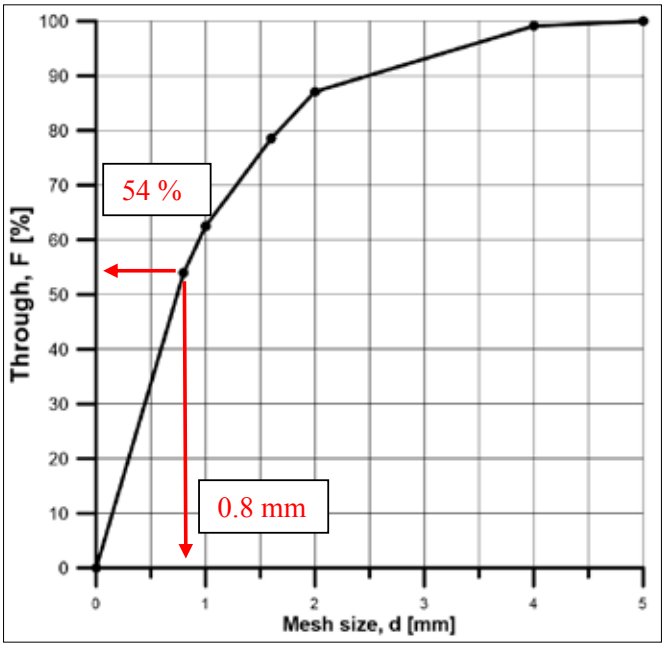

Fig. 2. Feed grain size distribution.
Rys. 2. Krzywa składu ziarnowego całości nadawy.
Source: Own study
Źródło: Badania własne

Due to the assumed technological result (the total product below the grain size d = 0.8 mm), in the next step, the feed was divided into grain classes below 0.8 mm and above 0.8 mm. Only samples prepared from the separated class above the grain size d = 0.8 mm were used for the crushing tests, as shown in Table 3 and Figure 3.

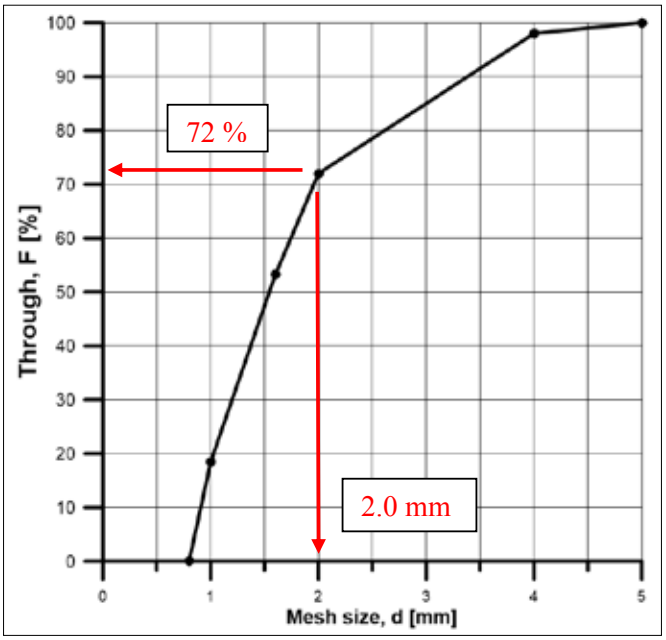

Fig. 3. Grain size distribution of salt samples used for grinding tests.
Rys. 3. Krzywa składu ziarnowego próbek soli wykorzystanych do badań rozdrabniania.
Source: Own study
Źródło: Badania własne

Table 3. Sieve analysis results of the salt samples used for crushing tests
Tabela 3. Wyniki analizy sitowej próbek soli wykorzystanych do badań rozdrabniania

Screen mesh size d [mm]	Through F [%]	Through sum ΣF [%]
0,8	0	0
1,0	18,4	18,4
1,6	34,8	53,2
2,0	18,8	72,0
4,0	26,0	98,0
5,0	2,0	100

Source: Own study
Źródło: Badania własne

ANALYSIS OF THE CRUSHING EFFECTS IN THE VIBRATORY JAW CRUSHER

In the first phase, crushing tests were carried out in a vibratory jaw crusher. The results of the crushing product grain size analysis are presented below. The results were compared regarding the possibility of achieving the assumed technological goal.

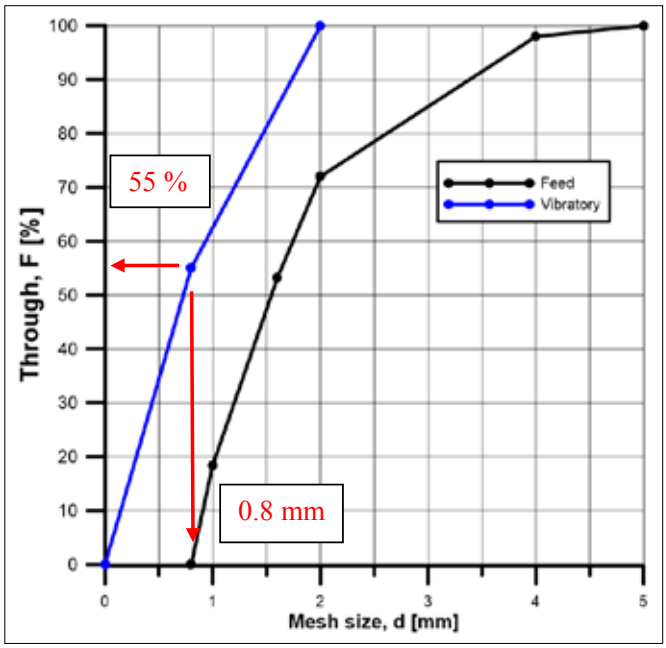

Fig. 4. Grain size distribution of the crushing product from the vibratory jaw crusher.
Rys. 4. Krzywa składu ziarnowego produktu kruszenia z wibracyjnej kruszarki szczękowej.
Source: Own study
Źródło: Badania własne

Table 4. Sieve analysis results of the crushing product from the vibratory jaw crusher

Tabela 4. Wyniki analizy sitowej produktu kruszenia z wibracyjnej kruszarki szczękowej

Screen mesh size d [mm]	Through F [%]	Through sum ΣF [%]
0,8	55	55
2,0	45	100

Source: Own study

Źródło: Badania własne

The table 5 shows the degrees of comminution obtained during the crushing of salt samples in the vibratory jaw crusher.

Table 5. Degrees of comminution obtained during the crushing of salt samples in the vibratory jaw crusher

Tabela 5. Stopnie rozdrobnienia produktu kruszenia z wibracyjnej kruszarki szczękowej

Degree of comminution	Value
i50	2,2
i90	2,0

Source: Own study

Źródło: Badania własne

ANALYSIS OF THE CRUSHING EFFECTS IN THE IMPACT HAMMER CRUSHER

In the second stage of the research, crushing tests were carried out in an impact hammer crusher with two sizes of the crusher's grate: 1.0 mm and 2.0 mm.

a) Grate with a mesh diameter of d = 1.0 mm

The 1.0 mm grate crushing product grain composition is presented in Table 6 and the grain size distribution on Figure 5.

Table 6. Sieve analysis results of the crushing product from the impact hammer crusher for grate mesh diameter d = 1.0 mm

Tabela 6. Wyniki analizy sitowej produktu kruszenia z kruszarki udarowej młotkowej dla rusztu o średnicy oczek d = 1,0 mm

Screen mesh size d [mm]	Through F [%]	Through ΣF [%]
0,8	85	85
1,6	15	100

Source: Own study

Źródło: Badania własne

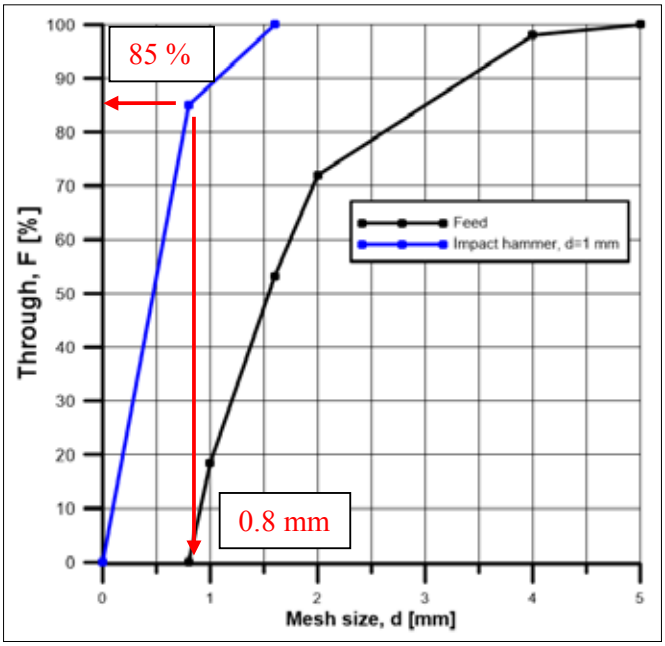

Fig. 5. Grain size distribution of the crushing product from the impact hammer crusher for grate mesh diameter d = 1.0 mm.

Rys. 5. Krzywa składu ziarnowego produktu kruszenia z kruszarki udarowej młotkowej dla rusztu o średnicy oczek d = 1,0 mm.

Source: Own study

Źródło: Badania własne

The table 7 shows the degrees of comminution obtained during the crushing of salt samples in the impact hammer crusher for a grate with a mesh diameter of d = 1.0 mm.

Table 7. Degrees of comminution obtained during the crushing of salt samples in the impact hammer crusher for a grate with a mesh diameter of d = 1.0 mm

Tabela 7. Stopnie rozdrobnienia podczas kruszenia w kruszarce udarowej młotkowej dla rusztu o średnicy oczek d = 1,0 mm

Degree of comminution	Value
i50	3,4
i90	3,2

Source: Own study

Źródło: Badania własne

b) Grate with a mesh diameter of d = 2.0 mm

The 2.0 mm grate crushing product grain composition is presented in Table 8 and the grain size distribution on Figure 6.

Table 8. Sieve analysis results of the crushing product from the impact hammer crusher for grate mesh diameter d = 2.0 mm

Tabela 8. Wyniki analizy sitowej produktu kruszenia z kruszarki udarowej młotkowej dla rusztu o średnicy oczek d = 2,0 mm

Screen mesh size d [mm]	Through F [%]	Through sum ΣF [%]
0,8	65	65
2,0	35	100

Source: Own study
Źródło: Badania własne

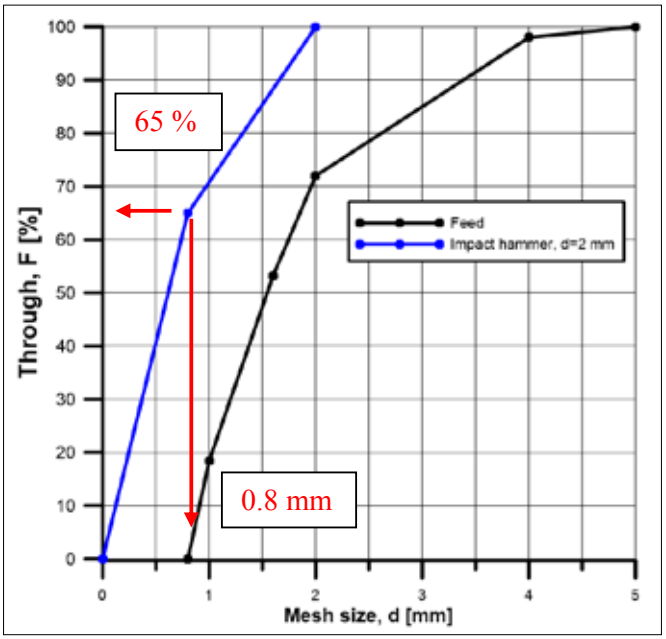

Fig. 6. Grain size distribution of the crushing product from the impact hammer crusher for grate mesh diameter d = 2.0 mm.

Rys. 6. Krzywa składu ziarnowego produktu kruszenia z kruszarki udarowej młotkowej dla rusztu o średnicy oczek d = 2,0 mm.

Source: Own study
Źródło: Badania własne

The table 9 shows the degrees of comminution obtained during the crushing of salt samples in the impact hammer crusher for a grate with a mesh diameter of d = 2.0 mm.

Table 9. Degrees of comminution obtained during the crushing of salt samples in the impact hammer crusher for a grate with a mesh diameter of d = 2.0 mm

Tabela 9. Stopnie rozdrobnienia podczas kruszenia w kruszarce udarowej młotkowej dla rusztu o średnicy oczek d = 2,0 mm

Degree of comminution	Value
i50	2,5
i90	2,0

Source: Own study
Źródło: Badania własne

SUMMARY

The research carried out at the Department of Machinery Engineering and Transport of the AGH University of Science and Technology has shown that the impact hammer crusher is fully suitable for grinding rock salt.

Analyzing the developed results of crushing rock salt samples, it can be concluded that better technological results, i.e. a greater share of the external grain class <0.8 mm, were obtained during crushing in a hammer impact crusher (85% of the product below 0.8 mm with the grate mesh diameter d = 1 mm and 65% with d = 2 mm). The mesh diameter of the grate mounted in the crusher has a decisive influence on the proportion of the desired grain size. It should be remembered that while reducing the mesh size of the grate has a positive effect on the grain size of the product; it significantly reduces the efficiency of the process. For this reason, using grates with too small mesh diameters is pointless. In conclusion, for grinding salt with given grain size, it is recommended to use an impact hammer crusher with a grate mesh diameter of about 2.0 mm. With this assumption, it is necessary to return the crushing product to the primary screen to separate grains with a diameter greater than 0.8 mm.

Based on the research results, a technological system for crushing salt was proposed for implementation (Figure 7). The proposed configuration of a technological system for rock salt crushing allows obtaining 100% of the product below the grain size d = 0.8 mm.

The proposed system consists of two primary machines (a screen and a hammer impact crusher) and appropriate belt conveyors enabling the delivery of the feed and collection of the crushing product as well as the return from the crusher to the screen. The analysis of the grain composition of the crushing product shows that in order to obtain the whole product below the grain size d = 0.8 mm, it will be necessary to use a crusher operating in a closed system (with return). Based on the system efficiency requirements and the rules for determining the mass stream of return (with a known amount of oversize grain from the crusher), the amount of return was estimated at approx. 1.5 Mg/h. This value should be taken into account when designing the capacity of the screen and crusher. Given the above, the screening capacity was estimated at approx. 27–30 Mg / h, while the crusher capacity was approx. 7–8 Mg / h. The return stream can be directed directly to the screen (as shown in Figure 7) or (e.g. for technical reasons) back to the charging hopper. In such a case, an increase in the efficiency of the charging point and the screen feeding system (conveyor) should be foreseen at the design stage.

It was also proposed to modify the classic shape of the working surfaces of the crusher hammers. Crushing materials in the small particle size range can be technically challenging and is associated with increased energy expenditure. For this reason, it is advisable to use procedures aimed at increasing the widely understood efficiency of the process (e.g. increasing yield, increasing the share of product desired grain classes, reducing the energy consumption of the process). One such operation is to change the shape of the functional elements (hammers) to increase the share of the lower grain classes in the crushing product (improving the graining – increasing the degree of comminution). Figure 8 shows a proposal to change the shape of the working surfaces of hammers.

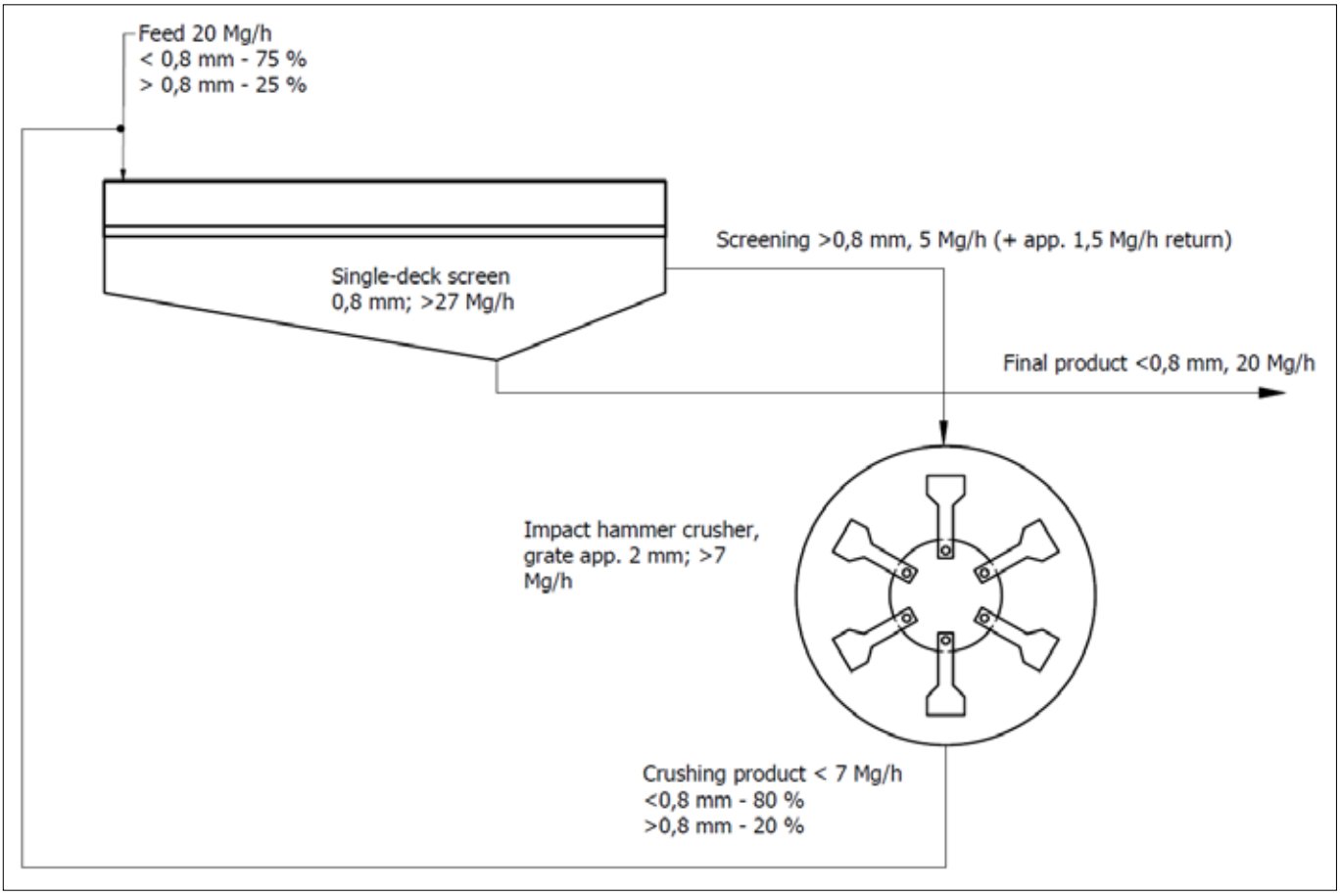

Fig. 7. Technological diagram of the proposed system for crushing rock salt.
Rys. 7. Schemat technologiczny proponowanego układu do rozdrabniania soli kamiennej.
Source: Own study
Źródło: Badania własne

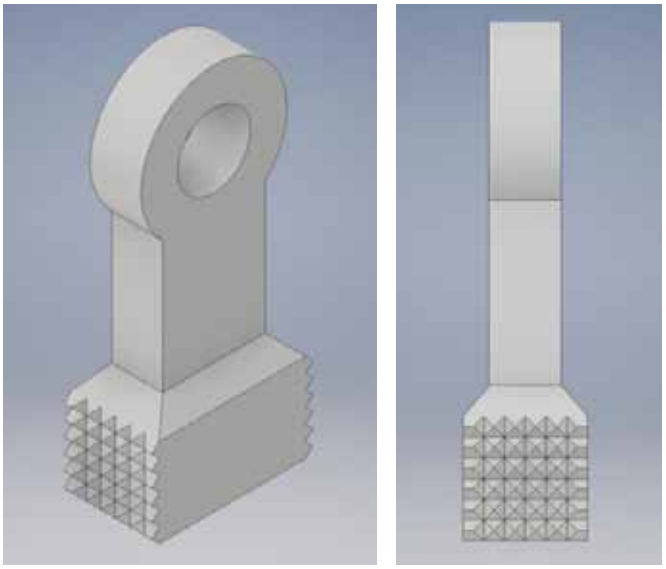

Fig. 8. The proposed shape of working surfaces of the crusher hammers.
Rys. 8. Proponowany kształt powierzchni roboczych młotków kruszarki.
Source: Own study
Źródło: Badanie własne

It is anticipated that appropriate „grooving" („knurling") of the hammer working surfaces may have a beneficial effect on the crushing product. Due to the introduction of additional sharp edges, which hit the salt grains, hammers may be more effective in crushing. The proposed pitch of "grooving" should be approx. 10 mm.

PODSUMOWANIE

Badania przeprowadzone w Katedrze Inżynierii Maszyn i Transportu Akademii Górniczo-Hutniczej wykazały pełną przydatność kruszarki młotkowej do rozdrabniania soli kamiennej.

Analizując opracowane wyniki kruszenia próbek soli kamiennej można stwierdzić, że lepsze rezultaty technologiczne, czyli większy udział zewnętrznej klasy ziarnowej < 0,8 mm, uzyskano podczas rozdrabniania soli w kruszarce udarowej młotkowej (85 % produktu poniżej 0,8 mm przy średnicy oczek rusztu d = 1 mm oraz 65 % przy d = 2 mm). Decydujący wpływ na udział pożądanej klasy ziarnowej ma średnica oczek rusztu zamontowanego w kruszarce. Należy jednak pamiętać, że zmniejszanie wielkości oczek rusztu wpływa korzystnie na uziarnienie produktu, jednakże znacznie zmniejsza wydajność procesu. Z tego powodu niecelowe jest używanie rusztów o zbyt małych średnicach oczek. Konkludując powyższe, do rozdrabniania soli o zadanym uziarnieniu zaleca

się zastosowanie kruszarki udarowej młotkowej o średnicy oczek rusztu około 2,0 mm. Przy takim założeniu konieczne jest zastosowanie zawrotu produktu kruszenia na przesiewacz wstępny w celu odseparowania ziaren o średnicach większych od 0,8 mm.

Na podstawie wyników badań zaproponowano do realizacji układ technologiczny do rozdrabniania soli, którego schemat pokazano na poniższym rysunku. Przedstawiony schemat proponowanego układu technologicznego do rozdrabniania soli kamiennej w konfiguracji umożliwiającej uzyskanie 100% produktu poniżej wymiaru ziarna d = 0,8 mm.

Zaproponowano układ składa się z dwóch maszyn głównych (przesiewacza i kruszarki udarowej młotkowej) oraz odpowiednich przenośników taśmowych umożliwiających dostarczenie nadawy i odbiór produktu kruszenia oraz realizację zawrotu z kruszarki na przesiewacz. Z przeprowadzonej analizy składu ziarnowego produktu kruszenia wynika, że w celu uzyskania całości produktu poniżej wymiaru ziarna d = 0,8 mm konieczne będzie zastosowanie kruszarki pracującej w układzie zamkniętym (z zawrotem). Na podstawie wymogów związanych z wydajnością układu oraz zasad określana strumienia masowego zawrotu (przy znanej ilości nadziarna z kruszarki) oszacowano ilość zawrotu na ok. 1,5 Mg/h. Wartość tą należy uwzględnić przy projektowaniu wydajności przesiewacza oraz kruszarki. Wobec powyższych, określono wydajność przesiewacza na ok. 27–30 Mg/h, natomiast wydajność kruszarki na ok. 7–8 Mg/h. Strumień zawrotu może być kierowany bezpośrednio na przesiewacz (jak przedstawiono na rysunku 6) lub (np. ze względów technicznych) z powrotem do kosza zasypowego. W takim wypadku należy przewidzieć na etapie projektowania zwiększenie wydajności punktu zasypu i układu zasilania przesiewacza nadawą (przenośnik).

Ze względu na dość duży kąt nachylenia pokładów przesiewaczy, których zdjęcia zostały przesłane we wcześniejszej korespondencji mailowej, należy rozważyć zwiększenie średnicy oczek sita przesiewacza do 1 mm. Może to korzystnie wpłynąć na pracę przesiewacza (ograniczy „zapychanie się" sita) przy równoczesnym zachowaniu akceptowalnego poziomu nadziarna w produkcie końcowym.

Zaproponowano również modyfikację klasycznego kształtu powierzchni roboczych młotków kruszarki. Rozdrabnianie materiałów w zakresie niewielkich ziaren może sprawiać pewne trudności techniczne i związane jest ze zwiększonymi nakładami energetycznymi. Z tego względu celowym jest stosowanie zabiegów mających na celu podniesienie szeroko rozumianej efektywności procesu (np. zwiększenie wydajności, zwiększenie udziału pożądanych klas ziarnowych produktu, zmniejszenie energochłonności procesu). Jednym z takich zabiegów jest zmiana kształtu elementów roboczych (młotków) mając na celu podniesienie udziału dolnych klas ziarnowych w produkcie kruszenia (poprawienie uziarnienia – zwiększenie stopni rozdrobnienia). Na rysunku 7 przedstawiono propozycję zmiany kształtu powierzchni roboczych młotków.

Przewiduje się, że odpowiednie „rowkowanie" („radełkowanie") powierzchni roboczych młotków może wpłynąć korzystnie na uziarnienie produktu kruszenia. Wynika to z wprowadzenia dodatkowych, ostrych krawędzi, które uderzając w ziarna soli spowodują efektywniejsze ich rozdrabnianie. Proponowana podziałka „rowkowania" powinna wynosić ok. 10 mm.

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INFLUENCE OF BIOLOGICAL PREPARATIONS AND DRYING METHOD ON THE CONTENT OF ESSENTIAL OILS IN BASIL AND MARJORAM®

Wpływ preparatów biologicznych oraz sposobu suszenia na zawartość olejków eterycznych w bazylii i majeranku®

Key words: marjoram, basil, essential oils, drying, foliar spraying.

This article is of an experimental and experimental nature. It consists of two parts: theoretical and research. The literature review includes the botanical characteristics of marjoram and basil and the nutritional use of these herbs. The article contains descriptions of the methods of drying herbs, as well as their quality parameters. Essential oils, their properties, methods of obtaining and examples of essential oils with the most popular applications were also discussed.

The practical part includes research on planting marjoram and basil, observing and watering plants. Then the harvesting and drying of the herbs, and the last stage of obtaining essential oils from both raw materials.

Słowa kluczowe: majeranek, bazylia, olejki eteryczne, suszenie, opryski dolistne.

Niniejszy artykuł ma charakter eksperymentalno – doświadczalny. Składa się z dwóch części: teoretycznej oraz badawczej. Przegląd literatury zawiera charakterystykę botaniczną majeranku i bazylii oraz spożywcze wykorzystanie tych ziół. W artykule znajdują się opisy metod suszenia ziół, a także ich parametry jakościowe. Omówione zostały również olejki eteryczne, ich właściwości, metody pozyskiwania oraz przykłady olejków eterycznych mających najpopularniejsze zastosowanie.

Część praktyczna zawiera badania dotyczące wysadzenia majeranku i bazylii, obserwowania i podlewania roślin. Następnie zbioru i suszenia ziół, a w ostatnim etapie pozyskania olejków eterycznych z obu surowców.

INTRODUCTION

Herbal plants, popularly known as herbs, are a numerous and diverse group of plants. In recent years, the interest in herbs, especially spice herbs, has increased, which is related to their taste, aroma and physiological properties. These raw materials are used in dietetics, cosmetics, horticulture and many other sectors of the economy. In the past, it was important that herbs came from wild meadows and backwoods. Harvest time was marked by moon phases, holidays, and other mysterious clues. As for the method of harvesting and processing the raw material, all kinds of orders and prohibitions were also in force. Contemporary herbalism is based mainly on the cultivation of herbs, but it is still recommended to obtain many species from natural sites. Herbs are used due to the rich content of bioactive compounds. These substances have many properties, especially medicinal. These compounds are: alkaloids, anthocyanins, tannins, organic acids, minerals, vitamins and many others. The work focuses mainly on the essential oils found in spice herbs, especially marjoram and basil. The ways of drying herbs and their use in everyday life will also be discussed [1, 6, 8, 9, 21].

The aim of the work is to investigate the effect of foliar spraying with biological preparations containing beneficial microorganisms and the drying method on growth, yielding and the content of essential oils in basil and marjoram. The research was carried out by means of an experimental method with the use of pot tests.

MATERIALS AND METHODS

The research material was basil and marjoram seeds from the same plantation, purchased in a construction and gardening market [4,11]. The cultivation from which the seeds come from is located in the village of Zielonki Parcela, located in the Mazowieckie voivodship. The name of the plantation is

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PlantiCo Zielonki Sp. zoo. The cultivars used in the research were common basil (*Ocimum basilicium L.*) and garden marjoram (*Origanum majorana L.*).

Basil is an annual plant species. According to the manufacturer's recommendations, the seeds should be sown between March and May. They should be sown rarely, in a warm and sunny place [2, 5, 12]. Watering in the evening should be avoided, the best time is noon. It is also important not to flood the plant, because then its roots will rot. Basil seeds are dark brown, oval in shape and about 15 mm long, while the plant itself should reach a height of 50 cm [3, 7, 16].

Garden marjoram is also an annual plant species with a strong, sweet, aromatic smell. As with basil, marjoram needs a sunny, windless place. The seeds are best sown in late March and early April. The initial growth period of the herb is slow, therefore it is important to loosen the soil at this time. Marjoram seeds are quite small, while the plant itself can reach a height of about 30 cm [9, 15, 18].

The pot experiment is "an experiment in plant breeding, conducted in laboratory conditions, in which the soil substrate can be differentiated in containers (vases) in a controlled manner and its effect on cultivated plants can be studied" [13].

The experiment was set up in a complete randomization system, which consisted in a random, random division of the studied objects into specific groups. Thanks to this division, each tested object had the same chances, which guarantees that the obtained results are statistically very reliable, and above all, no bias of the experimenter is revealed here [10, 16].

The first stage of the laboratory tests was to set up a pot experiment in a complete randomization system. For this purpose, 24 containers were used. Universal arable land was poured into each of them, approximately 3⁄4 of the height of the vases. The soil in each container was sprayed with a solution made of water with the addition of EmFarma (a natural microbial agent) in a ratio of 1:10 to the same weight. The weight of each container after watering was 160 g. [19, 20]

Then 15 seeds of basil were planted into 12 pots, and the same number of seeds of marjoram were planted in the remaining 12 pots. The herbs were sown on August 23, 2021. From that day, the plants were watered with only water until September 15, 2021, when the foliar spraying was first applied. The plant weight was determined with each watering. The spraying was applied to 6 pots of basil and 6 pots of marjoram, selected at random. The containers were numbered at this point: basil with spraying numbers 1–6, marjoram with spraying 7–12, basil without spraying 13–18, marjoram without spraying 19–24. The EmFarma water solution was prepared in a ratio of 1: 3. Spraying was applied at seven-day intervals until October 12, 2021.

The spraying used was the EmFarma Plus, it came from the equipment of our university. It is a microbial composition enriched with bacteria that accelerates the decomposition of organic matter and increases the availability of minerals, especially nitrogen. Useful microorganisms occurring in it support each other and, as a team, displace the pathogenic microflora [34]. EmFarma contains: SCD ProBio Plus mother cultures of living microorganisms, organic sugar cane molasses, revitalized, non-chlorinated water, salt and minerals. The use of EmFarma Plus is to increase the biological activity of the soil, improve its fertility and fertility, increase the availability of macro and microelements, increase the plant's ability to photosynthesize, increase plant immunity and vitality. The spraying serves to create a lumpy structure and to rationalize water management. It also neutralizes odors [14, 17]. The first sprouts appeared on August 27, 2021, i.e. exactly 4 days after planting.

The next step after spraying the herbs was drying them. The herbs were harvested, their weights were determined. The above-ground part was then separated from the underground part, and the weighing of both plant parts was also carried out. The number of leaves on the harvested plants was counted. The herbs were placed on newspapers and dried naturally in the sun, but in a closed, warm room. In this way, they were dried until November 16, 2021.

On November 16, 2021 the stage of drying the herbs was completed and the essential oils were determined using the Deryg's method.

The content of essential oils was determined after drying the herbs using the Deringg method:

1) weighed mass of raw material was placed in the flask and poured with water
2) the flask was connected to the apparatus, the receiver was filled with water, cooling was turned on
3) heating lasted 3 hours from the moment the contents in the flask began to boil and the first drop distilled
4) after distillation was completed, cooling was turned off and the oil was brought to a microscale
5) the results were read after 30 minutes
6) the volume of the oils was converted to 100 g of raw material
7) percentage of the calculated formula:

$$X=[\%] = ax100/m \quad (1)$$

X – the percentage of the oil
m – sample weight [g]
a – oil volume [cm^3]

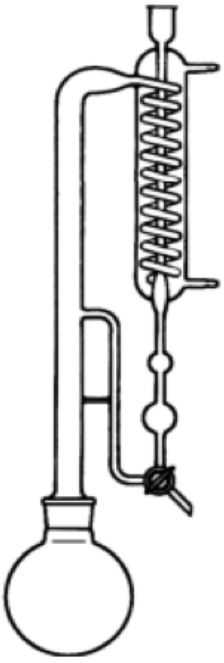

Fig. 1. Deryg's apparatus.
Rys. 1. Aparat Derynga.
Source: Own study
Źródło: Opracowanie własne

ANALYSIS AND DISCUSSION OF RESULTS

On the basis of the conducted research, the results of plant mass with and without spraying with preparations containing beneficial microorganisms were obtained. The results are shown in Tables 1 and 2

Table 1. Weight of plants sprayed before drying

Tabela 1. Masa roślin opryskiwanych przed suszeniem

Pot number	The mass of the whole plant [g]	Mass of the above-ground part of the plant [g]	Mass of the underground part of the plant [g]	Number of leaves
1	5,516	4,466	1,050	74
2	6,756	4,213	2,543	66
3	6,630	3,857	2,773	58
4	7,364	6,001	1.363	57
5	8,914	6,013	2,901	86
6	14,192	6,163	8,029	74
7	3,452	2,038	1,414	80
8	3,006	1,630	1,376	57
9	2,098	1,217	0,881	59
10	2,682	2,124	0,558	64
11	2,870	2,150	0,720	60
12	2,716	2,059	0,657	86

Source: Own study

Źródło: Opracowanie własne

Table 2. Weight of plants without sprayed before drying

Tabela 2. Masa roślin bez oprysku przed suszeniem

Pot number	The mass of the whole plant [g]	Mass of the above-ground part of the plant [g]	Mass of the underground part of the plant [g]	Number of leaves
1	6,866	5,288	1,578	85
2	6,309	4,934	1,375	64
3	4,987	3,309	1,678	68
4	11,216	6,256	4,960	68
5	7,775	5,909	1,866	68
6	6,855	5,421	1,434	61
7	8,911	4,824	4,087	128
8	4,320	3,312	1,008	130
9	3,937	2,517	1,420	106
10	5,334	2,767	2,567	93
11	6,265	3,447	2,818	116
12	6,033	4,030	2,003	135

Source: Own study

Źródło: Opracowanie własne

Table 3–6 shows the content of essential oils for basil and marjoram with and without spraying.

Table 3. Essential Oil Content of Basil Spray

Tabela 3. Zawartość olejków eterycznych w opryskiwanej bazylii

Pot number	The volume of essential oil [cm³]	Procentage [%]
1	0,0098	0,18
2	0,0095	0,14
3	0,0097	0,15
4	0,1	1,35
5	0,1	1,12
6	0,0098	0,007

Source: Own study

Źródło: Opracowanie własne

Table 4. Essential Oil Content of Marjoram Spray

Tabela 4. Zawartość olejków eterycznych w opryskiwanym majeranku

Pot number	The volume of essential oil [cm³]	Procentage [%]
1	0,0095	0,28
2	0,0098	0,33
3	0,01	0,48
4	0,01	0,37
5	0,0098	0,34
6	0,01	0,37

Source: Own study

Źródło: Opracowanie własne

Table 5. Essential Oil Content of Basil without Spray

Tabela 5. Zawartość olejków eterycznych bazylii bez oprysku

Pot number	The volume of essential oil [cm³]	Procentage [%]
1	0,0098	0,14
2	0,0093	0,15
3	0,01	0,2
4	0,0096	0,09
5	0.01	0,13
6	0,0098	0,14

Source: Own study

Źródło: Opracowanie własne

Table 6. Essential Oil Content of Majroram without Spray

Tabela 6. Zawartość olejków eterycznych majeranku bez oprysku

Pot number	The volume of essential oil [cm3]	Procentage [%]
1	0,01	0,11
2	0,009	0,20
3	0,01	0,25
4	0,012	0,22
5	0,012	0,19
6	0,011	0,18

Source: Own study

Źródło: Opracowanie własne

Figures 2–3 compare the essential oil content of basil and marjoram with and without spraying.

CONCLUSIONS

The aim of this study was to investigate the effect of foliar spraying and the method of drying on the content of essential oils in basil and marjoram. The first part focuses on herbs, their characteristics, origin, cultivation and requirements. Then the drying process was defined and ten methods of drying herbs were briefly described. In addition, the quality parameters characteristic of herbs, ingredients that are in herbs and what they are characterized by were discussed. In the next stage, the main issue of the work was discussed, i.e. essential oils were characterized, what they are, what properties they have and what methods of obtaining them are distinguished. There are also several essential oils of herbal origin and others, most commonly used by man. However, more broadly, the use of herbs is described in the last chapter. There, herbal plants were divided and the use and action of various parts of plants as spices were discussed. The use of marjoram and basil is also included.

The experimental part began with planting basil and marjoram seeds. 24 pots with herbs were watered 2–3 times a week, from August 23, 2021. until October 12, 2021 During this period, some plants were additionally watered with foliar spraying. Everything was done in a complete randomization system, the division of plants was completely random. The next stage of the experiment was collecting the herbs and subjecting them to the drying process. At harvest, each plant was properly weighed. Deryng's took place in the laboratory room, by the window, by the radiator, at a temperature of about 22°C. After the drying time had elapsed, the plants were harvested and subjected to the process of obtaining essential oils. This preparation was made by the Deryng method. Thanks to it, volumes of oils were obtained, which, after substituting to the appropriate formula, showed the percentage of essential oils in each of the plants.

Based on the research on the effect of biological preparations and the drying method on growth, yielding and the content of essential oils in marjoram and basil, the following conclusions were drawn:

1. The application of foliar spraying had an effect on the yield. The herbs that were sprayed had less leaves. The untreated plants had more of them, both in the case of marjoram and basil, which means that foliar spraying did not have a positive effect on the yield.
2. The application of foliar spraying stopped the herb growth process. Plants watered with spray water grew much slower than plants in which it was not applied.
3. During the drying of the raw material, the degradation of chlorophyll takes place, which changes the color of the herbs. Drying in natural conditions resulted in the loss of the green color characteristic of fresh herbs. Plants have lost their vivid colors, have gained a bit of gray. This may be because the drying process takes a long time.
4. The content of essential oils in basil, according to data, should be between 0.5 and 1.5%. The research showed that only two pots, numbered 4 and 5, achieved contents within this range. They were sprayed herbs, so it can be concluded that the foliar spraying had an effect on the content of essential oils in dried herbs, which is also visible in the figure 3–4.
5. The content of essential oils in marjoram, according to data, should be 0.2 to 2.5%. All sprayed herbs fall within this range. In the case of unsprayed marjoram, the content of essential oils was consistent with the above data only in three cases. This means that the application of the foliar spray had an effect on the content of essential oils in marjoram.
6. The use of foliar spraying in the cultivation of herbs increases the content of essential oils.

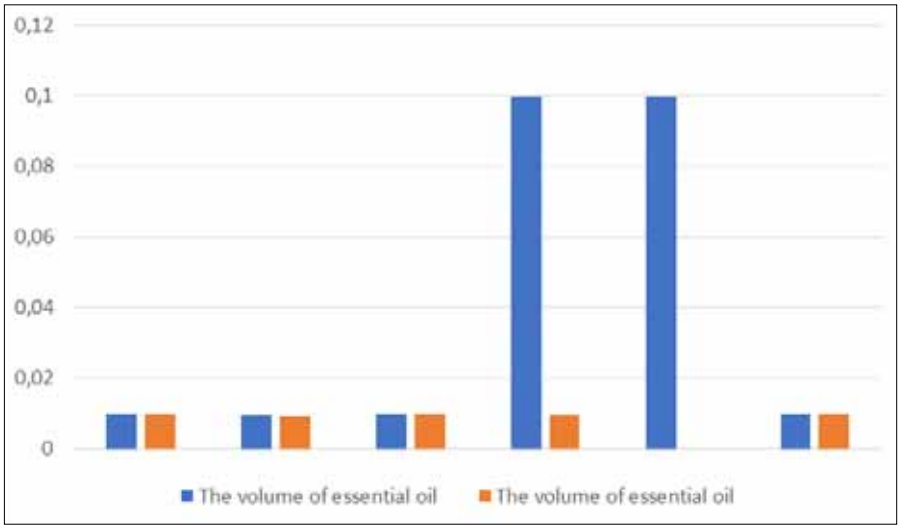

Fig. 2. Comparison of essential oils content in basil.
Rys. 2. Porównanie zawartości olejków eterycznych w bazylii.
Source: Own study
Źródło: Opracowanie własne

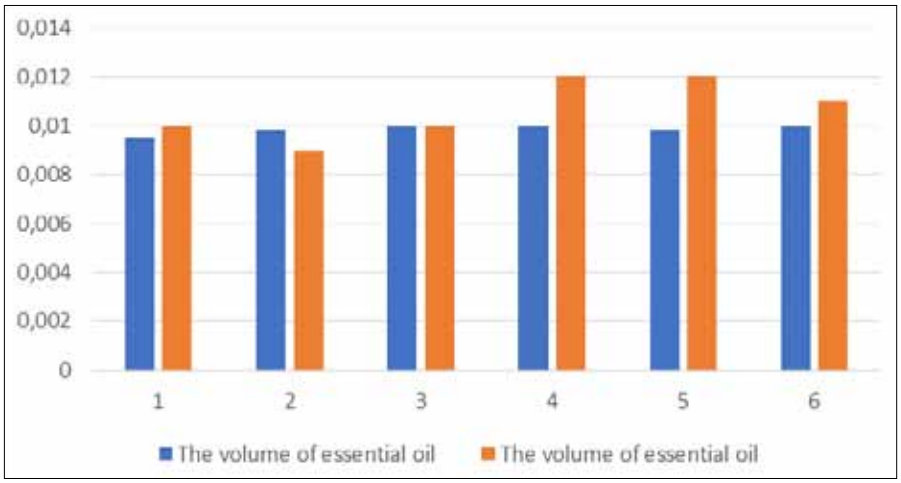

Fig. 3. Comparison of essential oils content in marjoram.
Rys. 3. Porównanie zawartości olejków eterycznych w majeranku.
Source: Own study
Źródło: Opracowanie własne

WNIOSKI

Celem pracy było zbadanie wpływu oprysku dolistnego i metody suszenia na zawartość olejków eterycznych w bazylii i majeranku. Pierwsza część skupia się na ziołach, ich właściwościach, pochodzeniu, uprawie i wymaganiach. Następnie zdefiniowano proces suszenia i krótko opisano dziesięć metod suszenia ziół. Ponadto omówiono parametry jakościowe charakterystyczne dla ziół, składniki jakie znajdują się w ziołach oraz czym się charakteryzują. W kolejnym etapie omówiono główne zagadnienie pracy, czyli scharakteryzowano olejki eteryczne, czym są, jakie mają właściwości i jakimi metodami pozyskiwania je się wyróżnia. Istnieje również kilka olejków eterycznych pochodzenia ziołowego i innych, najczęściej stosowanych przez człowieka. Szerzej jednak stosowanie ziół zostało opisane w ostatnim rozdziale. Tam podzielono rośliny zielarskie oraz omówiono zastosowanie i działanie różnych części roślin jako przypraw. Uwzględniono również użycie majeranku i bazylii.

Część doświadczalną rozpoczęto od sadzenia nasion bazylii i majeranku. 24 doniczki z ziołami podlewano 2–3 razy w tygodniu, od 23 sierpnia 2021 r. do 12 października 2021 r. W tym okresie niektóre rośliny dodatkowo podlewano opryskiwaniem dolistnym. Wszystko odbywało się w pełnym systemie randomizacji, podział roślin był całkowicie losowy. Kolejnym etapem eksperymentu było zebranie ziół i poddanie ich procesowi suszenia. Podczas zbioru każda roślina została odpowiednio zważona. Suszenie odbywało się w pomieszczeniu laboratoryjnym, przy oknie, przy kaloryferze, w temperaturze około 22°C. Po upływie czasu suszenia rośliny zostały zebrane i poddane procesowi otrzymywania

olejków eterycznych. Ten proces został wykonany metodą Derynga. Dzięki niej uzyskano objętości olejków, które po podstawieniu do odpowiedniej formuły, wykazywały procentowy udział olejków eterycznych w każdej z roślin.

Na podstawie badań wpływu preparatów biologicznych i sposobu suszenia na wzrost, plonowanie i zawartość olejków eterycznych w majeranku i bazylii wyciągnięto następujące wnioski:

1. Zastosowanie oprysku dolistnego wpłynęło na plon. Opryskiwane zioła miały mniej liści. W roślinach nieopryskanych było ich więcej, zarówno w przypadku majeranku, jak i bazylii, co oznacza, że opryski dolistne nie wpłynęły pozytywnie na plon.
2. Zastosowanie oprysku dolistnego zatrzymało proces wzrostu ziela. Rośliny podlewane wodą z opryskiwacza rosły znacznie wolniej niż rośliny, na które jej nie stosowano.
3. Podczas suszenia surowca następuje rozkład chlorofilu, który zmienia kolor ziół. Suszenie w warunkach naturalnych spowodowało utratę zielonego koloru charakterystycznego dla świeżych ziół. Rośliny straciły żywe kolory, zyskały nieco szarości. Może to być spowodowane długim procesem suszenia.
4. Zawartość olejków eterycznych w bazylii, zgodnie z danymi, powinna wynosić od 0,5 do 1,5%. Badania wykazały, że tylko dwie doniczki o numerach 4 i 5 osiągnęły zawartość w tym zakresie. Były to zioła opryskiwane, można więc wnioskować, że oprysk dolistny miał wpływ na zawartość olejków eterycznych w suszu, co również widać w tabeli 3 i 5.
5. Zawartość olejków eterycznych w majeranku według danych powinna wynosić od 0,2 do 2,5%. Wszystkie opryskiwane zioła mieszczą się w tym zakresie. W przypadku majeranku nieopryskanego zawartość olejków eterycznych była zgodna z powyższymi danymi tylko w trzech przypadkach. Oznacza to, że zastosowanie dolistnego sprayu wpłynęło na zawartość olejków eterycznych w majeranku.
6. Stosowanie oprysku dolistnego w uprawie ziół zwiększa zawartość olejków eterycznych.

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USEFULNESS OF THE SOUS-VIDE METHOD OF HEAT TREATMENT OF COD FILLETS®

Przydatność metody sous-vide obróbki termicznej filetów z dorsza®

Key words: sous-vide (SV), process efficiency, sensory quality, nutritional value.

The aim of the work presented in the article is to determine the effect of the form of the raw material (fresh fillets, frozen fillets, frozen cubes) on the amount of "thermal leakage" and selected quality characteristics of cod meat subjected to heat treatment using the "sous-vide" (SV) method. It has been found that, of the many forms of fish on the market, unground fillets are the most suitable form that can be sous-vide cooked. Frozen fillets are less useful, although the thermal leakage is similar to that of non-frozen fillets. Frozen cube obtained before freezing by pressing fish pieces is characterized by poor suitability for sous-vide processing, because it favors the formation of a very large (over 40%) thermal leakage and less favorable sensory quality. The heat treatment of fish meat requires a relatively short time, because after 15-30 minutes a product with a soft consistency can be obtained. However, in order to obtain a consistency that is acceptable to the consumer, the most appropriate time for a temperature of 60°C is a heating time of 45 minutes. The SV technology can be used for the heat treatment of cod meat, which is considered a delicate meat.

Słowa kluczowe: sous-vide (SV), wydajność procesu, jakość sensoryczna, wartość odżywcza.

Celem pracy przedstawionej w artykule było określenie wpływu formy surowca (filety świeże, filety mrożone, kostka mrożona) na wielkość „wycieku termicznego" oraz wybrane cechy jakościowe mięsa z dorsza poddanego obróbce termicznej metodą „sous-vide" (SV). Stwierdzono, że spośród wielu form ryb znajdujących się na rynku, najbardziej przydatną formą do obróbki termicznej SV są filety nierozdrobnione. Mniej przydatne są filety mrożone, aczkolwiek wyciek termiczny jest podobny jak w przypadku filetów niemrożonych. Mrożona kostka (sprasowane kawałki ryb poddane mrożeniu) charakteryzuje się słabą przydatnością do obróbki SV, gdyż sprzyja powstawaniu bardzo dużego wycieku termicznego oraz daje mniej korzystną jakość sensoryczną. Technologia SV może być stosowana do obróbki termicznej mięsa dorsza uznanego jako mięso delikatne. Już po 15-30 minutach stosowania SV w temp. 60°C uzyskuje się produkt o dość miękkiej konsystencji, a po 45 min – produkt o konsystencji pożądanej sensorycznie.

INTRODUCTION

Today's consumers are often looking for prepared foods that are nutritionally valuable, safe to use, free of additives and preservatives, affordable, and taste similar to food prepared at home [19, 20].

A modern heat treatment ensuring the above features of food is the "sous-vide" (SV) method. It differs from the methods used in traditional cuisine, first of all, the need to use thermostable "vacuum bags" [1, 38].

In addition, the special equipment required to monitor temperature and processing times has increased the cost of producing food using the SV method for many years and, as a result, limited its use in the food industry for a long time. Recently, this technique has become more affordable for use both in households and restaurants, as well as in industry and is gaining popularity at a growing pace [20].

Vacuum packing is therefore a physical barrier against water loss. It provides very efficient and consistent heat transfer from the water to the food product, which typically reduces processing time and increases efficiency. The main advantage of the SV method is the gentle cooking conditions and, due to the lower processing temperature and lack of oxygen in the bags, losses of nutrients, water, and volatile compounds are reduced, oxidation processes are inhibited and the shelf life of cooked products is thus increased [4, 38].

Also from the point of view of sensory quality, the benefits of using this method against other conventional techniques are observed. Food obtained by the SV method is generally considered to be "better tasting" and more flavoursome, which encourages the use of less salt in food preparation. Due to the anaerobic environment of the food, the use of the 'sous-vide' technique inhibits oxidative degradation of the various components, which is widely considered to be the main

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cause of unattractive tastes and flavours when other cooking techniques are used. Reducing or hindering fat oxidation processes and limiting the formation of Maillard compounds means that such prepared dishes are often treated as "dietetic" [7, 16, 21].

Studies have shown that SV food is convenient and quick to prepare, has low health risks and has a long shelf life [23]. In addition, SV cooking is suitable for various raw materials, for use both at home, in restaurants, in hospitals and industrial production [3].

By strictly controlling the processing conditions, i.e. time and temperature, it is possible to ensure reproducible product quality and achieve microbiological safety [1, 28, 32].

During SV processing, pasteurisation conditions are maintained, avoiding the risk of bacterial contamination, while inhibiting the growth of anaerobic bacteria in food during storage. Thus, such food can be rapidly cooled to around 0-30°C after processing and stored in the refrigerator for an extended period (up to five weeks on average) before being reheated and served [3].

In addition, the SV method promotes the preservation of better texture and colour of food [38]. SV cultivation is suitable for the processing of various vegetable and animal raw materials [22, 37], ultimately offering both ready-to-eat foods (usually after heating) and various intermediates for further use [9, 13, 27].

In the last decade, the SV method has been used primarily for the processing of various vegetables, including legumes, cabbage, carrots and other root vegetables [16, 17, 35], including meat [3, 30, 31, 36] and, to a much lesser extent, fish [8, 10, 11, 14, 25].

The paper aims to determine the impact of the form of raw material (fresh fillets, frozen fillets, frozen cubes) on the size of the "thermal leak" and selected qualitative characteristics of the "sous-vide" (SV) heat-treated cod meat.

MATERIAL AND METHODS

Fresh cod fillets, frozen cod fillets and industrially obtained frozen cod cubes were tested. **Thermal treatment** - the temperature of the heat treatment of fish, set at 60°C, was selected on the basis of literature data [38, 39]. A different treatment time was used, fixed at: 15-, 30-, 46- and 60-min. After packing the fish pieces in vacuum bags (by HENDI), they were placed in a vacuum packing machine (MULTIVAC Sp. z o.o. Poland). The Sous vide GN 1/1 device by HENDI was used to prepare fish meat in the SV technology.

Thermal leakage and weight loss were calculated using the gravimetric method. The weight loss of the meat was calculated according to the formula [18]:

$$\text{Loss of weight (\%)} = 100*[(\text{weight of raw meat} - \text{weight of boiled meat SV})/\text{weight of raw meat}]$$

The hardness was determined on a TA HD Plus Stable Mikrosystems texture analyzer. The results were presented as the value of the maximum force that had to be used to cut the entire sample with dimensions of 20/20/20 mm. A ready-made software application was used, which was designed to test the force necessary to cut the sample. For each sample, at least 10 measurements were made.

The color was determined using the colorimetric method on the COLORFLEX EZ spectrophotometer operating in the LAB system. At least 5 determinations were performed for each sample. In the case of fillets, the color was measured on the superaxial meat flap from the inside. In the case of frozen cubes - after grinding the sample.

The sensory evaluation of selected texture characteristics of the cooked cod meat with the SV method was carried out using the hedonic scale method in the range of 1 to 9. The evaluation was carried out by a 10-person team of experts trained in the given method. The following features were assessed in the study: hardness, stickiness and palpability of fish meat particles.

RESULTS AND DISCUSSION

One of the main disadvantages of the SV method is the appearance of an unwanted „leak" inside the package. As a result of heat treatment, the raw materials change the content of individual nutrients, water loss, and thus the weight of the meat is reduced. The leakage resulting from heat treatment is very diverse and depends on many factors, but also on the type and form of the raw material used (water exuded from the product because of the loss of water retention during the heat treatment) [15].

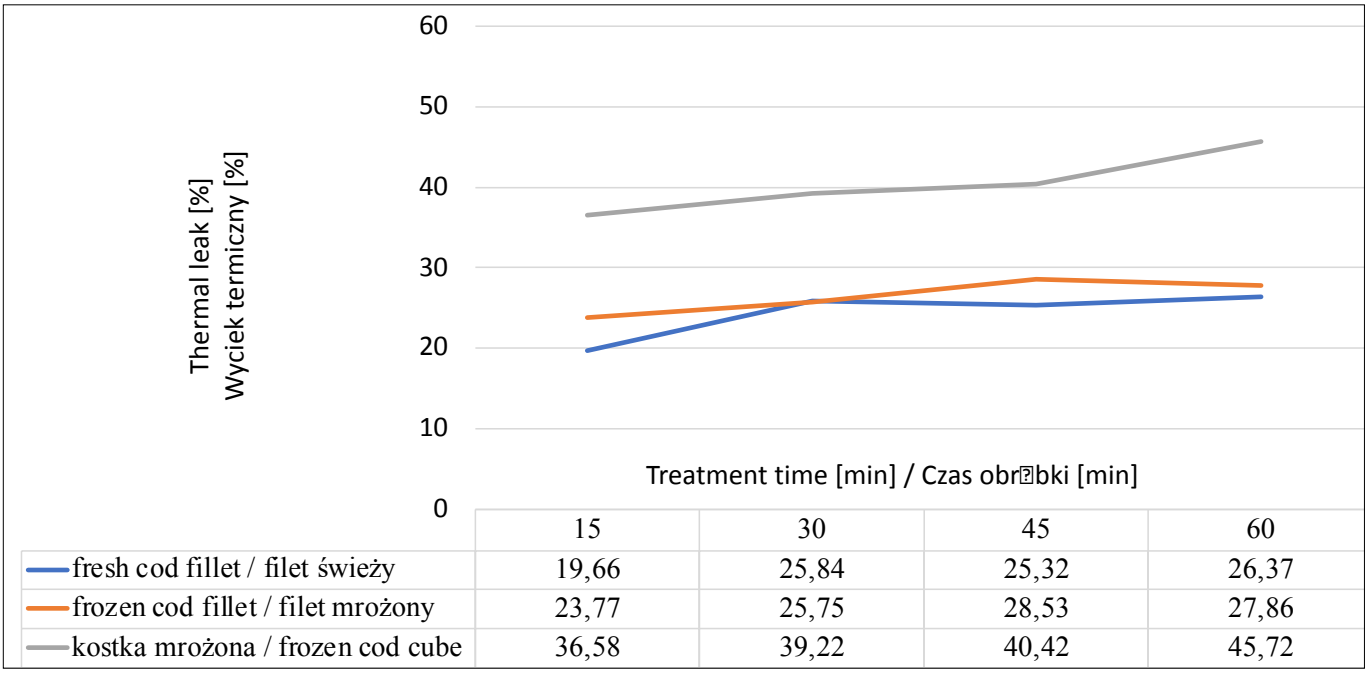
In Figure 1. the amount of thermal leakage resulting from cooking at different times of different forms of cod meat was compared. This leakage ranged from 19.66 to over 45% and depended on both the cooking time and the form of the raw material. For each SV cooking time tested, the leakage from the frozen cube was higher by approx. 20% of the leakage resulting from cooking whole fillets (both fresh and frozen). However, for each form of raw material, the highest leakage was observed after 15 minutes of processing. Extending the processing time resulted in a further increase in thermal leakage, which stabilized after approx. 30–45 min.

Thermal leakage during processing is a reflection of meat mass yield. Therefore, this paper also determined the loss of meat mass and calculated the efficiency of the process (Fig. 2).

Literature data indicate that thermal losses of the raw material mass during traditional cooking can reach up to 35% [34]. It is also indicated that, in the case of SV technology, the use of variable processing temperatures has a greater impact on the amount of meat weight loss than the duration of the process [18, 24].

Thermal leakage during proces sing is a reflection of meat mass yield. Statistical analysis showed that freezing the fish in the form of whole fillets did not significantly affect the weight of meat after cooking, and thus the efficiency of SV treatment. The efficiency of the SV process for whole fish fillets ranged from 72.5 to 75.7% and was approx. 13% higher than in the case of cooking a formed frozen cube, consisting of small pieces of cod (Fig. 2).

The meat of cod cooked by the SV method was subjected to sensory assessment at various times, determining its hardness (consistency) on a 9-point scale (Tab. 1). Irrespective of the form of the raw material, samples cooked for 45 minutes were



	15	30	45	60
fresh cod fillet / filet świeży	19,66	25,84	25,32	26,37
frozen cod fillet / filet mrożony	23,77	25,75	28,53	27,86
kostka mrożona / frozen cod cube	36,58	39,22	40,42	45,72

Fig. 1. Comparison of the amount of thermal leakage from different forms of cod meat during sous-vide cooking at different times.

Rys. 1. Porównanie wielkości wycieku termicznego z różnych form mięsa dorsza podczas obróbki termicznej metodą sous-vide w różnym czasie.

Źródło: Badania własne

Source: The own study

found to be "quite soft" and were comparable in this respect to samples cooked for 60 minutes. On this basis, 45 minutes was considered sufficient processing time for cod meat using the SV method.

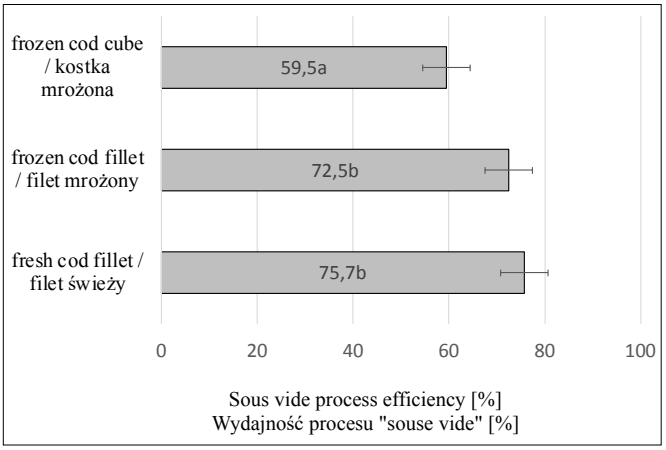


Fig. 2. The efficiency of the SV process of various forms of cod meat.

Rys. 2. Wydajność procesu SV różnych form mięsa dorsza.

Źródło: Badania własne

Source: The own study

In the consumer assessment of food products, an important aspect is the texture of the meat, which changes significantly after heat treatment, as demonstrated by the example of beef [29]. Such "cooking" at low temperatures makes the meat soft and easy to cut [6].

Table 1. The consistency of cod meat assessed by the method of a 9-point hedonic scale depending on the time of SV processing at the temperature of 60°C and the form of the raw material

Tabela 1. Konsystencja mięsa z dorsza oceniana metodą 9-punktowej skali hedonicznej w zależności od czasu obróbki SV w temp. 60°C oraz formy surowca

Treatment time [min] / Czas obróbki [min]	Fresh cod fillet / Filet z dorsza świeży	Frozen cod fillet / Filet z dorsza mrożony	Cube frozen from pieces of cod / Kostka mrożona z kawałków dorsza
15	6,1 ± 1,2	3,8 ± 2,0	4 ± 0,9
30	5,6 ± 0,9	5,4 ± 1,1	5,4 ± 1,2
45	**7,6 ± 1,2**	**6,9 ± 0,9**	**6,0 ± 0,9**
60	7,8 ± 0,8	7,0 ± 1,2	6,2 ± 0,8

Źródło: Badania własne

Source: The own study

Literature data show that the effect of SV cooking parameters on meat textureis inconclusive, as demonstrated with meat from slaughter animals. It is indicated that this is primarily related to the type of meat, differences in muscle cell diameter, thermostability of collagen and its content in the muscle. These differences are the result of, i.a.: the type of meat and muscle, the age of the animal, the maturation time of the meat, storage conditions and a combination of temperature and cooking time [2, 26].

In Table 2, the results of the instrumental measurement determining the hardness of cod meat subjected to 45-minute SV cooking at 60°C. The results are given as the minimum and maximum force necessary to completely cut the samples. There were no significant differences in the hardness of cooked cod meat for all tested forms of raw material.

Analysis of the texture of cod fillets after cooking using the SV method showed that the hardness of cooked meat did not depend on the form of the raw material (fillet /frozen cube) but significantly changed after heat treatment (Tab. 2).

This is also indicated by the literature data. Increasing the heating temperature (also in the SV method) significantly affects the shear strength, elasticity, cohesiveness and chewability of aquatic food products [12]. Also, Cropotova et al. [5] showed, using the example of mackerel, that the hardness of the fillets increased with increasing temperature in the SV method (60–90°C), with the additional use of vacuum favouring the desired hardness in a much shorter time, even at temp. 90°C.

Baldwin [1] explains this fact by the fact that the lysis of the connective tissue of fish meat in the temperature range of 50–70°C leads to the obtaining of soft meat, while the denaturation of myogenic fibrous proteins occurring at higher temperatures leads to the obtaining of hard meat. Colour components were determined in the L*, a*, and b* systems using the colourimetric method. The results are presented in Tab. 3.

One of the important characteristics taken into account by consumers is the colour of fish meat. The brightness (L*) of whole, raw fillets (fresh and frozen) did not differ significantly, but it showed significant variability in relation to the same fillets after cooking (L* parameters higher by approx. 10 units).

Table 2. Results of the instrumental measurement determining the hardness of cod meat after heat treatment with the SV method (60°C and 45 min)

Tabela 2. Wyniki pomiaru instrumentalnego określającego twardość mięsa z dorsza po obróbce termicznej metodą SV (60°C i 45 min)

Forma ryby	Value of the average and maximum force [N] necessary to cut the sample / Wartość średniej i maksymalnej siły [N] niezbędnej do przecięcia próbki	
	X average /średnie	X max.
Raw (fresh fillet) / Surowy (filet świeży)	8,1 ± 0,29a	9,02 ± 1,03A
Fresh fillet after heat treatment / Filet świeży po obróbce termicznej	3,17 ± 0,42b	6,33 ± 0,33B
Fillet frozen after heat treatment / Filet mrożony po obróbce termicznej	3,05 ± 0,99b	6,01 ± 0,45B
Cube frozen after heat treatment / Kostka mrożona po obróbce termicznej	2,95 ± 1,23b	5,93 ± 1,25B

*/ jednakowe oznaczenia literowe przy wartościach w kolumnach świadczą o braku istotnych różnic

the same letter signs next to the values in the columns prove that there are no significant differences

Źródło: Badania własne

Source: The own study

Table 3. Basic components of cod meat color, measured before and after heat treatment

Tabela 3. Podstawowe składowe barwy mięsa dorsza mierzone przed i po obróbce termicznej

Produkt / forma		Color parameters / Parametry barwy		
		L*	a*	b*
Raw cod \ Dorsz surowy	Fresh fillet / Filet świeży	79,6 ± 2,5 (76,10 – 82,62)	5,78 ± 1,10 (3,72 – 7,34)	4,91 ± 0,85 (3,7 – 6,15)
	Frozen fillet / Filet mrożony	79,2 ± 4,0 (73,92 – 85,43)	5,95 ± 0,86 (4,54 – 7,08)	3,65 ± 0,84 (2,74 – 4,96)
	Frozen cube / Kostka mrożona	53,31 ± 3,69 (50,70 - 55,92)	3,7 ± 0,86 (3,09 – 4,31)	10,06 ± 0,83 (6,45 – 14,67)
After heat treatment / Po obróbce termicznej (60°C, 45 min)	Fresh fillet / Filet świeży	89,00 ± 1,3 (87,99 – 91,97)	1,02 ± 0,41 (0,59 – 1,95)	19,06 ± 1,27 (17,27 – 21,45)
	Frozen fillet / Filet mrożony	86,3 ± 3,4 (84,2 - 91,52)	0,32 ± 0,11 (0,13 – 0,48)	20,49 ± 2,08 18,11 – 23,76)
	Frozen cube / Kostka mrożona	59,54 ± 1,64 (58,38 - 60,70)	2,25 ± 0,21 (2,11 – 2,40)	17,08 ± 0,76 (16,54 – 17,62)

Źródło: Badania własne

Source: The own study

The raw frozen cube was much darker than the raw fillets (L* parameter values by approx. 30 units lower in relation to whole fish lobes), was less saturated with red and yellow (lower parameters of the component a*) and more saturated with blue (approx. 2–3 times higher values of the b* parameter). Cod cubes were rated as more „blue" than uncrushed cod fillets.

After cooking SV, the meat of each tested form of fish was brighter (higher values of L* parameters) and was characterized by lower parameters of component a* (lower share of red and yellow) and much higher values of component b* (higher saturation with blue).

The colour of fish muscles is a species trait, conditioned, among others, by the activity of fish, the less active the lifestyle of the fish, the brighter the meat. White fish meat has been proven to be low in fat, a good source of easily digestible protein, minerals (selenium, calcium, phosphorus), vitamins (vitamin A, D, from group B) and n-3 and n-6 acids. Cod belongs to the family of cod, less active, with white, tender meat belonging to lean meat, recommended for use, especially in low-calorie diets [33].

As various authors point out [39], colour is one of the most direct and sensory indicators of food quality. Fish meat is susceptible to discolouration due to various biochemical processes occurring during heat treatment at high temperatures. You can get fish meat with an attractive, lighter colour by using SV cooking at a lower temperature, Cooking SV is an anaerobic treatment, which is also conducive to obtaining a lighter meat colour.

The meat of fish is similar in fibre to that of slaughter animals and poultry but is less hard. The texture of fresh fish depends primarily on the age and species of the animal, the nutritional status and the study of biochemical modifications occurring in the muscles after bleeding or dreaming. Fresh fish meat with low collagen content is less hard compared to collagen-rich fish. However, after heat treatment, fish meat containing more collagen is more juicy and brittle, and fish poor in collagen are more fibrous and dry. A distinction is therefore made between fish with very tender and brittle flesh, e.g. the sturgeon family and the perch family and some flatfish and fish with little brittle flesh, e.g. horse mackerel. The juiciness of cooked, roasted or raw meat depends on its water absorption, which also depends on the protein content [33].

CONCLUSIONS

Based on the results obtained, the following conclusions were drawn:

1. Of the many forms of fish found on the market, the most useful form suitable for heat treatment by the SV method are whole fresh fillets. Frozen fillets are less useful, although the resulting thermal leak is similar to fresh fillets.
2. Frozen fish cubes (obtained before freezing by pressing pieces of fish flesh) are characterised by poor suitability for SV processing, as they promote very high thermal leakage and the sensory quality of the meat is less desirable.
3. Processing fish meat using the SV method at 60°C requires a relatively short time. After 15–30 minutes, a product with a soft consistency can be obtained, and after 45 minutes – a product with a sensory desired consistency.

PODSUMOWANIE

W oparciu o uzyskane wyniki sformułowano następujące wnioski:

1. Spośród wielu form ryb znajdujących się na rynku, najbardziej przydatną formą nadającą się do obróbki termicznej metodą SV są całe filety świeże. Mniej przydatne są filety mrożone, aczkolwiek powstający wyciek termiczny jest podobny jak w przypadku filetów świeżych.
2. Mrożona kostka ryb (otrzymana przed mrożeniem poprzez prasowanie kawałków mięsa ryb) charakteryzuje się słabą przydatnością do obróbki SV, gdyż sprzyja powstawaniu bardzo dużego wycieku termicznego, a sensoryczna jakość mięsa jest mniej pożądana.
3. Obróbka mięsa ryb metodą SV w temp. 60°C wymaga stosunkowo krótkiego czasu. Po 15–30 minutach można uzyskać produkt o miękkiej konsystencji, a po 45 min – produkt o konsystencji pożądanej sensorycznie.

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INFLUENCE OF THE METHOD OF BREWING VARIOUS TYPES OF COFFEE ON THE CONTENT OF OXALATES IN THEM®

Wpływ sposobu parzenia różnych rodzajów kaw na zawartość w nich szczawianów®

Key words: coffee, Arabica, Robusta, anti-nutritional factors, oxalic acid, oxalates, infusion, brewing methods, brewing time, kidney stones.

The aim of this study presented in the article, the influence of various brewing methods on the oxalate content in different types of coffee was examined. The level of these compounds was determined by permanganometric titration in two coffee species: Coffea arabica and Coffea robusta, using three brewing methods as well as different brewing times. In the experimental part, the content of oxalates in the prepared coffee infusions was determined and the results were analyzed and discussed by comparing the obtained values with the available literature data, and then conclusions were drawn based on them.

Słowa kluczowe: kawa, Arabica, Robusta, substancje antyodżywcze, kwas szczawiowy, szczawiany, napar, metody parzenia, czas parzenia, kamienie nerkowe.

Celem pracy zaprezentowanej w artykule było zbadanie wpływu sposobu parzenia różnych rodzajów kaw na zawartość w nich szczawianów. Poziom tych związków oznaczono metodą manganometryczną w dwóch gatunkach kawy: Coffea arabica oraz Coffea robusta, wykorzystując trzy metody parzenia, a także różny czas zaparzania. W części doświadczalnej oznaczono zawartość szczawianów w przygotowanych naparach kawowych oraz dokonano analizy i dyskusji wyników, porównując uzyskane wartości z dostępnymi danymi literatury, a następnie na ich podstawie wyciągnięto wnioski.

INTRODUCTION

Coffee is a valued food product, mainly due to the distinctive taste and aroma that it signifies, but mainly due to its health-promoting properties. Caffeine is responsible for most of them. This compound has a beneficial effect on many organs, including increases the activity of the central nervous system and improves concentration. Caffeine also raises blood pressure and speeds up the transport of oxygen to the cells. In addition, it affects the digestive system, accelerates intestinal peristalsis, and its consumption may be a prophylaxis for the development of colon cancer. In addition to caffeine, coffee contains valuable polyphenols and diterpenes, which have an antioxidant effect. These compounds contribute to lowering the oxidative stress of the organism by fighting free radicals, the excess of which accelerates the aging processes of the organism, and contributes to the development of neoplastic diseases [12, 13 14]. Despite the number of health-promoting properties that we can attribute to coffee, it is also a source of anti-nutritional substances that may adversely affect the functioning of the body [2, 8, 9, 16]. These substances hinder the absorption of nutrients, i.e. proteins, carbohydrates, vitamins and minerals, thus adversely affecting the body's work. Their presence is conducive to the development of many deficiencies and disorders. These substances are generally of natural origin, but can also be intentionally added to food products or enter with contaminants. The main anti-nutritional compounds contained in coffee include tannins and **oxalates** [1, 10, 11]. Oxalic acid is found in plant-based products such as sorrel, spinach, rhubarb, coffee, tea, cocoa. It shows the ability to bind with minerals, i.e. calcium, magnesium and heavy metals, creating salts that are sparingly soluble in water. The most invasive is calcium oxalate, which only dissolves in highly concentrated acids. Its excess is deposited, among

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others in the kidney tubules, forming deposits and causing painful symptoms. In addition, the presence of oxalates in the body contributes to the deficiency of calcium ions in the bloodstream, and thus upset the calcium-phosphate balance. The ratio of oxalic acid to calcium, which should be less than 1, is important in determining the anti-nutritional effect of the product on the body [1, 5, 7, 19].

The aim of this study is to determine the level of oxalates in infusions made from two types of coffee, using different brewing methods, and to determine the effect of the method and time of brewing on the content of these compounds in the product. The conducted research is also aimed at raising awareness of the anti-nutritional oxalate content in coffee, thus influencing the rational planning of a low-oxalate diet in people with gout or a tendency to build up kidney deposits.

MATERIALS AND METHODS

Research was carried out on coffee infusions made from two types of coffee beans, using different brewing methods and a different brewing time. The following types of coffee beans were analyzed: Coffea arabica and Coffea robusta. Arabica was purchased at a retail point of sale in Opole, while Robusta, due to limited availability, was ordered via an online store.

The determination of oxalates in coffee infusions was based on three reactions:

1. Precipitation of an insoluble calcium oxalate with a 5% solution of calcium chloride $CaCl_2$.
2. Hot dissolving of calcium oxalate in 10% sulfuric acid solution.
3. Hot titration with 0.02 N potassium permanganate.

Robusta and Arabica infusions were prepared using three brewing methods: using a coffee maker, Frenchpress and in the form of traditional poured brewed coffee. To prepare the infusions, 4g of previously ground coffee beans and 100 ml of water at 100 ° C were measured on a technical scale [1].

The coffee brewing time was 5 minutes, then the obtained infusions were transferred to 100 ml beakers. In the case of brewed coffee, it was necessary to filter the infusion to separate the grounds from the infusion to obtain a clear solution.

For a more detailed analysis, the effect of coffee brewing time on its oxalate content was also investigated. Additionally, two infusions of each type of coffee were made using the traditional method. Coffee was brewed for 10 and 15 minutes. After making the coffee infusion, it was transferred in the amount of 2.5 ml to a centrifuge tube with the addition of 1.25 ml of a 5% solution of calcium chloride $CaCl_2$ and 1.25 ml of acetone. The whole was mixed by shaking the test tube and placed in the refrigerator for 30 minutes. Two repetitions were made for each method of brewing two types of coffee and the brewing time. After 30 minutes, the tubes were removed from the refrigerator and to centrifuge the resulting pellet, they were placed in a centrifuge for 10 minutes at 3000 rpm. The fluid from above the sediment was poured out. The resulting calcium oxalate precipitates were transferred to 100 ml conical flasks with 1.25 ml of 10% sulfuric acid H_2SO_4. Then, the obtained solutions were heated in a water bath and subjected to immediate titration with potassium permanganate until a pink color was obtained, which remained for about 1 minute.

ANALYSIS AND DISCUSSION OF RESULTS

The obtained results of titration with potassium permanganate allowed to determine the content of soluble oxalic acid in 100 g of coffee, if 1 ml of 0.02 N $KMnO_4$ corresponds to 0.9 mg $(COOH)_2$. The results are summarized in the tables below:

From the above research results, the choice of the brewing method has an impact on the content of soluble oxalates in the coffee infusion. These differences are visible in both examined types of coffee. This is also shown in the graph below.

Oxalate content determined based on tests using various methods of brewing coffee beans is in the range of 585 – 765 mg /100g of the product. The analysis of the chart shows that

Fig. 1. Methods of making coffee infusions.
Rys. 1. Metody sporządzania naparów kawowych.
Source: Own study
Źródło: Opracowanie własne

Table 1. Oxalate content depending on the brewing method

Tabela 1. Zawartość szczawianów w zależności od sposobu parzenia

SPOSÓB PARZENIA			
zawartość szczawianów [mg/100g]			
	KAWIARKA	**KAWA PARZONA**	**FRENCHPRESS**
ARABICA	585,00	675,00	540,00
ROBUSTA	720,00	765,00	675,00

Source: The own study

Źródło: Badania własne

Table 2. Oxalate content depending on the time of brewing using the traditional method of brewing coffee

Tabela 2. Zawartość szczawianów w zależności od czasu zaparzania stosując tradycyjny sposób parzenia kawy

CZAS TRWANIA			
zawartość szczawianów [mg/100g]			
	5 MINUT	**10 MINUT**	**15 MINUT**
ARABICA	675,00	765,00	967,50
ROBUSTA	765,00	810,00	1035,00

Source: The own study

Źródło: Badania własne

Fig. 2. Graph of the dependence of oxalate content in the infusion on the selected brewing method.

Rys. 2. Wykres zależności zawartości szczawianów w naparze od wybranej metody parzenia.

Source: The own study

Źródło: Badania własne

Robusta has a higher level of anti-nutritional compounds. The oxalate content in infusions made of this type of coffee was determined in the range of 675 – 765 mg /100g, thus from 90 to 135 mg / 100g more than the Arabica species. Comparing the obtained results with the available publications, one can notice discrepancies resulting from various factors. In the studies by Rusinek [15], which were based on the determination of the content of soluble oxalic acid in infusions of various types of tea and coffee, the level of these compounds in ground coffee oscillated around 537 mg/100g. This value is close to the lower threshold of the obtained results. The research methodology used by Rusinek was analogous to that used in this study, i.e. Brzozowska's manganometric method was used [1]. A higher level of tested anti-nutritional substances was also shown in Robusta coffee compared to Arabica coffee.

In the analysis by Sperkowska, Bazylak [17] the oxalate content in ground coffee was determined at the level of 799 mg / 100 g of dry matter, which in turn corresponds to the upper limit of the obtained results. Much greater results were obtained in the studies by Ulewicz-Magulska, Pawełkiewicz, Wesołowski [18]. In this case, the values ranged from 1497 to 2756 mg / 100 g of product. A comparison of the results obtained in various scientific studies showed significant discrepancies. An important factor influencing these differences is certainly the research material, which may come from various sources, have different origins and qualitative values. You should also pay attention to the degree of burnout of the grains, often indicated on the product label, but not in every case. Dark roast coffees have a higher oxalate content than medium or light roasted coffees. The grinding of the grains also has a significant influence on the amount of these compounds in the drink obtained from it. Infusions made of finely ground coffee beans contain relatively more oxalates compared to medium-ground coffees, as shown by the research of Sperkowska, Bazylak. However, no data on the influence of the brewing method on the content of soluble oxalates in the coffee infusion were found in the available literature sources. The obtained results indicate that coffee brewed using the traditional method has the highest content of the tested anti-nutritional compounds. The oxalate content in the infusion obtained with this method was, respectively, 675 mg/100 g for Arabica and 765 mg/100 g for Robusta. Often when drinking coffee prepared with this method, the grounds with oxalate compounds are also consumed with it, so their actual consumption may be even higher. A lower oxalate content was obtained in the infusions prepared in French Prague, the so-called frenchpressie and coffee shop. In the case of Arabica, the values were 585 mg/100 g (coffee maker) and 540 mg/100 g (Frenchpress). In turn, for Robusta, the level of these compounds was equal to 720 mg/100 g (coffee maker), 675 mg/100 g (Frenchpress). Table 2 contains the test results determining the content of oxalate compounds with an anti-nutritional effect in two types of coffee:

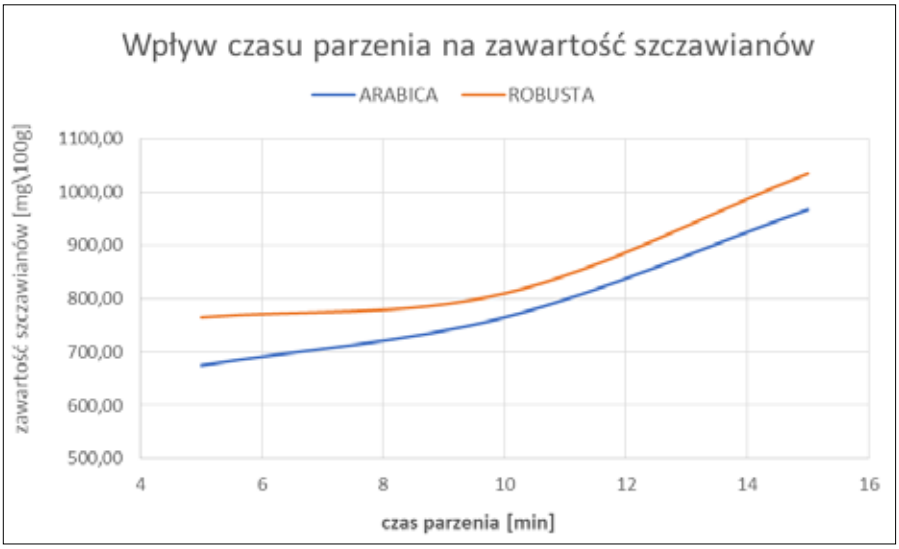

Fig. 3. The dependence of the oxalate content on the brewing time.
Rys. 3. Zależność zawartości szczawianów od czasu parzenia naparu.
Source: The own study
Źródło: Badania własne

Coffee arabica and Coffee robusta depending on the length of time it is brewed. The results are presented in graphic form.

The obtained test results are in the range of 675 – 1035 mg of oxalates soluble in 100 g of product dry matter. The amount of these compounds in coffee infusions prepared using the traditional method increases in proportion to the length of the brewing time. This is shown in the chart above, where it can also be noticed that this applies to both examined types of coffee. This is mainly due to the longer extraction of soluble oxalates in the coffee. In this case, the degree of grain grinding also plays an important role. Strong grinding of coffee beans facilitates the extraction of oxalate compounds for infusion, and an extended brewing time may increase the amount of these substances in the coffee. Whole coffee beans were used in the research, which were successively ground to a medium degree in an electric grinder. This degree of grinding of the beans slows down the penetration of soluble oxalates into the brew, as well as other substances contained in the coffee. In addition, coffee brewed for longer than the recommended 5 minutes with a higher concentration of oxalic acid is marked by a greater astringency in taste. It should be noted that the samples of coffee infusions were used in the research, for which 4 g of the product per 100 ml of water were used. The cut person drinks coffee made of 180 ml of water and two teaspoons of coffee corresponding to 9 g of ground beans – a proportion established by the National Coffee Association.

Converting the oxalate content to mg/g dry weight and averaging the results, the content of these substances was 6.0 mg/g of coffee in the case of Arabica and 7.2 mg /g in the case of Robusta coffee. The acceptable daily intake of oxalate compounds should not be higher than 250 mg per day in a healthy adult with no tendency to build up kidney stone plaques. In this case, it is allowed to consume up to 3 servings of coffee. However, it should be remembered that coffee is not the only source of this compound in the diet. Therefore, a moderate dose should be maintained in the form of 1–2 servings a day.

People at risk with kidney dysfunction and kidney stone formation disorders, the recommended dose is 50 mg, corresponding to 1 cup of coffee. Arabica coffee will be the right choice to reduce the daily intake of oxalates, as it has a lower amount of these compounds compared to Robusta. The research of Gasińska, Gajewska [4, 6] indicated that consumption of coffee and tea infusions influences the formation of kidney stones in 80%. Therefore, to rationally plan a low-oxalate diet, it is important to be aware of the content of these compounds in individual types of coffee, as well as the use of an appropriate brewing method and brewing time, to limit the absorption of anti-nutritional compounds into the body as much as possible. An important factor is also an adequate supply of calcium in the diet, eliminating the depletion of this element in the body, which results from binding with oxalic acid.

Table 3. Comparison of oxalate content per portions of coffee

Tabela 3. Porównanie zawartości szczawianów w przeliczeniu na porcje kawy

ZAWARTOŚĆ SZCZAWIANÓW			
	9 g kawy (1 porcja)	18 g kawy (2 porcje)	27 g kawy (3 porcje)
ARABICA	54 mg	108 mg	162 mg
ROBUSTA	65 mg	130 mg	194 mg

Source: The own study
Źródło: Badania własne

Table 4. Comparison of oxalate content per portions of coffee

Tabela 4. Porównanie zawartości szczawianów w przeliczeniu na porcje kawy

ARABICA	ROBUSTA
2,7 mg wapnia/ g kawy	3,2 mg wapnia/ g kawy
W 1 porcji kawy (9g)	
24,3 mg wapnia	28,8 mg wapnia
Ilość dodanego mleka (100 g – 120 mg wapnia)	
20 g	24g

Source: The own study
Źródło: Badania własne

If 0.9 mg of oxalic acid binds 0.4 mg of calcium in 1 g of coffee, 2.7 mg (Arabica) and 3.2 mg (Robusta) of calcium ions are bound by oxalate compounds, respectively. A preventive measure for the loss of this element in the body will be the addition of an appropriate amount of milk, which is a natural

source of calcium. 20–24 g of milk should then be added to 1 serving of coffee. It is worth noting that the addition of milk to coffee infusion will only reduce the loss of calcium ions in the body and will not reduce the amount of precipitated calcium oxalates. It is therefore important that the daily diet does not consist of excessive amounts of foods rich in these anti-nutritional compounds [2, 3, 15].

CONCLUSIONS

Based on the research, the influence of the method of brewing various types of coffee on the oxalate content in them, the following conclusions were drawn:

1. Regardless of how the coffee is brewed, the Robusta species has a higher content of soluble oxalate. Their content in 100 g of product dry matter fluctuates around 720 mg. In Arabica, the level of these compounds is 600 mg /100 g of coffee.
2. The varied oxalate content in the examined coffee species is influenced by many factors, including conditions of growing the coffee bush, which translate into the quality parameters of the brewed infusion, i.e. acidity, intensity and taste. Arabica has a higher acidity and a milder aroma compared to Robusta. This one is again characterized by a greater intensity of the infusion and a tartness in taste, which is due to, among others, higher oxalic acid content.
3. The conducted research allowed to show the influence of the method of brewing coffee on the content of oxalates in it. The highest amount of soluble oxalates was found in infusions obtained from both types of coffee brewed using the traditional method. It should be emphasized, however, that coffee grounds containing oxalate compounds are often consumed along with the infusion, which is why their actual consumption is higher.
4. The analysis of the results showed slight discrepancies in the oxalate content of the investigated infusions prepared using a coffee pot and Frenchpress. More of these substances were determined in both types of coffee brewed in the coffee maker.
5. The degree of grain grinding has a significant impact on the content of oxalate compounds in the infusion. Finely ground coffee infusions are characterized by a higher amount of these substances, which results from easier extraction of substances contained in the grain. The coffee beans used in this study were ground on average, comparing the obtained results with the available literature data, the oxalate content in the infusions tested was lower than in the case of fine ground coffees.
6. The length of brewing a coffee infusion has a significant effect on its oxalate content. The longer the brewing time, the higher the level of these compounds in the coffee. This relationship applies to both types of coffee. The reason for this phenomenon is a longer extraction of substances contained in coffee beans, including oxalates. As a result of the longer brewing, more of these compounds penetrate the brew and their level increases.
7. By comparing the obtained results with the acceptable daily dose of oxalates for a healthy adult, which is 250 mg per day, respectively, the permitted amount of coffee consumed at the level of 3 portions made from 27 g of coffee, with the limitation of other products that are the source of this anti-nutritional compound.
8. In order to compensate for the loss of calcium ions in the body due to the binding of this element by oxalic acid, supplement the calcium supply, e.g. by adding milk to a coffee brew.
9. For people suffering from gout and those with a genetic tendency to build up kidney stone plaque, it is recommended that coffee be eliminated from the daily diet or consumed in a limited amount.

WNIOSKI

Na podstawie przeprowadzonych badań wpływu sposobu parzenia różnych rodzajów kawy na zawartość w nich szczawianów sformułowano następujące wnioski:

1. Niezależnie od sposobu parzenia kawy gatunek Robusta odznacza się wyższą zawartością rozpuszczalnych szczawianów. Ich zawartość w 100 g suchej masy produktu oscyluje w granicy 720 mg. W Arabice poziom tych związków jest równy 600 mg/100 g kawy.
2. Na zróżnicowane zawartości szczawianów w badanych gatunkach kaw wpływa wiele czynników m.in. warunki upraw krzewu kawowca, które przekładają się na parametry jakościowe sporządzonego naparu, tj. kwasowość, intensywność czy smak. Arabika charakteryzuje się wyższą kwasowością i łagodniejszym aromatem w porównaniu z Robustą. Ta znowu odznacza się większą intensywnością naparu i cierpkością w smaku, którą zawdzięcza m.in. większej zawartości kwasu szczawiowego.
3. Przeprowadzone badania pozwoliły na wykazanie wpływu sposobu parzenia kawy na zawartość w niej szczawianów. Największą ilość rozpuszczalnych szczawianów zawierały napary otrzymane z obu gatunków badanych kaw parzonych metodą tradycyjną. Należy jednak podkreślić, że często wraz z naparem spożywane są także fusy, w których zawarte są związki szczawianowe, dlatego też ich realne spożycie jest wyższe.
4. Analiza wyników wykazała nieznaczne rozbieżności w zawartości szczawianów badanych naparów sporządzonych przy użyciu kawiarki oraz praski francuskiej (frenchpress). Więcej tych substancji oznaczono w obu gatunkach kaw parzonych w kawiarce.
5. Stopień zmielenia ziaren ma istotny wpływ na zawartość związków szczawianowych w naparze. Napary z kaw drobno mielonych oznaczają się wyższą ilością tych substancji, co wynika z łatwiejszej ekstrakcji substancji zawartych w ziarnie. Wykorzystane w niniejszej pracy ziarna kawy zostały średnio zmielone, porównując uzyskane wyniki z dostępnymi danymi literaturowymi zawartość szczawianów w badanych naparach była niższa w stosunku do kaw drobno mielonych.
6. Długość parzenia naparu kawowego oddziałuje w znaczącym stopniu na zawartość w nim szczawianów. Im dłuższy czas zaparzania tym poziom tych związków w kawie jest wyższy. Zależność ta obejmuje oba gatunki kawy. Przyczyną tego zjawiska jest dłuższa ekstrakcja substancji mieszczących się w ziarnach kawowych, w tym

także szczawianów. W wyniku dłuższego parzenia więcej tych związków przenika do naparu i ich poziom wzrasta.

7. Zestawiając uzyskane wyniki badań z dopuszczalną dzienną dawką szczawianów dla zdrowej osoby dorosłej, która wynosi odpowiednio 250 mg na dobę, można przyjąć dozwoloną ilość spożytej kawy na poziomie 3 porcji, sporządzonych z 27 g kawy, przy ograniczeniu innych produktów będących źródłem tego antyodżywczego związku.
8. W celu zniwelowania ubytków jonów wapnia w organizmie powstałych na skutek wiązania tego pierwiastka przez kwas szczawiowy, należy uzupełnić podaż wapnia, np. przez dodatek mleka do naparu kawowego.
9. Dla osób chorujących na dnę moczanową oraz tych, którzy są genetycznie obciążeni tendencją do tworzenia się złogów w postaci kamieni nerkowych zaleca się wyeliminowanie kawy z codziennej diety lub spożywane jej w ograniczonej ilości.

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THE USE OF OSMOTIC DEHYDRATION AND MICROWAVE-VACUUM DRYING FOR THE PRODUCTION OF APPLE SNACKS®

Zastosowanie odwadniania osmotycznego i suszenia mikrofalowo-próżniowego do wytwarzania przekąsek z jabłek®

Key words: dried fruit, fruit snacks, reduced pressure, microwave power.

The influence of time, microwave power, reduced pressure, and initial osmotic dehydration on selected indicators of microwave-vacuum drying of apple slices was investigated. 5 drying variants were used, differing in microwave power and pressure, and with osmotic treatment: A: 250 W / 3.5 kPa; B: 300 W / 3.5 kPa; C: 300 W / 5.5 kPa; D: 300 W / 6.5 kPa; E: 300 W / 6.5 kPa / initial osmotic dehydration. Apple drying was the most intensive in the case of variant B. Water activity of apples without pretreatment was at the level of 0.71-0.81, and initial osmotic dehydration caused a decrease to 0.52. All samples showed a darkening of the color and increased red color.

Słowa kluczowe: suszone owoce, przekąski z owoców, obniżone ciśnienie, moc mikrofal.

Badano wpływ czasu, mocy mikrofal, obniżonego ciśnienia i wstępnego odwadniania osmotycznego na wybrane wskaźniki suszenia mikrofalowo-próżniowego jabłek. Zastosowano 5 wariantów suszenia różniących się mocą mikrofal i ciśnieniem oraz z obróbką osmotyczną: A: 250 W/3,5 kPa; B: 300 W/3,5 kPa; C: 300 W/5,5 kPa; D: 300 W/6,5 kPa; E: 300 W/6,5 kPa/ wstępne odwadnianie osmotyczne. Suszenie jabłek najintensywniej przebiegało w przypadku wariantu B. Aktywność wody jabłek bez wstępnej obróbki była na poziomie 0,71-0,81, a wstępne odwadnianie osmotyczne spowodowało obniżenie do 0,52. Obróbka osmotyczna wpłynęła istotnie na ograniczenie skurczu suszarniczego. Próbki odznaczały się pociemnieniem barwy i zwiększeniem udziału barwy czerwonej.

INTRODUCTION

A characteristic feature of fruit and vegetable farming is the seasonality of harvesting and the occurrence of raw materials, which results in the limited availability of fresh fruit and vegetables. It is therefore necessary to process the raw materials so they can be available to consumers all year round. One of the main components of plant raw materials is water. Fresh apples contain about 85% water [8, 9]. Drying to reduce the water content is one of the oldest methods of food preservation and ensuring the microbiological safety of food and extending the use-by date. By drying, attractive snack products of high quality and nutritional value can be produced. It also makes it possible to process the production surplus of fruit and vegetable raw materials in the event of their abundant harvest [11]. Many changes occur in the material during drying, both physical and biochemical. The main noticeable phenomenon is the evaporation of moisture (water loss) and the associated physicochemical changes. The cell structure of the dried material shrinks, sometimes hardening or cracking. An undesirable effect of drying may be the loss of thermally sensitive compounds, for example, vitamins [2]. Inadequate drying conditions and methods contribute to the reduction of important nutritional and aromatic compounds and cause unfavorable organoleptic changes in the material. Obtaining high-quality dried material with the sublimation method is associated with high costs. Recently, a good solution seems to be the use of microwave-vacuum drying to preserve fruit and vegetables [3, 4, 12]. This method may develop on a larger scale, as it allows for shortening the drying time and at the same time maintaining the high quality of the product [4, 8].

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Properly dried fruit can be counted among products that are a source of health-promoting nutrients, such as fiber, vitamins, minerals, and antioxidant compounds. They are often an ingredient of breakfast cereals, muesli, granola, and bars. Such use of dried fruit can meet the needs of consumers focused on proper nutrition, and looking for high-quality products. Hence, the role of producers is to select appropriate processing processes, including taking into account the specificity of the raw material, in order to maintain its nutritional value [2].

The aim of the article is to investigate the effect of microwave power and reduced pressure as well as initial osmotic treatment on the kinetics of drying apple slices and their selected physicochemical properties.

MATERIALS AND METHODOLOGY

The research material was apples of the Royal Gala variety purchased in one of the supermarkets (Lidl). The fruits were stored in refrigerated conditions at a temperature of 4–5°C and relative air humidity of 85–90%. The seed chamber was removed from the apples with a special device (a cork borer) and then the apples were cut into slices 5 mm thick. Each slice was then cut into smaller pieces (quarters). In order to inhibit the color change, before drying, the raw material was immersed in a 0.5% citric acid solution at a temperature of about 20°C for 10 minutes, and then dried on a filter ball. An approximately 60% sucrose solution was prepared by dissolving sucrose in distilled water.

Table 1. Microwave-vacuum drying conditions for apples; variants of the drying kinetics

Tabela 1. Warunki suszenia mikrofalowo-próżniowego jabłek; warianty kinetyki suszenia

Drying parameters / Variants	Initial treatment	Microwave power [W]	Pressure [kPa]	Maximum temperature [°C]
A	-	250	3.5	70
B	-	300	3.5	70
C	-	300	5.5	70
D	-	300	6.5	70
E	Osmotic dehydration	300	6.5	70

Source: The own study

Źródło: Badania własne

Osmotic dehydration was carried out in a JW.ELECTRONIC type T-OSM water bath at a constant temperature of 50°C for 15 minutes. A sucrose solution with a concentration of 60% was used for the osmotic dehydration of samples weighing about 100 g. After dehydration, the material was rinsed under running water for 3–5 seconds and dried on filter paper. The pre-dehydrated samples (about 40 g) were dried in a PROMIS-μLAB microwave-vacuum oven with a maximum vapor temperature of 70°C, microwave power in the range of 250-350 W and reduced pressure in the range of 3.5–6.5 kPa. Drying consisted of four cycles, the second and fourth were without microwaves. By operating the duration of the process while maintaining constant microwave power parameters and the value of reduced pressure, the drying kinetics were determined (Table 1). The samples were assessed for changes in activity and water content, weight loss, color parameters, and shrinkage. Statistical analysis for three series of tests was performed using the Statistica 13 Trial program. One-way ANOVA and Tukey's test with significance level $\alpha = 0.05$ were used.

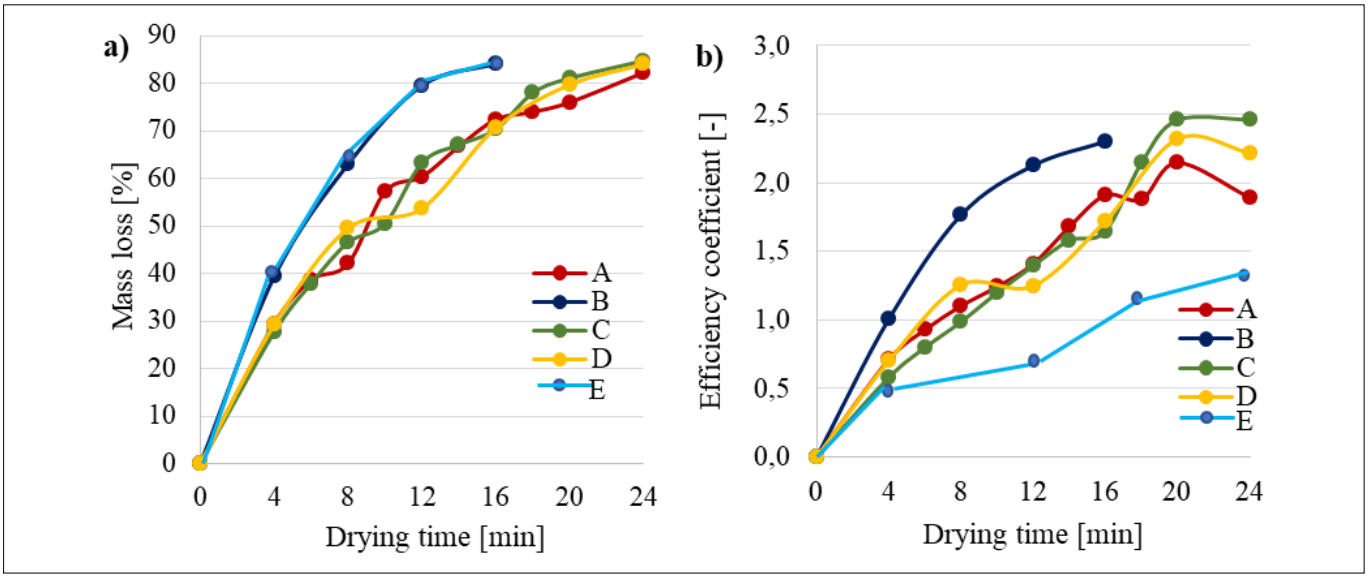
RESULTS AND DISCUSSION

Effect of microwave-vacuum drying parameters on the mass loss of apples

A significant effect of time on the mass loss of dried apples was observed. When using a shorter drying time, from 4 to 10 minutes, a mass loss of 28–57% was noted and significantly higher in samples dried for 20–24 minutes (76–85%) (Fig. 1).

Microwave power and reduced pressure did not significantly affect the mass loss of apples. Significantly greater mass losses were observed in the dried fruit of variant B (microwave power 300 W, pressure 3.5 kPa). After 12 minutes, the mass loss of these samples amounted to 79.6% and was 16.3–25.9% higher than for the other variants (Fig. 1a). The use of lower microwave power of 250 W (variant A) at the same pressure value resulted in a lower weight loss in the entire duration of the process. The change in pressure value at constant microwave power (300 W) did not cause significant differences in the mass loss for higher pressure values, i.e. 5.5 and 6.5 kPa (variants C and D). A significant effect was observed for the lowest pressure value (variant B), at which a significant increase in the mass loss of dried apples was noted in comparison with higher pressure values (variants C and D). There was no significant effect of the application of preliminary osmotic dehydration of apples in a 60% sucrose solution at 50°C on the mass loss of dried apples. Samples not subjected to initial osmotic dehydration (D) showed very similar values of mass loss in relation to the samples subjected to this treatment (E) in the entire drying time range (Fig. 1a).

There was no significant influence of microwave power on the efficiency coefficient calculated on the basis of the ratio of water loss to dry matter weight gain [7] (Fig. 1b), but some trends were observed. Higher values of the coefficient were found in apples dried using higher microwave power (300 W) compared to drying at lower power of 250 W, with constant values of other parameters (variants A and B). Drying at the pressure of 3.5 kPa (B) was characterized by a higher process efficiency coefficient than drying at the pressures of 5.5 and 6.5 kPa (variants C and D), but only at a higher microwave power (300 W). For shorter drying times, higher values were obtained for samples dried at a pressure of 6.5 kPa, however, for longer times, higher values of the efficiency coefficient were recorded at a pressure of 5.5 kPa (Fig. 1b). Such diversity of data probably contributed to the lack of a significant influence of pressure on the examined index. The use of initial osmotic dehydration significantly influenced the efficiency of the drying process (Fig. 1b). For samples initially osmotically dehydrated (variant E) in the whole range of the process duration, lower values of this coefficient were recorded compared to the samples



Factors	Time [min]	Microwave power [W]	Pressure [kPa]	Initial osmotic dehydration
Tested parameters	p - probability			
Mass loss	0.000*	0.899	0.924	0.554
Efficiency coefficient	0.000*	0.275	0.407	0.032*

Fig. 1. Kinetics: a) mass loss, b) apple drying efficiency coefficient; influence of microwave power and reduced pressure: A – 250 W / 3.5 kPa; B – 300 W / 3.5 kPa; C – 300 W / 5.5 kPa; D – 300 W / 6.5 kPa, E – osmotic dehydration / 300 W / 6.5 kPa. The standard deviation of the presented data did not exceed 7%.

Rys. 1. Kinetyka: a) ubytku masy, b) współczynnika efektywności suszenia jabłek; wpływ mocy mikrofal i obniżonego ciśnienia: A – 250 W / 3,5 kPa; B – 300 W / 3,5 kPa; C – 300 W / 5,5 kPa; D – 300 W / 6,5 kPa, E – odwadniaie osmotyczne / 300 W / 6,5 kPa. Odchylenie standardowe prezentowanych danych nie przekraczało 7%.

Source: The own study

Źródło: Badania własne

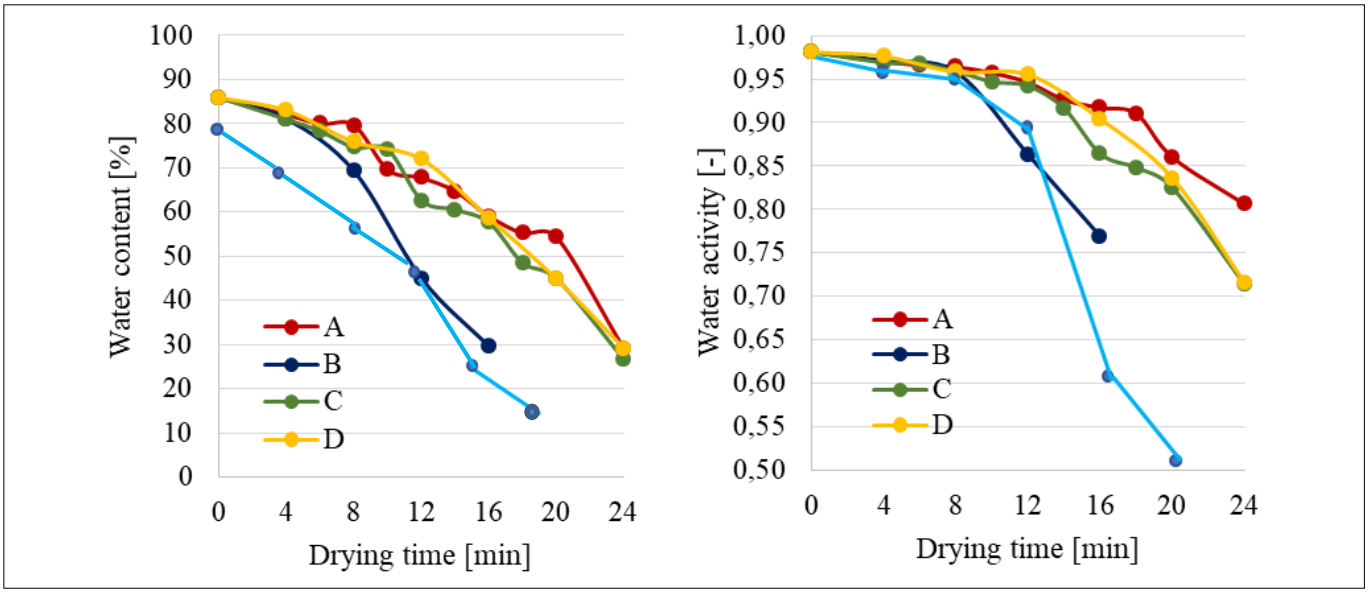
not subjected to preliminary dewatering (variant D) (Fig. 1b). For samples initially osmotically dehydrated (variant E), in the entire range of the process duration, lower values of this coefficient were recorded compared to samples not subjected to pre-osmotic treatment (variant D).

The use of preliminary osmotic dehydration before microwave-vacuum drying resulted in obtaining a lower water content and activity throughout the process (Fig. 2). After the short drying times, especially for the water activity, the differences were small. However, along with the extension of the processing time, significantly lower values of both indices of the samples of variant E were observed. Drying the samples pre-osmotically dehydrated for 16–20 minutes resulted in a decrease in water activity by 29–32% in relation to the non-dehydrated samples. Water activity for variant E during 20 minutes of drying was 0.519. This value was at the level showing full microbiological stability [10].

EFFECT OF MICROWAVE-VACUUM DRYING PARAMETERS ON THE COLOR OF APPLES

A significant effect of drying on the lightness of apple color was noted (Table 2). All the dried samples were characterized by lower values of the L* parameter than the color of fresh apples, i.e. at the level of 78.4. Depending on the process parameters, these values decreased by 3.1–33.0 units. This proves that the samples were darkening as a result of drying. Michalska et al. [9] showed that this effect can be attributed to non-enzymatic browning reactions that dried products undergo as a result of heat treatment. The use of microwave power of 250 W (A) and 300 W (B) caused a significant difference in the L* parameter in the samples dried for 16 minutes; those dried with more power were much darker. The significant influence of pressure and initial osmotic dehydration in sucrose solution on the brightness of the color of the dry was not shown.

Samples subjected to drying showed higher values of the a* parameter than in the case of the color of fresh apples (Table 2). In the study by Michalska et al. [9], changes in the values of the a* coordinate were noted during microwave-vacuum drying of apple slices, which was explained by the degradation of red pigments of dried fruit. The values of the b* and C parameters (Table 2) were quite varied and did not show any significant dependence on the drying conditions. In most of the samples, an increase in the share of the yellow color (parameter b*) was noted in comparison to the color of raw apples. Similarly, higher values of the C parameter in most samples may indicate a greater color saturation compared to the color of fresh apples. However, after longer drying times, a lower saturation was noted depending on the pressure used.



Factors	Time [min]	Microwave power [W]	Pressure [kPa]	Initial osmotic dehydration
Tested parameters	p - probability			
Mass loss	0,000*	0,899	0,924	0,554
Efficiency coefficient	0,000*	0,275	0,407	0,032*

Fig. 2. Kinetics: a) changes in water content, b) water activity of microwave-vacuum-dried apples; influence of microwave power, reduced pressure and osmotic treatment: A – 250 W / 3.5 kPa; B – 300 W / 3.5 kPa; C – 300 W / 5.5 kPa; D – 300 W / 6.5 kPa, E – osmotic dehydration / 300 W / 6.5 kPa. The standard deviation of the presented data did not exceed 7%.

Rys. 2. Kinetyka: a) zmiany zawartości wody, b) aktywności wody jabłek suszonych mikrofalowo-próżniowo; wpływ mocy mikrofal, obniżonego ciśnienia i obróbki osmotycznej: A – 250 W / 3,5 kPa; B – 300 W / 3,5 kPa; C – 300 W / 5,5 kPa; D – 300 W / 6,5 kPa, E – odwadniaie osmotyczne / 300 W / 6,5 kPa. Odchylenie standardowe prezentowanych danych nie przekraczało 5%.

Source: The own study

Źródło: Badania własne

Samples dried in 3.5 kPa (A and B) were characterized by the values of the C index at a fairly even level (24.0–32.2), while at 5.5 and 6.5 kPa (C and D), the initial color saturation was similar to the color of the raw material, and then increased or decreased significantly to 16.1-18.3. On the other hand, in the dried osmotically dehydrated (E), initially, the C values were the highest (about 35.0) and decreased to about 17.0. The values of the h parameter (Table 2), which were responsible for the color shade for all samples, were lower than the color of the raw material, the more so, the longer the drying time, and the shade on the color wheel became more yellow.

The absolute color difference ΔE (Table 2) was calculated on the basis of the difference in the L*, a*, and b* color parameters of dried apples in relation to the color of fresh fruit. The ΔE value in the range of 2.0–3.5 represents a slight color difference, while ΔE > 5 indicates a very large color difference between the samples, which is clearly noticeable by the human eye [1]. For all analyzed samples, regardless of the drying parameters used, the ΔE value was greater than 5.0, so drying caused a significant change in the color of apples in the range of 10.0–37.5, visible to the naked eye.

EFFECT OF MICROWAVE-VACUUM DRYING PARAMETERS ON SHRINKAGE OF DRIED APPLES

There was a slight effect of microwave power and lowered pressure on the shrinkage of dried apples (Table 3). Comparing the samples dried at the microwave power of 250 and 300 W (variants A and B), while maintaining constant values of the other parameters, greater shrinkage was recorded at the lower power (250 W), which was approximately 73.3%. Lower values, but a similar relationship was observed for the material pre-osmotically dehydrated. The use of higher microwave power during drying significantly reduced the material shrinkage of these samples. For variant E (300 W), the shrinkage was 66.7%, for variant F (350 W) – 60.0%. Jałoszyński et al. [5] obtained a similar relationship for quince fruit. They showed that with the increase in microwave power, the drying volume shrinkage decreased. In other studies, Jałoszyński et al. [6] noted the same tendency; lower microwave power determined greater root shrinkage of scorzonera, and higher power significantly limited it.

Table 2. Color parameters of selected microwave-vacuum-dried samples

Tabela 2. Parametry barwy wybranych próbek suszonych mikrofalowo-próżniowo

Variant	Time [min]	L*	a*	b*	C	h	ΔE
Fresh	-	78,4±1,2	-2,7±1,2	23,8±1,2	24±1,2	94±1,2	-
A	4	67,0±1,0	1,8±0,8	23,7±1,2	24,0±0,5	86,1±0,4	12,1±2,1
	8	49,2±1,4	7,6±1,7	24,9±1,2	28,2±0,8	72,2±1,6	31,4±1,4
	12	55,8±1,1	5,6±1,1	29,4±1,2	30,1±1,4	80,3±5,2	25,0±1,1
	16	75,4±1,2	3,9±1,6	31,9±1,2	32,2±1,7	81,2±3,2	11,0±1,7
	20	70,4±1,5	5,4±0,6	30,3±1,2	31,2±0,4	83,1±1,1	13,1±1,1
	24	61,4±2,2	8,7±0,9	26,4±1,2	25,0±1,5	65,3±1,5	21,5±1,2
B	4	59,1±0,2	5,5±1,2	24,7±1,2	25,1±1,9	78,1±0,5	21,1±1,4
	8	60,2±3,7	6,3±1,8	27,7±1,2	29,0±2,2	76,0±1,6	21,0±2,2
	12	68,2±0,5	6,8±1,4	30,3±1,2	31,3±2,3	78,0±1,4	15,0±0,2
	16	53,0±1,3	13,4±0,5	23,7±1,2	27,4±0,8	60,1±1,1	31,2±2,2
	20	52,4±1,1	13,0±1,2	22,5±1,4	27,1±0,2	59,8±1,2	31,2±1,3
C	4	67,0±1,4	-0,6±1,2	21,9±1,2	23,0±0,6	91,1±1,4	12,3±0,9
	8	47,0±3,2	10,1±04	26,3±1,2	32,1±3,2	70,3±1,5	34,4±2,3
	12	58,6±2,4	5,0±0,6	32,0±1,2	32,2±2,2	80,4±1,7	23,1±3,2
	16	73,8±0,9	3,1±0,2	30,0±1,2	29,0±082	87,0±1,2	10,0±0,8
	20	47,6±1,0	10,2±1,4	15,4±1,2	16,1±1,5	52,0±1,1	35,0±1,2
D	4	57,7±1,3	3,5±0,4	27,9±1,2	29,0±1,1	83,3±2,2	22,2±1,2
	12	61,6±1,1	2,4±0,2	29,2±1,2	31,2±1,0	86,0±3,0	18,3±1,8
	20	45,4±1,7	11,1±1,5	15,0±1,2	18,3±1,3	53,1±1,2	37,5±1,4
E	8	62,2±0,5	2,6±2,2	33,5±1,2	35,0±1,5	87,1±2,2	20,6±1,2
	16	63,4±0,8	6,9±1,3	25,3±1,2	27,3±1,7	76,2±2,4	18,0±1,6
	20	47,5±1,4	8,5±1,1	15,7±1,2	17,0±1,0	57,3±0,5	34,0±1,1

Source: The own study

Źródło: Badania własne

Table 3. Effect of microwave-vacuum drying conditions on apple shrinkage

Tabela 3. Wpływ warunków suszenia microwave-vacuum na skurcz jabłek

Drying parameters / Variants	Initial treatment	Microwave power [W]	Pressure [kPa]	Drying time [min]	Shrinkage [%]
A	-	250	3.5	16	73.3
B	-	300	3.5	16	70.0
C	-	300	5.5	16	70.0
D	-	300	6.5	16	70.0
E	Osmotic dehydration	300	6.5	16	66.7
F*	Osmotic dehydration	350	6.5	16	60.0

* dla wariantu F nie wyznaczano kinetyki suszenia a jedynie skurcz suszarniczy

Source: The own study

Źródło: Badania własne

No influence of pressure on drying shrinkage of samples without preliminary dewatering was demonstrated, at a pressure in the range of 3.5–6.5 kPa it was about 70%. The effect of osmotic dehydration on shrinkage has been reported; pre-dehydrated apples (variant E) showed lower shrinkage compared to the sample not subjected to preliminary drainage treatment (variant D).

CONCLUSIONS

Microwave-vacuum drying of apples in laboratory conditions, lasting up to 16–24 minutes, resulted in significant weight loss, up to 85%, and a decrease in water content and activity of up to 15–30%, higher with higher microwave power (in the range of 250–300 W) and higher pressure (in the range of 3.5–6.5 kPa) and after osmotic treatment. There was no effect of osmotic dehydration on mass loss. The osmotic treatment significantly reduced the efficiency of the process related to the reduction of water loss. Extending the drying time in the range of 0–24 minutes had a significant effect on the tested apple mass exchange indexes. The highest dry-ing efficiency occurred for variant B, with a power of 300 W and a pressure of 3.5 kPa. The lowest water activity (0.52) characterized the osmotically pre-dehydrated samples. The use of osmotic pre-treatment and microwave-vacuum drying with sufficiently high microwave power can be used to produce dried apples, i.e. a product that can be classified as a safe food.

Microwave-vacuum drying, regardless of the parameters used and the initial treatment resulted in diversified changes in the color of apples. All dried samples had a darker color and a higher red color. The absolute color difference of all dried samples was noticeable to the naked eye in relation to the color of the raw material.

The power of the microwaves slightly limited the drying shrinkage. Increasing the power from 250 to 300 W reduced the shrinkage from 73 to 70%. The beneficial effect was pre-osmotic dehydration and higher microwave power, which limited the shrinkage to 60–67%.

WNIOSKI

Suszenie mikrofalowo-próżniowe jabłek w warunkach laboratoryjnych trwające do 16–24 minut powodowało znaczące ubytki masy, sięgające 85% oraz obniżenie zawartości i aktywności wody sięgające 15–30%, większe przy większej mocy mikrofal w zakresie 250–300 W i większym ciśnieniu w zakresie 3,5–6,5 kPa oraz po obróbce osmotycznej. Nie stwierdzono wpływu odwadniania osmotycznego na ubytki masy. Obróbka osmotyczna w dużym stopniu zmniejszyła wydajność procesu związaną z ograniczeniem ubytku wody. Wydłużenie czasu suszenia w zakresie 0–24 minut miało istotny wpływ na badane wskaźniki wymiany masy jabłek. Największa efektywność suszenia wystąpiła dla wariantu B, przy mocy 300 W i ciśnieniu 3,5 kPa. Najniższą aktywnością wody charakteryzowały się próbki wstępnie odwadniane osmotycznie (0,52). Zastosowanie wstępnej obróbki osmotycznej i suszenie mikrofalowo-próżniowe przy odpowiednio wysokiej mocy mikrofal możne być wykorzystane do wytwarzania suszu z jabłek, tj. produktu, który można zaliczyć do żywności trwałej.

Suszenie mikrofalowo-próżniowe, niezależnie od zastosowanych parametrów oraz obróbki wstępnej, wpłynęło na zróżnicowane zmiany barwy jabłek. Wszystkie susze charakteryzowały się ciemniejszą barwą oraz większym udziałem barwy czerwonej. Bezwzględna różnica barwy wszystkich próbek suszonych była zauważalna „gołym okiem" w odniesieniu do barwy surowca.

Moc mikrofal wpłynęła na nieznaczne ograniczenie skurczu suszarniczego. Zwiększenie mocy z 250 do 300 W ograniczyło skurcz z 73 do 70%. Korzystny efekt powodowało wstępne odwadnianie osmotyczne i wyższa moc mikrofal, które ograniczyły skurcz do 60–67%.

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THE USE OF OM MEAT FROM CARP FOR THE PRODUCTION OF SHAPED PRODUCTS IN FISH PROCESSING®

Wykorzystanie mięsa OM z karpi do produkcji wyrobów formowanych w przetwórstwie rybnym®

Key words: carp processing, meat recovery, fish burgers.

The purpose of the research carried out as part of a several-year project "Development of a program for the use of modern, comprehensive carp processing technologies in aquaculture farms and fish processing plants", was to determine the technological suitability of meat recovered from carp backbones, and from sorter, mechanically damaged carp fillets. The manufacturing processes and recipe composition of burger-type molded products were designed with the addition of meat separated from the carp's backbones (50%). Selected chemical indicators in the raw material were determinedand in the proposed molded articles.

Słowa kluczowe: przetwórstwo karpi, odzysk mięsa, burgery rybne.

Celem przeprowadzonych badań w ramach kilkuletniego projektu „Opracowanie programu wykorzystywania nowoczesnych, kompleksowych technologii przetwarzania karpi w gospodarstwach akwakultury i w zakładach przetwórstwa ryb", było określenie przydatności technologicznej mięsa odzyskanego z kręgosłupów karpi (MOM), a także z wysortowanych, czyli uszkodzonych mechanicznie filetów z karpi. Zaprojektowano procesy wytwarzania i skład recepturowy wyrobów formowanych typu burgery z dodatkiem mięsa OM z karpi (50%). Przeprowadzono oznaczenia wybranych wskaźników chemicznych w surowcu i w proponowanych wyrobach formowanych.

INTRODUCTION

Mechanically separated meat (MOM) from carp backbones, obtained after filleting or flaking, is classified as a product with altered internal structure of the muscle tissue that can be obtained by mechanically or manually separating meat from bone parts, bones and skin [4].

Research carried out at the Sea Fisheries Institute – National Research Institute in Gdynia has shown that the most effective method of recovering meat from carp backbones after filleting or flaking is mechanical separation using drum separators [2].

The use of OM meat is a highly rational and efficient way to use the by-products from filleting or flaking whole fish. Mechanical separation ensures a high recovery of the edible meat. Depending on the type and treatment of the spine, the efficiency of OM meat recovery from the spine after filleting or flaking carp using the Baader 603 drum separator is [2]:

- 50% (raw backbones after filleting),
- 40% (raw spines after flattening),
- 69% (steamed backbones after filleting),
- 58% (steamed spines after flattening).

The yields shown refer to the weight of the raw or steamed meat recovered from the backbones to the weight of the raw or steamed backbones prior to separation.

MATERIALS AND METHODS

The research material used for technological trials was meat from sorted, mechanically damaged, skinless carp fillets and OM meat obtained from the spine after filleting carp. Due to the laboratory nature of the work, OM meat was obtained for testing by manual method. It does not change the fact that the presented technology for the production of molded products based on OM meat can be used in fish processing plants, with the use of mechanical separation of meat from bone parts.

As part of the research, manufacturing processes and the recipe composition of molded products such as fish burgers were designed, and laboratory tests were carried out to produce the proposed product.

In the recovered OM meat from carp and in meat from sorted skinless fillets, as well as in the produced samples of molded products, the following was marked dry matter (weight method), protein content (Kjeldahl method in the Kjeltec

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System apparatus), the total fat content (Soxhlet method) and the content of mineral compounds in the form of ash (weight method after sample mineralization) and table salt (NaCl). All determinations were made in triplicate.

RESULTS AND DISCUSSION

The quality and subsequent technological suitability of OM meat from carp are influenced primarily by the freshness of pre-treated fish. In order to ensure the highest sensory quality of the manufactured molded products, OM meat obtained from the backbones directly from the filleting of whole fish should be used. In the case of later use of OM meat, in order to extend its technological usefulness, it is recommended to store it at a temperature below -18° C for no longer than six months.

Table 1 shows the basic chemical composition of the recovered OM meat from carp and meat from sorted carp fillets without skin. Chemical composition tests were also carried out on raw OM meat immediately after it was recovered from the spine.

Table 1. Basic chemical composition [%] of carp OM meat and skinless carp fillet meat

Tabela 1. Podstawowy skład chemiczny [%] mięsa OM z karpi oraz mięsa z filetów karpi bez skóry

Component [%]	OM meat from carps	Carp meat without skin
Dry weigh	21,17±1,39	25,01±0,43
Fat	2,79±0,12	7,67±0,40
Protein	16,62±0,27	16,96±0,45
Total ash	0,97±0,01	0,90±0,05
NaCl	0,20±0,00	0,20±0,00

Source: The own study

Źródło: Badania własne

The obtained results of the basic chemical composition (Table 1) classify the OM meat from carp at a level similar to the meat from sorted fillets of carp without skin. One should only pay attention to the lower fat content of OM meat from carp compared to meat from sorted carp fillets without skin. This difference is classified as approximately 5%. In conclusion, it can be stated that the composition of OM meat from carp and meat recovered from sorted skinless fillets in the form of molded products creates a product that is a source of valuable and essential for the human body polyunsaturated fatty acids (PUFA), including fatty acids from the n-3 family.

The finished product is fish burgers based on OM meat from carp and meat from sorted carp fillets without skin, mixed in the set proportions (50% / 50%) with additives, breaded, packed in thermoformed multi-layer foil trays and sealed by heat sealing. Then frozen and stored at a temperature below -18° C (Photo 1).

The recipe composition of the product includes: minced meat - 82%, breadcrumbs – 16%, fish seasoning – 1.0%, salt – 0.5%, pepper – 0.5% [1].

Photography 1. Carp burgers.
Fotografia 1. Burgery z karpi.

Source: The own photography

Źródło: Fotografia własne

The process of producing carp meat burgers included:

1. pre-treatment of chilled fish (evisceration, head removal, filleting, skinning),
2. obtaining the appropriate spatial structure of the individual stuffing components in a grinder with a mesh diameter of 3 mm,
3. homogenization of the stuffing mass composition with the least possible damage to the structure of the minced meat OM,
4. giving a specific form, made of multi-ingredient stuffing, fish burgers,
5. breading,
6. hermetic packing,
7. freezing and storage of manufactured products at -18°C.

The proposed range includes fish burgers based on OM meat basic chemical composition was determined from carps and meat from sorted fillets without skin. The obtained results are presented in Table 2.

Table 2. Basic chemical composition [%] of molded products such as fish burgers

Tabela 2. Podstawowy skład chemicznych [%] wyrobów formowanych typu burgery rybne

Component [%]	Molded products with carps
Dry weight	34,35±0,16
Fat	6,93±0,03
Protein	15,62±0,09
NaCl	1,70±0,01

Source: The own study

Źródło: Badania własne

The research results show that carp burgers belong to the group of high-protein, low-fat products. The protein content is around 16%, while the fat content is around 7% in the entire

product. The increase in salt content was due to the addition of this substance as the basic seasoning emphasizing the taste of the product and constituting a preservative.

The produced fish burgers were characterized by an oval shape evenly sized, flat, slightly wavy, battered surface. The color was characteristic of the product, the taste and smell harmonized after frying, typical of the additives used. The texture is firm, juicy, no visible bones. The sensory quality of the product was determined at a high level on the basis of the assessed differentiators and was consistent with the table included in the non-obligatory standard PN-A-86769 [3].

SUMMARY

The assessment of the attractiveness of a product is influenced by the first impression of the consumer, most often caused by the evaluation of the unit packaging. On the other hand, the overall evaluation of the product is influenced by the features of sensory quality, such as taste, smell, color of the product or the texture of the fish. Produced fish burgers based on OM meat from carp and meat from sorted skinless fillets were characterized by a pleasant, essential smell, typical color and intense taste. The texture was defined as juicy, brittle.

In conclusion, it should be said that it was used in the production of burgers from carp, raw materials are a valuable source of nutrients, and their structure is suitable for the production of molded products.

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The developed processes for the production of new products based on carp meat are an innovative concept of their use for food purposes. The production of batches of carp burgers in laboratory conditions makes it possible to implement the developed technology in fish processing plants.

PODSUMOWANIE

Na ocenę atrakcyjności produktu wpływ ma pierwsze wrażenie konsumenta, najczęściej spowodowane oceną opakowania jednostkowego. Natomiast na całościową ocenę produktu wpływają wyróżniki jakości sensorycznej, jak np. smak, zapach, barwa produktu czy tekstura ryby. Wyprodukowane burgery rybne na bazie mięsa OM z karpi oraz mięsa z wysortowanych filetów bez skóry charakteryzowały się przyjemnym, esencjonalnym zapachem, typową barwą oraz intensywnym smakiem. Teksturę określono jako soczystą i kruchą.

Podsumowując, należy stwierdzić, że wykorzystane do produkcji burgerów z karpi surowce są w pełni wartościowym źródłem składników odżywczych, a ich struktura nadaje się do wytworzenia produktów formowanych.

Opracowane procesy wytwarzania nowych produktów na bazie mięsa karpi są innowacyjną koncepcją ich wykorzystania na cele żywnościowe. Wyprodukowanie w warunkach laboratoryjnych partii burgerów z karpi daje możliwość wdrożenia opracowanej technologii w zakładach przetwórstwa rybnego.

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EFFECT OF RIPENING PROCESS AND FAT CONTENT ON CHANGES IN VITAMIN K LEVEL OF CHEESE®

Wpływ procesu dojrzewania i zawartości tłuszczu na zmiany poziomu witaminy K w serach®

Key words: vitamin K_1, vitamin K_2, cheese ripening, HPLC method.

I*n this study, the vitamin K_1 (phylloquinone) and vitamin K_2 (menaquinone) contents of a selected range of cheeses were measured by high-performance liquid chromatography (HPLC) and compared with the fat content, maturation time and origin of the cheeses.*

In our study, the highest vitamin K_2 content was recorded in Gouda (678.12 ng/g), Edam (712.70 ng/g) and Emmentaler (733.10 ng/g) cheeses with comparable levels of vitamin K1 in the analysed products (31.60 ng/g, 34.63 ng/g and 24.35 ng/g, respectively) and fat content (27%, 28% and 30%, respectively), as well as in Gouda cheese with a fat content of 48% after 48 weeks of maturation (756.50 ng/g). The fat content of the cheese was a factor that influenced the vitamin K content, with products with lower fat content having lower total vitamin K content compared to the other products analysed.

Given the reports that poor vitamin K status is one of the risk factors for cardiovascular disease in the absence of conclusive evidence of adverse cardiovascular effects of dairy fats, cheese should be considered as an important dietary component for those concerned about heart health.

Słowa kluczowe: witamina K_1, witamina K_2, dojrzewanie sera, metoda HPLC.

W tym badaniu oznaczono zawartość witaminy K_1 (filochinonu) i witaminy K_2 (menachinonu) w wybranej gamie serów metodą wysokosprawnej chromatografii cieczowej (HPLC) i porównano z zawartością tłuszczu, czasem dojrzewania i pochodzeniem serów.

W badaniach własnych największą zawartość witaminy K_2 odnotowano w serach Gouda (678,12 ng/g), Edam (712,70 ng/g) i Emmentaler (733,10 ng/g) przy porównywalnych poziomach witaminy K_1 w analizowanych produktach (odpowiednio 31,60 ng/g, 34,63 ng/g i 24,35 ng/g) i zawartości tłuszczu (odpowiednio 27%, 28% i 30%), jak również w serze Gouda o zawartości tłuszczu 48% po 48 tygodniach dojrzewania (756.50 ng/g). Zawartość tłuszczu w serze była czynnikiem, który wpływał na zawartość witaminy K, przy czym produkty o niższej zawartości tłuszczu miały niższą całkowitą zawartość witaminy K w porównaniu z pozostałymi analizowanymi produktami.

Biorąc pod uwagę doniesienia, że słaby status witaminy K jest jednym z czynników ryzyka chorób sercowo-naczyniowych przy braku jednoznacznych dowodów na niekorzystny wpływ tłuszczów mlecznych na układ krążenia, sery powinny być traktowane jako ważny składnik diety osób, które dbają o zdrowie serca.

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INTRODUCTION

Dairy products have historically been linked to cardiovascular disease (CVD) risk due to their relatively high saturated fatty acids (SFAs) content [3], which has changed with research from the last decade showing that the association between SFAs and CVD is highly dependent on the type and chain length of SFAs present in a given food, as well as the type of food and other nutrients in it, which is known as the food matrix effect [11, 16, 33, 48]. While some foods high in SFA are associated with negative health consequences, others, such as dairy products, have a positive effect on CVD risk markers in multiple meta-analyses [1, 16]. A systematic review and meta-analysis on individual dairy products showed that the consumption of different dairy products has an individual impact on CVD risk markers [16]. Many of these studies specifically point to cheese as either a positively positive or neutral product in terms of CVD risk, despite its saturated fat content [12]. The specific matrix of cheese and the structure of the protein and other nutrients it contains may partly explain these benefits [19]. Cheese and curd are the most important sources of long-chain menaquinones (MK) in the Western diet [49]. A number of recent reviews highlight the need to understand the interactions between vitamin K_2, food structure and other chemical components to fully elucidate the health effects of the dairy matrix [19, 48].

During the cheese ripening process, a number of transformations take place, including physicochemical transformations (curd formation, whey syneresis, NaCl diffusion), microbiological transformations (autolysis of the sourdough starter, growth of secondary microflora such as non-sourdough *Lactobacillus* bacilli and technologically harmful microflora), and consequently all biochemical reactions take place under the influence of milk native, coagulating and bacterial enzymes [13, 44]. The growth of lactic fermentation bacteria is influenced by free amino acids, low-molecular-weight peptides, nucleotides, glutathione and vitamins present in milk. The opposite effect is exerted by the presence of fatty acids, immunoglobulins, lactoperoxidases, bacteriocins, residues of cleaning and disinfecting agents [13, 14, 44]. Dairy fat is relatively high in SFA content and has been associated with cardiovascular disease, yet evidence exists for either neutral or beneficial effects from cheese consumption, due to the specific food matrix [16, 19].

Vitamin K is an essential bioactive compound required for optimal body function [23]. The term vitamin K, or naphthoquinone, refers to a family of fat-soluble molecules which have a similar structure made by a 2-methyl-1,4-naphthoquinone ring but with different origin and function [24]. Currently, three primary forms are known, which differ in the side chains linked to the 2-methyl-1,4-naphthoquinone ring at the position 3 [21]; namely, these are vitamin K_1 (phylloquinone), vitamin K_2 (menaquinone), and vitamin K_3 (menadione). The main known biological function of vitamin K_1 is played in blood clotting, since it acts as a cofactor for the enzymatic conversion of glutamic acid (Glu) residues to gamma-carboxyglutamic acid (Gla) in vitamin K-dependent proteins (VKDPs), through vitamin K-dependent gamma-glutamyl carboxylase, localized in the endoplasmic reticulum of the cells of all mammalian tissues [10, 42], and for the conversion of protein-bound glutamate in carboxy-glutamate, needed for II, VII, IX, and X coagulation cascade factors, and for the natural anticoagulants proteins S and C [35, 40]. The source of vitamin K_1 is mainly represented by leafy or flowering vegetables (spinach, lettuce, broccoli, cabbage, Brussels sprouts, turnip greens), but chickpeas, peas, soya, green tea, eggs, pork, and beef liver also contain vitamin K_1 [37, 39, 54, 55]. Vitamin K_2 is synthetized essentially by intestinal microbiota and is denoted as menaquinone (MK); according to the length of the isoprene chain attached to the methylated naphthoquinone ring, several different forms could be identified, as numbered from 4 to 13 [29, 31]. Vitamin K_2 MK-4 is obtained from the conversion of phylloquinone or menadione and is found mainly in meat and animal by-products such as eggs, cow's milk and yoghurt [7, 23, 49]. On the other hand, K_2 MK-7 is a long-chain form also produced by intestinal bacteria and it is found in fermented food, such as cheese and soya [15, 49, 51]. The K_2 MK-4 and K_2 MK-7 are two of the most common menaquinones in the human diet, along with K_2 MK-8, K_2 MK-9, and K_2 MK-10 [7]. Considerable variability in values was also reported across cheese types and in different studies. Potential reasons include different starter cultures used, fermentation conditions, the fat content and milk source [57]. The difference in structure between K_1 and K_2 can be seen in their different rates of absorption, tissue distribution and bioavailability. Despite the differences in structure, both act as a cofactor for the enzyme gamma-glutamylcarboxylase, involving both hepatic and extrahepatic activity. Only the carboxylated proteins are active and promote the health profile of haemostasis [23]. Vitamin K_3, also known as menadione, was formerly considered to be a synthetic form of vitamin K. However, it has been demonstrated that vitamin K_3 could also originate in the intestine as the intermediate product of oral vitamin K_1 conversion to vitamin K_2, namely MK-4 [9, 56]. Vitamin K absorption occurs in different tracts of the intestine: vitamin K_1 is absorbed in the ileum; vitamins K_2 in the colonic portions. Efficient biliary and pancreatic function is essential for its adequate absorption [5]. Vitamin K molecules are incorporated into chylomicrons and then released to very low-density lipoprotein (VLDL) and lowdensity lipoprotein (LDL), with subsequent release to tissues. Vitamin K_1 and K_2 should be continually synthetized and supplied by intestinal bacteria, due to their relatively short half-life (17 h) [5]. The intake recommendations for vitamin K by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) are 65 µg /day for men and 55 µg /day for women, based on a calculated requirement of 1 µg /day/kg body weight [5].

Chronic kidney disease (CKD) is commonly associated with vitamin K deficiency. CKD is characterized by a secondary hyperparathyroidism: the progressive reduction of GFR leads to an increase of serum phosphate levels, a progressive hypocalcemia, and augmented fibroblast growth factor 23 (FGF-23) production [5]. Meanwhile, the reduced activity of the enzyme 1 alpha-hydroxylase induces a decrease of 1,25-dihydroxyvitamin D_3, further determining a parathyroid hormone (PTH) rising. High serum phosphate and FGF-23 levels also stimulate an increase of sclerostin production by osteocytes [5]. Sclerostin and FGF-23 are involved in the progression of vascular calcification (VC). Some of the serious complications of CKD are represented by cardiovascular disease (CVD) and skeletal fragility with

an increased risk of morbidity and mortality [5]. A complex pathogenetic link between hormonal and ionic disturbances, bone tissue and metabolism alterations, and vascular calcification (VC) exists and has been defined as chronic kidney disease-mineral and bone disorder (CKD-MBD). Poor vitamin K status seems to have a key role in the progression of CKD, but also in the onset and advance of both bone and cardiovascular complications [5, 58].

Vitamin K plays different roles, including in activating vitamin K-dependent proteins (VKDPs) and in modulating bone metabolism and contributing to the inhibition of VC [5]. Vitamin K is considered a possible marker of kidney, CV and bone damage in the CKD population and its potential use to promote health in this clinical setting is being investigated. Treatment strategies for osteoporosis and CV disease associated with CKD should include vitamin K supplementation [5]. According to a Scientific Opinion provided by the European Food Safety Authority (EFSA), the vitamin K dietary reference values (DRVs) for the European population are estimated to be 1 µg/kg body weight per day of phylloquinone, which corresponds to an amount of 70 µg phylloquinone/day for adults, both women and men. Since data about menaquinones absorption, function and content in the body or organs are limited, EFSA released adequate intake recommendations for phylloquinone only [17]. This amount of phylloquinone could play a role in reduction of CVD progression, especially in Arterial Hypertension acting on arterial calcification activity and arterial stiffening [4, 41, 46]. Intravascular thrombosis and pulmonary fibrosis in COVID-19 patients with pneumonia are significantly associated with disease severity [45]. Vitamin K is known to balance clotting mechanisms and prevent calcification and fibrosis of extrahepatic soft tissues. The paper by Souparnika et al [45] presented reports collected from WHO, PubMed, Scopus and Clinical Trial Registry databases searched using relevant keywords. Among the original articles were the few observational studies that showed reduced levels of vitamin K as well as activated extrahepatic vitamin K-dependent proteins (VKDP) in COVID-19 patients compared to healthy controls [28, 45]. Chronic treatment with vitamin K antagonists did not reduce the risk of in-hospital death. A docking study was conducted using Swiss docking and showed a significant interaction between menaquinone and SARS-CoV-2 major protease (SARS-CoV-2 Mpro). The studies presented show that vitamin K deficiency in COVID-19 may be caused by overuse of antagonists or faulty ingestion or absorption [45]. This causes an imbalance in the normal coagulation-anticoagulation mechanism by diverting available vitamin K to the liver, thereby causing a deficiency of the same in extrahepatic tissues, ultimately leading to thrombosis. This also prevents carboxylation and activation of extrahepatic VKDP required to prevent soft tissue calcification, leading to pulmonary fibrosis. The authors concluded that vitamin K supplementation should be considered as a potentially modifiable risk factor in severe COVID-19. Randomized controlled trials are recommended to provide more conclusive evidence in this regard [45].

Alzheimer's disease is defined as a progressive brain disorder that affects memory, thinking and language skills and the ability to perform the simplest of tasks [2, 27]. In a study by Huy et al. [26], serum levels of vitamin K_2 were reduced in Alzheimer's disease (AD) patients. Vitamin K_2 has the potential to slow the progression of AD and contribute to its prevention. Hadipour et al. [22] investigated the effects of vitamin K_2 at concentrations ranging from 5 to 200 µM in rat pheochromocytoma PC-12 cells to provide protection against hydrogen peroxide and β-amyloid-induced toxicity. In Alzheimer's disease, β-amyloid led to neuronal death through direct toxicity and by promoting apoptosis, which is prevented by vitamin K_2 [22]. Thus, the study showed, among other things, that pretreatment with vitamin K_2 decreased apoptosis signalling proteins (β-amyloid, caspase 3, etc.), attenuated ROS levels and increased glutathione levels. The study confirmed the protective role of vitamin K_2 mediated by its antioxidant and anti-apoptotic properties [22].

With the growing interest in the health benefits of long-chain menaquinones [50], it is important to have up-to-date data on vitamin K concentrations in the human diet. In the present study, we focused on the vitamin K content of different forms of cheese. We compared the vitamin K content of the most popular Dutch cheese taking into account the influence of ripening period and fat content, and also examined popular cheeses available in Poland and cheeses from different geographical areas in Europe and their relative vitamin K content. The data obtained can be used to calculate vitamin K intake from food frequency questionnaires in population-based studies.

MATERIALS AND METHODS

Reagents and standards

All solvents were of high purity: n-hexane and 2-propanol for vitamin extraction and acetonitrile, methanol and orthophosphoric acid for chromatographic analyses were purchased from Merck Life Science Sp.z.o.o. (Poland). Certified analytical standards for vitamin K_1 (Supelco, ≥99.0% purity) and vitamin K_2 (Supelco, 99.9% purity) were purchased from Sigma Aldrich. Vitamins K_1 and K_2 were identified by retention time and quantification was performed using the standard curve method. For this purpose, six dilutions of the analytical standard of vitamin K_1 and K_2 were prepared in acetonitrile with concentrations ranging from 5.15 to 250 µg/ml.

Origin of cheese samples for study

Most of the products mentioned in this paper were purchased in Polish supermarkets (industrial Gouda, Edam and Emmentaler cheeses) and specialty grocery stores (foreign cheeses), as well as from a Dutch manufacturer (Gouda cheese after different ripering time) for their analysis for vitamin K determination. Popular cheeses on the Polish market, differing in fat content, were selected. These cheeses were compared with those from different European countries (Greek, Italian and French cheeses). The fat content reported in this study refers to the content reported on the labels of the products selected for the study (Table 1). Immediately after transporting the samples from the place of purchase to the testing laboratory, all samples were stored frozen at -20□, protected from light and oxygen to prevent loss of vitamin K during the storage period until analysis.

Table 1. Study material
Tabela 1. Materiał badawczy

Sample description	Primary samples, n	Purchase location/Country of origin
Gouda cheese	2	Polish supermarkets /Poland
Edam cheese	2	Polish supermarkets /Poland
Emmentaler cheese	2	Polish supermarkets /Poland
Gouda cheese, 8 weeks of ripening	4	Dutch manufacturer / The Netherlands
Gouda cheese, 48 weeks of ripening	4	Dutch manufacturer / The Netherlands
Feta cheese	2	Polish specialty grocery stores/ Greece
Mozzarella cheese	2	Polish specialty grocery stores/ Italy
Grana Padano cheese	2	Polish specialty grocery stores/ Italy
Camembert cheese	2	Polish specialty grocery stores/ France

Source: Own study
Źródło: Opracowanie własne

Stages of the production of Dutch gouda cheese

The gouda cheese used in the study was produced from milk from Holstein-Friesian cows in their third and fourth lactation periods, kept at the Farm„De Bitenhoeve" located in the village of Haaften, the Netherlands. The average annual yield of cows was 12 000 kg of milk, while the daily average was 34 liters of milk, with 4.2% of fat and 3.3% of protein. The production of gouda cheese used raw milk obtained from evening milking using a Lely Astronaut automatic milking robot, which was pasteurized at 72°C for 15 seconds, then pumped from the pasteurizer to the cheese boiler and cooled to 32°C. After reaching the required temperature, deep-frozen concentrated starter cultures were added to the milk. After the initial fermentation period, the enzyme that causes coagulation of milk- rennet and calcium chloride were added to the processed milk. The milk was then subjected to thorough mixing. Subsequently, sodium (V) nitrate ($NaNO_3$) was added to the raw material. The milk thus treated was left until curdling (about 35 minutes). Once the curd was formed, it was evaluated using a cheese knife to see if the curd was ready for slicing. The curd was then sliced into 3-6 mm grains for about 10 min. After slicing the curd and pre-drying the resulting grains, the excess whey that had formed, in the amount of 30-40%, was drained off. The next step was grain drying, which involved removing excess whey from the grain by stirring the curd with warm process water. This was followed by reheating the grain to 38°C and re-drying it by intense stirring. After that, a grain compression test was carried out, namely, it was checked whether the grain was dry and did not stick together. After this step, the cheese grains were transferred to their respective molds and were subjected to turning after about 15 minutes of molding. The 10 kg cheeses formed in this way were pressed for 3 h. After this procedure, they were transferred to brine with a concentration of 22% and left for about 24 h. After this process, the cheeses were placed on appropriately prepared shelves and re-dried for another 24 h. In the next stage, the cheeses were covered with paraffin and turned daily for several consecutive days. After this time, the cheeses were transferred to a ripening room with 85% humidity and 12°C, where they were subjected to the ripening process. Care of the cheeses during ripening consisted of turning them (once a week) and wiping their surfaces and shelves with a chlorine solution. In order to obtain the appropriate sensory qualities, short- and long-matured gouda cheeses were aged in the ripening room for 8 weeks and 48 weeks, respectively. After reaching the required maturity, a total of 8 samples (4 of each type of cheese), with an average weight of 240 g, were taken from 4 pieces of short-matured gouda cheese and 4 pieces of long-matured gouda cheese. The cheese samples prepared in this way were then vacuum-packed (Figure 1) and transported in a portable isothermal container at a temperature of 4±1°C to the laboratory for quantitative and qualitative analyses including analysis of vitamin K content (Figure 2). The tests were carried out within the shelf life declared by the manufacturer.

Fig. 1. Samples of long and short matured Gouda cheese – vacuum packed.
Rys. 1. Próbki sera Gouda długo- i krótkodojrzewającego – pakowane próżniowo.
Source: (photo. J. Remiszewska)
Źródło: (fot. J. Remiszewska)

Extraction of vitamins from cheese samples

Sample preparation followed the procedure described by Schurgers and Vermeer [39].

The cheese sample was crushed, then an analytical portion of 1 g was taken, followed by the addition of 4 mL of 2-propanol and 2 mL of distilled water. After homogenisation, the mixture was heated to 60°C and then extracted with 8 mL of hexane. The hexane was evaporated and the sample was then re-dissolved in 2 mL of hexane. After prepurification over silica Sep-Pak cartridges, to allow for the final determination of vitamin K, the procedure was modified by replacing the solvent with acetonitrile and filtering through a 0.45 μm membrane filter immediately before analysis by high-performance liquid chromatography (HPLC) after prior evaporation of the solvent under a stream of nitrogen [47].

Analysis of HPLC

All analyses were performed on a Shimadzu HPLC system equipped with a photodiode array spectrophotometric detector (DAD) (Kyoto, Japan). Data were processed using LCSolution software. Chromatography was carried out at

Fig. 2. Samples of long (a) and short (b) matured Gouda cheese - cross-sectional area.

Rys. 2. Próbki sera Gouda długo- (a) i krótkodojrzewającego (b) – powierzchnia w przekroju.

Source: (photo. J. Remiszewska)

Źródło: (fot. J. Remiszewska)

25°C. Sample separation was performed on a Phenomenex Kinetex C18 column (150 x 2.1 mm) packed with 1.7 µm particles. The chromatographic conditions were as follows [43]: in gradient elution mode, a mixture of water and methanol (1:1, v/v) acidified to pH 3.0 with orthophosphoric acid (A) and acetonitrile (B) was used as the mobile phase, the eluent flow rate was 0.8 mL. The sample injection volume was 20 µL. Vitamins K_1 and K_2 were recorded in the same run. All data given are means of duplicate samples that were analyzed separately.

The limits of detection (LOD) and limits of quantification (LOQ) were checked experimentally using an established standard curve for a series of standard solutions [32].

DATA ANALYSIS

All analyses were conducted in triplicate and the data expressed as mean ± standard deviation.

RESULTS AND DISCUTION

Analyses of selected cheese samples for vitamin K determination were preceded using an HPLC/UV-DAD system (270 nm). To improve selectivity and ensure high accuracy, the evaluation focused on linearity, LOD and LOQ as validation parameters. Six different analytical standard solutions of vitamin K_1 and K_2 were analysed three times (each separately) by chromatography and regression equations were obtained (Table 2). The linearity of the detector response was established using the squared correlation coefficients (R^2) determined for the calibration curves and, at the same time, the regression line was shown to be linear over the range of all concentrations tested (Table 2). The limit of detection (LOD) and limit of quantification (LOQ) were determined according to the formulae: $3.3\times\sigma$ / S, and $10\times\sigma$ / S, respectively [32], where σ is the standard deviation of the response/signal and S is the slope of the calibration curve. In our study, the LOD and LOQ values for vitamins K_1 and K_2, respectively, are presented in Table 2.

Cheese is an important source of this microbiologically synthesised vitamin [52, 53]. Several studies have reported high levels of total and individual MKs in cheese and fermented dairy [20, 25, 30, 36, 38, 49, 53].

Selected cheeses commercially available in Poland with different fat contents and cheeses produced in the Netherlands with different ripening times were analysed for vitamin K_1 and vitamin K_2 content (Table 3). Dairy products are a relatively low source of K_1, but a good source of K_2, which was also confirmed in the conducted study. The presence of both types of vitamin K was found in all analysed cheeses, with lower vitamin K_2 content (468.20 ng/g) determined in the young cheese samples with a shorter ripening time than in the older cheese samples (756.50 ng/g), similar to the study by Vermeer et al. [49]. A study by Veermer et al. [49] found that in the most popular full-fat cheese (Gouda 13 weeks, 50% fat in dry matter), the

Table 2. Values of correlation coefficient, recovery, LOD and LOQ and regression formulas for K1 and K2 vitamins

Tabela 2. Wartości współczynnika korelacji, odzysku, LOD i LOQ oraz równania regresji dla witamin K_1 i K_2

Compound	Calibration Curve	Correlation coefficient (R^2)	Recovery (%)	LOD (µg/ml)	LOQ (µg/ml)
K_1	y = 1.4831x − 0.1171	0.9987	85.50	0.25	1.94
K_2	y = 0.4115x + 0.3638	0.9998	91.30	0.30	2.15

Source: The own study

Source: Badania własne

content of menaquinones was around 650 ng/g, while in the very young cheese (Gouda 4 weeks) it was significantly lower (473 ng/g). No significant differences were found between freshly cut cheeses and vacuum-packed products. Most likely, this difference is mainly due to increased levels of long-chain menaquinones in more mature cheeses, which come from bacterial growth during fermentation. The main factors influencing vitamin K_2 formation are the bacterial strains used and the scalding temperature, which has a direct influence on the bacterial species [53]. Mesophilic lactic acid bacteria such as *Lactococcus* and *Leuconostoc* species are known for their menaquinone formation potential. Thermophilic bacterial strains as well as high scalding temperatures lead to reduced amounts of menaquinones. In Emmentaler, 'eye'-forming propionic acid bacteria are responsible for the formation of tetrahydromenachinon-9 [MK-9(H_4)], which is typical of this variety [53]. The contribution of selected cheese types to vitamin K_2 supply can be very significant. The large differences between varieties can largely be explained by the cultures and processing procedures used, especially for the stages that have a large impact on the growth of the cultures, where the temperature chosen determines the survival of the different bacterial species [53]. Differences within a given variety, both between seasons (winter/summer) and between different cheese producers, can be very large, but cannot be reconstructed with the data collected. Further detailed research is required for this purpose [53].

Table 3. K_1 and K_2 content of cheeses purchased in Poland and the Netherlands

Tabela 3. Zawartość K_1 i K_2 w serach zakupionych w Polsce i w Holandii

Sample description	Fat content [g/100 g]	K_1 [ng/g]	K_2 [ng/g]
Gouda cheese	27	31.60±1.55	678.12±3.51
Edam cheese	28	34.63±1.77	712.70±4.10
Emmentaler cheese	30	24.35±1.80	733.10±2.89
Gouda cheese, 8 weeks of ripening	48	36.71±1.82	468.20±3.91
Gouda cheese, 48 weeks of ripening	48	39.45±1.46	756.50±5.40
Feta cheese	21	14.50±0.38	114.80±1.60
Mozzarella cheese	22	15.24±0.81	60.50±2.21
Grana Padano cheese	29	20.64±1.15	2.94±0.56
Camembert cheese	24	48.15±2.20	121.25±1.76

Concentrations are presented as the mean of duplicate analyses ± standard deviation with a variation coefficient < 15%.

Source: The own study

Source: Badania własne

The study Bertola at al. [6] analysed the effects of ripening temperature, type of packaging film and storage period before packaging on the degree of proteolysis and texture of Gouda cheese in order to determine the optimal ripening conditions. Gouda cheeses from a local plant were subjected to different ripening conditions. Only ripening time and temperature had a significant effect on water content, non-protein nitrogen concentration and rheological parameters. The results indicated that the texture characteristics of Gouda cheese ripened in low gas permeability plastic films were similar to those of traditionally ripened Gouda cheese. Texture development was accelerated by increasing the storage temperature [6].

When comparing cheeses from different countries in the study, significant differences in vitamin K_2 content were observed (Table 3). In particular, cheeses produced in Mediterranean countries (feta, mozzarella) were characterised by low vitamin K_2 content (114.80 ng/g and 60.50 ng/g, respectively), and Grana Padano cheese had negligible levels of K_2 compared to the products tested (2.94 ng/g). French Camembert cheese was characterised by higher levels of vitamin K_1 (48.15 ng/g) and K_2 (121.25 ng/g) compared to the other cheeses tested. Vermeer et al. [49] conducted a study of vitamin K_2 content in cheese and other foods. In a study by Vermeer et al. [49] the highest vitamin K_2 content in French cheeses was measured in Münster cheese (made from raw, unpasteurised milk) with 801 ng/g of total vitamin K_2. The two British cheeses measured (Cheddar and Stilton) contained medium to high amounts of vitamin K_2 (235 ng/g and 494 ng/g, respectively), as did the Swiss cheeses, Emmental (433 ng/g) and Raclette (323 ng/g), while Gruyère contained low amounts (65.30 ng/g). The study authors highlight the fact that the Swiss Emmental cheese contained almost exclusively K_2 MK-10, which is produced by the probiotic *Propionibacterium freudenreichii*, which is also thought to be responsible for the large holes and typical taste of this cheese. In contrast, the two Norwegian cheeses measured, Norvegia and Gamalost, contained relatively high amounts of vitamin K_2, 415 ng/g and 542 ng/g respectively Vermeer et al. [49]. Based on the global state of K_2 deficiency and the strong evidence indicating that it is a cardio-protective nutrient, the researchers recommend cheese as a component of a heart-healthy diet due to its vitamin K_2 content. However, the actual content of menaquinones varies considerably and depends on the type of cheese, maturation time, fat content and the geographical area where the cheeses are produced Vermeer et al. [49]. The results of the study showed that the total amount of K_2 in cheese ranged from 3 to 802 ng/g. Therefore, the researchers' recommendation for K_2 is in the range of 180–360 µg/day [49]. In the last decade, more and more attention has been paid to the health benefits of vitamin K_2, especially the long-chain menaquinones K_2 MK-6 through K_2 MK-9. This research complements important population-based studies that have shown that food-derived vitamin K (including cheese) improves long-term cardiovascular health outcomes by more specifically providing a spectrum of long-chain menaquinones, from menaquinones 5 to 10, while menaquinones 6, 7 and 9 are among the most bioactive, representing the best dietary source of menaquinones in Western countries [7, 8]. Nevertheless, it is important to be aware that the majority of the population cannot consume enough of these daily to obtain optimal amounts of vitamin K_2, nor is cheese a practical source for extracting menaquinones [7, 8, 19].

Recent study in the USA found that vitamin K_2 was present in higher amounts in the higher-fat dairy and yoghurt products tested compared to lower-fat and non-fat products [20, 57].

Vitamin K_2 is found in much higher amounts in cheese, but noteworthy is the significant variation in the same cheese varieties from different studies. For example, Fu et al. [20] reported values of 281 µg/100 g for total vitamin K in cheddar cheese, while Vermeer et al. [49] reported a much lower value for total vitamin K (25.66 µg/ 100 g) in the cheddar cheese analysed in their study. Values reported for blue cheeses are similarly variable, with total vitamin K values between 5.05 and 37.2 µg/ 100 g reported by Manoury et al. [36] from some French blue cheeses, while US blue cheeses ranged from 399.30 to 480.70 µg/ 100 g [20]. As MK content is mainly derived from bacteria, some specific fermentation factors in the cheese may influence these levels. Starter cultures are one potential influencing factor and are of particular importance in cheese production. Lactic acid bacteria (LAB) are commonly used as primary starter cultures in cheese production [18]. This is confirmed by several studies reporting high levels of total vitamin K_2 in Gouda cheese from the Netherlands (47.30-72.90 µg/ 100 g), Edam cheese from the Netherlands (64.70 µg/ 100 g), cheddar cheese from the USA (266.80–290.40 µg/ 100 g) and 4% fat Cottage cheese from the USA (49.10–55.70 µg/ 100 g) [20, 49]. Thermophilic fermented cheeses show much lower levels of MK compared to cheeses fermented by mesophilic bacteria. [57]. Manoury et al. [36] found no detectable levels of total vitamin K_2 in Comté cheese from France and Mozzarella cheese from Germany. Other studies have reported relatively low levels of total vitamin K_2 in Comté cheese (11.50–13.60 µg/ 100 g) and Mozzarella cheese (6.22 µg/ 100 g), and the main MK recorded in these cheeses is actually K_2 MK-4, which is not bacterially synthesised [25, 49]. Hojo et al. [25], Vermeer et al. [49] and Walther et al. [53] reported significantly higher levels of total vitamin K_2 in Emmental cheese of 30.80–39.50 µg/ 100 g, 43.30 µg/ 100 g and 13.30–60.40 µg/100 g, respectively, compared to studies by Koivu-Tikkanen et al [30] and Manoury et al [36], who found that these were relatively low at 5.13–6.61 µg/ 100 g and only 3.19–5.12 µg/ 100 g, respectively. Temperature, carbon source, aeration and metabolic mode were found to have an effect on the growth of lactic acid bacterial strains and MK content [34]. Therefore, ripening time alone cannot predict levels of K_2 vitamin, and further research is also needed in this area to clarify the optimal conditions for different fermented products [57]. In our study, high amounts of total vitamin K_2 were reported in Gouda (678.12 ng/g), Edam (712.70 ng/g) and Emmentaler (733.10 ng/g) cheeses with comparable levels of vitamin K_1 in these products (respectively, 31.60 ng/g, 34.63 ng/g and 24.35 ng/g) with the fat content of the analysed products (respectively, 27%, 28% and 30%). The fat content of cheese is another factor that may affect vitamin K content, with lower-fat products such as reduced-fat quark, cheddar cheese and cream having lower total vitamin K content compared to full-fat cheese or cream [20]. This may be due to the fact that vitamin K is a fat-soluble vitamin. Walther et al. [53] observed a positive correlation between fat content and K_2 MK-4 in Swiss-type cheese. However, they also noted a negative correlation between fat content and K_2 MK-6, K_2 MK-7, K_2 MK-8 and K_2 MK-9, and more in-depth studies are needed to clarify these reports.

Deadly diseases such as cardiovascular diseases or cancer are increasing day by day. Undoubtedly, at such a time, it is very important to identify which foods contain substances that support the body, and at the same time are beneficial and natural for health, such as vitamin K. Cheese, which is available to the Polish consumer and consumers in European countries, can be a good source of vitamin K_2 and a dietary ingredient so crucial in the fight against many dangerous diseases.

CONCLUSION

This study provided data on vitamin K levels in cheeses available in Poland and other European countries. All samples contained both forms of vitamin K. This study has contributed to a growing number of reports indicating that forms of vitamin K and their concentrations in foods, including cheese, may vary according to ripening time and regional differences, as these dictate not only the type of cheese, but also the fat and nutrient content. A larger project would be warranted to develop a comprehensive analytical database of food composition in the context of the occurrence of vitamin K (PKs and MKs) in a broad spectrum of foods commonly consumed in EU countries so that vitamin K intake can be estimated in a given population and the knowledge on the subject has become comprehensive.

PODSUMOWANIE

Badanie dostarczyło danych dotyczących poziomu witaminy K w serach dostępnych w Polsce i innych państwach europejskich. Wszystkie próbki zawierały obie formy witaminy K. Badanie to przyczyniło się do rosnącej liczby doniesień wskazujących, że formy witaminy K i ich stężenia w żywności, w tym w serze, mogą się różnić czasem dojrzewania i różnicami regionalnymi, gdyż dyktują one nie tylko rodzaj sera, ale także zawartość tłuszczu i składników odżywczych. Zasadny byłby większy projekt w celu rozwinięcia kompleksowej analitycznej bazy danych składu żywności w kontekście występowania witaminy K (PK i MK) w szerokim spektrum żywności powszechnie spożywanej w krajach UE tak, aby spożycie witaminy K mogło być oszacowane w danej populacji i wiedza na ten temat stała się kompleksowa.

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PORÓWNANIE METOD MODELOWANIA MATEMATYCZNEGO KSZTAŁTU SKORUPY JAJ KURZYCH®

Comparison of methods for mathematical modeling of the shell shape of hen's eggs®

Słowa kluczowe: jaja kurze, powierzchnia skorupy, metody modelowania.

W artykule przedstawiono dwie metody matematycznego modelowania powierzchni kształtu skorupy jaja kurzego. Bryłę 3D wg Mieszkalskiego złożono z powierzchni zewnętrznej skorupy, stosując krzywą Beziera, którą obracano według osi Z układu współrzędnych. Model matematyczny bryły 3D opiera się na długości osi długiej i krótkiej jaja oraz na współrzędnych punktów węzłowych i kontrolnych. Wg Prestona podłużny kontur jaja (model 2D) można opisać za pomocą czterech parametrów. Kontur zdefiniowany za pomocą metody Prestona pozwolił na określenie objętości i porównanie jej do wyników opracowań Stonehouse-a i Coulson-a. Wizualizacje modeli 2D i 3D wykonano w programie Mathcad. W proponowanych metodach nie uwzględniono wewnętrznej struktury jaja kurzego.

Key words: hen's eggs, shell surface, modelling method.

The article shows two methods for mathematically modelling the surface of the shell of a hen's egg. The 3D block of Mieszkalski was composed from the outside of the shell using the Bezier curve, which was rotated according to the Z-axis of the coordinate system. The mathematical model of the 3D body is based on the length of the long and short axis of the egg and the coordinates of the nodes and control points. According to Preston, the elongated contour of the egg (model 2D) can be described with four parameters. The contour defined by the Preston method made it possible to determine the volume and compare it with the results of Stonehouse and Coulson. The visualizations of the 2D and 3D models were created with Mathcad. The methods proposed do not take into account the internal structure of the hen's egg.

WSTĘP

Światowa produkcja jaj kurzych od lat wykazuje tendencję wzrostową [5]. Polska jest jednym z największych eksporterów tego asortymentu w Unii Europejskiej [3]. Podaż jaj z produkcji krajowej znacząco przewyższa zapotrzebowanie rynku wewnętrznego.

W dalszym ciągu, pomimo rozwoju technologii, wyzwaniem są metody selekcji jaj przeznaczonych do inkubacji [4]. Wsparcie tego procesu mogą stanowić metody obliczeniowe i graficzne.

Z geometrycznego punktu widzenia jajo ptasie jako ciało biologiczne jest ułożone prosto. Jednak specyfika kształtów jaj u różnych gatunków ptaków generuje pewne trudności w trakcie ich opisu i klasyfikacji. W warunkach terenowych jest możliwość wykonania tylko dwóch pomiarów z jaja: średnicy i długości. Z pewnością nie jest to wystarczające do pełnego opisu kształtu. Dodatkowe parametry można pobrać albo z rzutu płaskiego (plany, zdjęcia) lub za pomocą specjalnie skonstruowanych urządzeń [7].

Alimardani i in. porównali dwie metody modelowania wielkości jaj, wykorzystując algorytm przetwarzania obrazu, który oblicza mniejszą i większą średnicę jajka. W pierwszej metodzie zaproponowano model matematyczny. W drugiej zastosowano technikę sztucznej sieci neuronowej (ANN – Artificial Neural Networks) do oszacowania objętości jaja. Objętość jaj wyznaczona tymi metodami została porównana statystycznie z wartościami rzeczywistymi. Wyniki wskazały, że modelowanie matematyczne dało bardziej satysfakcjonujące rezultaty [9].

W 2009 roku Buchar i in. przedstawili wyznaczanie geometrii skorupy jaja, wykorzystujące i analizujące cyfrowy obraz jaja oraz techniki detekcji krawędzi. Wykryte punkty na konturze jaja zostały dopasowane za pomocą szeregu Fouriera. Uzyskane równania opisujące profil jaja posłużyły

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do obliczenia objętości, powierzchni i promienia krzywizny jaja z dużo większą dokładnością w porównaniu z wcześniej publikowanymi podejściami. Wykazano, że promienie krzywizny w punktach krytycznych profilu jaja (ostry koniec, tępy koniec i wartość maksymalna) są niezależne od indeksu kształtu jaja. Pole powierzchni jaja jest jednowartościową funkcją objętości jaja. Dzięki temu istnieje możliwość dokładnego oszacowania tej wielkości na podstawie doświadczalnie stwierdzonej wartości objętości jaja. Ocenę kształtu jaja i jego dalszych parametrów na podstawie cyfrowego obrazu jaja można przeprowadzić w bardzo krótkim czasie (rzędu sekund) przy pomocy np. programu MATLAB. Procedura ta może więc poprawić efektywność obliczeń, co jest bardzo przydatne w przemyśle drobiarskim i/lub badaniach biologicznych oraz rozszerza i udoskonala wcześniej publikowane metody [1].

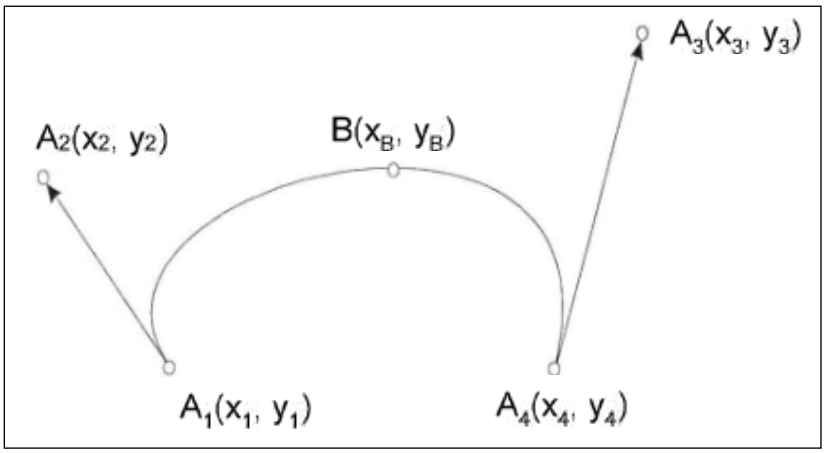
Celem artykułu jest przedstawienie dwóch metod matematycznego modelowania kształtu skorupy jaj kurzych oraz porównanie wyników z trzech wzorów na ich objętość.

MATERIAŁY I METODY

Materiałem badawczym było jajo kurze o następujących wymiarach: długość [a] – 65mm, średnica max [b] – 46mm, średnica min [c] – 46mm. Wybrane jajko było czyste, średniej wielkości, o gładkiej skorupce, bez uszkodzeń mechanicznych. Jajko zmierzono suwmiarką, następnie sfotografowano i wczytano do programu Inkscape. Obraz przeskalowano i wyznaczono kontury poprzecznych przekrojów jaja. Na podstawie krzywych Beziera wyznaczono współrzędne punktów kontrolnych i węzłowych. Za pomocą programu Mathcad zwizualizowano modele 2D i 3D według poniżej przedstawionego schematu.

Wymiary: długość a, średnica max b, średnica min c:

$$[a\ b\ c]=[65\ 46\ 46] \quad (1)$$



Rys. 1. Segment kubiczny krzywej Beziera: x1, y1, z1, x4, y4, z4 - współrzędne punktów węzłowych; x2, y2, z2, x3, y3, z3 – współrzędne punktów kontrolnych.

Fig. 1. Cubic segment of the Bezier curve: x1, y1, z1, x4, y4, z4 – coordinates of the nodes; x2, y2, z2, x3, y3, z3 – coordinates of the control points.

Źródło: Opracowanie własne na podstawie [6]

Saurce: Own study based on [6]

Współrzędne punktów węzłowych i kontrolnych dla krzywej wyznaczono wg rysunku 1. W macierzy (2) zamiast wymiaru z osi Y, wykorzystano wymiar z osi Z.

$$\begin{bmatrix} x_1 & z_1 \\ x_2 & z_2 \\ x_3 & z_3 \\ x_4 & z_4 \end{bmatrix} = \begin{bmatrix} 0 & a \\ 24.38 & 65 \\ 35.4 & 1.19 \\ 0 & 0 \end{bmatrix} \quad (2)$$

Na podstawie powyższych współrzędnych, wyznaczono równania parametryczne krzywej Béziera opisujące kontury jaja, które mają następującą postać:

$$x_i = \left(x_1 \times \left(1-\frac{i}{N}\right)^3 + x_2 \times 3 \times \frac{i}{N} \times \left(1-\frac{i}{N}\right)^2 + x_3 \times 3 \times \left(\frac{i}{N}\right)^2 \times \left(1-\frac{i}{N}\right) + x_4 \times \left(\frac{i}{N}\right)^3\right) \quad (3)$$

$$z_i = \left(z_1 \times \left(1-\frac{i}{N}\right)^3 + z_2 \times 3 \times \frac{i}{N} \times \left(1-\frac{i}{N}\right)^2 + z_3 \times 3 \times \left(\frac{i}{N}\right)^2 \times \left(1-\frac{i}{N}\right) + z_4 \times \left(\frac{i}{N}\right)^3\right) \quad (4)$$

gdzie: i – liczba wierszy w macierzy;
N – rozmiar macierzy.

Kąt obrotu krzywej Béziera obliczono na podstawie wzoru:

$$s_j = \frac{2 \times \pi \times j}{N} \quad (5)$$

gdzie: j – liczba kolumn w macierzy.

W celu uzyskania powierzchni 3D jaja, krzywe Beziera obrócono względem osi Z wykorzystując poniższe równania (6), (7), (8):

$$Xa_{i,j} = x_i \times sin(s_j) \quad (6)$$

$$Ya_{i,j} = x_i \times cos(s_j) \quad (7)$$

$$Za_{i,j} = z_i \quad (8)$$

Poniżej przedstawiono wyskalowane macierzowe równania współrzędnych X, Y, Z opisujące kształt zewnętrzy skorupy (9), (10), (11).

$$X = \frac{b}{\max(Xa)+(-1\times\min(Xa))} \times Xa \quad (9)$$

$$Y = \frac{c}{\max(Ya)+(-1\times\min(Ya))} \times Ya \quad (10)$$

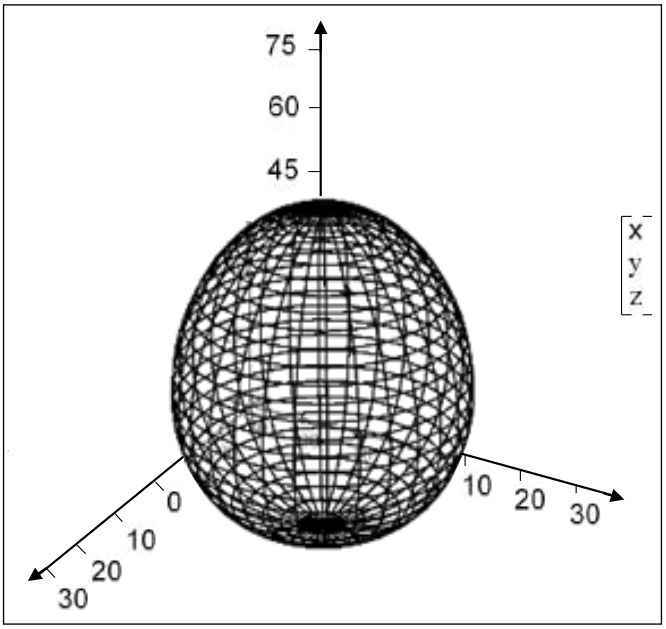
$$Z = \frac{a}{\max(Za)+(-1\times\min(Za))} \times Za \quad (11)$$

Bryłę jaja (rys. 2) złożono na podstawie modelu matematycznego opisującego powierzchnię zewnętrzną skorupy.

$$\max(X) + (-1 \times \min(X)) = 46 \quad (12)$$

$$\max(Y) + (-1 \times \min(Y)) = 46 \quad (13)$$

$$\max(Z) + (-1 \times \min(Z)) = 65 \quad (14)$$



Rys. 2. Model 3D bryły jaja kurzego.
Fig. 2. 3D-model of the hen's egg.
Źródło: Opracowanie własne
Saurce: Own study

Drugi model matematyczny opisujący charakterystykę skorupy jajka kurzego został przedstawiony na podstawie wzorów Prestona [8].

W macierzy (15) zapisano współczynniki, które różnią się w zależności od jaja i muszą być znalezione doświadczalnie.

$$\begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \end{bmatrix} = \begin{bmatrix} 0{,}07 \\ -0{,}1 \\ 0{,}1 \\ 0{,}1 \end{bmatrix} \quad (15)$$

Równania parametryczne przekroju podłużnego jaja przedstawiono poniżej (16):

$$x1_{il} = \frac{b}{2} \times \cos(\theta_{il}) \times (1 + c_1 \times \times sin(\theta_{il}) + c_2 \times sin(\theta_{il})^2 + + c_3 \times sin(\theta_{il})^3 + c_4 \times sin(\theta_{il})^4) \quad (16)$$

$$y1_{il} = \frac{-1 \times a}{2} \times \sin(\theta_{il}) + \frac{a}{2} \quad (17)$$

gdzie: a – punkt położony w połowie między dwoma końcami jaja;
b – połowa długości jaja

$$il = 0 \ldots 2 \times N \quad (18)$$

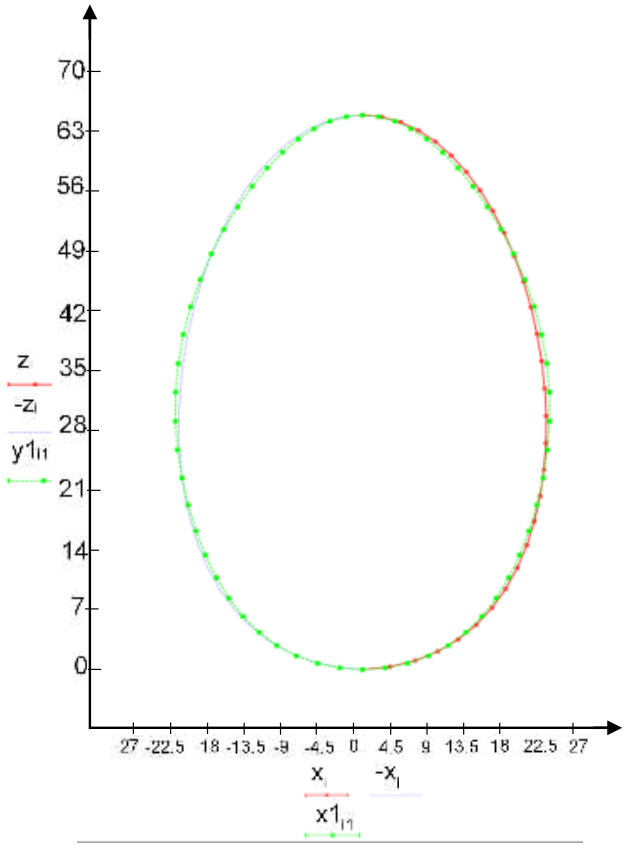
gdzie: N – rozmiar macierzy (przyjęto N=60)

$$\theta_{il} = il \times 2 \times \frac{\pi}{N \times 2} \quad (19)$$

Na rysunku 3 przedstawiono wykres jaja z modelu Prestona, dla którego:

$$\max(x1) + (-1 \times \min(x1)) = 46{,}04 \quad (20)$$

$$\max(y1) + (-1 \times \min(y1)) = 65 \quad (21)$$



Rys. 3. Wykres jaja z modelu Prestona.
Fig. 3. Egg graph for the Preston model.
Źródło: Opracowanie własne
Saurce: Own study

Porównanie modelu 3D skonstruowanego z krzywych Béziera z modelem Prestona przedstawiono poniżej:

$$n = 0 \ldots 15 \quad (22)$$

gdzie: n – numer kolejnego przekroju.

$$\Delta x_n = x_{15-n} - x1_{60-n} \quad (23)$$

$$\Delta y_n = z_{15-n} - y1_{60-n} \quad (24)$$

$$\Delta x1_n = x_{15+n} - x1_n \quad (25)$$

$$\Delta y1_n = z_{15+n} - y1_n \quad (26)$$

$$\Delta 1_n = \sqrt{(x_{15-n} - x1_{60-n})^2 + (z_{15-n} - y1_{60-n})^2} \quad (27)$$

$$\Delta 2_n = \sqrt{(x_{15+n} - x1_n)^2 + (z_{15+n} - y1_n)^2} \quad (28)$$

$$\Delta 1_n = \begin{bmatrix} 0{,}734 \\ 0{,}688 \\ 0{,}585 \\ 0{,}428 \\ 0{,}288 \\ 0{,}353 \\ 0{,}578 \\ 0{,}814 \\ 1{,}003 \\ 1{,}118 \\ 1{,}147 \\ 1{,}087 \\ 0{,}94 \\ 0{,}708 \\ 0{,}396 \\ 3{,}507 \times 10^{-15} \end{bmatrix} \quad (29)$$

$$\Delta 2_n = \begin{bmatrix} 0{,}734 \\ 0{,}758 \\ 0{,}815 \\ 0{,}942 \\ 1{,}121 \\ 1{,}309 \\ 1{,}468 \\ 1{,}573 \\ 1{,}615 \\ 1{,}599 \\ 1{,}53 \\ 1{,}414 \\ 1{,}243 \\ 0{,}989 \\ 0{,}599 \\ 1{,}648 \times 10^{-15} \end{bmatrix} \quad (30)$$

Objętość jaja wg Prestona wyrażono zależnością matematyczną poniżej:

$$VP = \frac{\pi}{6} \times 1 \times a \times (1 \times b)^2 \times \left(1 + \frac{2}{5} \times c_2\right) \quad (31)$$

$$VP = 6{,}914 \times 10^4 \quad (32)$$

Objętość wg Stonehouse obejmuje jajko łącznie ze skorupką – przedstawiono poniżej [10]:

$$VS1 = 0{,}524 \times 1 \times a \times (1 \times b)^2 \quad (33)$$

$$VS1 = 7{,}207 \times 10^4 \quad (34)$$

$$\frac{(VP - VS1)}{VP} * 100 = -4{,}246 \quad (35)$$

$$VS2 = 0{,}51 \times (a \times (b)^2) \quad (36)$$

$$VS2 = 7{,}015 \times 10^4 \quad (37)$$

$$\frac{(VP - VS2)}{VP} * 100 = -1{,}461 \quad (38)$$

Objętość wg Coulson [2] została oszacowana na podstawie objętości wewnętrznej, gdzie przyjmuje się, że wynosi ona 0,487.

$$VC = 0{,}487 \times (a \times (b)^2) \quad (39)$$

$$VC = 6{,}698 \times 10^4 \quad (40)$$

$$\frac{(VP - VC)}{VP} * 100 = 3{,}114 \quad (41)$$

PODSUMOWANIE

Przybliżone metody dają możliwość generowania modeli 2D i 3D jaj kurzych. Na podstawie przeprowadzonej analizy można stwierdzić, że modele z dużą dokładnością odzwierciedlają kształt skorupy. Równania przedstawione w modelu 3D zawierają parametry takie jak: długość osi krótkiej i długiej, współrzędne punktów kontrolnych i węzłowych odczytanych z krzywej Béziera. Model matematyczny Prestona korzysta z takich wymiarów jak długość, szerokość i asymetria. Dzięki wygenerowanemu konturowi możemy określić objętość, a objętość nie może być oszacowana na mniejszej liczbie pomiarów. Różnice w wynikach objętości jajka wynikają z różnych założeń przyjętych do obliczeń np. niektórzy autorzy wzorami opisują objętość jaja łącznie ze skorupką, a niektórzy z wyłączeniem skorupki. Wzór wg Stonehouse wyraża objętość całkowitą razem ze skorupką, a wynik wg Coulsona pokazuje objętość z wyłączeniem skorupki jajka kurzego.

SUMMARY

Approximate methods offer the possibility to generate 2D and 3D models of chicken eggs. Analysis shows that the models reflect the shape of the egg shell very accurately. The equations presented in the 3D model include parameters such as the length of the short axis and the long axis, the coordinates of the control points and nodes that are read from the Bézier curve. Preston's mathematical model uses dimensions such as length, width, and asymmetry. With the created contour we can determine the volume. The different results of the egg volume are due to different calculation assumptions, e.g. some authors use formulas to describe the volume of the egg including the shell and some with the exception of the shell. The Stonehouse formula gives the total volume including the shell and the Coulson result shows the volume without the shell of a chicken egg.

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AN ATTEMPT TO DEVELOP FAST DISSOLVING BIOPOLYMER-BASED POUCHES FOR INSTANT COFFEE®

Próba wytworzenia wysokorozpuszczalnych biopolimerowych opakowań jednostkowych do kawy rozpuszczalnej®

Key words: edible films, biopolymers, packaging, instant coffee.

The paper presents research on selected functional properties of edible films as a new type of fast-dissolving biopolymer-based packaging for instant coffee. The film production consisted of preparing aqueous film-forming solutions with biopolymers such as apple and citrus pectin, sodium alginate and soy protein isolate. The solutions were poured and dried at 50°C for 24 h. Water content, solubility in water, color and opacity, water vapor permeability and mechanical properties of analyzed films were investigated. The obtained results showed different film properties of which citrus pectin turned out to show the most desired functional properties for instant coffee, including transparency, good sealability and solubility in water.

Słowa kluczowe: folie jadalne, biopolimery, opakowanie, kawa rozpuszczalna.

W artykule przedstawiono badania wybranych właściwości użytkowych folii jadalnych jako nowego rodzaju szybko rozpuszczalnych biopolimerowych opakowań do kawy rozpuszczalnej. Produkcja folii polegała na przygotowaniu wodnych roztworów foliotwórczych z biopolimerami, takimi jak pektyna jabłkowa i cytrusowa, alginian sodu i izolat białka sojowego.

Roztwory wylano i suszono w temperaturze 50°C przez 24 h. Zbadano zawartość wody, rozpuszczalność w wodzie, barwę i nieprzezroczystość, przenikalność pary wodnej oraz właściwości mechaniczne analizowanych folii. Uzyskane wyniki wykazały różne parametry folii. Pektyna cytrusowa wykazywała najbardziej pożądane właściwości użytkowe dla kawy rozpuszczalnej, w tym przezroczystość, dobrą zgrzewalność i rozpuszczalność w wodzie.

INTRODUCTION

Biopolymer-based edible films have grown rapidly in recent times. This is due to changes in the awareness of society in the field of ecology and environmental protection, as well as for economic and health reasons. The use of packaging made of new, biodegradable, naturally occurring raw materials allows us to limit the use of packaging made of synthetic materials, which in turn reduces the amount of waste, including hazardous microplastics, mainly single-use plastic packaging [15]. Edible coatings are applied directly to the product, while the films are independent structures obtained outside the product in the form of a film [5]. The development of the technology of producing edible films allows for obtaining more and more diverse and better properties, with a simultaneous reduction in production costs. They depend mainly on the film-forming materials and the parameters in which they are formed. The film properties are influenced, among others, by material concentration and plasticizer used, solvent, film thickness, as well as pH and temperature [7, 18]. The main function of edible films is a selective barrier to water vapor, carbon dioxide, oxygen, aroma, and oils. In addition, they protect food products against the adverse effects of microorganisms, as a result extending their shelf life. They allow for the reduction of one the occurrence of mechanical damage and limit the influence of physical and chemical factors on the product [11]. They can also, by changing the color, inform about the expiry date of the product and thus effectively remind the consumer not to waste food [1]. Biodegradable materials also contribute to the improvement of the quality of the environment, as they are part of a modern

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approach to caring for a sustainable environment [17, 27] The possibility of using more and more new ingredients in the composition of films allows for innovative properties and better stability of edible packaging materials [6]. Packaging made of biopolymer films can, for example, be treated as active packaging, by using ingredients that prevent changes in the quality and freshness of food. It is also an alternative method of safer drug delivery [28]. The active properties of the films enable, among others, the release of antimicrobial substances, thanks to which the process of food degradation is delayed, substances that prevent browning and discoloration, improve the quality of the product, and carbon dioxide absorbing substances eliminate packaging swelling [16, 22], possible in the case of roasted coffee packaging.

Fast-dissolving sealable packaging is a subject of great interest in the last decade. One of the most favorable applications of edible films that dissolve quickly upon water contact is in individually portioned dry food, instant beverages or dry ingredients, including breakfast cereal, instant coffee or tea, and powders. In the literature, there are some examples of a new type of single-use packaging for oils and powders. Biopolymer-based single packaging from corn zein was also investigated to improve the shelf-life of sliced cheese [25] and in combination with soy protein isolate can be used as packaging for olive oil [3]. Different kinds of water-soluble pouches for oil protection were previously investigated also by others [9, 12, 14, 24]. Quilez-Molina et al. [21] analyzed vegetable-based bioplastic materials, obtained from the upscaling of food byproduct materials derived from the orange peel that showed a good potential for replacing plastics in single-use applications. Similar research was conducted by Sharma et al. [26] on chemically modified cellulose from rice husk blended with polyvinyl alcohol. The authors developed a heat-sealed packet, which exhibits comparable properties to commercially used flexible polyvinyl chloride films with optimized water barrier and biodegradable nature [2, 23]. Nawab et al. [19] also showed the potential of biopolymers from waste sources (mango kernel) as heat-sealable pouches for the packing of red chili powder. Janjarasskul et al. [13] developed edible, fast-dissolving sealable whey protein isolate-based films for packaging premeasured dry foods that are completely water-soluble, visually clear and glossy, and release their contents upon contact with water. Liu et al. [15] investigated heat-sealable soybean polysaccharide/gelatin blend films intended to be used as edible food packaging materials for instant coffee and coconut powder pouches. A similar combination of animal and plant-based biopolymers (pectin–sodium alginate/casein) as edible pouches was presented by Bora and Mishra [10]. Those examples show that the studies on sealable biopolymer-based single-use packaging are promising to minimize the use of petroleum-based materials. Therefore, this study aimed to try to produce fast-dissolving sachets based on various biopolymers, compare their properties to each other, determine the characteristic features of given biopolymers and evaluate the films as a new type of pouch packaging for instant coffee.

MATERIALS AND METHODS

Sodium alginate and low-methylated apple pectin were purchased from Agnex (Białystok, Poland). Citrus pectin was purchased from Hortimex (Konin, Poland). Soy protein isolate (Exelsoy 933EX, ~90% protein) was purchased from Exeller Polska Sp. Z o.o. (Piaseczno, Poland). Glycerol (Avantor Performance Materials Poland S.A.Gliwice, Poland) was used as a plasticizer. Instant coffee was purchased in the local market.

Film preparation

The film-forming solutions were prepared by casting method using distilled water as a solvent and sodium alginate, apple and citrus pectin at the concentration of 1.5%, whereas soy protein isolate was used at the concentration of 3% since lower amounts were unable to create a continuous film structure. The film-forming solutions were heated and stirred for 20 minutes using an RCT basic IKAMAG magnetic stirrer (IKA Poland, Warsaw) at the level of 250 rpm at a temperature of 60°C. After cooling, glycerol was added to the solutions, representing 50% of each biopolymer. The film-forming solutions were poured on Petri dishes in different amounts to control the similar film thickness. The samples were dried format 50°C in a laboratory dryer SUP-65W (WAMED, Warsaw, Poland). The dried films were conditioned in a climate chamber model KBF 240 (Binder GmbH, Tuttlingen, Germany) at 25°C and relative humidity of 50% for 48 h before testing.

Thickness

The thickness of the films was determined using an electronic gauge Thwing-Albert Instrument Company (Klimatest, Warsaw, Poland) with a precision of 1 µm. The results were obtained by measuring the thickness at ten random points, and then the mean and the standard deviation were calculated.

Water content

The water content of the films was determined by the drying method at 105°C for 24 h using a laboratory dryer SUP 65 W/G (WAMED, Warsaw, Poland) and expressed in percentages. The measurement was performed in triplicate.

Solubility in water

The prepared samples of edible films were cut into squares (20 x 20 mm). The samples were then dried at 105°C for 24 h and then cooled in a desiccator containing silica gel. The samples were reweighed and placed in 25 mL of distilled water. After 24 h of storage, occasionally shaken, the excess water was removed using filter paper. The samples were dried at 105°C for 24 h and reweighed. The water solubility of the edible films was determined in three repetitions and was calculated based on the method described by Rhim et al. [4].

Color

The color test was performed using the CR-400 model colorimeter (Minolta, Japan) in the CIE L^* a^* b^* system (L^* - lightness, a^* - green to red color, b^* - blue to yellow color). The measurement was performed in ten repetitions. For a better interpretation, the total color difference (ΔE) between the film and the white standard (L^*=92.36; a^*=-0.47; b^*=0.70) was calculated according to the method described by Mikus et al. [17]:

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

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

Film opacity

Opacity was determined according to the spectrophotometric method using the EVOLUTION 220 UV-Visible spectrometer (Thermo Electron Corporation, Waltham, MA, USA) and Thermo INSIGHT software. The absorbance was measured at 600 nm in ten repetitions, and an empty test cell was used as a reference. The opacity of the prepared material was calculated according to the method described by Han and Floros [10].

Water vapor permeability

The water vapor permeability was determined by the gravimetric method described by Debeaufort et al. [4]. The relative humidity difference was 50 and 100% at a temperature of 25°C. At least three replicates were performed for each film type, and the water vapor permeability was determined at a steady state and from the change in the cell mass as a function of time.

Mechanical properties

The ASTM standard method D882-02 [8] was used to determine tensile strength and elongation at the break of the analyzed films with at least six repetitions. The Texture Analyzer TA-XT2i (Stable Micro Systems, Haslemere, UK) with the Texture Expert software was used to process the results.

Pouch preparation and solubility in water

To obtain pouches, films were heat-sealed on four sides with an impulse laboratory heat-sealer PFS/FS-200B (Kegel Machines, Poznań, Poland) and approximately 2 g of instant coffee was placed inside the pouches. The samples were prepared according to the labeled instructions without removing the edible pouches. The pouches with instant coffee were stirred in approximately 200 ml of hot water (95°C) using an RCT basic IKAMAG magnetic stirrer (IKA Poland, Warsaw) at the level of 500 rpm. Visual observations were done and the time of solubility was measured.

Statistical analysis

Statistica 13 (StatSoft Inc., Tulsa, OK, USA) was used to analyze the obtained results. The analysis of variance (ANOVA) at a significance level of 0.05 was performed with Tukey's post hoc test to detect significant differences in film properties.

RESULTS AND DISCUSSION

Edible films were prepared by casting method from aqueous film-forming solutions using plant-based biopolymers such as apple and citrus pectin, sodium alginate, and soy protein concentrate and were developed and analyzed to use them as single-use pouch packaging for instant coffee. The photographs of the films were presented in Fig. 1. All films showed homogeneous and continuous structure, without pores and crack. Films based on citrus pectin and sodium alginate were visible and transparent, whereas films based on apple pectin and soy protein isolate were more opaque with beige color, which is due to the character of the origin powders used in the study.

The analyzed edible film films had a water content of 11.00–19.69%. Moisture is an important parameter influencing physical properties, including flexibility and organization of the film structure and barrier properties of the film [29]. The apple pectin film achieved the highest level of water content, while the soy protein isolate film had the lowest value. The differences may be due to the origin and the characteristic of the hydrophilic biopolymers. Substances containing a lot of components that easily absorb water, such as carbohydrates, protein, or fiber, interact with water molecules, retaining more water [20]. Low water content in soy protein-based films may be the result of using the same amount of glycerol as in the case of other biopolymers, but increasing the percentage of protein in the film-forming solutions to 3% affects the lower water retention capacity of the films. Glycerol is a hydrophilic plasticizer that has water-retaining properties [7].

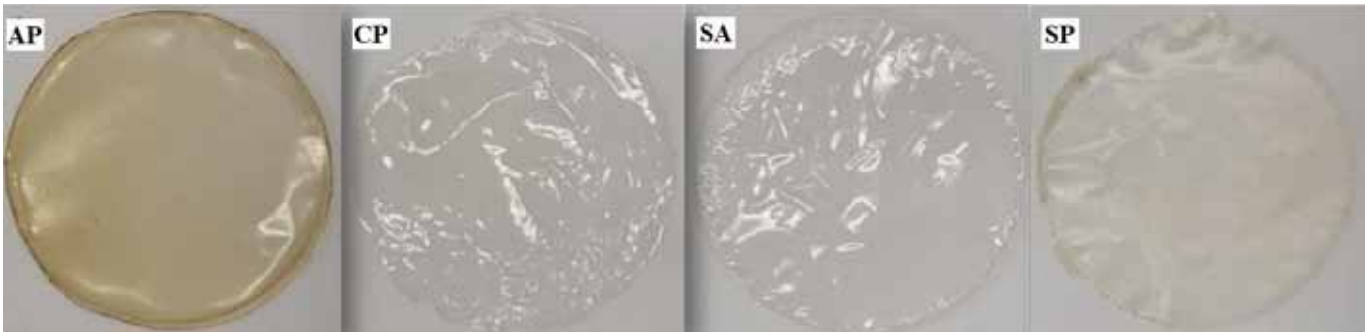

Fig. 1. Photographs of analyzed films based on apple pectin (AP), citrus pectin (CP), sodium alginate (SA) and soy protein isolate (SP).

Rys. 1. Fotografie analizowanych folii jadalnych z pektyny jabłkowej (AP), pektyny cytrusowej (CP), alginianu sodu (SA) i izolatu białka sojowego (SP).

Source: The own study

Źródło: Badania własne

Table 1. Water content and solubility in water of films based on apple pectin (AP), citrus pectin (CP), sodium alginate (SA) and soy protein isolate (SP)

Tabela 1. Zawartość wody i rozpuszczalność w wodzie folii wytworzonych z pektyny jabłkowej (AP), pektyny cytrusowej (CP), alginianiu sodu (SA) i izolatu białka sojowego (SP)

Film/ Folia	Water content/ Zawartość wody [%]	Solubility in water/ Rozpuszczalność w wodzie [%]
AP	19.69 ± 0.03 [b]	99.94 ± 0.00 [b]
CP	13.67 ± 0.72 [a]	99.93 ± 0.02 [b]
SA	14.56 ± 1.33 [ab]	99.98 ± 0.00 [b]
SP	11.00 ± 0.95 [a]	99.83 ± 0.02 [a]

Mean values ± standard deviations. Different superscript letters ([a-b]) within the same column indicate significant differences between the films ($p < 0.05$). Wartości średnie ± odchylenia standardowe. Różne litery indeksu górnego ([a-b]) w tej samej kolumnie wskazują na istotne różnice między foliami ($p < 0,05$).

Source: Own study

Źródło: Badania własne

Water solubility is a parameter that has two crucial aspects. Low solubility is useful to obtain a water-resistant film or coating, thereby rendering the package a moisture barrier. When designing instant coffee packages, high water solubility values are the most important parameter. The films made of sodium alginate were characterized by the highest solubility in water (99.98%), while films made of soy protein isolate had the lowest solubility (99.83%). However, all values were near 100% and the films retained their physical integrity during the analysis, which is attributed to the methodology and using high temperature (105°C). The differences in the obtained water solubility values may result from the different thicknesses of the individual films and the heterogeneous and porous structure. Nevertheless, the obtained values were similar to other biopolymer-based edible films [17].

Color is a crucial parameter influencing the consumer's choices as the most remarkable food quality attribute. Thus, it is expected for edible films to be transparent without the effect of coated or protected products. The color results for the analyzed films are shown in Table 2.

The results indicate that the lowest lightness of 88.66 (parameter L^*) was found for apple pectin, whereas all other films had significantly higher lightness from the range of 90.48–90.94. Values for the parameter a^* ranged from -1.36 for soy protein isolate to -0.50 for sodium alginate. Positive values of the parameter a^* indicate a greater proportion of red, while negative values indicate a greater proportion of green. For all the films tested, a tendency toward green color was observed more than the red one. The parameter b^*values ranged from 2.02 for sodium alginate to 8.87 for apple pectin. Positive values of the b* parameter indicate a greater proportion of yellow, while negative values indicate a greater proportion of blue. For all tested films, a tendency toward yellow color was observed, including films from apple pectin and soy protein isolate, which were characterized by a typical yellowish color. The obtained values of the total color difference (ΔE) were in the range of 2.57–8.99. According to the criterion adopted by the International Commission on Illumination, values in the range of 0–2 are unrecognizable for humans. An inexperienced observer will notice differences in color deviations in the range of 2–3.5, while clear differences are visible at values greater than 3.5 [17]. In the case of the tested samples, a clear difference can be observed only for films prepared from apple pectin and soy protein isolate.

Opacity is an important parameter from the consumer's point of view as it determines the visibility of the product. The analyzed films had opacity values in the range of 1.90–2.84 A/mm (Table 2), with the highest value for films from soy protein isolate. Such a high level of opacity may make it impossible to correctly identify the product contained in such packaging. The lowest values were recorded for films made of citrus pectin (1.90 A/mm). These films were highly transparent and easy to assess the product quality. However, more opaque packaging is better for minimizing UV radiation, thus creating a barrier to light and allowing some products to have improved shelf life.

Table 2. L^*, a^*, b^* color parameters, the total color difference (ΔE), and opacity (O) of films based on apple pectin (AP), citrus pectin (CP), sodium alginate (SA), and soy protein isolate (SP)

Tabela 2. Parametry barwy L^*, a^*, b^*, bezwzględna różnica barwy i nieprzezroczystość (O) folii wytworzonych z pektyny jabłkowej (AP), pektyny cytrusowej (CP), alginianiu sodu (SA) i izolatu białka sojowego (SP)

Film / Folia	L^*	a^*	b^*	ΔE	O [A/mm]
AP	88.66 ± 0.65 [a]	-0.85 ± 0.11 [b]	8.87 ± 1.47 [c]	8.99 ± 1.55 [c]	2.15 ± 0.34 [ab]
CP	90.70 ± 0.67 [b]	-0.59 ± 0.08 [c]	2.60 ± 0.79 [a]	2.57 ± 0.95 [a]	1.90 ± 0.22 [a]
SA	90.94 ± 0.46 [b]	-0.50 ± 0.08 [c]	2.02 ± 0.59 [a]	1.97 ± 0.66 [a]	1.98 ± 0.56 [ab]
SPI	90.48 ± 0.64 [b]	-1.36 ± 0.20 [a]	6.38 ± 0.96 [b]	6.07 ± 1.06 [b]	2.84 ± 0.87 [b]

Mean values ± standard deviations. Different superscript letters ([a-c]) within the same column indicate significant differences between the films ($p < 0.05$). Wartości średnie ± odchylenia standardowe. Różne litery indeksu górnego ([a-c]) w tej samej kolumnie wskazują na istotne różnice między foliami ($p < 0,05$).

Source: Own study

Źródło: Badania własne

Table 3. Water vapor permeability of films based on apple pectin (AP), citrus pectin (CP), sodium alginate (SA), and soy protein isolate (SP)

Tabela 3. Przenikalność pary wodnej folii wytworzonych z pektyny jabłkowej (AP), pektyny cytrusowej (CP), alginianiu sodu (SA) i izolatu białka sojowego (SP)

Film/ Folia	Water vapor permability/ Przenikalność pary wodnej [·10-11g/m·s·Pa]
AP	1.65 ± 0.26 [a]
CP	1.17 ± 0.25 [a]
SA	1.20 ± 0.28 [a]
SP	5.75 ± 0.13 [b]

Mean values ± standard deviations. Different superscript letters ([a-b]) within the same column indicate significant differences between the films ($p<0.05$). Wartości średnie ± odchylenia standardowe. Różne litery indeksu górnego ([a-b]) w tej samej kolumnie wskazują na istotne różnice między foliami ($p <0,05$).

Source: Own study

Źródło: Badania własne

Table 4. Tensile strength and elongation at break of films based on apple pectin (AP), citrus pectin (CP), sodium alginate (SA), and soy protein isolate (SP)

Tabela 4. Wytrzymałość na zerwanie i wydłużenie względne folii wytworzonych z pektyny jabłkowej (AP), pektyny cytrusowej (CP), alginianiu sodu (SA) i izolatu białka sojowego (SP)

Film/ Folia	Tensile strength/ Wytrzymałość na zerwanie [MPa]	Elongation at break/ Wydłużenie względne [%]
AP	1.26 ± 0.54 [a]	8.64 ± 1.92 [a]
CP	0.9 ± 0.05 [a]	4.83 ± 1.22 [a]
SA	5.16 ± 0.00 [b]	7.06 ± 0.02 [a]
SPI	4.40 ± 1.29 [b]	39.37 ± 4.61 [b]

Mean values ± standard deviations. Different superscript letters ([a-b]) within the same column indicate significant differences between the films ($p < 0.05$). Wartości średnie ± odchylenia standardowe. Różne litery indeksu górnego ([a-b]) w tej samej kolumnie wskazują na istotne różnice między foliami ($p <0,05$).

Source: Own study

Źródło: Badania własne

One of the main purposes of using edible films is to control water vapor migration between the coated food product and the surrounding atmosphere, which is also crucial for the present study due to the hygroscopic character of instant coffee. Therefore, water vapor permeability for analyzed films was evaluated and the results are presented in Table 3. The films had a water vapor permeability in the range of 1.17 to 5.75 10^{-11} g/m·s·Pa, which is rather similar to other biopolymer-based films plasticized with glycerol. Films with the addition of glycerol are usually characterized by higher hygroscopicity [7]. The films made of soy protein isolate were characterized by highest values of water vapor permeability, whereas other films had significantly lower values.

Mechanical strength and flexibility are important film features that help maintain the integrity and impermeability of food packaging [8]. Many different factors affect strength, the main ones are the type of biopolymer, the structural organization of the biopolymer chain, processing technology, and the degree of cross-linking [6]. Table 4 presents the results of the mechanical properties of analyzed edible films. The tensile strength of the film ranged from 0.9 to 5.16 MPa, and the most resistant films were those prepared from sodium alginate whereas the lowest ones were those prepared from citrus pectin. The ability to film elongate is a water humidity-dependent factor since moisture can play a role as a plasticizer in the film structure. The elongation at break for analyzed films ranged from 4.83 to 39.37%. The lowest elongation showed films from citrus pectin and the highest films from soy protein isolate. Molecular interactions enhanced by heat denaturation could be accountable for the differences in mechanical properties of analyzed films. The addition of a plasticizer, which was glycerol, may cause a decrease in the affinity between the biopolymer chains in the film matrix. As a result, the formation of hydrogen bonds between the plasticizer and biopolymers (polysaccharides or proteins) resulted in greater flexibility of the film [13].

All films showed very good sealability, however, pouches from sodium alginate were not stable and started to open after a few seconds. The ability to be hermetically sealed is very important for integral packaging to extend shelf life and protect its content through the product lifecycle [13]. Therefore, pouches prepared from apple or citrus pectin and soy protein isolate were taken into account to access the solubility in contact with water. All pouches prepared from the films based on citrus pectin dissolved totally and instantly (within less than 30 s), which is beneficial in many applications such as quick-dissolvable pouches or oral strips for the delivery of active compounds. Similar observations were for films from apple pectin, however, films from soy protein isolate needed more time to dissolve, especially for sealable areas of the films. This is likely due to thermal denaturation occurring during the heat-sealing process, causing soy proteins to crosslink and become water-insoluble. Although completely safe to eat, the insoluble heat-sealing area can potentially confuse and turn off consumers. Nevertheless, all analyzed films can be further investigated to improve their capacity to dissolve instantaneously upon contact with water.

SUMMARY

Edible films can be used as soluble sachets, bags, packets, or sachets containing powdered substances such as seasoning and flavoring additives for instant food, instant coffee, powdered milk, pasta, beverage mixes, tea leaves, and other food additives. In this context, films made of biopolymers including apple or citrus pectin, sodium alginate, and soy protein isolate were investigated. The tests showed different properties of edible films depending on the biopolymer used. Soy protein films were rejected despite having the best mechanical tensile strength because they did not dissolve in

Fig. 2. Photographs of edible pouches based on apple pectin (AP), citrus pectin (CP) and soy protein isolate (SP) with instant coffee and beverage prepared from citrus pectin pouch.

Rys. 2. Fotografie jadalnych saszetek z pektyny jabłkowej (AP), pektyny cytrusowej (CP) i izolatu białka sojowego (SP) z kawą rozpuszczalną oraz napój przygotowany z saszetki z pektyną cytrusową.

Source: The own study

Źródło: Badania własne

water due to heat denaturation at the seal. Apple pectin and sodium alginate showed the best properties, but the low seal strength of the sodium alginate film and the yellow color of the apple pectin film reduced the functionality of these films. The research confirms the possibility of using edible films made of citrus pectin as a unit packaging for instant coffee, which showed the desired physical properties and complete solubility of coffee sachets in water. Further research is needed to improve the functional properties of the film in terms of stability and performance of citrus pectin packaging with instant coffee.

PODSUMOWANIE

Folie jadalne mogą znaleźć zastosowanie jako rozpuszczalne saszetki, torby, paczki lub saszetki zawierające sproszkowane substancje, takie jak dodatki przyprawowe i smakowe do żywności typu instant, kawy rozpuszczalnej, mleka w proszku, makaronu, mieszanek napojów, herbat liści i innych dodatków do żywności. W tym kontekście zbadano folie wytworzone z biopolimerów, w tym z pektyny jabłkowej lub cytrusowej, alginianu sodu i izolatu białka sojowego. Przeprowadzone badania wykazały różne właściwości folii jadalanych zależne od zastosowanego biopolimeru. Folie z izolatu białka sojowego zostały odrzucone pomimo najlepszej wytrzymałości mechanicznej na rozciąganie, gdyż nie rozpuszczały się w wodzie z uwagi na denaturację cieplną przy zgrzewie. Pektyna jabłkowa oraz alginian sodu wykazywały najlepsze właściwości, lecz niska wytrzymałość zgrzewu folii z alginiatu sodu i żółte zabarwienie folii z pektyny jabłkowej obniżyły ich funkcjonalność. Badania potwierdzają możliwość wykorzystania folii jadalnych z pektyny cytrusowej jako opakowanie jednostkowe do kawy rozpuszczalnej, ponieważ wykazują pożądane właściowości fizyczne i całkowitą rozpuszczalność saszetek z kawą w wodzie. Niezbędne są dalsze badania w celu ulepszenia właściwości funkcjonalnych folii pod kątem stabilności i właściwości użytkowych opakowań z pektyny cytrusowej zawierających kawę rozpuszczalną.

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ANALIZA PARAMETRÓW GEOMETRYCZNYCH OWOCÓW TRUSKAWKI ODMIANY „MARMOLADA" NA POTRZEBY PROJEKTOWANIA URZĄDZEŃ DO ICH PRZETWARZANIA®

Geometrical parameters analysis of "Marmolada" strawberries for the purposes of equipment designing for their processing®

Słowa kluczowe: modelowanie, owoc truskawki, pomiar, pole powierzchni, objętość.

W artykule omówiono trzy metody pozyskiwania informacji o geometrycznych parametrach owoców truskawki. Pierwsza to metoda pomiaru bezpośredniego, wykonana za pomocą suwmiarki i modeli geometrycznych (metoda 1D). Druga to metoda wykorzystująca fotografię cyfrową i oprogramowanie typu CAD do tworzenia brył obrotowych na podstawie obrysu kształtu truskawki. Trzecia to metoda pomiaru przestrzennego modelu numerycznego otrzymanego za pomocą skanowania 3D (metoda 3D). Celem pracy była ocena wyżej wymienionych metod pomiarowych w zakresie dokładności wyznaczania pola powierzchni i objętości owoców truskawki. Z przeprowadzonych badań na owocach wynika, że spośród zastosowanych trzech metod wyznaczenia parametrów geometrycznych owoców najlepsze efekty uzyskano przy metodzie 3D. Do wyznaczenia pola powierzchni owoców truskawki metodą 1D można zastosować kulę (M1) i model bryły obrotowej (M_{BO}). Wyznaczając objętość owoców truskawki metodą 1D można wykorzystać kulę (M1) i elipsoidę obrotową (M4). Wykorzystując wymienione modele do wyznaczania pola powierzchni i objętości owoców popełnia się błąd względny pomiaru mniejszy od 7%.

Key words: modeling, strawberry fruit, measure, surface area, volume.

This article describes a three methods for acquiring information about the geometric parameters of strawberry fruit. The direct method involved measurements with the use of a caliper and geometric models (1D method). The second is a method that uses digital photography and CAD software to create revolving solids based on the contour of the strawberry shape. The third indirect method was based on digital models constructed by 3D scanning (3D method). The aim of this study was to evaluate the accuracy of the above measurement methods in determining the surface area and volume of strawberry fruit. The analysis of the three methods for determining the geometric parameters of strawberries revealed that the 3D method delivered more accurate results. In the 1D method, the surface area of strawberry fruit can be determined with the use of a sphere (M1) and a revolving solid model (M_{BO}). The volume of strawberry fruit can be determined with the use of a sphere (M1) and a spheroid (M4). When geometric models M1, M4 and M_{BO} were applied to measure the surface area and volume of strawberries, the mean relative error was less than 7% respectively.

WYKAZ OZNACZEŃ

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

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WSTĘP

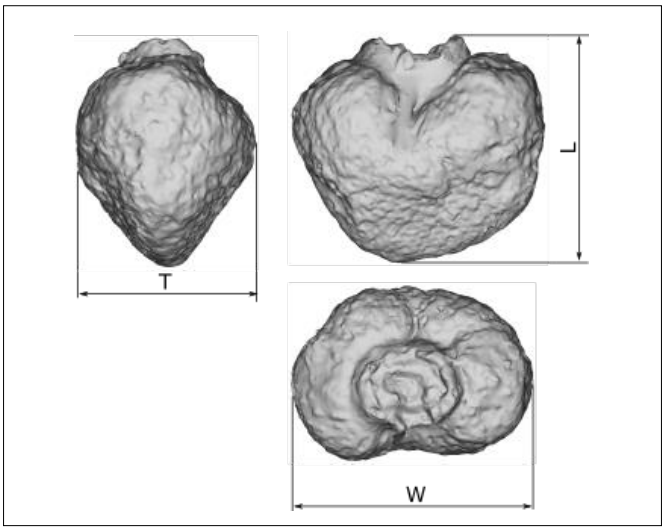
Pole powierzchni oraz objętość surowców rolniczych i spożywczych to parametry, które są wykorzystywane w planowaniu procesów zbioru, czyszczenia, zaprawiania, powlekania, obierania i pakowania [8, 10, 19, 20, 21]. Do pomiaru podstawowych parametrów geometrycznych są wykorzystywane przede wszystkim przyrządy miernicze pozwalające na bezpośredni pomiar liniowy. Do takich przyrządów zalicza się liniały, suwmiarki analogowe i suwmiarki elektroniczne [9, 12]. Wszystkie te metody pozwalają bezpośrednio i szybko określić wymiar liniowy badanego obiektu i są tanie. Pomiar obiektu i zapisanie wyniku odbywa się z reguły bez potrzeby specjalnego przygotowywania badanych próbek. Uzyskane wyniki pomiarów wyżej wymienionymi przyrządami pozwalają na określenie pola powierzchni i objętości badanych surowców za pomocą formuł matematycznych opisujących określone bryły geometryczne [4, 6, 7].

Metoda pomiaru oparta na rejestracji kształtu próbki w postaci chmury punktów polega na rejestracji położenia punktów tworzących model próbki za pomocą skanera 3D [14, 17]. Na bazie uzyskanego przestrzennego modelu numerycznego można wykonać dokładne pomiary metrologiczne [15]. Wykonanie modelu numerycznego tą metodą jest czasochłonne, ale pozwala na zapisanie uzyskanych wyników w pamięci komputera. Metodę tę można stosować do pomiarów surowców małych oraz dużych, kruchych i wrażliwych na uszkodzenia [1, 2]. W artykule omówiono trzy metody pozyskiwania informacji o fizycznych parametrach surowców. Pierwsza to metoda pomiaru bezpośredniego, wykonana za pomocą suwmiarki oraz podstawienie uzyskanych wyników do formuł matematycznych [3]. Druga to metoda oparta na wykorzystaniu fotografii cyfrowej badanej próbki do wykonania obrysu surowca i utworzeniu w programie typu CAD bryły obrotowej. Trzecia to metoda pomiaru przestrzennego modelu numerycznego otrzymanego za pomocą skanowania 3D.

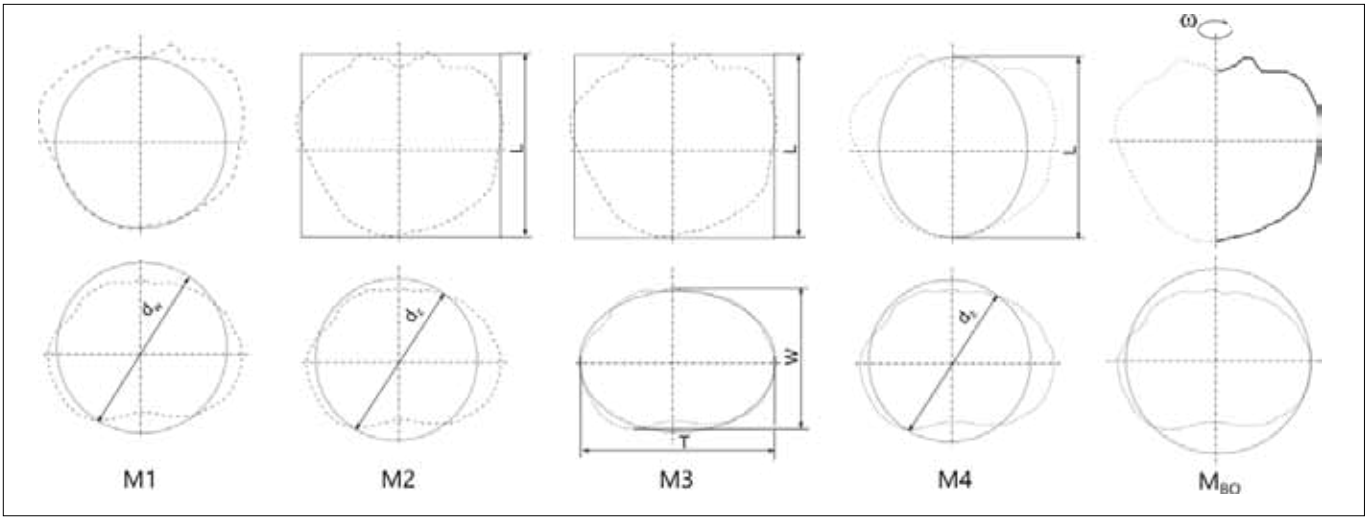
Celem artykułu jest ocena wyżej wymienionych metod pomiarowych w zakresie dokładności wyznaczania pola powierzchni i objętości owoców truskawki. Ocena dotyczy względnych porównań dokładności wyznaczania wyżej wymienionych parametrów geometrycznych.

MATERIAŁ I METODY

Materiał badawczy stanowiły owoce truskawki (*Fragaria*) zakupione w sieci sklepów spożywczych PSS Społem w Olsztynie. Do badań wybrano losowo 30 owoców bez widocznych uszkodzeń. Zebrane owoce przechowywano w chłodziarce, w której panowała stała temperatura 5±1°C. Do liniowych pomiarów owoców stosowano suwmiarkę elektroniczną o dokładności 0,01 mm. Długość, szerokość i grubość owoców truskawki wyznaczono zgodnie z rysunkiem 1.



Rys. 1. Model numeryczny truskawki.
Fig. 1. Numerical model of strawberry.
Źródło: Opracowanie własne
Source: Own study



Rys. 2. Modele geometryczne owoców truskawki: M1 – kula, M2 – walec, M3 – walec eliptyczny, M4 – elipsoida obrotowa, M_{BO} – bryła obrotowa; d_w – arytmetyczna średnica zastępcza, d_z – średnica zastępcza, L – długość, W – szerokość, T – grubość.
Fig. 2. Geometric models of strawberry fruits: M1 – sphere, M2 – cylinder, M3 – elliptic cylinder, M4 – spheroid, M_{BO} – revolving solid, d_w – arithmetic mean diameter, d_z – mean diameter, L – length, W – width, T – thickness.
Źródło: Opracowanie własne
Source: Own study

Do obliczeń pola powierzchni i objętości zastosowano 5 modeli geometrycznych składających się z wybranych brył geometrycznych (rys. 2).

Dla każdego modelu geometrycznego wyznaczono formuły matematyczne:

- model kuli (M1):

$$A_{M1} = \pi \cdot d_w^2 \quad (1)$$

$$V_{M1} = \frac{\pi \cdot d_w^3}{6} \quad (2)$$

- model walca (M2):

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

$$V_{M2} = \frac{\pi \cdot d_z^2 \cdot L}{4} \quad (4)$$

- model walca eliptycznego (M3):

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

$$V_{M3} = \frac{\pi \cdot W \cdot T \cdot L}{4} \quad (6)$$

- model elipsoidy obrotowej (M4) gdy: $\frac{L}{2} > \frac{d_z}{2}$

to:

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

$$= \frac{4 \cdot \pi \cdot d_z^2 + \pi \cdot L \cdot d_z \cdot e \cdot \arcsin(e)}{8} \quad (7)$$

gdzie:

$$e = \sqrt{1 - \frac{d_z^2}{L^2}} \quad (8)$$

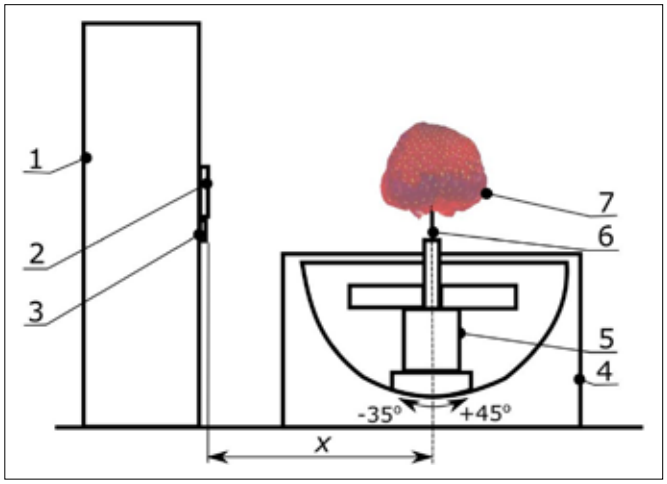
$$V_{M4} = \frac{\pi \cdot d_z^2 \cdot L}{6} \quad (9)$$

Występujące w modelach M1, M2 i M4 średnice zastępcze wyznaczano ze wzorów:

$$d_w = \frac{L + W + T}{3} \quad (10)$$

$$d_z = \frac{W + T}{2} \quad (11)$$

Model truskawki w postaci bryły obrotowej (M_{BO}) wykonano na podstawie fotografii owoców wczytanych do programu FreeCad [5]. Fotografie wykonano aparatem cyfrowym Casio EX-F1 z rozdzielczością 2816x2112 piksele. Aparat był zamocowany na statywie i znajdował się 40 cm nad fotografowanym owocem truskawki. Obrys krawędzi truskawki wykonano w module programu tworzenie części (*Part Design*) z wykorzystaniem krzywej złożonej. Pole powierzchni i objętość otrzymanej bryły obrotowej wyznaczono w programie FreeCad za pomocą makrodefinicji *FC-Info*. Budowę przestrzennych modeli numerycznych owoców wykonano za pomocą laserowego skanera 3D firmy Nextengine [13]. Owoce mocowano do stolika obrotowego z uchwytem (rys. 3). Gęstość skanowania owoców wynosiła 7 punktów na mm^2. Średni czas wykonania wszystkich skanów, z których składał się przestrzenny model numeryczny, wynosił około 30 minut.



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

Fig. 3. 3D scanning of strawberry fruits: 1 – 3D scanner, 2 – camera, 3 – laser diodes, 4 – rotary table with adjustable tilt, 5 – motor, 6 – needle, 7 – sample, *x* – distance between the sample and the scanner.

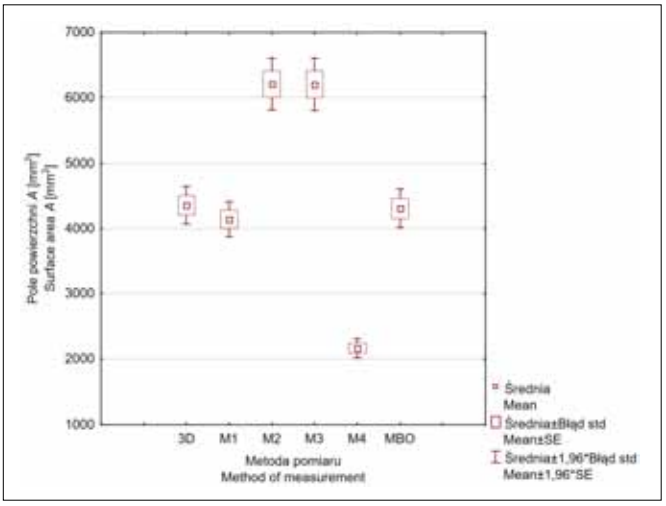
Źródło: Opracowanie własne

Source: Own study

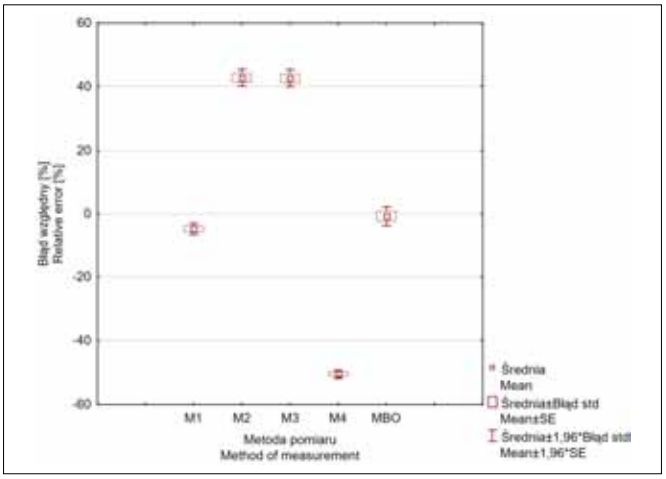
Serię uzyskanych skanów 3D tworzących przestrzenne modele numeryczne składano w programie komputerowym ScanStudio HD PRO [13]. Do wykonania pomiarów pola powierzchni i objętości na gotowych modelach (3D) wykorzystano program MeshLab [11]. Porównano istotności różnic między średnimi wartościami pola powierzchni całkowitej i objętości. Do obliczeń stosowano nieparametryczny test ANOVA rang Kruskala-Wallisa. Obliczenia przeprowadzono przy poziomie istotności $\alpha = 0{,}05$, posługując się programem statystycznym STATISTICA v.13 PL [16, 18].

WYNIKI BADAŃ I ICH ANALIZA

Skanowanie 3D owoców pozwoliło uzyskać przestrzenne modele numeryczne, na podstawie których można było określić pole powierzchni i objętość badanych owoców truskawki. Wartości pola powierzchni całkowitej owoców truskawki dla zastosowanych modeli przedstawiono na rys. 4.



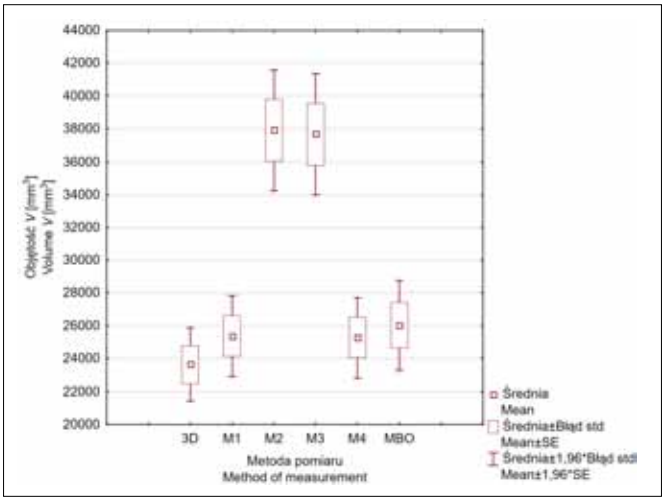
Rys. 4. Pole powierzchni owoców truskawki.
Fig. 4. Surface area of strawberry fruit.
Źródło: Opracowanie własne
Source: Own study



Rys. 5. Błąd względny wyznaczania pola powierzchni owoców truskawki.
Fig. 5. Relative error in determining the surface area of strawberries.
Źródło: Opracowanie własne
Source: Own study

Ocenę istotności różnic między parametrami owoców uzyskanymi za pomocą przyjętych metod badawczych przedstawiono w tabeli 1.

Zakładając, że uzyskane wyniki pomiarów pola powierzchni owoców truskawki metodą 3D nie są obarczone błędem, mogą one zatem stanowić bazę odniesienia dla wyników uzyskanych za pomocą pozostałych modeli. Błąd względny między wartościami uzyskanymi z zastosowanych modeli a uzyskanymi metodą 3D określono „błędem metody". Jak widać z rysunku 5 średni błąd względny pomiaru pola powierzchni wykorzystując modele geometryczne M1 i M_{BO} wynosił odpowiednio 4,70% i 0,80%. Pozostałe modele geometryczne dawały błąd większy od 5%. Przy zastosowaniu modeli geometrycznych rzeczywista powierzchnia owoców jest traktowana jako ciągła płaszczyzna bez zagłębień.



Rys. 6. Objętość owoców truskawki.
Fig. 6. Volume of strawberries.
Źródło: Opracowanie własne
Source: Own study

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

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

Pole powierzchni A (Kruskala-Wallisa test) / Area A (Kruskal-Wallis test) H(5, N=180)=128,48; p=0,000 Prawdopodobieństwa porównań wielokrotnych / Probability of multiple comparisons				
Metoda pomiaru Measurement method	**Liczebność próby Number of observations N**	**Suma rang Rank-sum**	**Średnia ranga Mean rank**	**Średnia Mean (mm²)**
3D	30	2519,00	83,96	4356,42[b]
M1	30	2246,00	74,86	4143,88[b]
M2	30	4332,00	144,40	6207,26[c]
M3	30	4294,00	143,13	6201,57[c]
M4	30	476,00	15,86	2160,42[a]
M_{BO}	30	2423,00	80,76	4309,46[b]

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

Źródło: Opracowanie własne
Source: Own study

Table 2. Results of the calculations to verify the significance of differences between mean values of volume
Tabela 2. Wyniki obliczeń weryfikacji istotności różnic między średnimi wartościami objętości

Objętość V (Kruskala-Wallisa test) / Volume V (Kruskal-Wallis test)
H(5, N=180)=61,50; p=0,000

Prawdopodobieństwa porównań wielokrotnych / Probability of multiple comparisons

Metoda pomiaru Measurement method	Liczebność próby Number of observations N	Suma rang Rank-sum	Średnia ranga Mean rank	Średnia Mean (mm2)
3D	30	1790,00	59,66	23640,89a
M1	30	2171,00	72,36	25376,70a
M2	30	4026,00	134,20	37911,39b
M3	30	3958,00	131,93	37682,93b
M4	30	2121,00	70,70	25274,26a
M_{BO}	30	2224,00	74,13	26015,57a

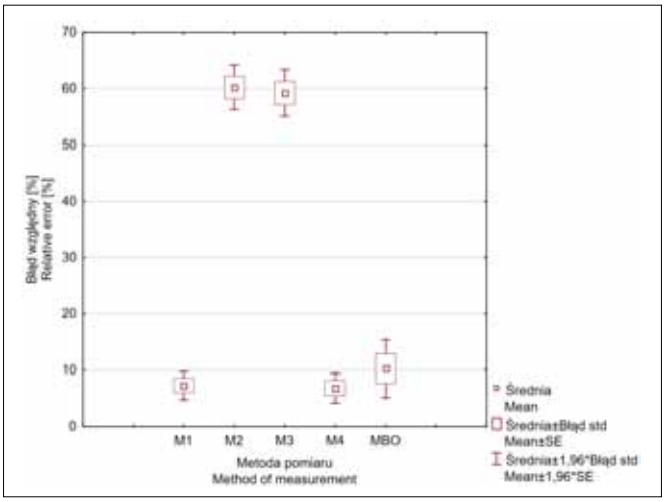
Wartości w kolumnach z takimi samymi literami nie różnią się istotnie; a, b ($P \leq 0,05$)
Values in columns marked with identical letters do not differ significantly: a, b ($P \leq 0.05$)

Źródło: Opracowanie własne

Source: Own study

Do określenia istotności między średnimi wartościami objętości wykorzystywano test ANOVA rang Kruskala-Wallisa. Wyniki szczegółowych analiz porównań przedstawiono w tabeli 2.

Zakładając, że pomiary objętości owoców truskawki metodą 3D nie są obarczone błędem, to mogą one stanowić bazę odniesienia dla wyników uzyskanych za pomocą modeli geometrycznych. Jak widać z rysunku 7 błąd metody pomiaru objętości owoców wykorzystując modele geometryczne M1, M4 i M_{BO} wynosił od 6,80% do 10,25%.



Rys. 7. Błąd względny wyznaczania objętości owoców truskawki.

Fig. 7. Relative error in determining the volume of strawberry.

Źródło: Opracowanie własne

Source: Own study

WNIOSKI

Z przeprowadzonych badań na owocach truskawki, wynika, że spośród zastosowanych trzech metod wyznaczenia parametrów geometrycznych owoców najlepsze efekty uzyskano przy metodzie 3D. Na podstawie przestrzennych modeli numerycznych można wyznaczyć parametry geometryczne (wymiary, powierzchnię, objętość) całych próbek jak i ich wybranych fragmentów. Pomiar pola powierzchni owoców z wykorzystaniem przestrzennych modeli numerycznych jest dokładniejszy niż pomiar pola powierzchni metodą bezpośrednią z wykorzystaniem modeli geometrycznych (metoda 1D). Do wyznaczenia pola powierzchni owoców truskawki metodą 1D można zastosować modele geometryczne M1 (kula) i M_{BO} (bryła obrotowa). Wyznaczając objętość owoców truskawki metodą 1D można wykorzystać modele M1 (kula) i M4 (elipsoida obrotowa). Wykorzystując wymienione modele do wyznaczania pola powierzchni i objętości owoców popełnia się błąd względny pomiaru mniejszy od 7%. Budowanie za pomocą inżynierii odwrotnej przestrzennego modelu numerycznego (metoda 3D) jest procesem wymagającym zachowania określonych warunków oświetleniowych, które na chwilę obecną nie są łatwe do spełnienia w warunkach polowych.

CONCLUSIONS

The analysis of the three methods for determining the geometric parameters of strawberries revealed that the 3D method delivered more accurate results. The geometric parameters (linear dimensions, surface area, volume) of entire samples and their selected fragments can be determined based on digital 3D models. The surface area of strawberries was more accurately measured using digital 3D models (3D method) than the direct method involving geometric models (1D method). In the 1D method, the surface area of strawberry fruit can be determined with the use of a sphere (M1) and a revolving solid (M_{BO}). The volume of strawberry fruit can be determined with the use of a sphere (M1) and a spheroid

(M4). When geometric models M1, M4 and M_{BO} were applied to measure the surface area and volume of strawberries, the mean relative error was less than 7% respectively. Building a numerical model (3D method) using reverse engineering is a process that requires maintaining good lighting conditions, which at present are not easy to apply in the field.

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FERMENTATION OF PLANT-BASED BEVERAGES USING LACTIC ACID BACTERIA – A REVIEW®

Fermentacja napojów roślinnych z wykorzystaniem bakterii kwasu mlekowego – przegląd literatury®

Key words: milk substitutes, fermentation, viability of bacteria, probiotics, food trends, plant-based beverages.

The number of people following plant-based diets is increasing tremendously. One of the most popular plant replacements for animal products is plant-based beverages, which are one of the food groups that are irreplaceable in the vegan food industry. With the growing popularity of plant-based diets, the demand for fermented plant-based beverages is also growing. This article provides a brief overview of the fermentation of plant-based beverages using lactic acid bacteria (LAB). The general characteristics of plant-based beverages were presented and the survival of LAB in different types of plant-based milk substitutes was analyzed. The biggest challenge facing producers of fermented plant-based beverages is to ensure a sufficiently high survival rate of probiotic bacteria, which are responsible for causing the health effect. This review showed that the presented milk substitutes made from cereals, pseudocereals, legumes, seeds, nuts, and other raw materials constitute a suitable matrix for the fermentation. Despite many studies and experiments, the topic is still relevant, with many scientific reports finding a place in top trade journals.

Słowa kluczowe: substytuty mleka, fermentacja, przeżywalność bakterii, probiotyki, trendy w żywności, napoje roślinne.

Liczba osób stosujących diety roślinne rośnie w zaskakująco szybkim tempie. Jednym z najpopularniejszych zamienników roślinnych produktów odzwierzęcych są napoje roślinne, które stanowią jedną z grup żywności niezastąpionych w wegańskim przemyśle spożywczym. Wraz z rosnącą popularnością diet roślinnych rośnie również zapotrzebowanie na fermentowane napoje roślinne. Niniejszy artykuł przedstawia krótki przegląd literatury dotyczącej fermentacji napojów roślinnych z wykorzystaniem bakterii kwasu mlekowego (LAB). Przedstawiono ogólną charakterystykę napojów roślinnych oraz przeanalizowano przeżywalność LAB w różnych rodzajach roślinnych substytutów mleka. Największym wyzwaniem stojącym przed producentami fermentowanych napojów roślinnych jest zapewnienie odpowiednio wysokiej przeżywalności bakterii probiotycznych, odpowiedzialnych za wywoływanie efektu zdrowotnego. Przegląd ten wykazał, że przedstawione napoje roślinne, wytworzone ze zbóż, pseudozbóż, strączków, nasion, orzechów i innych surowców, stanowią odpowiednią matrycę do procesu fermentacji. Pomimo wielu badań i eksperymentów, temat ten jest jednak nadal aktualny, a wiele doniesień naukowych znajduje swoje miejsce w czołowych czasopismach branżowych.

INTRODUCTION

Over the past decade, research is mainly focused on developing products targeting the changing demands of the consumer, by creating newer alternatives to health foods. Researchers focus on plant foods rich in dietary fibers, minerals, vitamins, and antioxidants. Such products are often classified as functional food, i.e. one that has a documented positive effect on the human body and its consumption may improve health and well-being, as well as reduce the risk of diseases [42, 46].

Plant-based products are often presented as a healthy, sustainable, and animal-welfare-friendly alternative [23]. These factors push the food industry and the global market toward the design, supply, and production of novel plant-based products [43]. Importantly, vegetarianism, veganism and the adoption of a plant-based diet are growing trends, mainly across Western countries. The number of people following plant-based diets is increasing tremendously, according to different vegan societies and consulting companies [1].

Throughout the years, the consumption of plant-based diets has increased considerably, which is the result of consumer decisions related to:

- health and environmental concerns;
- global trend of plant-based diets (vegetarian and vegan);

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- aversion to animal cruelty;
- widespread incidence of lactose intolerance or cow's milk protein allergy;
- flexitarian choice of food consumption;
- desire for a healthy lifestyle
- problems due to diets rich in cholesterol [1, 4, 13, 41].

One of the most popular plant replacements for animal products are plant-based beverages, which are one of the food groups that are irreplaceable in the vegan food industry. They are mainly used as milk substitutes; however these products are also used as an essential ingredient in many vegan food products such as plant-based yogurt, cheese, kefir, butter, ice cream, etc. [4, 44]. The global plant-based beverages market reached an estimated size of US $8.51 billion in 2016 and is forecasted to rise to a CAGR (compound annual growth rate) of 12.5% to triple a market volume of US $24.6 billion in 2025 [23]. Soy products are still dominating this market, but the emergence of alternative products from other plant sources (e.g. other legumes, cereals, nuts) has decreased its share [36].

With the growing popularity of plant-based diets, the demand for fermented plant-based beverages is also growing [3, 31]. Such products should contain lactic acid bacteria (LAB) that are naturally present in fermented milk drinks, including yoghurt, kefir, etc. LABs often exhibit probiotic properties and should show a similar survival in a plant matrix as in dairy products [39, 59]. This review provides a brief overview of fermentation of plant-based beverages using LAB. The general characteristics of plant-based beverages were presented and the survival of LAB in different types of plant-based milk substitutes was analyzed.

CHARACTERISTICS OF PLANT-BASED BEVERAGES

Plant-based beverages have gained immense popularity over the years among consumers avoiding cow's milk. Today, milk substitutes are commercially obtained from a variety of plant-derived ingredients [43]. Types of plant-based beverages obtained from various raw materials are presented in Figure 1. There is no stated definition and classification of plant-based beverages in the literature. They are fluids that results from breakdown (size reduction) of plant material extracted in water and further homogenization of such fluids. The size of particles and the stability of the final product depend on the nature of the raw material, the method used for disintegration and storage conditions [46]. Obtained products are similar in appearance and taste to conventional milk and are used for the same purposes. Derived from the water extraction of plant matrices, plant-based beverages are completely free from animal-based ingredients [23]. Depending on the raw materials, fortification and technology employed in the production processes, large nutritional composition variability, and differences in terms of technological and sensory features have been reported [23, 36, 43].

The production of plant-based drinks varies depending on the raw material used. However, each drink has several of the same production steps. Initially, the raw material is soaked and grounded. The obtained grounded product is extracted with water. The solid material is filtered, and the obtained liquid is supplemented with additional ingredients, mainly thickeners (e.g. sunflower lecithin, gellan gum), antioxidants (e.g. ascorbic acid), sweeteners, sea salt, fortifying substances (e.g. calcium, vitamin A, B2, B1, B12, D2, and E). The product is then homogenized, heat treated and packaged [4, 36, 41].

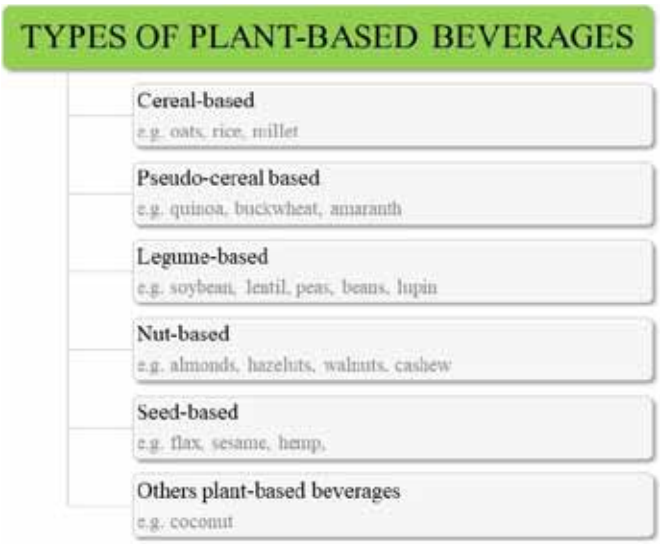

Fig. 1. Types of plant-based beverages.
Rys. 1. Rodzaje napojów roślinnych.
Source: Own study
Źródło: Opracowanie własne

There are great differences in the composition of different types of plant-based beverages. According to Fructuoso et al. [20], the variation in the amount of nutrients in different plant-based beverages was 6–183 kcal/100 mL for energy value; 0.00–22.29 g/100 mL for carbohydrate; 0.06–12.43 g/100 mL for protein; 0.00–19.00 g/100 mL for lipid; 0.00–4.40 g/100 mL for dietary fiber; and 0.00–1252.94 mg/100 mL for calcium [20]. Plant-based beverages are treated as milk substitutes but differ from cow milk in several ways. From the macronutrients point of view, the protein content of milk substitutes is generally lower than in cow's milk, but plant-based milk alternatives are richer in terms of fiber and unsaturated fatty acid content, are cholesterol-free and present a low glycemic index [4, 15, 24]. Plant proteins are generally of a lower nutritional quality compared to animal - derived proteins due to limiting amino acids (lysine in cereals, methionine in legumes) and poor digestibility [36]. Plant-based beverages are sometimes enriched with calcium, vitamin D, and B vitamins, but still many products on the market are not fortified [15, 23].

Plant-based beverages are rich in bioactive compounds, the presence of which has many health-promoting effects. These ingredients include e.g. beta-glucans, phytosterols, isoflavones, fatty acids, and lignans [41]. The presence of bioactive ingredients makes regular consumption of plant-based beverages associated with improved blood glucose and insulin resistance; reducing the risk of cardiovascular disease and diabetes; reducing the occurrence of some cancer and osteoporosis; supporting the immune system; as well as reducing the blood cholesterol level [4, 36, 41, 42].

There are also anti-nutritional factors (ANFs) in plant-based beverages, which negatively affect the sensory profile

as well as the bioavailability of macro- and micro- nutrients and protein quality [43]. ANFs are mainly oligosaccharides from the raffinose family, protease inhibitors, saponins and phytates. Another problem may be the presence of "beany" and "painty" off-flavors, originating from lipoxygenase activity [36]. It is possible to exclude these negative factors present in plant-based beverages as a result of various types of treatment, especially fermentation. Fermentation with LAB often results in an improved nutritional profile mainly due to the release of amino acids and bioactive compounds, decrease of ANF activities and enhancement of the protein digestibility [4, 43]. Furthermore, fermentation of milk substitutes improves sensory perception because it decreases the beany off-flavor of plant materials and provides desirable volatile flavors [1].

FERMENTATION OF PLANT-BASED BEVERAGES USING LAB

Bacteria of the genus *Lactobacillus* are among the most important bacteria used in the food industry, food microbiology and human nutrition. They have proven health-promoting properties, as well as playing a major role in food production. Until recently, the genus *Lactobacillus* included more than 250 species of bacteria, and a whole genome sequence analysis made in 2019 has shown that members of the genus are phylogenetically interwoven with other LAB genera [18]. Currently, the genus *Lactobacillus* is reduced to only 38 species around the type species, *Lactobacillus delbrueckii*, the other lactobacilli have been transferred to types with new names (however without changing the name of the species) [60]. Among the most important functions of these microorganisms are:

– imparting a specific flavor to food during the fermentation process through the release of diacetyl, hydrogen and sulfur;
– participation in the production of fermented foods (sauerkraut, pickled cucumbers, meat);
– participation in the production of fermented beverages (wine, beer) [16].

LAB are most often found on the surface of healthy or decomposed plant material, as well as in fermented products (including raw fermented meat), sewage, water, raw juices, and silage. In addition, they colonize human and animal organisms (genital organs, oral cavity, respiratory tract, and intestines). They belong to the non-pathogenic and beneficial intestinal microflora [26].

The addition of beneficial probiotic microflora to food leads to the hydrolysis of components such as proteins and lipids, which, as a result of this process, are transformed into substances that taste, smell and modify the texture of the product. This is extremely important in the subsequent perception of the product by the consumer. The introduction of probiotic strains into plant-based beverages is also an opportunity to enrich the diets of people who do not consume traditional fermented foods, such as sauerkraut or pickled cucumbers, due to their specific taste and texture [17]. Moreover, the addition of starter cultures to plant-based beverages can minimize the need for artificial stabilizers or flavorings, affecting the final nutritional and health value of the product [49].

Consumption of fermented plant-based beverages contributes to increasing the diversity of the gut microbiota, which controls most of the human body's processes. The more beneficial gut bacteria populate the intestines, among other things, the level of short-chain fatty acids (SCFAs) responsible for anti-inflammatory effects increases [49]. Probiotic bacterial cells colonizing the large intestine affect the proper functioning of the digestive system, immune system, or hormone function. Recent studies indicate that homeostasis of the gut microbiota is responsible for brain processes and works directly through the axis-microbiota-brain. Most of the serotonin is synthesized right in the gut, which is why gut dysbiosis can lead to the development of depression or other mental disorders. All these scientific reports make fermented foods and foods enriched with probiotic strains extremely necessary in the current food market [57].

The most important and key criterion for any fermented product is a sufficiently high viability of bacterial cells in the product during refrigerated storage. The number of viable bacteria in the product should be a minimum of 10^6 CFU/mL, a level that ensures that the product is able to produce a therapeutic effect on the consumer [19]. However, it is important to note that this number should be much higher, as bacterial cells are exposed to many harmful factors during the gastrointestinal passage. The high pH of gastric juice, the action of digestive enzymes and bile salts affect the loss of viability of probiotic cells and ultimately too few bacteria enter the large intestine, which will not be able to produce a health effect in the host. Ensuring sufficiently high levels of viable bacterial cells in a product is the biggest challenge for fermented food scientists [6].

THE VIABILITY OF LAB IN CEREAL – AND PSEUDOCEREAL-BASED BEVERAGES

Cereals and pseudo-cereals are a group of foods that are often fermented. This is due to their rich composition in terms of macro- and micro-nutrients, as well as their high content of fiber, the consumption of which is essential for the proper functioning of the digestive system [64]. Whole grain products contribute to reducing the risk of type 2 diabetes, cardiovascular disease, or obesity, among others [30]. Grains have been used to make traditional fermented beverages such as boza and mahewu popular in Africa, the Balkans and Turkey. The rise in popularity of such products in recent years has meant that the market for fermented foods is growing [10].

The cereal most often used in the production of fermented beverages is oats, which is mainly due to its delicate taste, acceptable to consumers. Not to forget the high content of fiber, essential amino acids and minerals such as magnesium, calcium, potassium and phosphorus [21]. Fermentation trials of oat beverages usually yield satisfactory results. Chen and colleagues fermented an oat with honey beverage using *Limosilactobacillus fermentum* PC1 bacteria and recorded the presence of probiotic bacteria at 7.96 log CFU/mL after 72 h of running the process. Storing the beverages under refrigeration (4°C) for 14 days did not significantly affect the loss of bacterial cell viability, which was finalized at 7.32 log CFU/mL. This study also showed that the fermentation

of oats improves antioxidant capacity, as well as increases the levels of gallic acid and catechins [11]. The production and use of fermented beverages is often targeted at specific gastrointestinal disorders to alleviate existing ailments or to supplement a deficient diet, such as when gluten or dairy is eliminated from the diet. *Lactiplantibacillus plantarum* subsp. *plantarum* WCFS1 fermented oat drink has been undergoing testing to verify its safety and performance in people with celiac disease. The survival rate of the probiotic bacteria was estimated at 8.9 log CFU/mL, so the drink exhibits a therapeutic effect at the level of the gut and intestinal microbiota. In addition, it showed significant anti-inflammatory activity and lowered cholesterol [27].

In recent years, on the podium of the healthiest and most nutritious cereals, is millet grain. This cereal has been undergoing a real renaissance for some time, so much so that dietary fasts based on dishes made from millet groats have been created [38]. However, despite the many health benefits of consuming millet groats, such measures are not supported by the scientific literature. Nevertheless, millet is of enduring interest to researchers due to its high content of omega-3 and -6 acids, polyphenols, flavonoids and fiber. There are 8.5 grams of fiber in 100 grams of dry millet, making millet an excellent matrix for developing probiotic products [3]. The additional prebiotic properties are not only positively perceived by potential consumers, but when combined with probiotic bacteria will allow the creation of a synbiotic product. A lactobacillus-fermented millet beverage showed an unusually large increase in bacterial biomass during the fermentation process, from an initial level of 5.0 log CFU/mL to 11 log CFU/mL [40]. Fermentation of the millet beverage with an allergen-free starter produced an attractive fermented product. After a 28-day refrigerated storage period, the millet beverages contained more than 10^6 CFU/mL and were positively evaluated by lactose-intolerant individuals [61].

Among gluten-free grains, one of the older but still very popular representatives is rice. Its unquestionable advantage of using it for fermented beverages is the sweet taste that can be obtained in the final product. This is due to the breakdown of carbohydrates into sugars during the processing. Despite the great popularity of rice and its many varieties, the scientific literature does not provide many examples of its use in vegetable beverages [12]. Cichońska and colleagues attempted to develop a rice beverage with the addition of probiotic bacteria. Fermentation of the rice base with bacteria of the genus *Propionibacterium* did not yield the expected results, but the addition of starter cultures of the genus *Lactobacillus*, *Saccharomyces* and *Bifidobacterium* allowed for satisfactory results. Immediately after fermentation, high numbers of live bacterial cells were recorded in the rice beverage: *Lactobacillus* sp. 7.42–8.23 log CFU/mL, *S. thermophilus* 8.01–8.65 log CFU/mL, *B. animalis* subsp. *lactis* 8.28–8.50 log CFU/mL and *P. freudenreichii* subsp. *shermanii* 4.80–5.56 log CFU/mL. During the refrigerated storage period, these values slightly decreased [12].

More and more data appearing in scientific databases, talk about the use of buckwheat as a matrix for fermented products. These are usually yogurts and fermented beverages, which, due to the specific taste of buckwheat grain, may not be the first choice of consumers, but after learning about the health benefits of consuming this pseudo-cereal, it is worth considering introducing it into the diet. Kowalska and Ziarno [29] attempted to develop a buckwheat beverage fermented with industrial cultures, two of which contained probiotic strains. Despite the lack of consumer tests to determine the taste, aroma and texture of the product, they succeeded in obtaining a beverage with a sufficiently high number of live bacterial cells at the refrigerated storage stage, exceeding 10^6 CFU/mL [28].

Another pseudo-cereal whose popularity is growing in recent years is quinoa, which is very popular among vegans, vegetarians and people who cannot consume gluten due to celiac disease or non-celiac gluten sensitivity. It has been proven that including it in the diet in combination with other healthy eating habits can effectively prevent the development of lifestyle diseases [8]. Urquizo and colleagues fermented quinoa beverage using *L. plantarum* subsp. *plantarum* Q823, *Lacticaseibacillus casei* Q11 and *Lactococcus lactis* ARH74 strains, of which *L. plantarum* subsp. *plantarum* shows probiotic potential. The 6-hour fermentation process allowed the multiplication of the starter microflora to a level of 9.5 log CFU/mL. After a one-month storage period, the number of viable bacterial cells dropped to 9 log CFU/mL [35]. Fermentation of quinoa beverage using *L. plantarum* subsp. *plantarum* strain P31891 permitted equally satisfactory results. The number of viable bacterial cells of the aforementioned strain was remarkably stable throughout the storage process and averaged 12 log CFU/mL [8].

THE VIABILITY OF LAB IN LEGUME-BASED BEVERAGES

Legumes have received a lot of attention in recent years from scientists involved in the production of functional and fermented foods [14]. For centuries, these plants have been part of human nutrition and have played a significant role in folk medicine, exhibiting multidirectional medicinal effects [45]. The growing number of people switching to plant-based diets creates the need to enrich the market with new plant-based products, into which legumes, characterized by a rich composition of macro- and micronutrients, fit perfectly. They are characterized by a high protein content, depending on the species and cultivation method, ranging from 20 to 35% [9].

In the context of the development of plant-based beverages from legumes, soybeans are the most popular, which can be seen by following the novelties appearing on store shelves. The same is true for the production of fermented plant-based beverages, it is soybeans that are one of the better matrices for developing such products. Due to its high nitrogen and carbon content, which are necessary for the fermentation process, soy is a good carrier for probiotics [44]. Soy beverage fermented with *Lactobacillus acidophilus* CH-5 and *L. casei* KN 291 strains had very good survival of bacterial cells. After the fermentation process, 10^8 CFU/mL of the product was determined in the soy beverage, which is a very good result, indicating that the product is capable of producing a therapeutic effect [65]. The addition of *Bifidobacterium longum* to the fermenting microflora showed in the study a slight decrease in the number of live probiotic bacteria cells to 10^7 CFU/mL [9]. In soy beverages fermented with a single

B. longum strain BIM B-647, which cell count was 8.2 log CFU/mL at the beginning of the fermentation process was characterized by very rapid production of bacterial biomass. After the fermentation process, the number of probiotic bacteria cells was found to increase by 2 logarithmic orders [58].

A matrix less commonly used to develop fermented beverages is beans. In Poland, the "*Piękny Jaś Karłowy*" variety predominates, which was used in the study by Ziarno et al. [63] to develop a fermented beverage. The bean-based beverage was fermented with a multi-strain microflora that included: *Lactobacillus delbrueckii* subsp. *bulgaricus* ATCC 11842, *Lactobacillus delbrueckii* subsp. *lactis* ATCC 4797, *L. fermentum* ATCC 9338, *L. plantarum* subsp. *plantarum* DSM 9843, *Levilactobacillus brevis*, *L. acidophilus* La3, *Lacticaseibacillus paracasei* BGP1, *L. casei* 01, *Lacticaseibacillus rhamnosus* LH32 and *Lactobacillus helveticus* LH-B01. After the fermentation process, slight decreases in the number of viable bacterial cells were recorded and ranged from 7.5 to 8.7 log CFU/mL. The obtained results allowed the authors to ensure the quality of bean-based beverages, which is the most important criterion during the production of such products [63]. In another study by Ziarno and co-workers, after fermentation of beverages made from germinated seeds of "*Piękny Jaś Karłowy*" beans with two starter cultures, a fermented product meeting the criterion of minimum therapeutic level was obtained. The number of viable bacterial cells after 28 days of refrigerated storage was > 10^6 CFU/mL [62]. Fermented beverages with pea and rice proteins have an equally stable microbiotic quality. A high number of live bacterial cells was recorded not only immediately after the fermentation process, but also after more than 4 months of refrigerated storage, when the number of live probiotic cells was 8.4 log CFU/mL. This is one of the better results that have been obtained in experiments on vegetable fermented beverages [2].

Legumes with high nutritional value also include lentils, which are characterized by high amounts of soluble, well-digestible proteins [52]. Like soybeans and peas, lentils are an excellent addition to the diets of people on vegetarian and vegan diets. The main purpose of developing fermented plant-based beverages is the desire to add variety to the diets of people on plant-based diets or those with specific gastrointestinal conditions. Dietary variety translates directly into a variety of bacteria that make up the intestinal microbiota. The addition of *L. acidophilus* ATCC 4356, *L. fermentum* DSM 20052 and *L. paracasei* subsp. *paracasei* DSM 20312 strains to a lentil beverage allowed the development of a product with a live bacterial cell content of 7 log CFU/mL after 28 days of refrigerated storage. The study presented here was the first performed using lentils as a matrix [55].

THE VIABILITY OF LAB IN NUT-BASED BEVERAGES

Nuts are very popular matrices for developing plant-based beverages, which provide an excellent base for the development of beneficial probiotic microflora. Nuts subjected to the fermentation process gain not only new flavor and aroma, but also their nutritional value increases [37]. One of the most popular nut-based milk substitutes on the market is cashew beverages. Shori et al. [47] investigated the effects of three strains of probiotic *Lactobacillus* spp. such as *L. rhamnosus*, *L. casei*, or *L. plantarum* in co-cultures with *Streptococcus thermophilus* and *L. delbrueckii* subsp. *lactis* on the changes of viability of LAB in yogurt made from cashew milk. All the tested samples showed high LAB survival during the 21-day storage - in the range of 8.04–8.30 log CFU/mL for *S. thermophilus* and 6.15–6.59 for *Lactobacillus* spp [47]. Similarly high survival of bacteria during fermentation was demonstrated by Bruno et al. [7] who evaluated the cashew nut milk as a matrix to deliver commercial probiotic strains (*Bifidobacterium animalis*, *L. acidophilus* and *L. plantarum*). High survival of the tested probiotic bacteria (> 8 log CFU/mL) was reported during 30 days of storage. A significant pH decrease was observed, but it did not affect the beverage's sensory acceptance, indicating that cashew nut milk is an adequate vehicle for delivering probiotics [7].

Another raw material that has dominated the plant-based beverage market in recent years is almond. The almond-based beverage was primarily introduced and marketed as an alternative milk beverage for children and adults suffering from health conditions that include cow's milk allergy and lactose intolerance [54]. It turns out to be also a suitable matrix for the fermentation process. In an almond beverage fermented with three different LAB isolates, bacterial counts ranged between 8.97 to 9.12 log CFU/mL after 24 hours of incubation [56]. High viability of probiotic bacteria was recorded also during storage in almond beverages fermented with *Limosilactobacillus reuteri* ATCC 55730 and *S. thermophilus* CECT 986. In each of the 31 samples, the number of viable bacterial cells exceeded 7 log CFU/mL after 28 days of refrigerated storage [5].

Among the nut-based beverages that may also be a suitable fermentation matrix are peanut-based milk substitutes. Peanut products have nutritional significance as they are rich in protein, minerals, and essential fatty acids such as linoleic and oleic acids, valuable components in human nutrition [42]. In a study by Utami et al. [53] the fermentation of peanut beverage was investigated using the probiotic strain of *L. paracasei* SNP-2. The numbers of LAB showed no marked reduction in the fermented peanut milk beverages during storage at 4°C for 21 days (>8 log CFU/mL), still sufficiently high to exert beneficial probiotic effects in the host [53]. Fermentation of the peanut beverage with the use of *Bifidobacterium pseudocatenulatum* G4 also allowed obtaining a product with probiotic bacteria high survival after 14 days of storage, which was above 6.60 log CFU/mL [25].

THE VIABILITY OF LAB IN SEED-BASED BEVERAGES

Seeds are an interesting raw material for the production of milk substitutes due to the fact that they are a good source of protein, minerals, fiber and oil. They are also known for their high antioxidant activity [48]. Research into seed-based beverages fermentation is limited and focuses mainly on the flaxseed-based beverages. Łopusiewicz et al. [32] investigated flaxseed oil cake as a potential substrate for the production of a novel kefir-like fermented beverage. Commercial kefir

grains containing *Lactococcus lactis* subsp. *cremoris*, *L. lactis* subsp. *lactis* biovar *diacetylactis*, *Leuconostoc mesenteroides* subsp. *cremoris*, *L. delbrueckii* subsp. *bulgaricus*, and *Saccharomyces cerevisiae* were used in the fermentation process. During 21 days of storage, the bacterial and yeast counts were maintained in the samples over the recommended for kefir level $>10^7$ CFU/mL and $>10^4$ CFU/mL for bacteria and yeast, respectively [32].

Flaxseed-based beverages fermented with the *L. rhamnosus* GG turned out to be effective in making an innovative probiotic drink. During storage at 6°C for 48 hours the viability of *L. rhamnosus* GG in all the tested samples was over the recommended probiotic minimum level ($> 10^6$ CFU/mL). Moreover, the fermentation improved antioxidant activity, polyphenolics and flavonoids content, whereas the viscosity of the samples decreased [34]. Similar results were obtained for flaxseed-based beverages fermented with *S. thermophilus*, *L. delbrueckii* subsp. *bulgaricus*, *L. acidophilus,* and *Bifidobacterium lactis* [33].

Another type of seed-based milk substitute that has been successfully fermented with LAB was hemp beverage. The hemp beverage was fermented with *L. casei* subsp. *rhamnosus* LCR 3013 and analyzed after their fermentation as well as on day 7, 14, and 21 of storage at a temperature of 4°C. On day 21 of cold storage, the number of viable *L. casei* cells in the tested beverage was at 7.35 log CFU/mL and met the therapeutic criterion. The authors concluded that the analyzed non-dairy beverages represented a category of novel food products, and their manufacture would contribute to the sustainable development of food production and the assurance of food safety [50].

THE VIABILITY OF LAB IN OTHER PLANT-BASED BEVERAGES

Among the other milk substitutes that do not fall into the above-described categories is mainly coconut beverage, which is the liquid that is extracted from the grated coconut white meat, which is rich in saturated fats, and is widely consumed in parts of Asia and South America [54]. Plant-based beverages based on matrices such as coconut are characterized by a mild taste and are often accepted by children as well [51]. Currently, the scientific literature has limited sources regarding information on fermented coconut beverages; many more reports can be found on pasteurized "coconut milk"-cow's milk alternatives. Researchers Mauro and Garcia [37] attempted to ferment coconut beverage with fairly common bacterial strains *L. reuteri* LR 92 and *L. reuteri* DSM 17938. The number of viable bacterial cells in stored samples of the plant-based beverages ranged from 6.87 to 8.50 log CFU/mL, with results below 7 log CFU/mL reported in only 2 of 24 samples [37]. Coconut water was also tested as a base for the development of beneficial starter microflora. A typically yogurt-like species of bacteria, *L. casei* L4, was added to the coconut matrix and reached a count of 9.47 log CFU/mL immediately after fermentation, while the count dropped to 7.84 log CFU/mL after a 28-day of refrigerated storage. In addition to very good bacterial survival, the starter microflora led to an increase in vitamin B12 levels [22].

CONCLUSIONS

The public's growing awareness of healthy eating, as well as the role the gut microbiota plays in maintaining health, has led to the development of such a food industry as functional foods. The biggest challenge facing manufacturers of fermented plant-based beverages is to ensure that the number of probiotic bacteria responsible for causing the health effect is high enough. The survival rate of individual bacterial strains depends on the type of plant matrix used, as well as the availability of nutrients. Not enough carbon and nitrogen is one of the reasons for insufficient growth of bacterial biomass, due to the inefficient fermentation process. The technological process itself, the fermentation temperature as well as the final pH of the product have the greatest influence on the final number of viable bacterial cells in fermented plant-based product. Scientists are working to find the best way to keep bacterial cell viability as high as possible in various types of products. The current interest in plant matrices is justified by the growing popularity of plant substitutes for animal-based food, including fermented plant products. The use of appropriate technological processes may allow to obtain products with high nutritional value and health-promoting properties, which are intensified by the addition of probiotics.

PODSUMOWANIE

Rosnąca świadomość społeczeństwa na temat zdrowego odżywiania, jak również roli jaką odgrywa mikrobiota jelitowa w utrzymaniu zdrowia, doprowadziła do rozwoju takiej gałęzi przemysłu spożywczego jaką jest żywność funkcjonalna. Największym wyzwaniem jakie stoi przed producentami fermentowanych napojów roślinnych jest zapewnienie odpowiednio wysokiej liczby bakterii probiotycznych, które są odpowiedzialne za wywoływanie efektu zdrowotnego. Przeżywalność poszczególnych szczepów bakteryjnych jest uzależniona od rodzaju użytej matrycy roślinnej, jak również dostępności składników odżywczych. Zbyt mała ilość węgla oraz azotu jest jedną z przyczyn niedostatecznego wzrostu biomasy bakteryjnej, ze względu na mało wydajny proces fermentacji. W największym stopniu na finalną liczbę żywych komórek bakteryjnych w roślinnym produkcie fermentowanym ma wpływ sam proces technologiczny, temperatura fermentacji, jak również końcowe pH produktu. Naukowcy pracują nad znalezieniem najlepszego sposobu na zachowanie maksymalnie wysokiej żywotności komórek bakteryjnych w różnego rodzaju produktach. Obecne zainteresowanie matrycami roślinnymi jest uzasadnione rosnącą popularnością roślinnych zamienników produktów odzwierzęcych, w tym roślinnych produktów fermentowanych. Zastosowanie odpowiednich procesów technologicznych może pozwolić na otrzymanie produktów o wysokiej wartości odżywczej i właściwościach prozdrowotnych, które są intensyfikowane poprzez dodatek probiotyków.

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BEER AGING PROCESS®

Proces starzenia piwa®

Key words: beer, shelf life beer, sensory properties, volatile components, technological condition.

Currently, the main quality problem of beer is the change in its chemical composition during storage, which influences the sensory change of the drink. Unlike some wines, brewing is usually considered negative for the quality of the taste.
Properly carried out technological activities, from the selection of raw materials to the bottling, can significantly improve the flavor durability of the beer.
The aging process of the beer as expressed by the evaluation of the flavor stability of the beer is described by various analytical parameters as well as by sensory evaluation of beer. The analytical assessment usually relates to different tracer substances or to the capture of substances accelerating or inhibiting the oxidation process. However, the proper analysis to determine the flavor durability is the sensorics, which is the final sensory evaluation of the beer should always be carried out.

Słowa kluczowe: piwo, trwałość piwa, cechy sensoryczne, komponenty lotne, warunki technologiczne.

Obecnie głównym problemem jakościowym piwa jest zmiana jego składu chemicznego podczas przechowywania, co wpływa na zmianę sensoryczną napoju. W przeciwieństwie do niektórych win, starzenie piwa jest zwykle uważane za negatywne dla jakości smaku.
Odpowiednio przeprowadzone czynności technologiczne, począwszy od wyboru surowców aż po rozlew mogą w wyraźny sposób poprawić trwałość smakową piwa.
Proces starzenia piwa wyrażony oceną stabilności smakowej piwa jest opisany przy użyciu różnorodnych parametrów analitycznych jak również za pomocą oceny sensorycznej piwa. Ocena analityczna odnosi się zazwyczaj do różnych substancji wskaźnikowych lub wychwycenia substancji przyspieszających bądź hamujących proces utleniania. Właściwą analizą do określenia trwałości smakowej jest ostatecznie sensoryka, stąd też należy zawsze dodatkowo przeprowadzać ocenę degustacyjną piwa.

INTRODUCTION

As for other food products, also for beer, several quality aspects may be subject to changes during storage. Shelf-life of beer is mostly determined by its colloidal, microbiological, foam, colour and flavour stabilities. The appearance of hazes and the growth of beer spoilage micro-organisms is considered as the main troublecausing phenomena [7, 8].

Beer flavour is the result of a complex interaction between hundreds of chemical compounds and even more taste and olfactory receptors. Such compounds that impart taste can be sensed directly on the tongue, while aroma will refer to any volatised compounds that can be perceived either through the nose or retro-nasally through the back of the mouth [4].

With the increasing export of beer, due to market globalisation, shelf-life problems may become extremely important issues for all breweries. Beer aging is a very complex phenomenon and action. This overview on the chemistry of beer aging intends to illustrate the complexity of the aging reactions [8].

Several quality aspects of beer are subject to change during storage. Alteration of the flavor profile in particular is of great concern to brewers since flavor is considered as the main quality parameter. Moreover, a commercial beer should be consistent and satisfy the expectations of the consumer at all times [5].

At present, there is more to aged flavour than meets the eye. It is obvious that the fresh flavour profile is disturbed by the appearance of various aged flavours and, on the other hand, an increase or decrease of many compounds is observed during ageing. However, it remains difficult to explain observed sensory changes based on analytically determined chemical compounds [4].

Flavour deterioration is the result of both formation and degradation reactions. Formation of molecules, at concentrations above their respective flavour threshold leads, to new noticeable effects, while degradation of molecules to concentrations below the flavour threshold may cause loss of initial fresh beer flavours. Furthermore, interactions between different aroma volatiles may enhance or suppress the flavour impact of the molecules [8].

Oxidation processes, due to oxygen uptake during beer production, are considered to be a major cause of stale flavour development in beer. It is often reported that absorption of oxygen in the mash, during filtration, during boiling, in wort and beer, leads to oxidation, which can damage the flavour.

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The general belief is that wort aeration has a negative impact on wort quality, which results in more rapid beer staling, though literature describing aeration related wort oxidation processes is very scarce [3].

CHANGES (CHEMICAL AND PHYSICOCHEMICAL) IN BEER DURING STORAGE

Information on beer staling reveals only few reports dealing with the actual sensory changes during beer storage. Figure 1 is a description of the sensory changes during beer storage and is by no means applicable to every beer. A constant decrease in bitterness is observed during aging. In contrast to an initial acceleration of sweet aroma development, the formation of caramel, burntsugar and toffee-like aromas (also called leathery) coincides with the sweet taste increase [2, 8].

The intensity of the ribes flavour decreases. Cardboard flavour develops after the ribes aroma. In turn, cardboard flavour constantly increases to reach a maximum, followed by a decrease. Furthermore, a very rapid formation of what is described as ribes flavour is observed. The term ribes refers to the characteristic odour of blackcurrant leaves (Ribes nigrum). Besides these general findings, other reported changes in flavour are harsh after-bitter and astringent notes in taste and wine- and whiskey-like notes in strongly aged beer [8].

From the start of research on staling compounds, carbonyls attracted most attention. Such compounds were known to cause flavour changes in food products such as milk, butter, vegetables and oils. Remarkable increase in the level of volatile carbonyls in beer during storage, is parallel with the development of stale flavours. Acetaldehyde was one of the first compounds for which a concentration increase was observed in aged beer. First described (E)-2-nonenal as a molecule, which on addition to beer, induces a cardboard flavour similar to such flavour in aged beer. Further, the identification, in heated acidified beer, of (E)-2-nonenal, as the molecule responsible for cardboard flavour, was considered a breakthrough in beer flavour [8].

In turn, volatile esters introduce fruity flavour notes and are considered highly positive flavour attributes of fresk beer. Isoamyl acetate, produced by yeast, e.g., gives a banana-like flavour. However, during storage, the concentration of this ester can decrease to levels below its threshold level which results in a diminished fruity flavour of beer. In contrast, certain volatile esters like etyl lactate, ethyl phenylacetate, ethyl formate, ethyl furoate and ethyl cinnamate are synthesized during beer aging. The formation of ethyl 3-methyl-butyrate and 2-methylbutyrate to the development of winy flavours. Lactones or cyclic esters, such as c-hexalactone and c-nonalactone (peach, fruity) tend to increase in concentration and the latter molecule is considered important for the flavour of aged beer [8].

Other components, like non-volatile compounds in beer can be important for taste and mouthfeel. Changes in concentration may therefore induce important sensory alterations. Iso-α-acids, the main bitterness substances in beer, are particularly sensitive to degradation during storage which results in a decrease in sensory bitterness. The iso-a-acids comprise six major components: the trans and cis-isomers of isocohumulone, isohumulone and isoadhumulone. The trans-isomers are much more sensitive to degradation than the cis-isomers. The concentration ratio trans/cis isomer was proposed as a good marker for the flavour deterioration of beer. Apart from iso-a-acids, polyphenols are some of the more readily oxidized beer constituents There are only few reports on beer storage-related changes in amino acids. In general, a slight decrease is observed of some individual amino-acids and glutamine has been proposed as a staling marker [8].

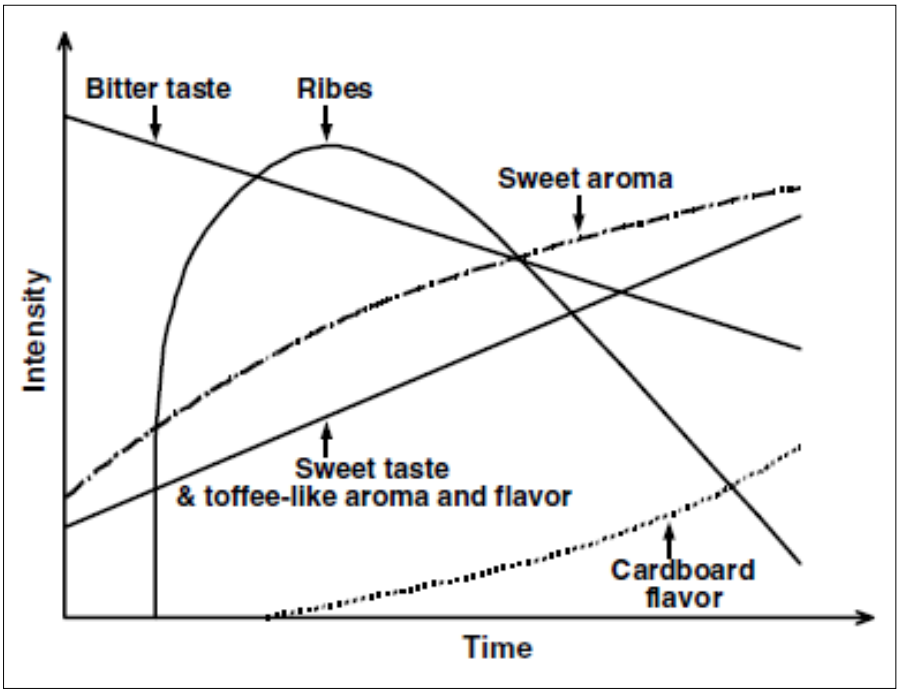

Fig. 1. Sensory changes during beer aging.
Rys. 1. Zmiany sensoryczne piwa podczas jego starzenia.
Source: Dalglish 1977 [2]
Źródło: Dalglish 1977 [2]

MECHANISMS OF AGING OF BEER

Chemically, beer can be considered as a water-ethanol solution with a pH of around 4.2 in which hundreds of different molecules are dissolved. These originate from the raw materials (water, malt, hops, adjuncts) and the wort production, fermentation and maturation processes. However, the constituents of freshly bottled beer are not in chemical equilibrium. Thermodynamically, a bottle of beer is a closed system and will thus strive to reach a status of minimal energy and maximal entropy. Consequently, molecules are subjected to many reactions during storage, which eventually determine the type of the aging characteristics of beer. Although many

conversions are thermodynamically possible, their relevance to beer aging is mainly determined by the reaction rates under practical storage conditions. The reaction rate is a function of substrate concentrations and rate constants, which differ between reaction types and which are temperature-dependent. In practice, reaction rates increase with higher substrate concentrations and storage temperatures [4].

Soon after the importance of carbonyl compounds for beer staling was revealed, pathways for their formation were suggested. From the beginning, reaction mechanisms leading to (E)-2-nonenal have been the focus of this research. Many routes have been studied in beer model systems and it therefore remains difficult to tell to what extent a particular reaction mechanism is relevant under normal storage conditions.

The most important alcohols in beer are ethanol, 2-methyl-propanol, 2-methyl-butanol, 3-methyl-butanol and 2-phenyl-ethanol. Various researchers have reported that the concentrations of the corresponding aldehydes increase during beer aging, in particular when oxygen was present. High temperatures, low pH and the supplementation of additional higher alcohols to beer led to higher concentrations of aldehydes. Moreover, direct oxidation of alcohols by molecular oxygen was not possible in beer model systems, unless melanoidins were present. A reaction mechanism was proposed in which alcohols transfer electrons to reactive carbonyl groups of melanoidins. Molecular oxygen accelerates the oxidation of the alcohols, probably because the melanoidins are transformer in such a way that the reactive carbonyl groups are involved in the electron-transfer system [4].

Amino acids in stored beer can be a source of aldehydes. observed an increased formation of 2-methyl-propanal and 3-methyl-butanal when either valine or leucine were added to beer and oxygen was present. The reaction was catalysed by Fe and Cu ions. This was explained by a Strecker reaction between amino acids and α-dicarbonyl compounds. The reaction involves transamination, followed by decarboxylation of the subsequent a ketoacid, resulting in an aldehyde with one carbon atom less than the amino acid. Additional α-dicarbonyl compounds in beer are possibly formed by the Maillard reaction, the oxidation of reductones or the oxidation of polyphenols. Strecker degradation is only important at strongly increased amino acids contents, but not at the amino acid concentrations normally present in beer (±1 g/l) [4, 8].

In turn aldol condensation of carbonyl compounds is possible under the mild conditions existing in beer during storage. For example, (E)-2-nonenal was formed by aldol condensation of acetaldehyde with heptanal in a model beer stored for 20 days at 50°C and containing 20 mmol/l of proline. In these reactions, the amino acids may be the basic catalysts through the formation of an imine intermediate. This pathway can produce carbonyl compounds with lower flavour thresholds from carbonyls present in beer which are less flavour active, and which can be formed by other pathways. Although the aldol condensation pathway seems plausible, it is not clear whether the amounts of reaction products are sufficiently high to reach threshold concentrations under normal beer storage conditions.

Formation of many distinct compounds during ageing, degradation of acetate esters can occur, resulting in a decrease of fresh flavour. Acetate esters determine the fresh flavour of beer greatly and might be able to mask the perception of other flavour compounds. Therefore, the appearance of aged flavour notes can be accelerated upon acetale ester degradation. Hence, the potential masking effect of IAA (Iso-Amyl Acetate) on 2-MB and methional was studied. This was performed by determining THs (thresholds) of aldehydes in beer with an extra added amount of IAA to the test, as well as the reference beer. Comparing the THs with those determined in beer without addition might give an idea of masking effects exerted by IAA.

Nevertheless, it can be concluded that the presence of higher IAA concentrations can affect the TH value considerably, indicating once again that the TH of a compound is highly dependent on the reference beer and that masking effects might play an important role in decelerating the appearance of aged flavours [1, 4].

From the point of view of improving beer flavor stability, wort aeration methods used in modern fermentation technology, such as high gravity brewing and large cylindroconical tank systems, were investigated in detail using a novel electron spin resonance method, which could determine the endogenous antioxidant activity (EA) value. The results showed that the optimization of wort aeration methods in the multifilling fermentation systems ("Drauflassen") was essential for controlling the EA value of the finished beer as well as fermentation performance. The key point in the optimization of wort aeration methods was to consider the yeast growth phase at the time of wort aeration and the quantitative ratio of additional aeration to the first aeration depending on the fermentation conditions. Based on the extensive series of studiem on improving the oxidative flavor stability of beer, the relationships between the EA value and sulfite level in beer are considered. A strategy for improving oxidative flavor stability of beer is also proposed [3, 6].

The ESR (Electron Spin Resonance) is one of the method can be successfully applied to analyze the effect of wort aeration methods on the oxidative flavor stability of beer when using multifilling methods. The results show that optimization of wort aeration methods and of other multifilling methods such as the filling time of additional wort, pitching procedures, the quantity of additional aeration, are very important in influencing fermentation performance and the EA value of finished beer. The key points in the optimization of wort aeration methods are the yeast-growth phase at the time of additional aeration and the quantitative ratio of additional aeration to the first aeration. Sulfite is one of the most important antioxidants to enhance the EA value of beer. However, it is also shown that the EA value of beer is determined not only by sulfite levels in beer, but also by the balance in levels of both prooxidants and antioxidants. These results show that the EA value is a useful tool to predict the flavor stability of beer, because the EA value is a total index that may reflect the balance of prooxidants and antioxidants in beer [6].

PODSUMOWANIE

Niniejszy przegląd podsumowuje aktualną wiedzę na temat procesów starzenia piwa przechowywanego w dłuszym okresie czasu. Materiał opisuje również mechanizmy reakcji, które odpowiadają za niniejsze procesy „aging beer". Ponadto omówiono związek między procesem produkcji a stabilnością smaku piwa. Opóźnienie procesu starzenia a jednocześnie wydłużenie świeżości piwa na półkach sklepowych jest jednym z najważniejszych działań podejmowanych przez producentów piwa. Browary przeprowadzają próby jakościowe z różnymi ustawieniami parametrów technologicznych w celu poprawy jakości piwa po dłuższym okresie czasu.

CONCLUSION

This overview summarizes the current knowledge about the aging processes of beer stored over a long period of time. The material also describes the reaction mechanisms that are responsible for this "beer staling" process. In addition, the relationship between the production process and the stability of the beer flavor was reported. Delaying the aging process and at the same time extending the freshness of beer on store shelves is one of the most important activities undertaken by beer producers. Breweries carry out quality tests with various settings of technological parameters in order to improve the quality of beer over a longer period of time.

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THE USE OF FRUIT BIO-WASTE ON THE EXAMPLE OF APPLE POMACE®

Wykorzystanie bioodpadów owocowych na przykładzie wytłoków jabłkowych®

Key words: apple pomace, fruit pomace, waste management**,** fruit residues.

Apple processing generates a huge amount of bio-waste in the form of pomace, which instead of being managed, contribute to environmental pollution. Apple pomace is formed mainly at the stage of apple processing and food production. It is valuable material that can be reused in a agriculture industry according to the circular economy concept. Unprocessed or slightly processed fruit residues can be converted into animal feed or be used as biofertilizers. Apple pomace contains valuable substances and compounds that can be successfully used in food, cosmetic and pharmaceutical products. Another form of using apple pomace is the extraction of biofuels. According to the idea of sustainable development rational management of bio-waste benefits economically, reduces environmental pollution and contributes to the reduction of greenhouse gas emissions.

Słowa kluczowe: wytłoki jabłkowe, wytłoki owocowe, gospodarka odpadami, pozostałości owoców.

Przetwórstwo jabłek generuje ogromną ilość bioodpadów w postaci wytłoków, które zamiast być zagospodarowane, przyczyniają się do zanieczyszczenia środowiska. Wytłoki jabłkowe powstają głównie na etapie przetwarzania jabłek i produkcji żywności. Jest to cenny materiał, który może być ponownie wykorzystany w przemyśle rolniczym zgodnie z koncepcją gospodarki o obiegu zamkniętym. Nieprzetworzone lub lekko przetworzone pozostałości owoców mogą być przekształcane w paszę dla zwierząt lub stosowane jako bionawozy. Wytłoki jabłkowe zawierają cenne substancje i związki, które z powodzeniem mogą być stosowane w produktach spożywczych, kosmetycznych i farmaceutycznych. Inną formą wykorzystania wytłoków jabłkowych jest produkcja biopaliw. Zgodnie z ideą zrównoważonego rozwoju, racjonalne gospodarowanie bioodpadami przynosi korzyści ekonomiczne, zmniejsza zanieczyszczenie środowiska i przyczynia się do redukcji emisji gazów cieplarnianych.

INTRODUCTION

The events of recent years have changed the perception of many underestimated issues and problems related to balanced development of food production. Among the many factors, the growing adverse climate changes resulting from global warming caused by human activity, the growth of the human population, the depletion of natural resources, including drinking water, and more recently the spectre of food shortages and the growing energy and economic crisis play a fundamental role. In this context, the inefficient use of globally produced food is one of the biggest problems. It is estimated that 1/3 of the food produced in the world is wasted in the food chain. According to European Commission statistics, it is estimated that in the European Union 20% of the total food produced is lost or wasted. The result is a huge amount of waste that is a potential nutritional value, contains valuable bioactive compounds and instead of being managed**,** contributes to environmental pollution.

Fruits and vegetables are characterized by a high amount of waste, which is formed mainly at the stage of processing and production of food [4, 5]. Agricultural and food by-products are a valuable source of fiber and antioxidants. They contain a number of bioactive substances such as phenolic compounds, carotenoids, vitamins**,** polyunsaturated fatty acids, minerals and pigments. Plant by-products **include husks, seeds, pods, stems, roots, pulp and peel residues, and** under-ripe, over-ripe fruits that, **despite their nutritional value, are still rejected by the** food industry [12]**.** As **part of** the circular economy framework, bio-waste can be composted, used in the production of animal feed, used in food and pharmaceutical products, used in the production of cosmetics, packaging, bioenergy production [10, 11]. The increase in environmental awareness in modern societies promotes the use of natural, nutritionally valuable substances contained in bio-waste for food production. This idea meets the expectations of consumers regarding healthy food. According to the data of the Statistics Poland in 2020, total production of cereals in

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Poland was 35.5 million t, rapeseed – 3.1 million t, potatoes – 7.8 million t, sugar beet 14.9 million t, fruit trees production in orchards – 3.9 million t, including the largest share apples – over 3.5 million t, field vegetables production – 3.9 million t, fruit production from berry plantations and fruit bushes in orchards – 0,6 mln t (Table 1).

Table 1. Production of main crops in 2020 in Poland

Tabela 1. Zbiory głównych ziemiopłodów w 2020 r. w Polsce

Specification	in million tones
Cereals total	35,5
Rapeseed and turnip rape	3,1
Potatoes	7,8
Sugar beet	14,9
Field vegetables	3,9
Tree fruit	3,9 (**Apple 3,5**)
Berries	0,6

Source: The own study based on Statistics Poland data [29]

Źródło: Opracowanie własne na podstawie danych GUS [29]

According to estimates**,** in Poland, from 20 to 30% of the harvest was wasted, which is from 13.94 to 20.91 million tons of bio-waste. A key challenge is to use natural resources while reducing environmental pollution. The circular economy concept is an interesting proposal to support the reuse of resources in the agricultural industry [8]. In the near future, it is expected that, due to increasing nutritional needs, the proper management and use of food waste will be carried out on a large scale. The European Commission has defined food waste as a priority area and has established mandatory monitoring and reporting on food waste by Member States and has committed to achieving the Sustainable Development Goal (Directive (EU) 2018/851) [13]. In 2021, as part of the reduction of food waste, the European Commission has developed a "Farm-to-Fork Strategy" that will comprehensively cover the issues of the food chain and the value of food [9]. The proper management of food by-products, especially fruit residues is beneficial for the environment and brings measurable economic benefits. The aim of the study, based on data from the literature, was to describe on the basis of the apple pomace issues related to bio-waste management.

APPLE POMACE CHARACTERISTICS

With a production of 3.5 million tons per year, Poland is the fourth largest apple producer in the world, after China, USA and Turkey. Taking into account that about 50% of apples are subject to processing, the amount of bio-waste generated in 2020 in Poland, based on Statistics Poland data, can be estimated at about 0.5 million tons [29]. The main by-product of apple processing is pomace formed in the production of juice and cider, which contain potentially valuable components. The pomace consists of peel, core, seeds, calyx, stems and pulp [26]. Apple pomace represents 20–35% of the fresh weight. The main component of apple pomace is the pulp and peel, which account for 94.5%. The other ingredients are seeds – 4.1% and fruit stalks – 1% [7]. The potentially valuable components, which are phenolic compounds are concentrated in the seed and peel. Dietary fiber in apple pomace consists of soluble and insoluble fibers [19]. Apple dietary fiber consists of cellulose, hemicellulose and pectin. It is estimated that pectin from apple pomace may have a prebiotic effect. Undigested pectin reaches the large intestine where it is a fermentation substrate for commensal bacteria. The use of dietary fiber can have beneficial health-promoting effects [6]. In addition to undigested dietary fiber, apple pomace contains a significant amount of starch and sugar, which also promotes fermentation processes carried out by microorganisms. The composition of sugars in pomace depends on the variety of apples. According to Queji (2010), the average content of apples is 23% fructose, 14.4% sucrose, and 6.7% glucose, respectively [25]. Apple pomace also contain phosphorous, calcium, magnesium and iron [31].

Other components of apple include oil, the main ingredients of which are unsaturated fatty acids, mainly linoleic and oleic acid [16]. Apple bio-waste contains organic acids like oxalic acid, malic acid, and citric acid [22]. Apple seeds contain a cyanogenic glycoside, amygdalin. The degradation of amygdalin in the human intestine can lead to cyanide formation. However, the probability of poisoning is negligible because this would require the consumption of 800 g of apple pomace [21]. A potential problem may be the content of pesticides, because apple plants are intensively sprayed with pesticides, so before processing it is necessary to carry out a toxicological analysis [2]. Apple pomace can be considered as a safe product that can be successfully used in the food chain as part of the **circular** economy framework.

USE OF APPLE POMACE

Apple pomace, like other fruits and vegetables, has a high water content (>70 %), which makes it susceptible to rapid rotting. Hence the requirement to immediately process the pomace after it has been obtained, e.g.drying, so as to prevent rotting processes. To obtain potentially valuable components contained in apple pomace, techniques such as extraction, chemical or biological conversion or synthesis should be used [6]. Processing apple residues requires a professional approach and additional investments that should be economically justified. One of the forms of apple biomass management is the extraction of nutritionally valuable substances from it, e.g. for the production of nutrafarmaceuticals or cosmetics [15]. The second is the use of unprocessed or slightly processed waste, e.g. as an additive to various food products or for the production of feed or bio-fuels [21].

The addition of fruit and vegetable to food products can change their characteristics and affect sensory properties. In order to enrich food products with valuable substances and compounds derived from apple pomace, a small addition (from 3% to 20%) is usually enough. This amount of additive makes it possible to maintain the characteristics of food products and their quality parameters, such as taste, color, texture at a level acceptable to consumers. This is crucial, when making purchasing decisions [24]. The use of apple pomace in bakery products containing fiber, polyphenolic compounds,

flavonoids contributes to the increase in antioxidation activity, which results in a potential, beneficial pro-health effect and the possibility of classifying these products as functional foods. Reis et al. (2014) applied the addition of 20% apple pomace to scones, achieving a fourfold increase in polyphenol content, a 3.3-fold increase in flavonoids and a 3.1-fold increase in proanthocyanidins [28]. Additional benefits result from a decrease in caloric value and glycemic index, which is particularly important in the case of confectionery bakery products [1]. For example, the addition of apple pomace (5%, 10%, or 15%) in cake making can avoid the addition of other flavoring ingredients, as cakes prepared with apple pomace had a pleasant fruity flavor [30].

An interesting issue is the addition of apple pomace to various meat products, including mutton, beef pâtés, poultry sausages and mutton nuggets. Apple pomace is usually used in an amount of about 10%, which does not have a significant impact on the culinary quality and properties of meat products, and is an important source of dietary fiber [18, 27, 32, 33].

Apple pomace due to its high content of phenolic compounds and antioxidants has great potential for cosmetic applications [2]. Due to the fact that they are products of natural origin, the interest in them is more motivating for the cosmetics industry [14]. Thanks to the antibacterial and anti-inflammatory properties of phenolic compounds derived from apple pomace, they can also be used in dermatology [15].

Apple pomace can also be used to produce non-toxic and environmentally friendly biopolymers [31]. In innovative experimental studies, biodegradable film, packaging materials cups, plates and objects 3D were produced from apple pomace [17, 20]. The use of fruit and vegetable bio-waste for the production of films and packaging brings a number of additional benefits resulting from their antioxidant and antibacterial properties. In addition, these packages are a barrier to gases and volatile compounds, they are also characterized by tensile strength [3]. Due to pollution and progressive degradation of the natural environment, increased greenhouse gas emission and lack of water, the management of bio-waste for the production of biodegradable packaging is a particularly desirable trend. However, the production of biopolymers from apple pomace on an industrial scale requires further work.

A promising strategy for the apple industry is to obtain bioenergy from bio-waste. The bioenergies obtained this way (ethanol, methane, hydrogen, electricity and heat) are characterized by low greenhouse gas emissions and lead to a reduction in the use of fossil fuels. In addition to biofuels, biorefineries can source value-added products such as biofertilizers, organic acids, antioxidants, enzymes, dietary fiber, emulsifiers and other natural bio-based materials used both in the food industry and in other fields [23]. Developing a biorefinery using bio-waste requires environmentally friendly technology to economically exploit it on a commercial scale.

CONCLUSIONS

In the food industry, reducing the generation, reuse and recycling of bio-waste are key to the circular economy transformation strategy. For this reason, the basic issue at present is the valorisation of organic waste. By-products of fruit and vegetables should be considered as a raw material that can be converted into an edible or useful form and as a source of valuable ingredients for use in food and other production in industries. Apple bio-waste can be used directly or after minimal processing. Pomace is used as animal feed and as agricultural fertilizer. Apple pomace can be successfully added to food products, including bakery, meat, increasing the fiber content and antioxidant properties, giving them health-promoting properties and functional food characteristics. Information from scientific research indicating the possibility of a wide use of apple pomace is important for the agri-food industry. The use of properly developed technologies and their implementation can bring economical benefits and will have a positive impact on the natural environment.

PODSUMOWANIE

W przemyśle spożywczym ograniczenie wytwarzania, ponowne wykorzystywanie i recykling bioodpadów mają kluczowe znaczenie dla strategii transformacji gospodarki o obiegu zamkniętym. Z tego względu obecnie podstawowym zagadnieniem jest waloryzacja odpadów organicznych. Produkty uboczne owoców i warzyw powinny być traktowane jako surowiec, który może być przekształcany do formy jadalnej lub użytecznej oraz jako źródło cennych składników do wykorzystania w produkcji żywności i innych gałęziach przemysłu. Bioodpady jabłkowe mogą być stosowane bezpośrednio lub po minimalnym ich przetworzeniu. Wytłoki mogą być wykorzystane jako karma dla zwierząt i jako nawóz rolniczy. Wytłoki jabłkowe mogą być dodawane z powodzeniem do produktów spożywczych, w tym piekarniczych, mięsnych, zwiększając zawartość błonnika i właściwości przeciwutleniające, nadając im właściwości prozdrowotne i cechy żywności funkcjonalnej. Informacje z badań naukowych wskazujące na możliwość szerokiego zastosowania wytłoków jabłkowych są ważne dla przemysłu rolno-spożywczego. Zastosowanie odpowiednio opracowanych technologii i ich wdrożenie może przynosić korzyści materialne i będzie miało pozytywny wpływ na środowisko naturalne.

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A BRIEF REVIEW OF THE LITERATURE ON ANIMAL AND VEGETABLE FATS WITH PARTICULAR EMPHASIS ON MUTTON TALLOW AND HEMP OIL®

Krótki przegląd literatury w zakresie tłuszczów zwierzęcych i roślinnych ze szczególnym uwzględnieniem tłuszczu baraniego i oleju konopnego®

Key words: fats, muton tallow, hemp oil, properties of fats.

The paper updates information about animal and vegetable fats. The global market for oils and fats is presented and their potential industrial applications are pointed out. Due to ever-changing dietary preferences, the paper pays more attention toward two fats. Mutton tallow was presented as an animal fat. A fat that, compared to beef tallow and lard, has a lower palmitic acid content and a higher stearic acid content. In the opinion of the authors, a fat that is insufficiently popular but with beneficial nutritional characteristics is hemp oil. In addition to the characteristics of this oil, the paper presents the world acreage of hemp cultivation and the volume of hemp seed production.

Słowa kluczowe: tłuszcze, łój barani, olej konopny, właściwości tłuszczów.

W artykule uaktualniono informacje w zakresie tłuszczów zwierzęcych i roślinnych. Przedstawiono światowy rynek olejów i tłuszczów oraz wskazano na ich potencjalne zastosowania w przemyśle. Ze względu na ciągle zmieniajcie się żywieniowe preferencje w artykule większą uwagę zwrócono w kierunku dwóch tłuszczów. Jako tłuszcz zwierzęcy przedstawiono łój barani. Tłuszcz który w porównaniu z łojem wołowym i smalcem charakteryzuje się niższą zawartością kwasu palmitynowego a wyższą kwasu stearynowego. W opinii autorów tłuszczem niedostatecznie popularnym, ale o korzystnych cechach żywieniowych jest olej konopny. W artykule poza charakterystyką tego oleju przedstawiono światowy areał uprawy konopi oraz wielkość produkcji nasion z konopi.

INTRODUCTION

Fats and oils are essential components of the human diet. In terms of physiology, they are the main source of energy, while being a carrier of fat-soluble vitamins (A, D, E and K) and components needed for the proper development and functioning of the body, i.e., essential fatty acids (EFAs) or antioxidants [16]. The content of the indicated ingredients, unique rheological properties as well as the versatility of use make fats a raw material in the food, cosmetic, pharmaceutical and oleochemical industries [51]. In recent years, they have also become the object of interest for scientists and technologists related to the biofuel industry [51].

From a chemical point of view, natural fats and oils are mixtures of lipids [22]. As defined by Nichols et al. [43] lipids belong to organic compounds of natural origin. Continuing the statement of the above author, these compounds are insoluble in water, but soluble in organic solvents, and their basic molecular building blocks are hydrocarbon chains. On the other hand, another author [16], indicates that this definition should not be interpreted literally and rigorously, because there are also lipid compounds that are partially or completely soluble in water. Regarding the division of lipids, due to the similarities in chemical structure, they were divided into three groups, including: simple, complex and derivative (secondary) lipids [16].

The terms "fats" and "oils" are often used interchangeably, although the use of this nomenclature is also guided by their melting point or the origin of the raw material [43, 44]. From a chemical point of view, triacylglycerols are the main constituent of fats and oils, which are esters of fatty acids (FA) and glycerol [16]. Triacylglycerols belong to the subgroup of lipids, belonging to simple lipids [16]. They usually account for more than 95% of all fat components [22]. The remaining components are most often mono- and diacylglycerols, free fatty acids, phospholipids, sterols, hydrocarbons, vitamins, or antioxidants [16, 22].

Kowalski and Makara [32] provide a different classification of fats. The authors focus mainly on the origin of these ingredients, hence their division into animal and vegetable fats. Animal fats are obtained from milk or tissues of land and sea animals, while vegetable fats are obtained from fruits, nuts or oilseeds [3, 32]. In order to extract oil or fat from plant

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and animal raw materials, the following methods are used: pressing, rendering and solvent extraction. The selection of the technique for obtaining the product depends on the type of raw material [20].

Fats and oils used as ingredients in food, cosmetic or pharmaceutical products have a key impact on shaping their quality, giving them unique sensory and physicochemical properties [54]. The fatty components of the above-mentioned products contribute, among others, to the consumer's senses during contact with them, such as taste, smell or appearance [45]. Moreover, these compounds influence the improvement of the functional features of products, shaping, among others, their texture, consistency or spreadability [62]. The quality of fat is shaped by its stability in relation to physicochemical interactions, and precisely changes that occur under the influence of physical and chemical factors. An important criterion of the quality of fats is also microbiological stability [16]. The criteria for consumer evaluation of fats are taste and aroma, and recently also the quality of fat is associated by consumers with its nutritional value (the presence of essential unsaturated fatty acids or omega-3 and omega-6 acids). In general, it can be said that fat is a very important component of the products in which it occurs. The essential features of products, for which, among others, fat is responsible, are presented in Figure 1.

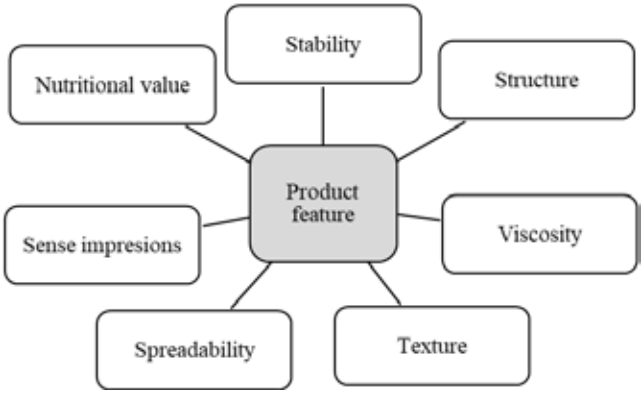

Fig. 1. Selected product features depending on the properties of the fat used.

Rys. 1. Wybrane cechy produktu zależne od właściwości użytego tłuszczu.

Source: Based on: [1, 23, 45, 62]

Źródło: Opracowano na podstawie: [1, 23, 45, 62]

The aim of the study was to compile in a new look information in the field of fats, while emphasizing two well-known but still not quite popular fats: hemp oil and mutton tallow.

FATS AND THEIR QUALITY DETERMINANTS

The quality of fats or oils is influenced by parameters, both physical and chemical, which depend mainly on the source of their origin, the processing they have been subjected to as well as the transport and storage conditions in which the fat or the product containing it is kept [55]. Thus, it can be concluded that the quality of fats and oils is shaped not only by their manufacturers or distributors, but also by consumers after the purchase. Despite the huge impact of proper storage and use of fat after purchase, as indicated by Shahidi and Ambigaipalan [55], consumers often ignore this fact and do not pay much attention to these actions. Table 1 presents selected parameters determining the quality of fats and oils.

Table 1. Selected parameters determining the quality of fats and oils

Tabela 1. Wybrane parametry determinujące jakość tłuszczów i olejów

Physical parameters	Chemical parameters
Relative density	Fatty acid composition and their distribution
Refractive index	TAG composition
Viscosity	Iodine value
Colour	Saponification value
Melting point	Acid value
Turbidity	Polar lipids and phospholipids content
Consistency	Heavy metals content
Solidification point, solid fat content	trans-fatty acids content
Odour and taste	Oxidative stability (e.g., peroxide value, p-anisidine value, TOTOX, OSI, Rancimat AOM)

Source: [55]

Źródło: [55]

THE GLOBAL OILS AND FATS MARKET AND THEIR INDUSTRIAL APPLICATIONS

According to an analysis performed by Expert Market Research, the value of the global animal and vegetable fats and oils market in 2019 was USD 227.9 billion. Further dynamic growth in the value of this market is forecasted, which may reach nearly USD 361.65 billion in 2025 (Expert Market Research, 2020). According to the information provided by Mielke [39], the global consumption of the 17 most important fats and oils (identified by *Oil World*) doubled between 1995 and 2015, from 92.9 million tonnes to 204.3 million tonnes (**Fig. 2**). For many years, the global market of fats and oils has seen an increasing dominance of raw materials of plant origin, mainly palm, soybean, sunflower and rapeseed oils (**Fig. 3**). Animal fats are a minority on the market compared to those of plant origin. In 2015, the global consumption of vegetable fats and oils was 179.4 million tonnes, while that of animal origin was only 26.7 million tonnes [39]. Among animal fats, beef tallow and pork lard have the largest market share, which account for 4.4% and 4.1% of the total production of fats and oils, respectively (Expert Market Research, 2020).

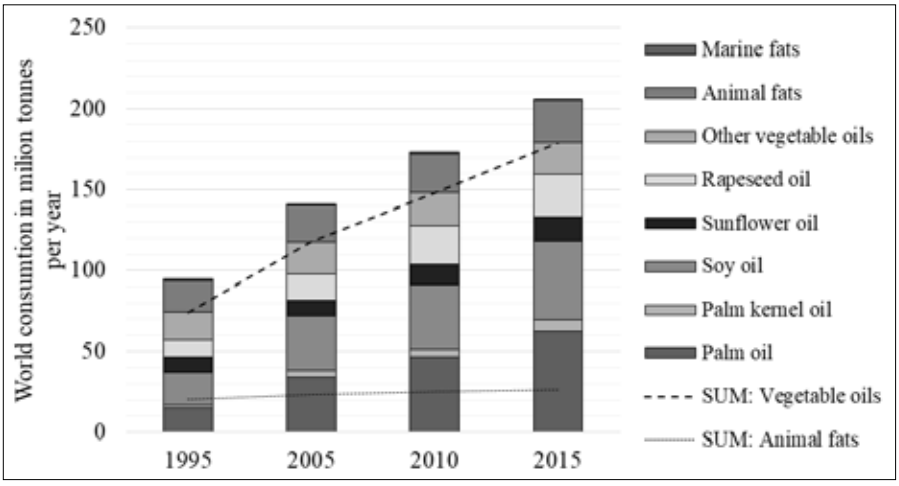

Fig. 2. World consumption of the 17 most important fats and oils between 1995 and 2015.

Rys. 2. Światowe spożycie 17 najważniejszych tłuszczów i olejów w latach 1995–2015.

Source: [39]: 175

Źródło: [39]: 175

Animal fats are generally a component accompanying animal raw materials, or they are a waste from the process of obtaining these materials [2]. For this reason, the production of animal fats is not dictated by the demand for them, but increases with the increasing demand for animal products, i.e., milk, meat or wool [2]. Compared to vegetable oils, animal fats have a much more diverse fatty acid composition [61]. The main fatty acids characterizing triacylglycerols of fats and oils from terrestrial animals are saturated acids, i.e., palmitic, stearic, and monounsaturated oleic acid [8]. The fatty acid profile is most influenced by the animal species, its health condition, maturity, lactation phase and the location of fat in its body [44]. The main fatty acids found in marine fat triacylglycerols are: palmitic, oleic, docosahexaenoic (DHA) and eicosapentaenoic (EPA). The last two fatty acids are among the health-promoting factors recommended in the consumer's diet, especially when it should be aimed at lowering the content of saturated fatty acids, cholesterol and the risk of coronary heart disease [33]. For this reason, it is believed that among many types of animal fats, fish oils are of the greatest importance for health [8]. Another fatty acid characteristic for animal fats, also showing health-promoting value, is conjugated linoleic acid (CLA). This acid is present mainly in the milk and meat of ruminants [31]. Many clinical studies have shown that CLA exhibits various biological effects, i.e., it has anti-inflammatory, anti-atherosclerotic, anti-cancer and antioxidant properties [24, 31].

The quality of fats is the main criterion for the use of animal fats in many industries. The highest quality fats are used in the food industry. However, only less than 5% of the produced fats of animal origin is used in human nutrition ([8]. For food purposes, pork lard and beef tallow are most often used, which are utilized for frying and baking [2, 8]. Another important direction of the usage of these raw materials is their application as animal feed ingredients, where they are the main source of energy, a carrier of vitamins and EFAs [2]. Animal fats of lower quality are used for technical purposes. Due to the demand for saturated fatty acids in the oleochemical industry, they are utilized in the production of soaps, cosmetics and lubricants. Animal fats have also found application in the biofuel industry, although, for economic reasons, their importance as a raw material for the production of biofuels is much lower than that of vegetable fats and oils [2].

The most common fatty acids present in triacylglycerols of vegetable fats and oils are unsaturated fatty acids - oleic and linoleic, and saturated fatty acids - palmitic and stearic [8, 41]. In vegetable oils, unsaturated fatty acids are predominant, which from a nutritional point of view are very beneficial and recommended in the human diet as opposed to saturated acids [30]. However, it should be noted that the fatty acid profile is not always identical for a given plant species, it depends, among others, on the maturity and condition of the plant, soil type or climatic conditions [44].

Analysing the directions of use of vegetable fats and oils, it can be concluded that the production of food products with their participation is of the greatest importance. The current nutritional trends focus mainly on consumer needs and the nutritional quality of food products [34]. The goal is that the consumer should be well informed and consciously make purchasing decisions in the selection of fat and the product containing it. Broader knowledge allows consumers to react much earlier and, above all, to act preventively in terms of diseases caused by an inadequate diet. There are many scientific reports in which the authors confirm that replacing animal fats with vegetable oils in the diet is justified and pro-health behaviour [38, 49, 60]. As indicated by Forouhi et al. (2018) [19], increasing the consumption of unsaturated fatty acids while reducing the consumption of saturated fatty acids may result, among others, in reduced risk of developing coronary heart disease.

Vegetable fats and oils are also utilized in the cosmetics industry. Currently, these materials are successfully used in skin care products [4]. They can show various properties, depending on the raw material they come from. Fats in cosmetic preparations have a moisturizing, protective, nutritional, smoothing, soothing, etc. functions [4]. Due to the natural, active ingredients present in vegetable fats and oils, some of them have been used in medicine as they have a therapeutic or supportive effect, for example in the treatment of liver diseases [4]. Most vegetable fats and oils are also used in the oleochemical industry. Examples are coconut oil and palm kernel oil, which serve in this industry as a source of lauric acid [22]. In recent years, there has been an increase in the use of vegetable fats and oils as raw materials supplying fatty acid methyl esters for the production of biofuels [21]. In Europe, rapeseed oil is most often used for this purpose, in Japan - waste frying oil, in the USA - soybean oil (or beef tallow), and in Malaysia - palm oil [21]. Moreover, vegetable fats and oils are used in the production of lubricants, soaps, wood preservatives, as well as components of animal feed [4, 7, 34].

PHYSICOCHEMICAL PROPERTIES OF MUTON TALLOW

Mutton tallow is obtained from various parts of the sheep carcass (*Ovis aries*) [50]. It accounts for about 3% of the body weight of the sheep [7]. This fat is characterized by a specific smell and usually a white colour, although it also occurs in a shade of cream or light pink [32]. At a temperature of 15–20°C, mutton tallow shows a firm or brittle consistency [32].

The main fatty acids in mutton tallow triacylglycerols are palmitic, stearic and oleic acids (Table 2). Saturated fatty acids constitute about 70% of all fatty acids present in this fat (Table 2). As indicated by Richards et al. (2020) [50] compared to beef tallow, which also comes from a ruminant mammal, mutton tallow has a higher stearic acid content and, at the same time, a lower oleic acid content (Table 2). This is due to the rumen mediated biohydrogenation of unsaturated fatty acids, with varying levels depending on the species [50]. In the process of biohydrogenation of linoleic acid to stearic acid, a nutritionally beneficial conjugated linoleic acid (CLA) is also formed [29]. According to the same authors, mutton tallow has the highest CLA content among animal fats.

Table 2. Main fatty acids (%) of selected animal fats

Tabela 2. Główne kwasy tłuszczowe (%) wybranych tłuszczów zwierzęcych

Fatty acid	Beef tallow	Mutton tallow	Pork lard	Chicken fat
Myristic acid	2.7 – 4.8	2.8 – 4.9	1.4 – 1.7	1.3
Palmitic acid	20.9 – 28.9	19.5 – 21.3	23.1 – 28.3	23.2
Palmitoleic acid	2.3 – 9.1	1.4 – 2.3	1.8 – 3.3	6.5
Stearic acid	7.0 – 26.5	17.6 – 28.9	11.7 – 24.0	6.4
Oleic acid	30.4 – 48.0	33.2 – 40.4	29.7 – 45.3	41.6
Linoleic acid	0.6 – 1.8	1.2 – 3.4	8.1 – 12.6	18.9
Trans fatty acid isomers	1.3 – 6.6	11.0 – 14.6	1.1 – 1.4	nd

Source: Richards et al. [50]

Źródło: Richards et al. [50]

In general, the fatty acid composition of mutton tallow is similar to the fatty acid composition of vegetable solid fat, i.e., cocoa butter, although they are distinguished by the melting profile [37]. This is due to the distribution of fatty acids in triacylglycerol molecules. The saturated fatty acids in mutton tallow, but also in other fats of animal origin, are mainly located in the internal position of the TAG (*sn*-2) [52]. Contrary to animal fats, in vegetable fats, saturated fatty acids are found mainly in the outer positions of the TAG (*sn*-1 and *sn*-3) [37].

PRODUCTION AND DIRECTIONS OF USE OF MUTTON TALLOW

Mutton tallow is a waste product formed mainly in meat processing plants and slaughterhouses [5]. This fat is mainly produced in countries with a high consumption of mutton, and large numbers of sheep [7]. According to the statistical data shared by the Food and Agriculture Organization of the United Nations [18], the world production of mutton tallow in 2018 was about 560,000 tonnes (Table 3). The largest share, amounting to over 50% of world production, was recorded in Asia (Table 3). In Europe, about 74,000 tonnes of mutton tallow were produced in 2018, which accounts for approximately 13% of world production (Table 3).

Table 3. Mutton tallow world production

Tabela 3. Światowa produkcja łoju baraniego

Region	Mutton tallow – production (x 10^3 ton)	Mutton tallow – percent of world production (%)
Africa	61	11.0
North America	2	0.4
South America	11	2.0
Central America and Caribbean	3	0.5
Asia	293	52.6
Europe	74	13.3
Oceania	112	20.1
World	557	100.0
Poland	0.10	0.02

Source: FAOSTAT (2020), data may include official, semi-official, estimated or calculated data [18]

Źródło: FAOSTAT (2020), dane mogą zawierać dane oficjalne, półoficjalne, szacunkowe lub obliczone [18]

The main world producers of mutton tallow in 2018 were China, Australia and Iran, whose share in the global production of this waste was 18.6%, 14.8% and 7.9%, respectively (Table 3, Figure 3). The countries in the top ten largest producers of mutton tallow manufactured about 64% of the world's production of this fat (Figure 3). In the case of European countries, the largest producers are Great Britain, Spain and Romania (Figure 3). The production volume of mutton tallow in 2018 in Poland was about 100 tonnes (Table 3) (26th place among European countries) [18].

In general, mutton tallow is usually used for technical purposes [58]. The main direction of its use is in the soap industry [17]. In contrast, in some countries where pork is not eaten for religious reasons, mutton tallow is often found in consumers' diets. It is usually used in Turkish, Moroccan, Algerian and Tunisian dishes [57]. However, due to the specific smell of both mutton meat and fat, which is not always accepted by consumers, the use of mutton tallow for food purposes is limited [59]. Moreover, due to current consumer concerns about saturated fatty acid intake and its effect on blood cholesterol level, consumption of saturated fatty acids has been reduced [27]. Other potential uses of mutton tallow in the food industry mentioned by Irshad et al. (2015) [25] is using it as an ingredient in margarines, shortenings or sweets.

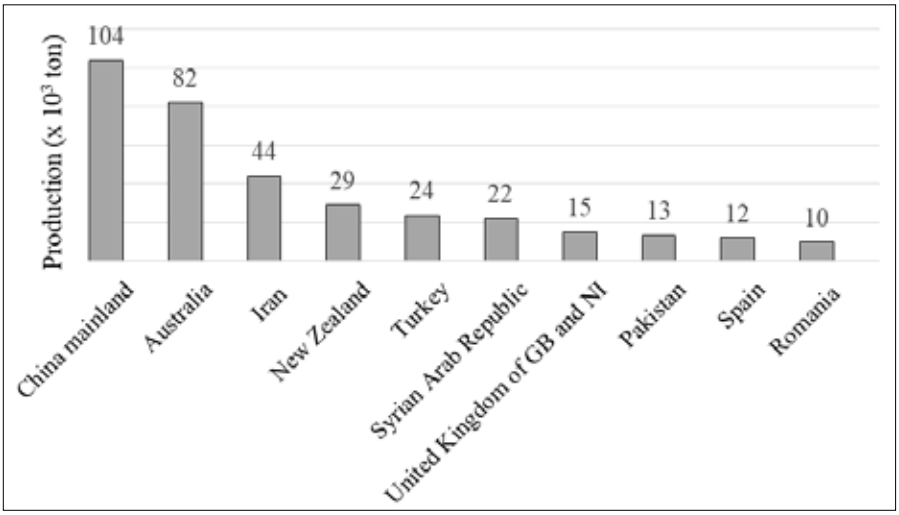

Fig. 3. The production volume of mutton tallow.
Rys. 3. Wielkość produkcji łoju baraniego.

Source: FAOSTAT (2020), data may include official, semi-official, estimated or calculated data [18]

Źródło: FAOSTAT (2020), dane mogą zawierać dane oficjalne, półoficjalne, szacunkowe lub obliczone [18]

Many authors have proposed the potential use of waste mutton tallow in other industries. Authors [6, 42, 47] showed that mutton tallow is a suitable raw material for obtaining high-quality fuel - biodiesel. Such use of waste fat brings not only economic benefits, due to the low price of the raw material, but also environmental benefits [53]. Mutton tallow can also be used as an ingredient in animal feed to change their texture and facilitate the combining of ingredients [53].

HEMP SEED OIL CHARACTERISTICS (*CANNABIS SATIVA* L.)

Hemp seed oil is obtained from the seeds of the hemp (*Cannabis sativa* L.). These plants have been used in the world for thousands of years [9]. Currently, hemp has great social and economic importance due to the variety of its uses [14]. These plants are a raw material for the production of food, special-purpose textiles, biodegradable plastics, and animal feed [14]. In addition, hemp is also used for medicinal purposes, and it was first mentioned in traditional Chinese medicine [9].

The oil constitutes about 36% in hemp seed [10]. It is mainly obtained by pressing or extraction methods. Hemp seed oil has a multidirectional effect on the human body, when applied both internally and externally [12]. Due to the fact that hemp seed oil is a source of EFAs, it is used as a component of light body oils, which show high penetration into the skin [46]. Its high nutritional value is related with, among others, a unique composition of fatty acids and a favourable ratio of omega-6 and omega-3 fatty acids [14].

Generally, despite the enormous potential of hemp seed oil in terms of its nutritional and health-promoting properties, the awareness of consumers in Poland about this material and its possible use is quite low [48]. In their study, the authors presented the respondents' knowledge of the active ingredients of hemp seed oil, its effect on the skin, and its use in cosmetic formulations. They stated that a significant proportion of respondents did not know the active substances found in hemp seed oil, nor their beneficial effects on healthy as well as pathologically changed skin. As many as a quarter of respondents indicated that this oil has a hallucinogenic effect. The authors also concluded that consumer education is needed to increase their awareness of hemp seed oil.

HEMP CULTIVATION AREA

Hemp has been cultivated for centuries, mainly to produce fibres for making fabrics and clothes, around the world [11, 36]. In the twentieth century, there was a significant reduction in the cultivation of hemp in many parts of the world due to, among others, introduction of acts prohibiting the cultivation of hemp due to the content of psychoactive cannabinoids, and the dissemination of other sources of textiles [11, 36]. Some countries have regulated the legal limit of the concentration of psychoactive cannabinoids in the plant, which facilitated the expansion of the cultivation area of this species [36]. Overall, in recent years there has been a significant increase in interest in hemp seeds, especially in terms of their nutritional properties and therapeutic action [35, 36].

Statistical data on the global area of hemp cultivation in the literature are not consistent. According to EIHA (European Industrial Hemp Association), in 2015 the area of hemp cultivation in Europe was approx. 25,000 hectares [13]. The main European hemp producers in Europe in 2015 were France and the Netherlands [13]. The same authors claim that the latest data on the volume of hemp seed production in Europe indicated by EIHA refer to 2013, and according to the report, it was 11,500 tonnes. In the same year, around 13% of the seeds produced in Europe were used to produce food-grade oil. According to the statistical data provided by the Food and Agriculture Organization of the United Nations [18] the global hemp cultivation area in 2018 was approximately 32,000 hectares (Table 4). The largest area of hemp cultivation, representing just over 50% of the global area in 2018, was recorded in France (Table 4). The remaining countries with a relatively large area of cultivation were Russia, China and Chile, whose acreage constituted, respectively: 14.6%, 13.5% and 8.3% of the global acreage. The main global producer of hemp seeds in 2018 was France, and its share in world production was almost 88% of world production, which corresponds to less than 12,000 tons (Table 4).

Comparison of the statistical data with other studies, discussed in this subsection, indicates a general trend that definitely draws interest in the production and use of this plant raw material. According to the data of both EIHA and Faostat [13,18] an increase in the cultivation area has been observed in recent years in Europe, as well as worldwide.

Table 4. The global area of hemp cultivation and the volume of hemp seed production
Tabela 4. Światowy areał uprawy konopi i wielkość produkcji nasion konopi

Country	Cultivation area (ha)	Percent of world cultivation area (%)	Hemp seed – production (x 10^3 ton)	Percent of world production (%)
Chile *	2660	8.3	1.5	1.1
China *	4342	13.5	11.8	8.3
France **	16511	51.4	125.4	87.7
Hungary *	1606	5.0	0.4	0.3
Iran *	193	0.6	0.2	0.1
Poland *	59	0.2	0.03	0.02
Romania *	799	2.5	0.1	0.1
Russia **	4691	14.6	2.1	1.5
Spain **	140	0.4	0.8	0.5
Turkey **	6	0.02	0.003	0.002
Ukraine *	1133	3.5	0.6	0.4
World	**32140**	**100.0**	**142.9**	**100.0**

* FAO estimates

** official data

Source: FAOSTAT [18]

Źródło: FAOSTAT [18]

PROPERTIES, STRUCTURE AND IMPORTANCE OF HEMP SEED OIL

Refined hemp seed oil is clear and colourless [58]. Unrefined, is characterized by a dark green colour, resulting from the presence of chlorophyll substances [36]. The antioxidant components present in hemp seed oil, thus protecting it against oxidation, are tocopherols, polyphenols and carotenoids [26]. Other compounds also found in unrefined hemp seed oil include tocotrienols, phospholipids, minerals, and phytosterols [40].

The health-promoting effects of hemp seed oil are related, among others, with the fact that it is a source of cannabinoids [15]. Hemp seeds themselves do not contain these compounds, but are contaminated with them when in contact with other parts or secretions of the plant [15]. The content of tetrahydrocannabinol (THC) in hemp, which has psychoactive properties, is regulated by law. The limit of concentration of this compound in plant dry matter in the European Union is 0.2% [14]. Due to such limitations, the THC content in hemp seed oil is very low and usually does not exceed 5 mg/kg [15].The cannabinoid with the highest percentage in hemp seed oil is cannabidiol (CBD), which has no psychoactive effects, but has many positive effects on the human body [15]. Cerino et al. (2020)[14] indicate that CBD has immunomodulatory, spasmolytic, anticonvulsant, anti-inflammatory and anti-anxiety effects.

The fatty acid composition of hemp seed oil is significantly different from that of other commercial oils on the market (Figure 4). Unsaturated acids account for over 90% of all fatty acids in this oil. In contrary to most vegetable oils, hemp seed oil is characterized by a high content of polyunsaturated fatty acids (PUFA), which constitute about 84% of all acids found in this oil. Among the vegetable oils shown in Figure 4, only

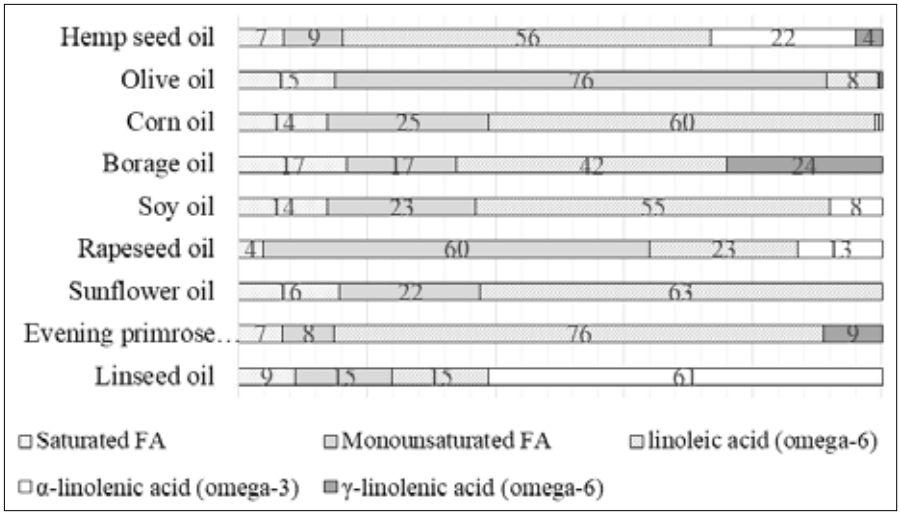

Fig. 4. Profile of main fatty acids (%) of selected vegetable oils.
Rys. 4. Profil głównych kwasów tłuszczowych (%) wybranych olejów roślinnych.

Source: Based on: Callaway and Pate [10]

Źródło: Opracowano na podstawie: Callaway and Pate [10]

one – evening primrose oil – has a similar PUFA content to hemp seed oil.

The main fatty acids with the highest percentage in hemp seed oil are linoleic acid (omega-6), α-linolenic acid (omega-3) and oleic acid [36]. The presence of linoleic and α-linolenic acids is beneficial for consumers, especially for those who are looking for food or a diet that includes antiarrhythmic, anticoagulant or anti-inflammatory effects [35]. As indicated by Oomah et al. (2002) [46] and Cerino et al. (2021) [14] the ratio of omega-6 to omega-3 polyunsaturated fatty acids in this oil is approx. 3:1, which is the correct proportion in relation to proper human nutrition [56]. Such a ratio may have the effect of lowering the level of „bad" cholesterol in the blood (LDL – low-density lipoproteins), as well as lowering blood pressure [10]. The nutritional value of hemp seed oil is additionally enhanced by the presence of γ-linolenic acid, belonging to the omega-6 fatty acids [36]. It reveals a pharmacological effect, among others, in regulating the body's inflammatory responses [28].γ-linolenic acid is a rather rare acid not found in the popular used vegetable oils. In addition to being present in hemp seed oil, it is also a component of evening primrose oil or borage oil [10].

SUMMARY

The material presented above confirms that fats are important components of food. They are raw materials in many industries, i.e. such as food chemical, pharmaceutical and chemical. The data presented in the paper in terms of interest in these ingredients confirm that there is still more interest on the side of vegetable fats. The fatty acid composition of hemp oil indicated in the paper confirms the beneficial nutritional values for this oil. Unsaturated acids account for more than 90% of all fatty acids present in this oil, which allows it to stand out from other vegetable oils and thus draw closer attention to it. Despite the fact that mutton tallow is an animal fat, the authors believe that it is a fat that should also be of interest to consumers or producers in the fat industry. This type of fat is characterized by reduced amounts of palmitic and stearic acids compared to other solid fats. In addition, it has the important ingredient linoleic acid CLA.

PODSUMOWANIE

Przedstawiony powyżej materiał potwierdza, że tłuszcze są ważnym składnikiem żywności. Są surowcami w wielu gałęziach przemysłu, tj. takich jak spożywczy, farmaceutyczny i chemiczny. Przedstawione w pracy dane w zakresie zainteresowania tymi składnikami potwierdzają, że wciąż większe zainteresowanie jest po stronie tłuszczów roślinnych. Wskazany w pracy skład kwasów tłuszczowych oleju konopnego potwierdza korzystne wartości odżywcze tego oleju. Kwasy nienasycone stanowią ponad 90% wszystkich kwasów tłuszczowych obecnych w tym oleju, co pozwala mu wyróżnić się na tle innych olejów roślinnych, a tym samym zwrócić na niego baczniejszą uwagę. Pomimo faktu, że łój barani jest tłuszczem zwierzęcym, autorzy uważają, że jest to tłuszcz, który powinien zainteresować również konsumentów czy producentów z branży tłuszczowej. Ten rodzaj tłuszczu charakteryzuje się zmniejszoną ilością kwasów palmitynowego i stearynowego w porównaniu do innych tłuszczów stałych. Ponadto posiada ważny składnik kwas linolowy CLA.

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EFFECT OF ULTRASOUND ON THE CONTENT OF BIOACTIVE COMPOUNDS AND SELECTED QUALITY PARAMETERS IN BERRY JUICES®

Wpływ ultradźwięków na zawartość związków bioaktywnych oraz wybrane parametry jakościowe w sokach z owoców jagodowych®

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Key words: berries, ultrasound, juice, proposed treatment, processing options.

Current nutritional trends make consumers interested in foods and beverages that provide bioactive compounds with health-promoting effects. Such compounds include anthocyanins, which are polyphenolic compounds with anti-inflammatory, anti-carcinogenic and antioxidant properties. Berry juices, used in beverage production, are a good source of polyphenols, especially anthocyanins. This paper discusses the effect of ultrasound on the quality in terms of chemical composition, sensory and microbiological quality of berry juices. The results of current research directions of ultrasounds application are discussed; both at the stage of pulp processing prior to juice pressing and the direct juice treatment. The research indicates that the use of ultrasound can be an alternative to other methods of treating the raw material before pressing, and due to the non-thermal nature of the process does not cause serious degradation of anthocyanins. What's more, the use of this technology will make it possible to lower the temperature of the pasteurization process, which make possible to preserving the sensory qualities of the juices.

Słowa kluczowe: owoce jagodowe, ultradźwięki, sok, proponowana obróbka, opcje przetwarzania.

Aktualne trendy żywieniowe powodują, że konsumenci są zainteresowani żywnością oraz napojami, które dostarczają związków bioaktywnych o działaniu prozdrowotnym. Do takich związków należą antocyjany, które są związkami polifenolowymi o właściwościach przeciwzapalnych, przeciwkancerogennych i przeciwutleniających. Soki z owoców jagodowych, wykorzystywane w produkcji napojów, są dobrym źródłem polifenoli, a w szczególności antocyjanów. W niniejszym artykule omówiono wpływ ultradźwięków na jakość soków z owoców jagodowych pod względem składu chemicznego, jakości sensorycznej i mikrobiologicznej. Omówiono wyniki aktualnych kierunków badań dotyczących wykorzystania tej technologii zarówno na etapie obróbki pulpy przed tłoczeniem soku, jak i utrwalania wyrobów gotowych. Badania wskazują, że zastosowanie ultradźwięków może stanowić alternatywę dla innych metod obróbki surowca przed tłoczeniem, a ze względu na nietermiczny charakter procesu nie powoduje poważnej degradacji antocyjanów.

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INTRODUCTION

Improving the quality of juices and other kinds of beverages (especially the content of valuable natural antioxidants) through the use of modern ultrasonic methods has been a recent challenge for more than 40 years for a growing number of food scientists worldwide. The scope of ultrasound energy applications is wide and includes improving the following processing steps: cooking, cutting, defoaming, deagasing, drying, emulsification, extraction, mixing, thawing [7]. The food industry has become interested in the usage of ultrasound because its action can trigger chemical and physical reactions, enabling a wide range of commercial applications. One of the most popular applications of ultrasound is to optimize the extraction of bioactive substances [10: 18, 19]. Ultrasound treatment procedures are sometimes referred to as "sonication," and in juice production technology they are carried out directly on fruit, fruit pulp or the produced juice to improve production yield, product stability and increase content of bioactive compounds. One of the most recent applications is the use of ultrasound in post-harvest processing of fruits and vegetables, where ultrasound acts as a potential trigger for the synthesis of phenolic compounds (this form of interaction with raw materials will not be considered in this paper). It should be remembered that the indicated group of compounds is determining the quality (chemical, sensory and microbiological) of juices, wines and other fruit products, because the concentration of these compounds directly affects, the quality of the product [1, 4, 12, 14]. Fruit of permanent plants with soft flesh, the seeds of which are in the jelly-like pericarp, are called berry fruits [5], eg currants, gooseberries, grapes, blueberries, cranberries. Andrzej Jarczyk (1933–2022) added that in the industrial classification used in Poland, the presented group also includes: raspberries, blackberries, strawberries and wild strawberries. Berry juices have gained great importance in the category of functional food products, as their consumption reduces the risk of chronic and degenerative diseases. This is due to the high content of antioxidant compounds such as polyphenols, among other anthocyanins, in the raw materials used in production. However, conventional thermal processing reduces the content of these compounds, which is why alternative technologies such as ultrasounds are currently being researched [9: 52]. The search for new non-thermal preservation technologies continues to grow, also because traditional thermal processing can have undesirable effects on the sensory properties of juices and the content of valuable nutritional components.

The purpose of this article is to attempt to systematize selected studies concerning the effect of ultrasound on the content of bioactive compounds in berry fruit juices with references to their quality parameters. By design, this analytical study was prepared using the desk research methodology using a systematic literature review of The Google Scholar database (Google Ireland Limited). The following keywords were used: juice, berries, ultrasound. The publication date criteria used were narrowed to the 2012–2022 range. Towards the introduction of some basic terms, selected printed studies were used.

THE IMPACT OF ULTRASOUND ON THE QUALITY OF BERRY JUICES IN TERMS OF CHEMICAL COMPOSITION, SENSORY AND MICROBIOLOGICAL QUALITY

The content of bioactive substances in berry juices is right after the quality of the raw materials used, the second critical factor affecting the content of bioactive compounds is degree of extraction. In the category of fruit juices, berry juices are usually utilized as components of beverages or other products, since juice without any additives is often too sour or tart to be suitable for consumption without dilution. The quality of such an intermediate must be even better in order for a small additive to adequately fulfil the technological function, as a dye for example. The use of ultrasound in the pressing process of berry juices is an interesting proposal for non-thermal processing of raw materials to obtain high-quality products. Such issues have been addressed in numerous scientific works. These studies indicate that ultrasonic technology has the potential to preserve bioactive compounds and reduce microbial contamination. An example of such an experiment was conducted on blackberry fruit pulp subjected to sonication. Ultrasonic processing was performed by a ultrasonic homogenizer with 20 kHz frequency and 750 W of power, over a period of 10 min. The content of bioactive compounds and antioxidant activity was analyzed in extracted juice. During storage, the juice obtained with ultrasound treatment preserved more than 90% of the anthocyanins and showed a significant reduction in microbial load [9: 48–52]. An interesting approach is to study not only the levels of compounds in the fresh juice, but to demonstrate that health-promoting compounds have been increased in the finished product by pretreatment with ultrasound. An example of this approach is the evaluation of the use of ultrasound in American grapes for its effect on the extractability of the juice and the concentration of phenolic compounds in the juice and the wine produced from those fruits. Sonication of the samples was carried out in an ultrasonic bath with a power of 270 W and a frequency of 40 kHz, ultrasounds exposure times were 0, 3, 5, 7 and 10 minutes, depending on the object. [3: 148–152]. As exemplified by the bayberry juice, all US treatments significantly reduced PPO activity in the treated juice, enzyme involved in browning process. PPO activity decreased by 53.23% and 12.84% at 90 and 181 W/cm2 for 10 min, respectively. A noteworthy fact is that as the intensity or duration of ultrasound increased, the rate of PPO inactivation increased rapidly. [1].

It is also worth noting, what impact on the sensory quality of products have ultrasound treatment. In some studies [2, 9, 11, 13], tests involving a sensory panel are also implemented in parallel with physicochemical measurements. An example of this approach is a study [2] that tested the application of ultrasound with different power densities and exposure times on grape fruit, and then evaluated the effects of these treatments on the total polyphenol content and sensory quality of the juices. Ultrasound processors with a nominal power of 130 W or 750 W (depending on the object) with a fixed frequency of 20 kHz and exposure times of 1, 5 and 10 minutes were used for sonication. In this case, ultrasound increased total polyphenol content by up to 83%, and the treatments

also improved the sensory qualities of the juices, which were indicated as preferred by the sensory panelists [2: 72]. Another case under consideration is the participation of ultrasound in the processing of raw materials, as an aid to enzymes in the juice extraction process. The use of enzymes in the fruit juice process is essential for the production of most fruit juices [4, 12]. An example of work on this topic is an experiment [12] in which the goal was to study the effect of commercially used enzymes and ultrasonic treatment on the extraction efficiency and antioxidant properties of mulberry juice. Incubation of samples for 120 min combined with ultrasonic treatment at 45°C for 60 min cause the highest juice yield and antioxidant content in the final product [12: 11]. Juice preservation and storage is another important factor affecting the quality of the final product. Ultrasonic technology is used in juice pasteurization to reduce microbial contamination and lower the activity of enzymes that oxidize polyphenolic compounds. Ultrasound, as a non-thermal method, can support the processes of berry juice pasteurization allowing to reduce the loss of valuable health-promoting compounds present in raw juice. In a study aimed at evaluating the effect of ultrasound on the physicochemical properties and antioxidant activity of blackberry juice, treatment of the product with ultrasound resulted in a reduction in the number of microorganisms, while its physicochemical properties remained unchanged [11: 3]. The authors' results showed that ultrasonic treatment can preserve blackberry juice without compromising its antioxidant and sensory properties. On the list of studies examples, strongly emphasizing proposed treatments or processing options useful for berry juices are: the potential use of a combination of microwaves and ultrasound to increase the functional value of berry juices [8] or a nonthermal pasteurization created by ultrasound, high pressure and pulsed electric fields [15]. The first study was also performed on blackberry juice. Juice processed with ultrasound showed a significant reduction of microbial contamination, in line with the observations of other authors [9: 52]. Another paper describes a study of the effects of various process parameters of ultrasound treatment, aimed at inactivation of *Botrytis cinerea* mold in red grape juice. The study also considered the effect on quality parameters during storage. The best results in reducing microbial contamination were obtained in a facility combining ultrasound with the addition of natamycin. Very importantly, no significant changes in pH, titratable acidity, extract values, color changes and sensory values were observed during the storage period. The equivalent nonthermal pasteurization approaches (ultrasound, high pressure, and pulsed electric fields) proposed strawberry juice resulted with a relevant comparison of three technologies in terms of microbial quality (reduction of the initial microbial population *E. coli* inactivation to an acceptable level), physicochemical properties, and phytochemical characteristics. Processed strawberry juice in the sonicator (at 517.1 mW/mL acoustic energy density, 24 kHz frequency, temperature increase up to 55.1°C after a come-up time of 4 min) obtained phytochemical retention after processing represented in changes in percentage on following levels: total phenolic content TPC: -0.2%, total anthocyanin content TAC: 8.9% and radical scavenging activity RSA: 17.3% [15].

The combined use of natamycin and ultrasound proved to be effective in reducing *Botrytis cinerea* contamination without causing a loss of juice quality [14]. A similar pattern was followed in a study that undertook to find levels of ultrasound and the addition of pomegranate extract and geraniol to optimize the preservation of strawberry juice. The optimal combination consisted of 0.15 μL/mL geraniol, 360 μg/mL pomegranate extract and 30 min of ultrasound treatment. This treatment was able to significantly reduce microbial contamination, with a low impact on sensory attributes, while improving the antioxidant activity of the product compared to untreated juice samples. In addition, it reduced *E. coli* contamination to undetectable values. In this way, the optimized treatment allowed for an extended shelf life and significantly improved the safety of the strawberry juice [13: 17]. Similar results were obtained in a study, which evaluated the effect of ultrasonic treatment on the physicochemical properties, polyphenol and anthocyanin content, antioxidant capacity and microbiological stability of blackberry juice. The results showed that the pH and extract content increased in juice obtained with ultrasounds usage, compared to conventionally pasteurized juice and raw juice produced without treatment. The treatment lasted 10 minutes, and a frequency of 20 KHz was applied. Similarly positive for the object treated with ultrasound are the differences found in the parameters of color, polyphenol content and antioxidant activity. The authors emphasize the potential of the method and declare that the application of ultrasonic treatment can be used to obtain a functional beverage for human consumption, which retains its sensory characteristics after one month of storage [9: 48-52]. Among the studies considering the impact of this technology on the content of health-promoting compounds, there are also examples in which the authors focused on the stability of vitamins during the storage period of products. The purpose of one work was to evaluate the effect of ultrasonic treatments on the total content of *L*-ascorbic acid and on selected physicochemical characteristics of grape juice during storage. In this publication, samples sonicated and stored for 17 days had a higher L ascorbic acid content than samples prepared by the traditional method [6: 1259].

SUMMARY

Based on the presented research, it can be summarized that the use of ultrasound both at the stage of juice production and its preservation has a beneficial effect on the quality of the obtained products. The use of this method makes it possible to reduce the temperature of the process, which enable to preserve the value of the products and its sensory characteristics. However, it should be remembered that not all laboratory observations are consistent with the literature data presented above. It is possible to allege experiments with conclusions indicating that ultrasound has no effect or a negative effect on the quality of juices. The scientific teams working on ultrasounds application in food production are using variety of equipment and other experimental schemes. Those differences have impact on the content of bioactive compounds in obtained products, hence the conclusions may vary. The technology does not always lead to increased extraction or product stability. Interesting example is a paper discussing a case in which grape fruits of the 'Cabernet Sauvignon' variety were treated with ultrasound in various combinations. However, the observed effects varied depending on the combination [3: 152].

Part of the ultrasound treatments did not show positive results in terms of the concentration of bioactive compounds, and even promoted the degradation of anthocyanins at a significant level. An increase in anthocyanin content in juice as a result of US application in grapes was observed only in the harvest of a given season and more significantly in samples with a higher storage period. In these samples, the observed ranges of increase vary between 15%-25%, compared to control with the same storage period. Such observations make it clear that the application aspect of this technology has great potential; however, it needs more thorough research to become more predictable and controllable.

PODSUMOWANIE

Na podstawie przedstawionych badań można stwierdzić, że zastosowanie ultradźwięków zarówno na etapie produkcji soku jak i jego utrwalania ma korzystny wpływ na jakość otrzymywanych produktów. Zastosowanie tej metody umożliwia obniżenie temperatury procesu, co sprzyja zachowaniu wartości produktów i ich cech sensorycznych. Pamiętać należy jednak, że nie wszystkie badania laboratoryjne są zgodne z przedstawionymi powyżej danymi literaturowymi. Natknąć się można na doświadczenia zakończone wnioskami wskazującymi na brak wpływu bądź negatywny wpływ ultradźwięków na jakość soków. Pewne jest, że zespoły naukowe pracujące nad tym zagadnieniem stosują różnorodne urządzenia oraz inne schematy doświadczeń, więc wpływ ultradźwięków na zawartość związków bioaktywnych może być zróżnicowany. Nie zawsze technologia ta prowadzi do zwiększenia ekstrakcji czy stabilności produktów. Zachęcającym przykładem jest praca omawiająca przypadek, w którym owoce winogron odmiany ‚Cabernet Sauvignon' traktowano ultradźwiękami w różnych kombinacjach. Obserwowane efekty były jednak zróżnicowane w zależności od kombinacji [3: 152]. Większość zabiegów oddziaływania ultradźwięków nie wykazała pozytywnych rezultatów w zakresie stężenia związków bioaktywnych, a nawet sprzyjała degradacji antocyjanów na znacznym poziomie.

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Key words: isotonic drinks, energy drinks, functional drinks, bioactive substances.

Energy and isotonic drinks are the functional drinks. The energy drinks contain bioactive substances, such as: caffeine, taurine, inositol, guarana, glucuronolactone and carnitine. These substances, and in particular the high caffeine content, reduce the feeling of fatigue with increased physical and mental effort. However, the main effect of isotonic drinks is hydration and replenishment of electrolytes, which are lost through sweat during physical exertion. In recent years, the demand for energy and isotonic drinks has increased. Although this market is still the smallest percentage in the production of non-alcoholic beverages, it attracts a lot of interest not only among consumers, but also nutrition specialists. Although these products are intended for a specific group, they are more and more often used by young people, students who do not always require the use of this type of drink in their diet. Therefore, it would be important to educate people in different age groups on the consumption of energy drinks and isotonic drinks.

Słowa kluczowe: napoje izotoniczne, napoje energetyczne, napoje funkcjonalne, substancje bioaktywne.

Napoje energetyzujące oraz izotoniczne zaliczane są do napojów funkcjonalnych. W skład napojów energetyzujących wchodzą substancje bioaktywne, tj.: kofeina, tauryna, inozytol, guarana, glukuronolakton i karnityna. Substancje te, a w szczególności duża zawartość kofeiny, wpływa na zmniejszenie uczucia zmęczenia przy wzmożonym wysiłku fizycznym oraz psychicznym. Głównym działaniem napojów izotonicznych jest nawodnienie organizmu oraz uzupełnienie elektrolitów, które tracone są wraz z potem podczas wysiłku fizycznego. W ciągu ostatnich lat zwiększa się zapotrzebowanie na napoje energetyzujące oraz izotoniczne. Pomimo iż, rynek ten wciąż stanowi najmniejszy procent w produkcji napojów bezalkoholowych, to jednak wzbudza on bardzo duże zainteresowanie nie tylko konsumentów, ale i specjalistów w zakresie żywienia. Mimo, że produkty te są przeznaczone dla specyficznej grupy, to coraz częściej sięgają po nie ludzie młodzi, studenci, którzy nie zawsze wymagają stosowania w swojej diecie tego typu napojów. Istotna byłaby edukacja żywieniowa wśród osób w różnych grupach wiekowych, dotycząca korzyści i zagrożeń wynikających ze spożycia napojów energetyzujących oraz izotonicznych.

INTRODUCTION

Energy and isotonic drinks are products classified as functional food, i.e. food that can positively affect one or more functions of the body. These drinks are intended for people with increased physical and mental activity. The purpose of energy drinks is to increase the body's efficiency. The main bioactive ingredients of energy drinks are caffeine and taurine and they are responsible for improving memory, reaction time and logical thinking efficiency. The composition of energy drinks also includes: inositol, guarana, glucuronolactone, carnitine and B vitamins [6]. Isotonic drinks are intended mainly for people with increased physical activity. The primary function of such drinks is to hydrate and restore levels of electrolytes, carbohydrates, and other nutrients. These drinks are also most often enriched with minerals such as sodium, potassium, chloride, calcium, phosphorus and magnesium, which are excreted from the body along with sweat. These drinks may also contain amino acids, B vitamins and simple sugars [11].

In recent years, the demand for this type of drink has increased. Although this market is still the smallest percentage in the production of non-alcoholic beverages, it attracts a lot of interest among consumers and nutritionists [21]. Although these products are intended for a selected group of people, they are often used by children, adolescents and students who should not consume this type of drink or do not always require their use in their diet. Therefore, nutritional education about the benefits and risks of consumption of energy and isotonic drinks in different age groups would be important.

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ENERGY DRINKS AND THEIR BIOACTIVE SUBSTANCES

Energy drinks are drinks that can be classified as functional drinks, i.e. drinks that provide other health benefits in addition to their basic nutritional functions. Mainly, it is reducing the feeling of fatigue and improving efficiency with increased work of the body, both during physical and mental effort. Quick supplementation of energy expenditure and improvement of concentration [16]. Energy drinks, due to their specific composition and the addition of bioactive substances, differ from other non-alcoholic drinks. Therefore, these drinks are intended mainly for people with increased physical activity, increased mental effort or for drivers [31]. In practice, however, it may look a bit different, because due to the spread of marketing, young people and even children more and more often reach for this type of drink.

The main ingredients of energy drinks are water and sugar, which can become a real threat to young consumers when consuming large amounts of the drink. The ingredients that make these drinks unique are biologically active substances, such as: caffeine, taurine, guarana, inositol, L-carnitine, ginseng or glucuronolactone. As an additive, you can often find B vitamins, such as: thiamine, riboflavin, niacin, pantothenic acid, vitamins B_6 and B_{12} and minerals: potassium, sodium, calcium, magnesium, chlorine and phosphorus. There are also energy drinks with fruit or fruit and vegetables on the market [6].

Caffeine is a biologically active substance that is present in the highest amounts in energy drinks. Caffeine is a type of alkaloid from the methylxanthine group [19]. It is mainly found in coffee, tea, cocoa, but also more and more often delivered to the body in the form of energy drinks. It is very quickly absorbed from the gastrointestinal tract into the bloodstream because after 30-60 minutes from consumption, 99% of caffeine reaches its maximum concentration in the blood and with it is delivered to all tissues in the human body [17]. Caffeine can cross biological membranes, including the blood-brain barrier and the placental barrier, reaching the fetus and amniotic fluid. In adults, caffeine is almost completely metabolized by the liver. Its major initial metabolite is paraxanthine, the others are theophylline and theobromine. In the final stage of metabolism, 1- methylxanthine and 1-methyluric acid are formed. A small percentage of caffeine, only 1-5%, is excreted in urine. Caffeine metabolism depends to a large extent on the physiological state. That is why in pregnant women it is extended up to 3 times. According to recommendations issued by the European Food Safety Authority (EFSA), pregnant women should not consume more than 200 mg of caffeine per day, while in healthy adults, the safe dose for consumption is 400 mg of caffeine per day, and if caffeine is consumed within 2 hours, the dose should not exceed 200 mg [6, 21]. One normal serving of an energy drink (250 ml) provides about 80 mg of caffeine. Caffeine affects the human body in various ways. The main mechanism of action of caffeine is to block adenosine receptors, which results in increased secretion of dopamine, adrenaline and serotonin. After consuming caffeine, the central nervous system is stimulated, blood vessels dilate and blood pressure rises. As a result, it leads to the improvement of physical and mental efficiency, improvement of concentration, logical thinking, increased creativity and reduction of the feeling of fatigue. Caffeine also has a psychostimulating effect, thanks to which it increases self-confidence and even reduces depression. Excessive consumption of caffeine, over 500 mg per day, can lead to nervousness, anxiety, tremors, palpitations, hot flushes, headache, and sleep disturbances. Excess caffeine may also lead to gastrointestinal disturbances associated with recurrent vomiting [38].

Taurine or 2-aminoethanesulfonic acid is a non-protein amino acid. It can be mainly supplied to the body from food, it is found, among others, in: crustaceans, fish, red meat, turkey, chicken. Taurine can also be synthesized endogenously from methionine and cysteine [28]. Taurine is involved in many physiological processes in the human body. It increases the metabolism of glial cells, which increases mental and physical performance and reduces nervous tension. It will contribute to better concentration and mood improvement [7]. This amino acid also has an anti-inflammatory effect, regulates blood pressure, and with a high supply, it can protect against coronary artery disease. Taurine can also help you burn fat faster during training and improve respiratory efficiency. Studies have found that a significant dose of taurine – 6 g per day increases lipid oxidation by 38% during moderate exercise [1]. Additionally, taurine influences the proper functioning of skeletal muscles during physical exertion, reducing the concentration of lactates and free fatty acids. In energy drinks, taurine is intended to reduce fatigue. This mechanism is based on inhibiting the secretion of serotonin released during training, which is responsible for the relaxation of the body. As a result, taurine allows for longer and more effective work. There is very little information available in the studies available about the negative effects of taurine on the body. In energy drinks, it is most often present in a dose of about 400 mg per 100 ml of the product.

Guarana (Paullinia cupana) is a climbing plant native to Brazil. It is a natural source of caffeine because its fruits are rich in this ingredient. Guarana has a stimulating effect, but these properties are usually attributed to 2.5 to 5% caffeine on a dry weight basis. In addition to caffeine, guarana also contains saponins and polyphenols, including tannins and catechins. In combination with caffeine, these substances give an extended stimulating effect and increase fat oxidation during physical exertion [36]. Additionally, guarana delays fatigue, improves cognitive functions and positively affects well-being [27].

Glucuronolactone is an organic chemical, an ester of glucuronic acid. In the body, it is formed in the liver as a result of glucose metabolism. It is very rare in natural food. It is more commonly found as an additive in fortified foods. Currently, no studies have been conducted on the effect of glucuronolactone on the cardiovascular system [14]. Glucuronolactone may be responsible for faster removal of harmful metabolic products from the body, increase energy, improve concentration and reduce the feeling of sleepiness. In energy drink it is present in amounts of approx. 24–240 mg per 100 ml. The NOAEL dose, i.e. the highest dose of the substance with no adverse effects, was established at the level of 1000 mg/kg body weight [14].

Inositol is an organic chemical compound often referred to as vitamin B_8, although it can be synthesized from phytic acid by a man. In food, it is found in whole grains, citrus fruits, nuts, yeast, and legumes. Inositol improves the lipid profile and participates in the metabolism of fat and cholesterol. It also exhibits anti-inflammatory and antioxidant properties [25]. Inositol acts on the nervous system, it is necessary for the stimulation and conduction of nerve stimuli. Its deficiency can lead to excitability, nervousness, and insomnia. In energy drinks, it is present in doses of about 20 mg per 100 ml and the daily requirement for this ingredient is about 1 g. According to studies, inositol in a dose from 6 to even 18 g per day does not cause any negative effects on the adult's body. In some cases, the subjects developed mild bloating or diarrhea [25].

L-carnitine is a non-protein amino acid supplied to the body in the largest amounts with food, i.e. meat, milk, fish, dairy products. It can also be synthesized in the liver and kidneys from lysine and methionine. L-carnitine plays an important role in fat metabolism as it is involved in the transport of long-chain fatty acids to the mitochondria, where they perform an energetic function. Studies also show that L-carnitine can reduce body weight and adipose tissue mass, and at a dose of 2-3 g per day, it can contribute to the improvement of fasting blood sugar [5]. Therefore, it can be found more and more often as an additive in drinks for slimming people, sports drinks and energy drinks. The excessive consumption of L-carnitine and its negative effects on health are rare [7]. In some cases, it has been observed that L-carnitine supplementation at a dose of 5 g per day and more may cause nausea, abdominal pain and diarrhea [5].

Some energy drinks contain ginseng, but it is not a bioactive substance, but a medicinal plant that contains a very large amount of biologically active substances. Ginseng comes in many varieties, which differ in their chemical composition, and thus have a different effects on the human body. The active compounds found in ginseng include ginsenosides, i.e. saponins from the group of glycosides, which have a positive effect on the functioning of the nervous, cardiovascular and immune systems, as well as have antibacterial and anticancer effects [34]. Ginseng in energy drinks is usually found in small amounts, so to achieve the desired therapeutic dose, which is usually from 100 to 400 mg per day, you should consume two portions of such a drink a day, which may contribute to other unfavorable properties [7].

RISKS RELATED TO THE CONSUMPTION OF ENERGY DRINKS

The consumption of energy drinks in Poland is becoming more and more popular. Since 2012, we can observe a systematic increase in the value of retail sales in this product group. Due to the noticeable increase in the consumption of energy drinks, they are more and more often the cause of discussion and research by scientists in the field of nutrition. This is due to the risks that may affect the health of people consuming this type of drink. Your first concern when consuming energy drinks is that sugar is one of the main ingredients in these drinks. According to research, it is the consumption of sugar-sweetened beverages that can largely contribute to weight gain, and thus to overweight and obesity. These diseases are a serious problem of the 21st century in every age group. The consequence of high consumption of these drinks may be an increased risk of type 2 diabetes and cardiovascular disease. Another concern is the high dose of caffeine found in energy drinks. Although caffeine increases fat oxidation and may affect weight management, it is believed that caffeine in combination with sucrose increases the risk of overweight and obesity by increasing carbohydrate oxidation and inhibiting fat oxidation [15, 23, 37].

Another risk related to the presence of caffeine in energy drinks is the possibility of consumption of these products by children under 16 years of age. Caffeine can have a very strong effect on a child's body. It can cause severe abdominal pain, nausea, nervousness, agitation, insomnia and, in large amounts, even dehydration in this age group. Pregnant women are also more exposed to caffeine, so 200 mg of caffeine per day is considered a safe dose. For a healthy person, this is 400 mg per day. Caffeine crosses the placental barrier and can obstruct blood flow to the placenta and inhibit nutrient transport to the fetus. This may contribute to the birth of a child with lower birth weight, premature birth and even miscarriage [20, 22].

The effect of energy drinks on the work of the cardiovascular system may also be disturbing. Drinks with a high caffeine content are not recommended for people with cardiovascular disease. Some studies show that consuming more caffeine may contribute to the aggravation of cardiovascular diseases, as they may contribute to an increase in blood pressure and may increase the risk of myocardial infarction [2, 9, 10, 18, 24].

The greatest amounts of energy drinks are consumed by young people aged 19-25 and are often mixed with alcohol. Often, such mixtures are consumed at social gatherings. This combination can lead to serious health effects. Energy drinks, through their stimulating effects, have the opposite effect on the body from alcohol, reducing its sedative effects, confusing and producing the confusing feeling of being sober. This leads to even greater consumption of alcohol, causing an increased risk of intoxication. People who consume this type of mixture have a three times higher probability of alcohol intoxication and four times higher risk of driving a motor vehicle, which results from an incorrect assessment of sobriety [3, 12, 35].

ISOTONIC DRINKS – DEFINITION AND INGREDIENTS

Isotonic drinks are intended mainly for people with increased physical activity. They play an important role in hydrating the body and supplying lost electrolytes, carbohydrates and other nutrients that are excreted during increased activity. Their effective hydration results from adequate osmolality. According to the European Union regulations, drinks with an osmolality of 300 mOsm/kg ± 10% are isotonic drinks. Due to osmolality, we also distinguish hypotonic drinks – with lower osmolality (<270 mOsm/kg) and hypertonic drinks with higher osmolality (> 330 mOsm/kg) [26, 32]. Osmolality is the number of moles of osmotically active substances dissolved in 1 kg of the solvent. These compounds lower the chemical potential of water. Osmolality is a measure of the osmotic pressure that results from the passage of water through

a semipermeable membrane when there is a substance on one side that is impermeable to the membrane, i.e. an osmotically active substance, and pure water on the other. If two solutions have the same osmotic pressure, we call them isotonic solutions. This is the case with the human body and isotonic drinks, because the osmotic blood pressure in adults is 275 to 295 mOsm/g on average, which is the osmotic pressure of an isotonic drink. This contributes to shortening the time of fluid absorption in the body and restoring the water and electrolyte balance. The osmolality of a drink depends on the minerals it contains and the type of carbohydrates [32].

Isotonic drinks mainly consist of water, carbohydrates, and electrolytes. The essential mineral is sodium. It is believed that only sodium is an essential mineral in the prescription of isotonic drinks, as sodium deficiency leads to rapid dehydration of the body. Through sweating, other minerals such as potassium, calcium, magnesium, chloride and phosphate are also lost, but not in such large amounts as sodium. The above-mentioned ingredients are also added to isotonic drinks [30, 33]. During physical exertion, sodium contributes to the maintenance of optimal body temperature, enabling proper thermoregulation. Supports the absorption of water, carbohydrates and other electrolytes. Sodium in isotonic drinks is usually present in amounts from 400 to 1100 mg/l, but amounts above 460 mg/l and even 600 mg/l are considered appropriate. With very strong dehydration of the body and high intensity of physical exertion, the effective concentration is 1150 mg of sodium per liter of drink. Carbohydrates in isotonic drinks are usually about 6 g in 100 ml of drink and are usually glucose, maltodextrin, fructose and sucrose. You can also often find drinks sweetened with aspartame and acesulfame K. Isotonic drinks are often enriched with B vitamins [4, 13, 26, 32].

THE MARKET OF ENERGY AND ISOTONIC DRINKS

The consumption of energy drinks in Poland is becoming more and more popular. Since 2012, we can observe a systematic increase in the value of retail sales of energy drinks, amounting to approximately PLN 1.15 billion. In 2015, Poles spent almost PLN 1.3 billion on energy drinks. The average Pole drank more than 3 liters of energy drinks per year and spent an average of EUR 8 on them. Compared to other European residents, energy drinks are most often consumed by the British. On average, the average UK resident bought over 8 liters of energy drinks in 2015 and spent almost € 31 on them. Poles buy energy drinks most often at discounters (65%), supermarkets (55%) and hypermarkets (51%). However, sales at gas stations are of great importance for the Polish market of energy drinks, as many as 28% of Poles declare that they buy energy drinks there [8, 29].

The sports drinks market is not as big as that of energy drinks. Often these two markets are combined as functional drinks of which around 80% of sales are energy drinks and around 20% are isotonic drinks. However, the value of the sports drinks market continues to grow. This is due to changes in human behavior and an increase in awareness of a healthy lifestyle and physical activity. People more and more often decide to play sports, use the gym or fitness, which makes them choose isotonic drinks to replenish fluids and electrolytes during physical activity. In 2015, the Polish isotonic drinks market amounted to PLN 203 million, it is 2.6% of the European market and it ranks 9th among all European Union countries. The countries in which this market is the largest and accounts for almost 80% of the entire European Union market are: Spain, Germany, Great Britain and Italy. Among the above-mentioned countries, Spaniards consumed the most isotonic drinks in Europe in 2015 and on average 5.5 liters of isotonic drinks per person. The second place was taken by Great Britain and German, with 2.2 liters per person. On average, a Pole consumed 0.9 liters of an isotonic drink in 2015 [26, 29].

In Poland, the sports drinks market is dominated by 3 brands and they account for approximately 87% of the entire market in Poland. More and more often, we can find isotonic drinks produced by supermarkets under their own brand names, which are available only in a selected chain of supermarkets or shops. These drinks are usually cheaper and therefore more accessible to a larger number of consumers. Available isotonic drinks come in a variety of flavors and colors, with various vitamin and fruit additives. Beverages without added sugar are becoming more and more popular. Marketing of isotonic drinks aimed at people interested in sports may also contribute to the increase in sales because more and more often on bottles and in advertisements we can see the image of leading Polish sportsmen achieving success in their disciplines [26, 29].

CONLUSIONS

Energy and isotonic drinks are functional drinks. Energy drinks contain bioactive substances such as caffeine, taurine, inositol, guarana, glucuronolactone and carnitine. These substances, and in particular the high caffeine content, reduce the feeling of fatigue with increased physical and mental effort. The main effect of sports drinks is to hydrate and replenish electrolytes, which are lost through sweat during exercise. In recent years, the demand for energy and isotonic drinks has increased. Although this market still accounts for the smallest percentage in the production of non-alcoholic beverages, it is of great interest to consumers and nutritionists.

Although these products are intended for a specific group, they are more and more often used by children, adolescents or students who should not consume this type of drink or do not always require it in their diet. Therefore, it would be important to educate people of different age groups about the consumption of energy drinks and isotonic drinks, which would also indicate the benefits and risks of their consumption.

PODSUMOWANIE

Z analizy dostępnych publikacji naukowych – krajowych i zagranicznych wynika, że napoje energetyzujące i izotoniczne to napoje funkcjonalne. Napoje energetyczne zawierają substancje bioaktywne, takie jak: kofeina, tauryna, inozytol, guarana, glukuronolakton i karnityna. Substancje te, a w szczególności wysoka zawartość kofeiny, zmniejszają uczucie zmęczenia przy wzmożonym wysiłku fizycznym i umysłowym. Natomiast głównym celem spożywania napojów izotonicznych jest nawodnienie i uzupełnienie elektrolitów, które są tracone z organizmu wraz z potem podczas

aktywności fizycznej. W ostatnich latach wzrosło zapotrzebowanie na napoje energetyczne i izotoniczne. Choć rynek ten wciąż stanowi najmniejszy procent w produkcji napojów bezalkoholowych, to cieszy się dużym zainteresowaniem zarówno konsumentów, jak też specjalistów z dziedziny żywienia. Produkty te przeznaczone są dla konkretnej grupy osób, jednak coraz częściej sięgają po nie dzieci, młodzież lub studenci, którzy nie powinni spożywać tego rodzaju napojów lub też nie zawsze wymagają stosowania ich w swojej diecie. Istotna byłaby więc edukacja żywieniowa wśród osób w różnych grupach wiekowych, która dotyczyłaby korzyści i zagrożeń wynikających ze spożycia napojów energetyzujących oraz izotonicznych.

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CREATION OF THE BRAND OF REGIONAL PRODUCTS AS AN ELEMENT OF LOCAL DEVELOPMENT®

Kreowanie marki produktów regionalnych jako element rozwoju lokalnego®

Key words: branding, regional product, local development.

Branding of regional products in local development is very important. These products are part of both building the national identity of many regions of the EU that produce and sell them, as well as being unique in terms of taste, utility, but also safe for health. Awareness of their existence and full identification is low. After all, a product brand includes not only word and graphic elements, but also, and perhaps most importantly, all the feelings and associations associated with a branded product or service, which ultimately influence customers' purchasing decisions.

Słowa kluczowe: kreowanie marki, produkt regionalny, rozwój lokalny.

Kreowanie marki produktów regionalnych w rozwoju lokalnym jest bardzo ważne. Produkty te są elementem zarówno budowania tożsamości narodowej wielu regionów UE, które zajmują się ich produkcją i sprzedażą, jak również są niepowtarzalne pod względem walorów smakowych, użytkowych, ale także bezpieczne dla zdrowia. Świadomość ich istnienia i pełnej identyfikacji jest mała. Marka produktu obejmuje bowiem nie tylko elementy słowno-graficzne, ale również, a być może przede wszystkim, wszelkie odczucia i skojarzenia związane z produktem lub usługą sygnowaną daną marką, które w ostatecznym rozrachunku wpływają na decyzje zakupowe klientów.

INTRODUCTION

All over the world, countries, regions and even localities are competing with each other. This competition is not only about resources or finding a domestic or foreign investor, but increasingly about tourists and even future residents (especially young ones). One way for individual administrative units to improve their competitive position is to develop a recognizable image. In order to be noticed among competing regions, it is necessary to stand out. A distinct, original, unambiguous and attractive to buyers image is therefore extremely important to ensure the success of the marketing efforts of places.

Food products are increasingly clearly divided into industrial and high-quality foods. The latter, if it has EU or national certification, is counted as culinary heritage. Thus, the way a dish is prepared is based on traditional ways of making it resulting from the history of the region. In addition, the raw materials used in a given dish have specific characteristics resulting from natural conditions peculiar to a particular place. Such products are mainly produced on a small scale, which means that their uniqueness becomes a unique resource of the area, which can be used when building promotional strategies for particular places.

Poland is a country with great traditions, having excellent conditions for producing food products of high quality and unique taste parameters. Biodiversity combined with a beautiful landscape provide an excellent basis for the development of a market for traditional foods. Consumers are increasingly choosing to purchase regional products in order to, among other things: experience the flavors of a particular region. Traditional and regional products are characterized by high quality and a certain chemical composition, so for those who care about healthy eating, it is an interesting proposition.

BRAND CHARACTERISTICS

The purpose of this study is to analyze the impact of regional product branding on local development. From the buyer's point of view, there are many factors that guide them in choosing regional products. They can be divided into three groups, namely economic, socio-cultural and psychological factors. However, in determining consumer preferences, one must always keep in mind that every individual is different, and it is not easy to determine exactly what guides them in choosing such products.

Branding was seen solely as an identifier to emphasize ownership and originality. At the beginning of the 20th century, it began to serve primarily the function of distinguishing the products of a particular manufacturer from those of other manufacturers. Over time, however, with increasing competition, the brand began to be viewed not only through the prism of benefits for the manufacturer, but primarily in

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terms of added value for the customer. This has given rise to a different view of the role a brand plays [1].

In the ISO international standard (10668:2010), it is defined as a pertinent, marketing function-related intangible asset including (but not limited to) names, terms, signs, symbols, logos and graphic designs or combinations thereof, intended to identify goods, services or entities, or to create distinctive images and associations in stakeholders, thus generating economic benefits. It should be noted that the definition quoted above, although it seems to reflect well the economic sense of a brand, is not the only one found in the literature. It can be defined in different ways. This undoubtedly demonstrates the complexity of its essence and multidimensionality [2].

Indeed, a brand includes not only the verbal and graphic elements that are expressed in a trademark, but also, and perhaps most importantly, all the feelings and associations associated with a branded product or service that ultimately influence customers' purchasing decisions.

According to De Chernatona, brand is a multifaceted concept, the understanding of which is often shallowed and reduced to visual aspects. The multidimensionality of this concept is well illustrated by the iceberg metaphor. What is perceptible to the customer and what is colloquially interpreted as a brand constitutes only about 15% (logo, name, slogan), the remaining 85% are the invisible processes (such as committed personnel, their skills, well-developed logistics process, etc.) that create added value inside the organization, and it is these that give brands a competitive advantage [3].

Competitive advantages are enjoyed by those companies that have managed to build brands that win the trust and loyalty of buyers. Creating a good brand is a difficult and lengthy process, the success of which largely determines whether a company can succeed in the market. A brand, on the one hand, provides benefits to buyers and its owner, while on the other hand, the strength of a brand creates barriers that competitors must overcome in order to occupy a certain market position.

De Chernatony further points out that one of the biggest challenges in the brand-building process «is to coordinate all value-adding activities to achieve an integrated brand.» The subject of analysis in this paper is the concept of regional branding. It is variously understood and used in different contexts [3]. The following interpretations of the concept can be found in the literature:

- regional brand, by which is meant a brand built for products intended for and sold in a particular regional market, such as beer market brands, mineral water brands), juices and other products; investors of such brands are now often large transnational corporations;
- regional brand understood as the brand of a regional product, i.e. a product traditionally produced in a given region based on the resources and heritage of a given region and closely related to its identity. These are most often food products, such as oscypek, thatch's povidla, Podhale bryndza, sękacz, etc., but also textile products (such as Koniakow lace) or other products (such as Podhale ciupaga), and regional tourism products (such as the Trail of Wooden Architecture, the Land in Check, etc.) [4].

Many inexperienced entrepreneurs focus on developing the visible elements of the brand – the name, logo, packaging, etc. These activities are, of course, necessary to bring a product to market, but they should be the result of some general assumptions, the so-called brand strategy [8]. This is a short document that synthetically describes the essence and uniqueness of the brand, outlines how it should be positioned. This strategy may include such elements as the profile of the target segment, the benefits of buying the brand, the personality/archetypes of the brand, the essence of the brand, etc., and is the basis for further more detailed undertakings – it determines the points of contact between the consumer and the brand (e.g., it influences not only the choice of the brand name, the appearance of the logo, but also the form and content of the advertising message, the design of the packaging and many others). Brand strategy does not have a formalized structure or form. In fact, any professional branding or advertising agency has its own proprietary strategic tool.

Closely related to the brand strategy is the brand communication strategy. Well-planned marketing communications support the implementation of the brand strategy (it can even be assumed that without effective communications it is not possible to implement the brand strategy) [8]. One of the many brand-building strategies for agricultural commodities is to emphasize their geographical origin and/or traditional and/or organic recipe. This is social quality-building, requiring close cooperation between the various links of the market channel in agribusiness, which manage common resources, called club goods such as quality marks [5].

Competitiveness is defined as the potential for opportunities and the ability of a market entity to meet competition. This, in turn, refers to the process leading to the presentation of one's own offerings to consumers as more advantageous than others in the same industry. Rival entities seek the same benefits, at the same time and with the same rules, and the realization of the interests of some threatens the realization of the interests of others. Competitiveness determines the position of an entity from the point of view of its resources, capabilities, opportunities and potential in relation to the market structure [9].

REGIONAL PRODUCT AND LOCAL DEVELOPMENT

P. Bryła through regional products defines the concept of collective brand (shared brands). According to him, on the basis of economic theory, collective brands take on the characteristics of club goods because, on the one hand, they are characterized by exclusivity (they remain in the possession of a specific economic unit), on the other hand, they are non-competitive in nature (all partners can reap the benefits without harming the others). The image of regional and traditional food products is shaped by the brand of individual producer groups, as well as the collective brand, which is based on the image of geographical uniqueness or ways of producing products. It is important that the effect of transferring the image of the area of origin to the product is stronger the less financial resources the producer has. From the point of view of business development, the use of collective brands based on the area of origin increases the attachment of companies to a particular region through specific access to raw materials and

the location of production itself. And thanks to the strategy of offering regional and traditional products, competitiveness is increased, especially for micro, small and medium-sized entrepreneurs, who would not be able to create their strong brand on their own [4]. It should be noted that in the case of a collective brand, it is crucial to create its identity, build its reputation and protect this reputation by all participants. Thus, the promotion of regional products through a collective brand is not only conducive to maintaining existing markets, but also serves to win new ones. It also serves to protect local traditions and customs, environmental order and the stability of the area of origin. When creating the promotion of an area, it is worth noting that consumers can be influenced by various characteristics of traditional and regional products, both objective and subjective. In promotion, one can refer to the natural qualities. External features related to, for example, the way the product is produced, processed and consumed can be used. These features can refer to the subjective, material or symbolic qualities of traditional and regional products. Appealing to emotions gives the idea of «being part of a community,» and to ethical or cultural values is perceived by consumers as protecting tradition, supporting local producers or favoring environmental protection. It is also possible to use features that emphasize the social status of consumers (these products, due to cost-intensive ways of producing them, are much more expensive than products of so-called industrial food). When using offers to promote the culinary heritage of a region, two models can be used:

– in the first place, show the region, city, place and say: «come here, stay here, visit us, because there is a lot going on here»;
– start with the product: offerings, events, happenings. First show what is happening, and only then – where the customer will find us [7].

The literature points out that the second approach is better, as tourists choose attractions and places that offer these attractions. However, it should be borne in mind that at the outset, regional products are certainly a resource, not at all necessarily perceived as a reason for tourist travel (an element of the tourist product) on their own. Instead, they are an added value to a particular region, helping to distinguish it from its competitors and playing a key role in assessing visitor satisfaction. However, the evaluation of a particular place will depend on the number and quality of all places offering these products. It is worth mentioning that promotion only supports the consistent policy of local authorities in the management of an area. Here, too, originality and creativity begin to count, and so, for example, in several small Italian cities, decision-makers have come to the conclusion that they have no chance in competition with large and well-known tourist destinations and have begun promoting the slow cities program. They advertise themselves as places where life is slower, but more comfortable and stress-free, thus safer and longer. The process of promoting a specific territorial unit involves recognizing the needs and desires of the audience, then shaping an appropriate offer, communicating available information about it, offering this offer at the right time, place and price, selecting the right tools and using them consistently. Promotion is like any investment, which may or may not help gain a competitive advantage [6].

SUMMARY

Regions, like cities, are viewed in terms of a product. Like any product, a territory requires strategic, long-term action to stand out from the competition. Image campaigns of regions shape the offer and convey their proposition to the addressees (investors, tourists, residents), but the key to the success of promotional and image campaigns of cities and regions is the idea of reaching the audience. In the age of globalization, it must reflect the uniqueness of the of a given place, which is why territorial marketing reaches for uniqueness, from here it is only a step to use regional cuisine, which is a tourist attraction of a given region on a par with natural and anthropogenic values. However, in order to attract the interest of potential tourists, it must be a finished product, in which gastronomic proposals will be combined with tourist and cultural offers, events, heritage and history of the region. A good promotion must also not lack excitement. The inclusion of regional culinary in the promotion of the region by example shows that joint marketing of the region and the catering industry is possible. The product provides an opportunity to extend the season and reach new groups of audiences, including foreign customers. By promoting specific culinary events, restaurants and the chefs working there, a luxury brand of the region is built. There are many benefits of having regional products in a region, namely: use of natural resources and activation of the local population, capital or cultural inputs that have been blocked or are not fully utilized, increase the development of the region, strengthen economic activity, diversify products in the region, promote the region and cultural heritage, introduce new strategies for action, by mobilizing local actors, promotion for small businesses, increase the value of the product and traceability, protection in the home territory and throughout the European Union.

PODSUMOWANIE

Regiony, podobnie jak miasta, postrzegane są w kategoriach produktu. Jak każdy produkt, terytorium wymaga strategicznych, długoterminowych działań, aby wyróżnić się na tle konkurencji. Kampanie wizerunkowe regionów kształtują ofertę i przekazują swoją propozycję adresatom (inwestorom, turystom, mieszkańcom), jednak kluczem do sukcesu kampanii promocyjnych i wizerunkowych miast i regionów jest pomysł na dotarcie do odbiorców. W dobie globalizacji musi odzwierciedlać wyjątkowość danego miejsca, dlatego marketing terytorialny sięga po niepowtarzalność, stąd już tylko krok do wykorzystania kuchni regionalnej, która jest atrakcją turystyczną danego regionu na równi z walorami przyrodniczymi i antropogenicznymi. Aby jednak wzbudzić zainteresowanie potencjalnych turystów, musi to być gotowy produkt, w którym propozycje gastronomiczne zostaną połączone z ofertami turystycznymi, kulturalnymi, wydarzeniami, dziedzictwem i historią regionu. W dobrej promocji nie może zabraknąć również emocji. Przykład włączenia kuchni regionalnej w promocję regionu pokazuje, że wspólny marketing regionu i branży gastronomicznej jest możliwy. Produkt daje szansę na wydłużenie sezonu i dotarcie do nowych grup odbiorców, w tym klientów zagranicznych. Promując konkretne wydarzenia kulinarne, restauracje i pracujących w nich szefów kuchni, budowana jest luksusowa

marka regionu. Korzyści z posiadania produktów regionalnych w regionie jest wiele, a mianowicie: wykorzystanie zasobów naturalnych i aktywizacja miejscowej ludności, zablokowane lub nie w pełni wykorzystane nakłady kapitałowe lub kulturowe, przyspieszenie rozwoju regionu, wzmocnienie aktywności gospodarczej, dywersyfikacja produktów w regionie, promowanie regionu i dziedzictwa kulturowego, wprowadzanie nowych strategii działania poprzez mobilizację lokalnych aktorów, promocja dla małych firm, zwiększanie wartości produktu i identyfikowalności, ochrona na terenie macierzystym i na terenie całej Unii Europejskiej.

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INSECTS AS FOOD – OPPORTUNITIES AND CONSTRAINTS®

Owady jako żywność – możliwości i ograniczenia®

Key words: novel food, insects, source of protein, plant protein, opportunities, constraints.

The interest of the food and feed industry in animal protein alternatives is increasing worldwide. Among the most commonly used alternatives are plant proteins, but interest in insect proteins as well as the use of whole insects in food is still growing. The aim of this study was to analyze the possibilities of using edible insects in food as well as the limitations associated with their use in food products. The production process, safety issues, consumer opinion, popularity of insects in different corners of the world, nutritional value, as well as the sustainability of insect production as a protein source compared to conventional production are discussed. The opportunities as well as the limitations in the use of insects in food were highlighted. Many examples of the use of insects in equal food products were also given. Despite the emerging economic and environmental opportunities associated with the use of edible insects as a protein alternative in the future, there are still some limitations and restrictions on the industrialization of edible insects in food products, from the breeding, processing and promotion of edible insects to their acceptance among consumers.

Słowa kluczowe: nowa żywność, owady, źródło białka, białko roślinne, możliwości, ograniczenia.

Zainteresowanie przemysłu spożywczego jak i paszowego alternatywami białka zwierzęcego jest coraz większe na świecie. Wśród najczęściej wykorzystywanych alternatyw są biała roślinne, niemniej jednak zainteresowanie białkiem owadzim jak również wykorzystaniem całych owadów w żywności nadal rośnie. Celem artykułu była analiza możliwości wykorzystania jadalnych owadów w żywności jak również ograniczeń związanych z ich użyciem w produktach spożywczych. Omówiono proces produkcji, kwestie dotyczące bezpieczeństwa, opinii konsumenckiej, popularności owadów w różnych zakątkach świata, wartości odżywczej, jak również zrównoważonej produkcji owadów jako źródła białka w porównaniu do produkcji konwencjonalnej. Zwrócono uwagę na możliwości jak i ograniczenia w zastosowaniu owadów w żywności. Podano również wiele przykładów wykorzystania owadów w różnych produktach spożywczych. Pomimo pojawiających się możliwości ekonomicznych i środowiskowych związanych z wykorzystaniem jadalnych owadów jako alternatywy dla białka w przyszłości, nadal istnieją pewne ograniczenia i restrykcje w uprzemysłowieniu jadalnych owadów w produktach spożywczych, od hodowli, przetwarzania i promowania jadalnych owadów po ich akceptację wśród konsumentów.

INTRODUCTION

Population development continues to increase, as well as the impact of agriculture in meeting human food on climate change, has led to many studies being conducted to find alternative proteins that are still of high quality and affordable, but are more environmentally friendly. Beef is one of the most consumed protein sources, but unfortunately it is the food that requires the most environmental inputs and has the greatest impact compared to other protein sources [87]. On the other hand, vegetable protein groups, such as legumes, require fewer environmental inputs than beef, but production on an industrial scale requires fuel, fertilizers and pesticides, which are close to beef and chicken [87]. Thus, it is necessary to have other alternative protein sources to fill the gap.

Protein is one of the most important nutrients in life. Besides water, protein is the most abundant compound in the human body. Protein plays a role in the growth and maintenance of body tissues, especially in the formation of structure, function, and regulation of organ tissues in the body so that it needs to be regenerated continuously [89]. In addition, proteins also play

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a role in the formation of hormones and antibodies, storage and transportation of molecules, as well as enzymes that play a role in biochemical reactions in the body [89]. Insufficient protein intake can lead to malnutrition [13].

Meeting protein needs can be met through the consumption of high-protein foods. It can be in the whole form (raw, cooked or processed) or designated food products that contain either protein from animal or plant sources [10]. Animal protein majorly can be obtained from dairy, meat, seafood and eggs [10]. While vegetable protein can be obtained from plants such as cereal, legumes, nuts, seeds and microalgae [10]. The quality of animal and vegetable protein varies, depending on the content of essential amino acids that are important in physiological requirements and nitrogen balance and bioavailability in the human body [15; 87].

Animal protein in terms of its essential amino acid content has a greater value when compared to vegetable protein. In addition, protein contained from animal sources also brings other nutrients needed by the body such as fatty acids and certain micronutrients, namely zinc and vitamin B12 [15]. Vegetable proteins such as nuts are high in unsaturated fatty acids in the form of MUFA (monosaturated fatty acid) and PUFA (polysaturated fatty acid), as well as protein which is quite high when compared to animal protein, but the anti-nutritional content found in nuts can reduce its bioavailability in the body and low consumption of animal protein such as vegetarian food which consumes more vegetable protein, causing a lack of intake of micronutrients zinc and vitamin B12 [85]. Thus, it is recommended to consume a balanced diet of plant and animal foods to meet each other's body needs.

OPPORTUNITIES AND CONSTRAINTS

Edible insects in the past and today

Insects are arthropod species with a chitinous exoskeleton, a three-part body (head, thorax, and abdomen), jointed legs, compound eyes, and two antennae [57]. Insects are the only flying invertebrates that are cold-blooded and undergo metamorphosis in order to adjust to seasonal changes, breed swiftly, and have vast populations [96]. Their respiratory systems are resistant to air and vacuum pressure, as well as high altitude flying and radiation, and they rarely require parental care [96]. Insects may be found in almost any habitat, with the exception of the ocean, where just a few species exist [96].

Insects are currently one of the foodstuffs whose potential has begun to be explored to meet human food needs. More than 2000 insect species have been consumed worldwide [98] (Table 1). Eating insects as a food usually come with the term entomophagy. The name "entomophagy" is derived from the Greek words "*entomos*" (insects) and "*phagein*" (to eat), and the combination of both terms implies "insect eating" [79]. There are differences in the eating habits of edible insects in various countries, much influenced by the culture of food consumption, religion and its availability in various regions [40]. For some region like in the western culture, eating whole insects is still uncommon thing to do [78], but for other regions, it is still a preference for their delightful taste, event collecting insects is a part of enjoyable activities [70].

Table 1. Common insect species consumed worldwide and harvested nowadays

Tabela 1. Popularne gatunki owadów spożywane na świecie i hodowane współcześnie

Common consumed insect	Common harvested insects
Silkworm (*Bombyx mori*)	Grasshoppers (*Melanoplus foedus, Acrida turrita* (L.), etc)
Catterpillars (Cirina forda)	Silkworm (*Bombyx mori*)
Palm Weevil (*Rhynchophorus ferrugineus* (Oliv.), *Rhynchophorus phoenicis* (Fabr.), etc)	House Cricket (*Acheta domesticus*)
Ants (*Oecophylla sp.*, *Camponotus japonicus* Mayr, etc)	Mealworms (*Tenebrio molitor*)
Grasshoppers (*Melanoplus foedus, Acrida turrita* (L.), etc)	Locust (*Locusta migratoria*)
Locust (*Locusta migratoria*)	Termites (*Macrotermes nigeriensis*)
Beetles (*Onitis spp.,Copris spp.,Heliocopris spp.*)	Cicada (*Orientopsaltria spp., Dundubia intermerata Walker, Cicadidra spp.*)
Crickets (*Acheta domesticus, Gryllus assimilis*)	Dragonfly (Order Odonata)

Source: Own elaboration based on [27, 39, 48]

Źródło: Opracowanie własne na podstawie [27, 39, 48]

Insects as food

Despite the fact that 80 percent of the world's population is accustomed to eating insects, the consumption of edible insects is yet unexplored and considered inappropriate by many civilizations. Insects are a novel meal, and knowledge on the safety and nutritional value of edible insects is limited, particularly given their wide variety [86]. Many studies state the potential of insects as a future food solution due to their affordability, quality and sustainability. The development of edible insects is also expected to solve several problems at once both in terms of economy, food, nutrition and the environment. Currently, consumption of edible insects is still mostly dominated in western areas with wider and varied food acceptance [68]. In Australia, research and a long-term road map for the development of these edible insects have also been established to explore the potential of local edible insects [77]. While in Asia itself, several countries have made edible insects as one of the commonly consumed food ingredients such as in Thailand, Vietnam and Myanmar [40; 39].

Eating insects whole or just with visible body parts might be hard for people raised in Western society. People in environments where insects have not been ingested for a long time prefer to incorporate insects into meals in such a manner that they are unrecognizable [78]. These considerations imply that ‚hiding' insects in products will make them more approachable in the future. In practice, dried insects can be crushed or pulverized, while raw or cooked insects can be ground or mashed, resulting in an unidentifiable insect shape [67].

Table 2. Insects as a food - opportunities and constraints

Tabela 2. Owady jako żywność - możliwości i ograniczenia

Opportunities	Constraints
1. Insects are frequently consumed as a delicacy, and insects are not inferior to other protein sources such as fish, poultry, and cattle. 2. Insects are clean, pleasant, and nutritious. 3. People who have eaten insects before have a significantly more positive attitude toward entomophagy than people who have not, and are more likely to eat them again. 4. Insects in the form of powder can be a good approach to develop many kinds of insect-based products that is more acceptable to the consumers. 5. Edible insects are potential to be developed by the food industry as food and feed enrichment and fortification materials. 6. Insects can be a solution to several problems at once (nutrition, food, economy and environment) due to their quality, affordability and sustainability. 7. „Green consumer", a fitness and health oriented consumer may be the main target for insect-based products due to his concern for health 8. Insects can be promoted as something unique and exciting for the consumers. 9. Insects can be reared and harvested throughout the year, almost all parts of their body can be consumed, have high fertility and growth rates, and are more efficient in converting the substrate they consume into body mass. 10. Insects have a high feed conversion efficiency value. 11. Insects have great potential in solving environmental problems. They are one of the solutions to the growing issue of climate change. 12. The small farm model has the ability to grow a greater variety of insects, reduce genetic diversity loss, and reduce the likelihood of an insect illness spreading across a colony. 13. Edible insects can provide protein (20-70% of raw protein), amino acids (30-60%), fat (10-50%) and minerals and vitamins. The minerals and vitamins contained include phosphorus, sodium, iron, copper, zinc, manganese, potassium, vitamins B1 and B2 and niacin. 14. Crickets show superior nutritional value with a higher content of protein, minerals (iron, zinc and magnesium) and fat with less SFA, but higher PUFA content. 15. Insects can provide equivalent nutrients, not only compared to meat, but also from other food sources such as shellfish, nuts, vegetables and even fruit.	1. Insects in Europe are synonymous with discomfort and are associated with dirt, fear of contamination and disease, as well as psychological and biased perceptions of taste, smell and color. 2. A common belief is that insects are unclean, unsanitary and/or disease carriers. 3. Western aversion to entomophagy contributes to the widespread view that entomophagy in developing countries is motivated by hunger and is solely a survival mechanism 4. Several challenges need to be considered in the safety of food based on edible insects, namely the content of anti-nutritional compounds, allergens, biological and other chemical hazards. 5. Edible insect producers are expected to be able to comply with local food product regulations. 6. Like other food products, edible insects must be kept under hygienic conditions and constantly inspected for nutritional content and taste to maintain their quality. 7. The nutritional content of edible insects will be influenced by several factors, including: the type of species and its processing, growth stage, sex, and external factors such as weather, food, and the edible insect's habitat. 8. As interest in raising insects for commercial purposes increases, significant steps will need to be taken to ensure that the supply of insects does not harm the environment. 9. Harvesting of insects under natural conditions will soon be insufficient to meet demand. Processing will have to be automated. 10. Harvesting insects in the wild is the most common method of collecting insects in most nations. In some cases, the cost of insects can be much higher than the cost of meat. 11. When evaluating insect breeding, it is important to identify aspects that affect the substrates or feeds used, as well as the conditions in which the insects are placed. 12. Breeding insects should have access to high quality nutrients, be allowed to express natural behavior, be free from discomfort, pain, injury and disease during the breeding process, and be housed in a breeding environment that is as close to their natural environment as possible to maximize animal welfare. Killing methods that guarantee a quick death are also recommended. 13. In the case of insects, more research is needed to assess their ability to transmit diseases. 14. The most effective methods to ensure the survival and reproduction of insects should be studied and developed.

Source: Own elaboration based on [6, 8, 12, 19, 27, 32, 33, 34, 38, 39, 40, 43, 52, 67, 73, 78, 79, 82, 96, 97, 99, 100, 102]

Źródło: Opracowanie własne na podstawie [6, 8, 12, 19, 27, 32, 33, 34, 38, 39, 40, 43, 52, 67, 73, 78, 79, 82, 96, 97, 99, 100, 102]

Table 2 and the further part of the article present the most important points indicating the opportunities but also the constraints arising from the use of edible insects as food.

Popularity of insects in different corners of the world

Currently, the consumption of edible insects that are still not common is caused by various things. The meta-analysis conducted by Wassmann et al. [102] regarding the willingness to consume (Willingness to Consume/WTC) of insects, showed a correlation between "fear of food change" (food neophobia), "disgust", and "expectations of discomfort by eating insects" and WTC. However, this can be overcome in the long term by introducing insects as food, such as by developing education on the concept of eating insects and providing direct experience of "eating insects" in the community [102]. Research by Suthar et al. [90] shows projections of edible insects in the future with various scenarios that may occur both as food and feed. So that food products based on edible insects will be very potential to be developed in the future.

ASIA

Entomophagy is a common practice in several Asian nations. Some nations in the Asia Pacific area have access to information on edible insects, however it is scattered [106]. There is relatively little published material for peninsular Malaysia, Myanmar, Nepal, Pakistan, many Pacific islands, and Taiwan, while Australia, Indonesia, Papua New Guinea, the Philippines, and Vietnam still have knowledge gaps. In nations with a long history of this practice, diminishing insect eating has been recorded as diets have transitioned to a more westernized pattern, followed by a population movement to urban regions [97]. However, there is an exception to this pattern in Southeast Asia [107].

In Malaysia, although there is no specific regulation for insect used, the laws apply to food safety and quality including the use of insects [55]. In China, although the Ministry of Health has allowed silkworm pupae as food in 2014, the food safety standards for edible frozen fresh silkworm pupae available in local area of Guangxi Zhuang Autonomous Region (DBS45/030 – 2016) [54]. Meanwhile in Thailand, the authority about edible insects falls under Food and Drug Administration, Ministry of Public Health with the regulation Food Act B.E.2522 [29]. In Republic of Korea, in order to support the insect farmer and national economy, some legal measurement has been established [84]. The same goes to Thailand, where Thai National Bureau of Agricultural Commodity and Food Standards (ACFS) from the Ministry of Agriculture made a guideline to cricket farming [66] and rearing silkworm for silk production [65].

EUROPE

Except for those who have allergic responses, humans, particularly those from North America and Europe, can consume insects if they do not know what they are eating [78]. In Western societies, where protein is still primarily derived from domesticated animals (cow, pig, chicken, etc.) and proteinaceous seed (pulses), insects are almost related with discomfort: mosquitoes and flies invade homes, the former leaving behind unwanted bites; termites destroy wood possessions; and some insects end up in meals, triggering the disgust factor [96]. A mechanical vector, such as a house fly, can take up an infectious agent on the exterior of its body and transport it to food [96]. These are some of the reasons why the European Society refuses to eat edible insects, and deliberate human entomophagy is uncommon in westernized societies [105]. With such a background, it is not surprising that insects in Europe relate to dirt, fear of contamination and disease, as well as a psychological and biased perception of taste, odor, and color [12]. With proof that insects are clean, pleasant, and nutritious [32], there are potential to investigate the cultivation of human-grade insects for human consumption and to expand the prospect of substituting animal products with insects.

The Western dislike for entomophagy contributes to the widespread idea that entomophagy in the developing world is motivated by famine and is purely a survival mechanism [96]. This is not the truth, since insects are frequently consumed as a delicacy, and insects are not inferior to other protein sources such as fish, poultry, and cattle. Furthermore, due to the ecological benefits of insects over other animal protein sources, shifting from animal products to consuming insects might have significantly impact animal product consumption in nations [86]. There are already hints that customer attitudes in developed countries such as the United States and the United Kingdom are shifting [45], and the barrier to include insect-derived components in other products, such as powder [7], may not be as high. Some studies on accepting entomophagy conducted in European countries such as the Netherlands [56] have found that people who have eaten insects before have a significantly more positive attitude toward entomophagy than people who have not, and are more likely to eat them again. As a result, it appears critical to encourage individuals to take „the first step" and become acquainted with eating insects [78]. As a result, giving informative education to the customers on entomophagy should be performed [56].

All insect-based product has been authorized as novel food in 2018 and fall under novel food regulation EU 2015/2283 [24]. In the European Union, reared insects including in "farmed animals" [22] and it is regulated under animal livestock health and biosecurity measures on transmissible diseases [23]. To prevent issues related to spongiform encephalopathies, processed animal proteins (blood products, gelatin, collagen, hydrolyzed proteins of animal origin and derived from ruminants) cannot be used as a substrate for insects [21]. There are some exceptions, such as processed animal protein products from seven insect species that can be used as part of the formulation for aquaculture feed and pet food in the European Union, they are *Hermetia illucens, Musca domestica, Tenebrio molitor, Alphitobius diaperinus, Acheta domesticus, Gryllodes sigillatus* and *Gryllus assimilis*) [25].

AMERICA

It is noteworthy to mention that pre-Western cultures has been practice entomophagy [88]. Around 90 species of edible insects have been consumed in North America [48]. Some of them are Coleoptera (beetles, weevils, borer), Diptera (shore fly, botfly larvae), Hemiptera (water bug, honey bee, cicada), Orthoptera (locust, mormon cricket), Hymenoptera (ants, wasp, hornet), Lepidoptera (butterflies, moths) [88]. Certain insects such as locust, wild honey, cricket, katydid and grasshopper are being mentioned in bible and in Sunnah based on the beliefs spread in America [88]. Guine et al. [37] also recorded that tarantula spiders being consumed in Latin America (Cambodia and Venezuela). In South America, Termites are more popular to be consumed uncooked like a snacks [37]. The past practices of entomophagy are better documented in western part of North America than other parts (eastern and northern areas) [88]. There is an assumption that eating insects related to negative perspective and starving condition [88]. Although it is currently still uncommon to use insects as food in most western regions such as North America, but insect-based food such as cricket powder or insects offered by a restaurant are starting to become well known for the sustainable reason of offering food rich in cheap proteins [88].

The legal framework for food uses of edible insects and its derivatives products in America fall within the oversight of the United States of America Food and Drug Administration (FDA) informal policy the same goes to other food [27]. If they are added to processed food, e.g. as an ingredient or additives, it falls under Generally Recognition as Safety (GRAS).

AUSTRALIA

Witchetty grubs, Honey ants, and Bogong moths (*Endoxyla leucomochla*, *Myrmecocystus mexicanus,* and *Agrotis infusa*) are among the insects that are included in the traditional diet of indigenous Australians (also known as the 'bush tucker' diet) [72], but the consumption of insects in Australia is otherwise considered to be a novelty. Perceptions of insects as pests [96], dirty, unpleasant, and hazardous [58], have a detrimental impact on the adoption of insects as a source of nutrition. Customers' resistance to eating insects has related to sentiments of disgust [12; 41; 53; 101], which are frequently associated with beliefs of risk, such as insects being unclean, unsanitary, and/or disease carriers [97].

Currently, Ponce-Reyes and Lessard [77] has made a roadmap for strategic growth of edible insects in emerging Australian market. For the regulation, according to the Food Standards Australia New Zealand (FSANZ) Advisory Committee on Novel Foods (ACNF), some edible insect species (*Z. morio, T. molitor* and *A. domestica*) are considered non-traditional food, but not novel food [27; 30]. This means that they need to follow the regular Food Standards Code [31].

AFRICA

The African diets consist of a vast variety of wild foods, which include edible insects. In Africa, there are about 1,500 edible insect species. As the prices of beef, poultry, and fish continue to climb throughout the world, a fantastic opportunity for insects to supply mankind's and livestock's animal protein demands now and, in the future, has surfaced [78]. In Africa, the demand for edible insects is increasing, mostly because animal protein is becoming more expensive and scarcer [78]. The desire for healthier alternatives and insects has increased, and this has enormous potential in animal feed production. A wide range of insects are consumed [78].

In tropical African countries, the majority of bug species are harvested from the wild, with the majority of harvesting carried out by women. As an example, in the wild, palm beetle grubs are gathered from raffia or palm stems, and their availability is related to seasonal fluctuations. In traditional settings, the method used to capture insects from the wild is heavily influenced by the behavior of the insects. Palm weevils can be attracted to artificially created breeding grounds, and the sound made by cricket species can be used to detect the species in question. Some nocturnal fliers, such as termites and grasshoppers, can be enticed into traps using artificial illumination. In order to control some insects found in trees or bushes, it is possible to apply glue to the top of a branch, twig, stick, or stem [39].

While various insect species are consumed in many African countries, there appears to be a lack of specific regulatory frameworks for using insects as food [36]. There are some exceptions, such as mopane caterpillars (*Imbrasia belina*) are considered edible according to Botswana's food law [36]. In South Africa, insect (termites and black soldier fly maggots) farming is mainly carried out for use as animal feed [69]. Recently, the Kenya Bureau of Standards (KEBS) approved three National Standards that will guide the primary production of edible insects and their processed by-products. Guidelines for insect farmers on how to ensure the safety of the harvested produce by specifying the necessary minimum infrastructure and environmental requirements are provided by KS 2921:2020 [51]. Meanwhile processed edible insects products requirements for food and feed are regulated in DKS 2922-1: 2020 [49] and DKS 2922-2: 2020 [50].

Production and economical aspects of edible insects

At first, edible insects were only taken from the wild and then processed on a household scale. Then the number of requests made the insects began to be kept for breeding and then sold. Researchers have begun to develop a lot of technology for rearing edible insects in several species [40]. Its relatively small size and rapid reproduction make insect breeding not requiring large areas of land and difficult handling [40]. One bowl of cricket eggs can produce 3 kg of adult crickets, while in the cultivation area which can consist of 450 tubes it can produce 450 to 750 kg per harvest cycle (45 days) [40]. The net profit from one cycle of harvesting crickets can generate up to 50% of gross revenue if sold to collectors and can earn more if selling directly to the retail market [40]. It is estimated that the net profit that can be obtained from a 60 m2 breeding plot can be as much as $1250 or about $21/m2/year [39]. The profit depends on the size of the breeding grounds [40]. In addition, the price of crickets will also continue to increase along with the stage of growth [40].

Table 3. Comparison of feed conversion, water, global warming potential and land required to produce 1 kg of poultry, pork, beef and insects

Tabela 3. Porównanie konwersji paszy, wody, współczynnika ocieplenia globalnego i terenu potrzebnego do wyprodukowania 1 kg drobiu, wieprzowiny, wołowiny i owadów

Species	Edible share [%]	Feed conversion animal food (kg) /live weight	Global warming potential (CO_2-eq)	Water footprint water [l] /protein [g]	Land use area [m2] /protein [kg]
Beef	40	25	88	112	201
Pork	55	9.1	27	57	55
Poultry	55	4.5	19	34	47
Insects	80	2.1**	14*	23*	18*

*mealworms **cricket

Source: [27, 63, 74, 97]

Źródło: [27, 63, 74, 97]

Edible insects can be reared and harvested throughout the year, almost all parts of their body can be consumed, have high fertility and growth rates, and are more efficient in converting the substrate they consume into body mass [27]. According to Imathiu [43], edible insects have a high feed conversion efficiency value, one example is crickets which have a higher efficiency of converting feed into „meat" compared to poultry (2x), pigs (4x) and livestock (12x).Table 3 compared the conversion of feed, water, global warming potential and land required to produce 1 kg of poultry, pork, beef and insects.

Environmental impact of edible insects

Apart from their economic and nutritional value, insects have great potential in solving environmental problems. Livestock production is considered the sector that has the most negative impact on the ecology of global warming compared to other anthropogenic activities, both directly and indirectly (72-78% of total agricultural emissions) [99]. Insects are one of the solutions to the growing issue of climate change [38]. One of the quantitative methods for assessing greenhouse gas (GHG) emissions and other environmental parameters (such as land use and energy) is LCA (Life Cycle Assessment), in which these parameters will be calculated during the life cycle of a product [99]. Based on this LCA analysis, mealworms produce the least amount of GHG compared to other animal production [74]. The same thing was also shown by Dobermann et al. [14] which states that insect breeding produces the least amount of GHG compared to standard size large livestock and is equivalent to chickens per kilogram basis. This is due to less land use and less carbon emissions and emissions than other food sources from the agriculture and livestock sector [27] (Table 3). So that the development of insects as nutritious food is expected to suppress the use of other nutritional food sources that produce higher GHGs.

Farming and rearing technology of edible insects

Wild harvesting of insects is the most frequent method of collecting insects in most nations. In certain cases, the costs of insects might be far higher than those of meat [79]. Furthermore, according to seasonal and regional differences, insects may not be present in the wild all year round due to the lack of available resources [79]. As a result, industrial scale insect production, supported by sustainable insect breeding, farming, and processing technology, can reduce the limits on insect availability while also lowering the price of edible insects on the market [79]. Considering that growing or farming insects is now a modest component of the edible insect business, the consequences for the sector's long-term viability are currently uncertain [79]. Habitat conservation is one of the environmental advantages of farming, but the natural environment must be preserved as a source of regeneration and as a safety net, and it will continue to be crucial for local food supply and livelihoods. Given the increased interest in insect raising for commercial purposes, it will be necessary to make significant steps to ensure that the supply of insects does not damage the environment [79].

Food insects now provide a relatively small but rapidly expanding niche in the food market [26] and gathering insects in the wild will soon be insufficient to fulfill demand in the near future. Pesticide usage (*Aegiale hesperiaris* in agave) and environmental degradation (pollution by aquatic Hemiptera) can cause ecosystem deterioration in the wild [80]. It follows that to make insects a sustainable nutritional component for humans, enormous amounts of insects must be produced on a continuous basis, and both farming and processing must be automated.

From a small single cage to a large semi-automated factory, there are many different scales at which insect farming can actually occur [79]. Developing insect factories may lead to the usage of fewer species, but the small farm model has the ability to grow a greater variety of insects, reduce genetic diversity loss, and reduce the likelihood of an insect illness spreading across a colony [78]. As a result, insect farming for food and feed is becoming a more popular economic venture [78]. In addition, there is an increasing international interest in utilizing insects as feed since global demand is increasing and the supply of fishmeal is decreasing, resulting in the need to discover acceptable alternatives, such as insects, that can be farmed in huge quantities [78].

When evaluating insect rearing, it is important to determine the aspects that influence the substrates or feed used, as well as the conditions in which the insects are placed [78]. These considerations differ based on the bug species in question [78]. It just takes a few days to raise black soldier flies to maturity, but it takes several months to produce crickets to maturity. The temperature of the living environment has an influence on the rate of growth [78]. The nutritional composition of feed is crucial; for example, a very little amount of protein is harmful to insect growth, whereas a large amount of protein results in an excessive generation of dry uric acid [95]. The selection of feed is a complex balancing act between the cost of the feed and the growth rate of the insect being raised. Suboptimal nutrition during pregnancy and lactation can result in increased vulnerability to illness and cannibalism in animals, as has been demonstrated in the case of crickets and mealworms. In order to properly house insects, it is necessary to consider the insect's food requirements. The components that are accessible in the feed have a significant function to play. The availability of these components is dependent on a variety of factors like as pH, moisture, airflow, particle size, and so on. The availability of nutrients in feed is increased for most insects when the particle size of the meal is reduced. A coarser substance, on the other hand, is chosen for easier rearing (both in terms of feeding and cleaning).

The effectiveness of the insect production system is critical to the viability of producing insects as a source of sustainable protein in the long term. As a result, the quality of the insect food has an influence on both the protein contribution and the ecological impact of the insect [59]. When fed grain-based diets on a scale of economic importance, populations of crickets were shown to have no improvement in protein conversion efficiency when compared to broiler chickens that were fed identical diets, according to the study [59]. However, broiler diets have been optimized for decades, and it is possible that the efficiency of cricket raising will rise as a result of better feed. Erens et al. [19] have proposed that farmed insects should have access to high-quality nutrients, be allowed to express natural behavior, be free of discomfort, pain, injury, and disease during the breeding process, and be housed in a breeding environment that is as close to their natural environment as possible in order to maximize

animal welfare. They also recommend killing ways that are guaranteed to result in quick death. Although freezing and deep frying are widely employed to eliminate insects, there has been little research on their influence on animal welfare and food quality [78]. The practice of mass insect raising for food and feed is still in its infancy, and greater research into the possibility of disease transmission is required [27]. However, due to the fact that insects are taxonomically distinct from humans as compared to conventional cattle, the danger of zoonotic infection is believed to be extremely minimal [78]. In general, the FAO recommends that when beginning mass raising, regardless of the insect species being raised, a parallel line should always be maintained in case of culture failures or crashes [27].

The most effective methods for ensuring insect survival and reproduction should be studied and developed, for example, providing food resources, creating suitable habitats, harvesting sustainably (for example, allowing repairs to ant and wasp nests), and employing semi-rearing techniques such as those used for wild silkworms, among other things [78]. Feasible strategies to assist in the conservation of insect populations include recording their importance to people's livelihoods, examining relationships between insect harvesting and the ecology, and enforcing existing regulations. It has been proposed that the development of rules regarding the use and trade of insects for human consumption in many countries may be delayed by the existing lack of clarity in the terminology used to describe insect consumption at the time of writing [11]. It is critical to have a clear and comprehensive legal framework in place to promote new approaches to moving from the size of domestic insect raising to the scale of industrial insect rearing [78].

Nutritional value of edible insects

The potential of insects as food cannot be separated from their nutritional content both in terms of quantity and quality. Hanboonsong et al. [40] stated that in general, edible insects can provide protein (20-70% of raw protein), amino acids (30-60%), fat (10-50%) and minerals and vitamins. The minerals and vitamins contained include phosphorus, sodium, iron, copper, zinc, manganese, potassium, vitamins B1 and B2 and niacin [40]. However, there are several challenges in terms of food safety that need to be considered, namely the content of anti-nutritional compounds, allergens, biological hazards and other chemical hazards [43]. So that producers of edible insects are expected to be able to follow local regulations regarding food products. In addition, just like other food products, edible insects must also be maintained in hygienic conditions and continuously controlled for nutritional content and taste in order to maintain their quality [100]. The nutritional content of edible insects will affect several factors, including: the type of species and its processing [40], growth stage [52], gender [33; 73] and external factors such as weather, food, and the habitat of the edible insects [39].

Protein is not only assessed in terms of quantity, but also in terms of quality. The quality of protein from various food sources varies, depending on the content of essential amino acids that are important in physiological needs and nitrogen balance and bioavailability in the human body [15; 87]. Since 1989, FAO has recommended the Protein Digestibility Corrected Amino Acid Score (PDCAAS) method to assess protein quality, in which the limiting amino acid value is multiplied by protein digestibility [26]. However, this PDCAAS method has limitations where the calculation is carried out by assuming that all amino acids have the same digestibility as the whole protein (crude protein) [60]. Whereas each amino acid has a bioavailability that can only be determined accurately at the end of the small intestine (ileum) and fermentation in the hind intestine can affect the fecal excretion of amino acids, so there can be differences in the bioavailability of each type of amino acid [104]. According to FAO experts, protein quality is considered good if the value ranges from 75.0 to 99.9% and is considered very good if the value reaches 100% or more [26].

Research conducted by Ghosh et al. [34] which analyzed the nutritional profile of 5 types of commercial edible insects (3 beetle species; *Allomyrina dichotoma*, *Protaetia brevitarsis*, *Tenebrio molitor*, and 2 cricket species; *Teleogryllus emma, Gryllus bimaculatus*) in South Korea, showing that there are 17 types of amino acids (8 essential, 1 conditionally essential and 8 non-essential) and 26 fatty acids (12 SFA, 6 MUFA and 8 PUFA), where in addition to the amino acid methionine, other amino acids meet the protein recommendations of FAO/WHO/UNU [103]. Compared to other animal proteins (chicken meat and eggs), crickets show superior nutritional value with a higher content of protein, minerals (iron, zinc and magnesium) and fat with less SFA, but higher PUFA content (except in *A. dichotoma*) [34]. According to Payne et al. [76], the nutritional profile of edible insects has a wider variety than the type of meat that is often consumed, so that insects as food have the potential to overcome the problem of malnutrition. The same thing was stated by [6] in a study analyzing the nutritional profile of 3 types of edible insects in Nigeria (*Zonocerus variegatus*, *Macrotermes bellicosus* and *Cirina forda*) which turned out to have adequate nutritional content and can be used as an alternative food source to fight the problem of malnutrition. In addition, in terms of the proportion of macronutrient composition, insects can provide equivalent nutrients, not only compared to meat, but also from other food sources such as shellfish, nuts, vegetables and even fruit [82]. Other functional attributes of edible insects are also potential to be developed by the food industry as food and feed enrichment and fortification materials [6]. Table 4 shows the application possibilities of edible insects in different types of food.

CONCLUSIONS

Edible insects are a potential source of nutritious food, especially as a protein alternative. There are also positive aspects regarding the economic and environmental impacts of using edible insects as protein alternatives in the future. Despite the emerging opportunities, there are still some restrictions and limitations to the industrialization of edible insects in food products, from the breeding, processing and promotion of edible insects to their acceptance among consumers. Regulations on the use of edible insects still vary around the world, although local regulations have been applied in some areas. It is also important to carry out detailed research and deeper analysis on the economic and environmental aspects related to the use of edible insects as a future alternative to

Table 4. Insects as a food – examples from the market

Tabela 4. Owady jako żywność – przykłady z rynku

Type of product	Name of product	Company name	Country	Species of insect
Bar (protein bar, energy bar)	Jimini's Protein Bars Fig & Chocolate	Jimini's	France	Cricket
	Insect Protein Bars	Essento	Germany	Cricket
	Altimate Protein Bar	Altimate	Singapore	Cricket
Beer	Grasshopper Saison	Brouwerij De Molen	Netherland	Grasshopper
	Crna Smrca	Insektarij	Croatia	Cricket
Bread	Mayu no Tayori Croissant, Mayu no Tayori Madeleine	Pasco	Japan	Silkworm
	Sirkkaleipä	Fazer	Finland	Cricket
Burger	Bux Burger	Bug Foundation	Germany	Buffalo Worm
Candy and chocolate	Edible Insects & Bug Candy	Meat Maniac	USA	Cricket, Larvet, Ant
	Silkworm Pupae Chocolate Covered	Thailand Unique	Thailand	Silkworm
	InsectNside	Hotlix	USA	Cricket, Worm, Ant
Cookies	Chocolate Chirp Cricket Protein Cookie Mix	Chirps	USA	Cricket
Crackers	Small Giants, Cracker Bites	Jimini's	France	Cricket
Crips/Chips	Chirps Cricket Protein Chips	Chirps	USA	Cricket
Gourmet	Hiroshima Crickets	Takeos	Japan	Cricket
Granola	Bugbites	Entis	Finland	Cricket
	Granola	Jimini's	France	Buffalo Worm
Meat replacement	Sirkkis	Entis	Finland	Cricket
Milk	Ento Milk	Gourmet Grubb	South Africa	Cricket
Oil	Buffalo Mealworm Oil (BMO)	AdalbaPro	Netherland	Buffalo Mealworm
Pasta	Aldento, La Base D'un Repas Sain Et Équilibré	Goffard Sisters	France	Mealworm
	Protein Pasta	Jimini's	France	Buffalo Worms
Pasta sauce	Mealworm Bolognese, Cricket Bolognese	One Hop kitchens	Canada	Mealworm, Cricket
Powder/Flour	Cricket Protein Powder	Eat Grub	United Kingdom	Cricket
Sausages	High Protein Sausages	The Bricket	Thailand	Cricket
	Sirkka Nakki (Cricket Sausages)	Mattila Bros	Finland	Cricket
Shots	Bugs'n Shot	Syngja	Denmark	Cricket
Spices/seasoning	Sal de gusano, Gusano de Maguey	Real de Oaxaca	Mexico	Agave Worm
Soft drinks	Tagame cider	Takeo	Japan	Giant Waterbug
Spirits	Mezcal Worm (Mezcal Con Gusano)	Monte Alban	Mexico	Worm
	Anty Gin, Ant Snaps	Nordic Food Labs	Denmark	Ant
Tsukudani	Inago Tsukudani	Inago Tsukudani	Japan	Hornet larvae, Grasshopper

Source: Own elaboration based on [1, 2, 3, 4, 5, 9, 10, 16, 17, 18, 20, 28, 35, 42, 44, 46, 47, 58, 61, 62, 64, 71, 75, 81, 83, 91, 92, 93, 94, 108]

Źródło: Opracowanie własne na podstawie [1, 2, 3, 4, 5, 9, 10, 16, 17, 18, 20, 28, 35, 42, 44, 46, 47, 58, 61, 62, 64, 71, 75, 81, 83, 91, 92, 93, 94, 108]

protein. What can be seen is that the edible insect industry is growing strongly, and it is not impossible that many more products using edible insects will be on the market in the future.

WNIOSKI

Jadalne owady stanowią potencjalne źródło odżywczej żywności, zwłaszcza jako alternatywy białka. Istnieją również pozytywne aspekty dotyczące ekonomicznych i środowiskowych skutków wykorzystania jadalnych owadów jako alternatywy dla białka w przyszłości. Pomimo pojawiających się możliwości, nadal istnieją pewne ograniczenia i restrykcje w uprzemysłowieniu jadalnych owadów w produktach spożywczych, od hodowli, przetwarzania i promowania jadalnych owadów po ich akceptację wśród konsumentów. Regulacje dotyczące wykorzystania owadów jadalnych nadal różnią się na całym świecie, chociaż w niektórych obszarach zastosowano lokalne regulacje. Ważne jest również, przeprowadzenie szczegółowych badań i głębszych analiz na temat ekonomicznych i środowiskowych aspektów związanych z wykorzystaniem owadów jadalnych jako przyszłej alternatywy dla białka. To co można zauważyć to, że branża związana z produkcją owadów jadalnych mocno się rozwija i nie jest wykluczone, że w przyszłości pojawi się na rynku znacznie więcej produktów z wykorzystaniem jadalnych owadów.

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VITAMIN D FORTIFICATION IN DAIRY PRODUCTS – POSSIBILITIES TO IMPROVE VITAMIN D INTAKE®

Produkty mleczne wzbogacone w witaminę D – możliwości zwiększenia jej spożycia®

Key words: food fortification, vitamin D, dairy products.

This review presents vitamin D and its importance to the human body and issues related to the fortification of foods with vitamin D. Such foods may constitute an integral part of the daily diet and contribute to a health-promoting nutrition model. It is, therefore, imperative that foods fortified with vitamin D constitute part of a well-thought-out strategy to increase the intake of this deficient nutrient and, in the long term, help to balance the diet and thus improve vitamin D status. Increasing vitamin D intake should be considered a public health priority. Attention should be paid to fortified dairy products which can contribute to increasing vitamin D deficiency intake.

Słowa kluczowe*:* wzbogacanie żywności, witamina D, produkty mleczne.

W artykule przedstawiono witaminę D i jej znaczenie dla organizmu człowieka oraz zagadnienia związane ze wzbogacaniem żywności w witaminę D. Żywność tego typu może stanowić integralny element codziennej diety i wpisywać się w prozdrowotny model żywienia. Z tego względu konieczne jest aby żywność wzbogacona w witaminę D wpisywała się w dobrze przemyślaną strategię zwiększenia spożycia deficytowego składnika odżywczego i w działaniu długoterminowym pomagała w zbilansowaniu diety, a co za tym idzie poprawiała stan odżywienia witaminą D. Zwiększenie spożycia witaminy D należy uznać za priorytet zdrowia publicznego. Na uwagę zasługują fortyfikowane produkty mleczne, które mogą przyczynić się do zwiększenia spożycia deficytowej witaminy D.

INTRODUCTION

In recent years, there has been an increased interest in vitamin D and its supply from the diet, including the possibility of increasing its intake through the consumption of fortified foods. This interest is justified as its consumption from natural sources (oily fish) is considered low. Increasing the intake of this vitamin is the goal of various nutritional strategies, both in preventive programmes (use of supplements) and food production (fortification) [3, 7, 9, 14, 18, 27, 35, 42]. Increasing vitamin D intake should be considered a public health priority [9, 12, 14, 19, 23, 25, 30, 35].

As consumers become more interested in maintaining or improving their health, there is a growing demand for foods fortified with nutrients, including vitamin D [5, 9, 11, 14, 25, 42]. Dairy products stand out in this group. Not only does milk contain several essential nutrients necessary for growth, development and the maintenance of optimal health, but it is also considered an important staple food and can be used as a vehicle for the supply of other nutrients [4, 5, 7, 8, 10, 18, 27, 36, 41, 42]. Thus, it provides excellent opportunities for the food industry to use **milk and dairy products** as vehicles for vitamin D fortification [9, 14, 16, 21, 25, 26, 39, 40, 41, 44, 45]. Even if the natural content of vitamin D in cow's milk is low (0.1–1 µg/L in full fat milk) [15], the consumption of milk fortified with vitamin D has shown to be effective in improving the vitamin intake [5, 8, 10, 11, 12, 18, 20, 26, 27, 36, 39, 41, 45]. Improving vitamin D intake through food fortification represents an inexpensive intervention that can improve the health of the population [16, 21, 42, 44].

It is well known that there is vitamin D deficiency among the vast majority of the world's population [3, 17, 18], including in Poland [13, 22, 29, 35]. Its primary source is synthesis in the skin. Nowadays, the importance of cutaneous synthesis for the body's vitamin D supply is diminishing due to lifestyle changes and reduced sun exposure. Of all food products, oily fish is the richest source of vitamin D, however, its consumption beyond the Scandinavian countries and southern Europe is insufficient [3, 9, 14, 18, 27]. For vitamin D deficiency prevention, consideration is being given to fortifying more selected food products to which cholecalciferol or ergocalciferol is added during food processing. To address the challenge of low vitamin D intake, consideration should

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

be given to identifying food groups that can contribute to increasing vitamin D intake [7, 9, 17, 18, 25, 27, 36, 42].

Low vitamin D status is a global public health issue and vitamin D food fortification may help to improve vitamin D intakes and status at the population level [3, 9, 11, 17, 23, 24]. Dairy products appear to be such a group [5, 10, 12, 14, 18, 20, 25, 26, 27].

This article aims to present the role and importance of vitamin D to the body, its level of occurrence in food and selected aspects of food fortification, with particular emphasis on the importance of dairy vitamin D-fortified products.

VITAMIN D IS IMPORTANT FOR HEALTH

Vitamin D is a fat-soluble vitamin that is essential for bone health and facilitating muscle function. Vitamin D plays a significant role in calcium and phosphate metabolism and prevents rickets in children and osteomalacia in adults (bone softening), or osteoporosis in adults (loss of bone density). Vitamin D deficiency is associated with muscle weakness and osteoporosis and can contribute to an increased risk of falls and fractures. Additionally, there is growing evidence suggesting a connection between vitamin D deficiency and non-skeletal health outcomes [2, 23, 28, 30].

Vitamin D belongs to the group of fat-soluble steroidal compounds, with two most essential forms: vitamin D3 (cholecalciferol) and vitamin D2 (ergocalciferol). Both vitamin D3 formed in the skin and vitamin D3 and D2 derived from dietary sources undergo a metabolic cycle in the body producing biologically active metabolites. The first hydroxylation step occurs in the liver by the vitamin D-25-hydroxylase (CYP2R1) to calcidiol (25-hydroxyvitamin D3 (25(OH)D and the final hydroxylation step occurs in the renal proximal convoluted tubules by the vitamin D-1-hydroxylase (CYP27B1) [1, 2, 3, 18, 27]. Synthesis of the active form of vitamin D – $1,25(OH)_2D$, occurs in the kidneys and other tissues, underpinning its systemic multidirectional pleiotropic action, with possible roles in diabetes, cancer, ischemic heart disease, and autoimmune and infectious diseases [2, 23, 28, 30, 35].

The most commonly used marker of vitamin D status is 25(OH)D that is measured in blood serum/plasma to determine vitamin D level because it shows vitamin D loading from dietary intake and sunlight exposure, as well as the conversion of vitamin D from fat stores in the liver. Vitamin D deficiency is defined as 25(OH)D < 50 nmol/L and vitamin D insufficiency is defined as 25(OH)D < 75 nmol/L [29, 30].

SOURCES OF VITAMIN D, CURRENT SITUATION, ISSUES AND CHALLENGES

Vitamin D belongs to the group of fat-soluble steroidal compounds, with two most essential forms: vitamin D3 (cholecalciferol) and vitamin D2 (ergocalciferol). D3 is obtained from the diet (through natural or fortified foods or supplementation) or it can be synthesised in the skin via the action of UVB radiation (290–315 nm). Vitamin D2 is derived from mushrooms and yeasts after UVB irradiation, the consumption of which is relatively low [3, 14, 18].

Synthesis of vitamin D following exposure of the skin to UVB radiation is the predominant source of the vitamin for most people in Poland during the summer months (May to September) [13, 22, 29, 30, 35]. Actual endogenous synthesis of vitamin D is also limited by climatic conditions and protective measures against skin cancer (sun avoidance, use of UV filter creams) [30, 35]. There are relatively few dietary sources of vitamin D3, the richest being oily fish and and fish liver oil, which are not commonly consumed in many diets [9, 14, 15, 25, 27]. Among foods, oily fish (eel, salmon, herring, mackerel) contain the highest amount of cholecalciferol, but their consumption in Poland is low and infrequent [13, 22, 35].

Other sources include egg yolks, meat products and also fortified foods, such as some dairy products (especially fluid milk, yogurts), some breakfast cereals, and fat spreads which provide a portion of the recommended intake of vitamin D [3, 7, 9, 18, 25]. High intake of meat and milk products is typical for a western diet and provides a contribution to the total vitamin D intake, however contributes lower content of vitamin D compared to fish. It is estimated that natural foods only cover about 20% of the daily vitamin D requirement [13].

Moreover, products fortified with vitamin D, i.e. those to which cholecalciferol or ergocalciferol are added during technological processes, can play a vital role in the supply of vitamin D. Dietary intake of vitamin D can be improved by fortified food products that are increasingly available on the market, e.g. some dairy products, margarines and spreadable fats, ready-to-eat breakfast cereals [3, 5, 8, 9, 10, 11, 12, 18, 20, 24, 25, 27, 36, 41, 42]. Except for infant formula and margarine, there is currently no mandatory fortification policy for vitamin D in the Poland, so voluntarily practice can vary considerably across the industry and manufacturers [7, 34, 43].

Dietary supplements are an additional concentrated source of vitamin D, intended to supplement the diet and reduce the risk of vitamin D deficiency. It is particularly relevant for at-risk groups who should take vitamin D supplements throughout the year. Other groups of the population are advised to supplement with vitamin D between October and March when exposure to sunlight does not ensure enough cutaneous synthesis [30, 35].

The results of studies on the evaluation of various forms of vitamin D indicate a preference for vitamin D3 (cholecalciferol) rather than vitamin D2 (ergocalciferol) in the prevention of vitamin D deficiency. Vitamin D3 appears to be more effective than vitamin D2 in raising serum 25-hydroxyvitamin D concentration, which has implications for the choice of a supplement [37].

Based on national and international research findings, dietary sources of vitamin D and its dermal synthesis are insufficient to provide the body with an adequate supply of this vitamin. Most of the population's average daily vitamin D intake is below the recommended dietary standard and does not ensure optimal levels of vitamin D (as measured by 25(OH)D serum levels) [3, 13, 19, 29].

With few natural dietary sources of vitamin D, food fortification and dietary supplements serve as important methods for ensuring a sufficient vitamin D intake of the population. Therefore, public health strategies addressing fortification, biofortification and supplementation are needed to ensure that current vitamin D targets are met [3, 5, 9, 14, 18, 25, 27, 30, 35, 36].

NUTRITIONAL RECOMMENDATIONS AND DIETARY INTAKE

According to the current dietary reference values [13], the requirements for vitamin D are set at the Adequate Intake (AI) level. The vitamin D intake of 15 µg/day represents the average adequate intake to achieve a serum 25(OH)D of ≥50 nmol/L. This target value is considered to cover the requirement of the majority of the population in relation to the optimal calcium absorption and related bone health [6, 13]. The EFSA recommend the upper daily limit below 100 µg/day (4000 IU) [6].

Numerous studies show an average vitamin D intake well below the recommended standard. In Europe, vitamin D intake is generally between 3 and 5 µg per day [4, 14, 18, 22] and even with values of 2.2 µg [17], with higher intakes in Northern Europe (up to 11–14 µg/day) [8, 10, 24]. In Poland, vitamin D intake is also well below the recommendations. Average daily intake is about 1,4–5,1 and 0,6–3,5 µg/day, respectively, in adults and children [13].

The deficient intake of vitamin D in the Polish population is reported in several studies, with attention drawn to the high prevalence of vitamin D deficiency in winter when sun-induced vitamin D synthesis is insufficient [22, 29, 30, 35]. It should be noted that an important source of vitamin D is supplementation. In Poland, vitamin D is routinely prescribed to infants and young children. Further supplementation for age-school children, as well as for adults, is advised based on official recommendations [30, 35].

However, given the increasing popularity of supplements and their uncontrolled use, such intervention entails the risk of exceeding the upper tolerable intake level. Excess intake of vitamin D in the form of pharmaceutical preparations and/or supplements leads to hypervitaminosis [6, 38].

Moreover, many peoples don't consume milk (and other fortified foods) meaning that vulnerable subgroups, such as those with low milk consumption for a variety of cultural and other reasons, are at risk of vitamin D deficiency [4, 18].

Given that the majority of Poles consume less than the currently recommended intake of vitamin D from food [13], consideration should be given to strategies to improve vitamin D intake by increasing both the amount of vitamin D added to foods and the range of foods eligible for fortification [7].

To improve the vitamin D status at population level, food fortification, dietary supplementation and public education all need to be considered as practical strategies to be pursued [3, 9, 18, 25, 27, 30, 35, 42]. Additionally, adults who want to ensure a sufficient vitamin D status as well as certain risk groups may require additional consideration in terms of addressing low vitamin D status by dietary supplementation, with the aim to reach the target levels of 30 to 50 ng/mL (75 to 125 nmol/L) [30, 35].

EU FORTIFIED FOODS REGULATION

Fortification of food refers to the adding of nutrients, most commonly one or several vitamins and/or minerals, to food in connection with the production process.

Relevant legislation addressing fortified foods:

- Regulation (EC) No. 1925/2006 of the European Parliament and of the Council on the addition of vitamins and minerals and of certain other substances to foods: Annex I – Vitamins and minerals which may be added to foods; Annex II – Vitamin formulations and mineral substances which may be added to foods; Annex III - Substances whose use in foods is prohibited [31].
- Regulation (EC) No. 1924/2006 of the European Parliament and of the Council on nutrition and health claims made on foods [32].
- Regulation (EU) No. 1169/2011 of the European Parliament and of the Council on the provision of food information to consumers [33].

FOOD FORTIFICATION TO INCREASE VITAMIN D INTAKE – OPPORTUNITIES FOR THE FOOD INDUSTRY

In addition to adhering to a balanced diet, it is clear that alternative food-based strategies are required to help the consumers meet the dietary recommendations for vitamin D [3, 14, 18, 25, 27, 42]. Endogenous synthesis is only possible during spring and summer at Poland's latitude; during autumn and winter in Poland, vitamin D has to be obtained exclusively from the diet (including food fortification and vitamin D supplements) [22, 29, 30, 35].

Three potential strategies for addressing poor micronutrient intakes have been identified by the WHO/FAO: (1) increasing the diversity of foods consumed, (2) food fortification, and (3) supplementation [42]. Also, the valuable contribution that fortified milk makes to vitamin D intakes among consumers has been acknowledged [8, 10, 11, 12, 14, 18, 20, 24, 25, 26, 27, 36, 39, 41, 42, 44, 45].

There is increasing evidence to support the role of vitamin D food fortification in maintaining or improving the vitamin D status. It is essential that the fortification is of mass coverage and that the additive is added to commonly consumed foods, such as various fluid milk and other dairy products [18, 25, 27, 42]. Mandatory fortification of staple foods offers the greatest benefits to public health, through an improved diet which includes vitamin D-fortified foods and having a bigger impact at the population level [10, 11, 27, 36].

As defined by FAO/WHO Experts, food fortification is the addition of one or more nutrients to selected products, whether or not they occur naturally in that product. The overarching aim of food fortification is to prevent and remedy existing deficiencies of one or more nutrients in entire populations or specific population groups [42]. A distinction is made between the following types of fortification: compensatory restoration, used to make up for losses; intervention, aimed at preventing deficiencies of a particular nutrient; and enhancement, used to

improve the nutritional value and attractiveness of a product and to make it more like its natural counterpart [42].

Several rules and regulations define the extent and quantities of substances that can be added to food. In the case of vitamin D, the two major forms: cholecalciferol (vitamin D3) and ergocalciferol (vitamin D2) are added to foodstuffs [31, 34]. Vitamin D fortification policies for food are presented in Table 1.

Table 1. Vitamin D fortification policies in selected European countries

Tabela 1. Wzbogacanie żywności w witaminę D w wybranych krajach europejskich

Country	Fortification policy
Austria	No mandatory fortification
Belgium	Mandatory: Margarines and spreadable fats Voluntary: milk, dairy drinks, plant-based beverages
Czech Republic	No mandatory fortification
Finland	Mass fortification of milk, margarine/fat spread; Voluntary: yoghurt, plant-based substitute, bread, cereals
France	No mandatory fortification
Germany	No mandatory fortification
Greece	No fortification policy
Iceland	Low-fat milk, some imported foods (vegetable oils and cereals)
Ireland	Mandatory: margarine Voluntary: milk, cereals
The Netherlands	No mandatory fortification; Voluntary fortification: only for certain fats and oils, dairy products
Norway	Voluntary: low-fat milk
Switzerland	No mandatory fortification
Sweden	Low-fat milk, fermented milk products, margarine
UK	Margarine, bread, cereals

Source: On study based on: [23]

Źródło: Opracowanie własne na podst.: [23]

Furthermore, besides the documents shared by the European Union countries, each country has its own regulations. Poland also has relevant acts regulating vitamin D fortification in this scope. Only fortification with vitamin D of normal and reduced-fat margarine (maximum amount not exceeding 7.5 µg/100 g) [34] and infant formula, as well as modified milk for children is mandatory. Other foods can be fortified with vitamin D on a voluntary basis, including e.g. cow's milk and dairy products, substitutes of plant origin, instant cocoa drinks and breakfast cereals [7].

Following an evaluation of voluntarily vitamin D-fortified products on the Polish market, it was shown that they differ significantly in terms of energy and nutritional value. Based on an analysis of the range of these products, it was estimated that the implementation of fortified products such as milk, yoghurt, sugar-free cereals and fruit juice into the diet resulted in a 3.0-fold increase in vitamin D content. In contrast, replacing non-fortified products with fortified products such as flavoured milk, breakfast cereals and other cereal products resulted in a 3.5-fold increase in dietary vitamin D content, with a significant increase in added sugars, including a 2-fold increase in sucrose [43]. There is concern that consumption of foods slated for voluntary fortification would ultimately be associated with higher intakes of sugars and/or saturated fatty acids as well as suboptimal food-intake patterns, it is necessary to recommend vitamin D-fortified products with health-promoting properties of foods, i.e. low in added sugars, salt and/or saturated fatty acids [7, 43].

In addition to naturally occurring vitamin D, its content can be increased during production through biofortification. Addition of vitamin D to the food products by fortification (direct addition to food) or biofortification (e.g. addition to animal feed or UVB irradiance of animals or produce) may be appropriate strategies to improve vitamin D intakes [3, 5, 14, 18, 27]. The addition of vitamin D to food is effective in improving circulating 25(OH)D concentrations using many food vehicles; the effect on vitamin D status was greater when baseline 25(OH)D concentrations were <50 nmol/L and when the fortification dose was ≥10 µg/d [5].

VITAMIN D FORTIFICATION OF DAIRY PRODUCTS – EXAMPLES OF PRACTICES

Milk has been widely used as a vehicle for vitamin D fortification because it is a staple food with good implementation and acceptance by the population. Table 2 shows the various techniques used to fortify milk with vitamin D. Encapsulation seems to be an indispensable tool to design vitamin D materials with the desired functionality to deliver vitamin D through beverages, with advantages over the direct addition and emulsification approaches [21, 40].

Vitamin D fortification was initially used in cow's milk to prevent rickets. Today, in addition to liquid milk, other foods are used as a vehicle for the enrichment substance. The term fortification usually describes the process by which D_3 or D_2 is added during food processing [7, 16, 18, 21, 27, 40, 41, 42, 44, 45].

Vitamin D fortification can be a voluntary or mandatory practice. Only a few countries (e.g. Finland, Canada, and the US), have introduced regulated milk fortification to increase dietary vitamin D intake [10, 11, 12, 18, 27]. Examples of vitamin D fortification of milk and dairy products are shown in Table 3.

Fortified milk products have been an important source of vitamin D and a major dietary determinant of serum 25(OH) D in countries with national fortification policy, such as e.g. Finland, Canada and the US, whereas their role has been smaller in countries where fortification is not mandatory, such as in Sweden and Norway [10, 11, 27, 36]. In most European countries there is no mandatory fortification of milk and dairy products (except for infant formulae and follow-up milks) [18].

Table 2. Fortification approaches of vitamin D-fortified dairy products

Tabela 2. Przykłady wzbogacania produktów mlecznych w witaminę D

Products / Formulation	Fortification level IU (40 IU= 1 µg)	Vitamin Stability	Sensory Properties
HTST 2% fat milk /Water dispersible Vit D3	250 IU / 240 mL	Tolerate HTST No loss of Vit D3 during storage at 4°C	No significant changes in composition and sensory attributes
UHT 2% fat chocolate milk / Water dispersible Vit D3	100 IU / 240 mL	Tolerate UHT No loss of Vit D3 during storage at 4°C	No significant changes in composition and sensory attributes
Milk / Vit D3 Spray Drying	600 IU or 1000 IU/200 mL	Stability loss <10% after 12 weeks of storage period	NE
UHT 3% and 8.5% fat milk / Vit D2-protein complexes	500 IU/L	Higher stability during storage at -20°C, followed by 4°C and 37°C	NE
Milk / vit D2 - encapsulation	600 IU/L	Stable during pasteurization, boiling, sterilization, packaging, and storage conditions	NE
Milk-based beverage (Indian origin) / Vit D3-nanostructured lipid carrier	400 IU/100 mL	High physicochemical stability against temperature, ionic strength and pH	No significant changes in composition and sensory attributes

Legend: ND – not defined; NE – not evaluated
Legenda: ND – niezdefiniowane, NE – niemierzalne

Source: On study based on: [21, 40]

Źródło: Opracowanie własne na podst.: [21, 40]

Table 3. Examples of vitamin D-fortified dairy products

Tabela 3. Produkty mleczne wzbogacone w witaminę D

	Dairy products	Fortification level µg (1 µg= 40 IU)	Food serving
Finland	Fluid cow's milk*	2.5	250 ml or 1 cup
	Yogurt	0.5 – 1.0	per 100 g
United States	Fluid cow's milk*	2.5 – 5.0	250 ml or 1 cup
	Yogurt	1.5 – 5.0	per 170 g
	Cheese	1.5	slice (16 g)
Canada	Fluid cow's milk*	2.5 – 5.0	250 ml or 1 cup
	Yogurt	1.0	per 100 g

*Mass fortification (usually mandatory)

*Fortyfikacja masowa (obligatoryjna)

Source: On study based on: [10, 27]

Źródło: Opracowanie własne na podst.: [10, 27]

Food enrichment increases the intake of deficient nutrients and helps balance the diet. It is an effective method for large population groups, but it must be a long-term measure to be effective. Vitamin D enrichment of foods (mandatory or voluntary based on national recommendations) is currently used in a few European countries [10, 11, 12] and some North American countries [36]. The amount of added vitamin D varies in these countries, as do the food matrices [16].

Milk and dairy products are considered a suitable matrix for vitamin D enrichment [3, 9, 10, 16, 18, 21, 41]. Natural vitamin D concentrations in whole milk ranges from 0.34 to 0.84 IU/g of fat and unfortified milk is not a significant source of this vitamin D. Fortified milk and dairy products are one of the most frequently used sources of vitamin D [40, 44, 45].

Some countries have a mandatory milk enrichment policy. The recent results of the meta-analysis provide evidence of the need to enrich foods with vitamin D. Based on these results, the authors conclude that systematic supplementation and food enrichment can significantly reduce cancer mortality in Europe [23]. While some European countries have already introduced widespread vitamin D enrichment in foods, in others, only a few foods are enriched or not enriched at all [23].

It should be noted that currently the extent of food fortification varies between countries and coverage is not universal, implying that these products do not significantly supplement vitamin D supply, save for infant and young children's formulas, where fortification is mandatory [9, 27]. Bearing in mind the results of recent studies, the preferred strategy for improving vitamin D status is food enrichment at the population level, provided that sufficient monitoring is carried out and population groups are defined [4, 8, 9, 10, 11, 12, 36]. Milk, yoghurt and other dairy products are indicated as an important product group where enrichment could be at a level of approximately 0.1 µg/100 g [10, 11, 18, 27].

Other options, such as biofortification of food products of animal origin like eggs and farmed fish, may also be considered as additional ways to increase vitamin D intake in the population [14]. Meat, on the other hand, should be carefully considered as an additional way to increase vitamin D intake in the population [7, 13].

It should also be stressed that the problem of restricting milk enrichment is also related to the fact that not everyone in the population consumes milk (e.g. due to lactose intolerance) while the idea of compulsory enrichment is to protect the

general population. Thus, the preferred enrichment approach may be adding vitamin D to other foods, which may also lead to improved vitamin D nutritional status [4].

An excellent example of an effective strategy is the vitamin D3 enrichment of liquid milk (1 µg/100 g) and margarine and fat spreads (20 µg/100 g), as confirmed by an 11-year Finnish study assessing the vitamin D status of different groups of the country's population. It was shown that the concentration of 25(OH)D levels in the blood increased from 48 to 65 mmol/l, and the prevalence of deficiency, assessed as 25(OH)D<30 nmol/l, decreased from 12 to 1 per cent of the studied subjects. Fluid milk products' contribution to dietary vitamin D intake changed from 4 to 34% in the same period [Jääskeläinen,2018]. Similar beneficial effects of the introduced nutritional intervention of a diet containing 20 µg/day of vitamin D, which included the following fortified products, i.e. yoghurt, cheese, eggs and bread, were also reported in a study of women in Denmark. After the 12-week intervention, there was a statistically significant increase in 25(OH)D concentrations and a reduction in the proportion of people deficient in this vitamin D to 3% compared to a control group of 23% [8].

Increasing vitamin D intake is possible through an adequate diet with the inclusion of fortified products and additional sources in the form of dietary supplements. Nevertheless, given the increasing popularity of supplements and their uncontrolled use, such intervention risks exceeding the upper tolerable intake level. Excess intake of vitamin D in the form of pharmaceutical preparations leads to hypervitaminosis. Symptoms include hypercalcaemia, hypercalciuria with risk of renal tubular damage and renal stone formation, and increased calcium deposition in certain soft tissues and blood vessels. The cases of hypervitaminosis D described in the literature were mainly due to mistaken or unintentional administration of high doses of vitamin D preparations [38]. Therefore, in line with national recommendations for optimal prevention of vitamin D deficiency and increased vitamin D intake, it is advisable to act on a population-wide and individual level [9, 18, 27, 42].

The enrichment ingredient should be assimilable, evenly distributed, and unchanged during transport, storage, and cooking. The addition of an enrichment ingredient must not impair the organoleptic characteristics or increase the price of the product. The doses used should be sufficient to achieve the intended effect, but not pose a risk of overdose or antagonistic interaction with other nutrients [7, 16, 38, 42]. The ingredient should be listed in the product formulation and its content indicated in the nutritional information on the packaging [33]. Only specific enrichment substances can be used for fortification [7, 32, 42]. In general, the choice of carrier is up to the food producers, and the purchase decisions are up to the end consumers [39].

The choice of milk and dairy products as a vehicle for enrichment is also supported by other meta-analysis results [1], which confirmed a favourable association between dairy consumption and a lower risk of type 2 diabetes. Dairy product consumption (total) was shown to be associated with a significantly lower risk of T2D (RR: 0.81-0.83), particularly for the consumption of low-fat dairy products (RR: 0.82), and yogurt (RR: 0.74-0.86). In contrast, no such relationship was found for high-fat dairy. In these studies, the relationship was quantified, where the risk of type 2 diabetes is reduced by each unit increase in intake of dairy products (total) (200-400 g/d) or low-fat dairy products (200 g/d) [1].

A dietary modelling analysis has been performed to explore the potential effect of the fortified cows' milk of all types (whole, semi-skimmed, skimmed and 1% milks) with 1, 1.5 and 2 µg vitamin D/100 g. Baseline intakes were estimated to increase from 2.0 µg/day to 4.2, 5.1 and 5.9 µg/day, respectively. At the highest level (2 µg/100 g), the proportion of the population meeting the dietary recommendations would increase to just over 12% (from <1%) and the greatest impact was apparent in children [41].

A recent meta-analysis evaluated evidence that vitamin D-fortified products (dairy product, juice, grain product, oil and combination of dairy and grain products) can be a suitable solution for tackling vitamin D deficiency; an average of 2 nmol/l increase in 25(OH)D concentration for each 100 IU vitamin D intake per day is expected for general adult population [24].

While milk and dairy products are fortified with vitamin D, either mandatorily or optionally, their total contribution to vitamin D consumption and status is still unknown [16]. In observational studies, vitamin D-fortified fluid milk (ordinary milk and fermented items) contributed to higher vitamin D consumption and 25(OH)D status [10, 11, 12, 24, 25, 36, 41].

The fortification of cow's milk with vitamin D is strongly recommended by some governments as it represents a good vehicle for vitamin D, able to provide a small but significant amount of vitamin D, contributing to reaching the adequate daily intake [26].

In particular, the fortification of milk is recommended in Finland (1 µg/100 g in milk, yogurt and sour milk), while in Sweden fortification is mandatory for milk with a fat content below 3% (0.38–0.50 µg/100 g), and a similar approach is being adopted in Canada (0.825–1.125 µg/100 g) [10, 25, 36].

The safety of consumption of vitamin D-fortified foods has been confirmed by EFSA. Data from surveys carried out in European countries indicate that vitamin D intakes from all sources, including fortified foods, within commonly consumed diets, are far below the ULs for both adults and children [6]. Fortification of foods is the preferred strategy to increase the vitamin D intake. Milk, yogurt and other milk products should be fortified with around 10 µg/L (400 IU/L) [18].

SUMMARY

1. Increasing vitamin D intake should be considered a public health priority. To improve the vitamin D supply, the following course of action is recommended:
   - Increase dietary variety and consumption from natural sources (oily fish), and also intake of vitamin D-enriched foods, with particular attention to milk and dairy products, as well as consumption of foods naturally rich in vitamin D. When selecting additionally fortified products, the amount of other ingredients (e.g. simple sugars, fats) limited by current dietary recommendations should be taken into consideration.
   - Increase safe sun exposure during the summer months,

which is an endogenous source of vitamin D. It is worth noting that from October to March cutaneous synthesis is practically non-existent and, therefore, an appropriate vitamin D supplementation is then necessary.

- If vitamin D status is insufficient, it is advisable to implement regular supplementation with recommended doses, particularly in late autumn and winter months. These recommendations should be undertaken along with other dietary recommendations.

2. Addition of vitamin D to the dairy products by fortification, especially milk and other dairy products (in particular fermented) may be appropriate strategies to improve vitamin D intakes and status at the population level.

PODSUMOWANIE

1. Zwiększenie spożycia witaminy D należy uznać za priorytet zdrowia publicznego. W celu poprawy stanu zaopatrzenia organizmu w witaminę D, rekomendowane jest:
   - Zwiększenie urozmaicenia diety oraz spożycia tłustych ryb morskich, a także spożywania żywności wzbogaconej w witaminę D, ze szczególnym uwzględnianiem mleka i przetworów mlecznych, a także spożywania żywności naturalnie bogatej w witaminę D. Przy wyborze produktów wzbogaconych dodatkowo należy mieć na uwadze ilość innych składników (np. cukrów prostych, tłuszczów) limitowanych aktualnymi zaleceniami żywieniowymi.
   - Zwiększenie bezpiecznej ekspozycji na słońce w miesiącach letnich, stanowiącej endogenne źródło witaminy D. Należy zaznaczyć, że od października do marca synteza skórna praktycznie nie zachodzi i wtedy konieczna jest profilaktyczna suplementacja witaminą D.
   - W przypadku niewystarczającego spożycia witaminy D zalecane jest uzupełnienie w formie suplementów diety, zwłaszcza w okresie późnojesiennym i zimowym. Suplementację witaminą D należy prowadzać razem z innymi zaleceniami żywieniowymi.
2. Wzbogacanie produktów mlecznych, zwłaszcza mleka i innych przetworów (szczególnie fermentowanych) może być odpowiednią strategią poprawy spożycia witaminy D, a także stanu zaopatrzenia organizmu na poziomie populacyjnym.

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UNCONVENTIONAL YEASTS IN THE BREWING INDUSTRY®

Niekonwencjonalne drożdże w piwowarstwie®

Key words: beer, yeast, non-*Saccharomyces*.

Nowadays, brewers are looking for new ways to impart original and desirable sensory qualities to their products. Hundreds of different types of malts, raw materials, spices and hop varieties are available at their disposal. Nevertheless, virtually all of the currently used brewing yeast strains belong to two closely related species: S. cerevisiae and S. pastorianus. The possibility of using yeasts from outside the Saccharomyces genus to obtain interesting sensory characteristics and to lower alcohol content has been studied extensively in the wine industry. More recently, this issue has also gained attention in the brewing industry. However, a major obstacle to the use of these yeasts is the fact that they are often characterized by insufficient ethanol production, as well as low levels of resistance to this compound. For this reason, research on the use of non-Saccharomyces yeasts focuses on selecting strains that exhibit desirable properties, or they are often used in mixed fermentations with Saccharomyces yeast.

The article presents the current state of knowledge on selected non-Saccharomyces yeasts: Brettanomyces spp., Torulaspora delbrueckii, Lachancea thermotolerans, and Metschnikowia pulcherrima, and describes their possible applications in the brewing industry.

Słowa kluczowe: piwo, drożdże, drożdże nie-*Saccharomyces*.

W dzisiejszych czasach piwowarzy poszukują sposobów na nadanie oryginalnych i pożądanych cech sensorycznych swoim produktom. Do ich dyspozycji dostępne są setki różnych rodzajów słodów, surowców niesłodowanych, przypraw oraz odmian chmielu. Mimo to, praktycznie wszystkie z aktualnie używanych szczepów drożdży piwowarskich należą do dwóch blisko spokrewnionych gatunków: S. cerevisiae i S. pastorianus. Możliwość zastosowania drożdży spoza rodzaju Saccharomyces do uzyskiwania interesujących cech sensorycznych oraz obniżania zawartości alkoholu jest od lat badana w przemyśle winiarskim. Od niedawna, to zagadnienie zainteresowało również przemysł piwowarski. Dużą przeszkodą przy zastosowaniu tych drożdży jest jednak fakt, że często ich szczepy charakteryzują się niedostateczną produkcją alkoholu, jak i niskim poziomem odporności na ten związek. Z tego powodu, badania dotyczące zastosowania drożdży spoza rodzaju Saccharomyces skupiają się na wytypowaniu szczepów wykazujących pożądane właściwości lub stosowane są tzw. fermentacje mieszane, głównie z drożdżami Saccharomyces.

Artykuł przedstawia aktualny stan wiedzy na temat wybranych drożdży nie-Saccharomyces: Brettanomyces spp., Torulaspora delbrueckii, Lachancea thermotolerans i Metschnikowia pulcherrima oraz opisuje ich możliwe zastosowanie w przemyśle piwowarskim.

INTRODUCTION

Recent decades have resulted in a multidirectional development of the brewing industry, both in the domestic and global markets. The market, which previously sought to consolidate under the banner of multinational corporations, that focused mainly on bottom-fermented beers, has undergone a breakthrough, which we now refer to as the beer revolution. This phenomenon resulted in the emergence of many new beer styles, as well as the evolution of existing ones. As a result, brewers both at home and in breweries, are looking today for newer and newer ways to achieve beers with unique sensory qualities that can meet consumer expectations. It should be noted that brewers already have a whole range of options available for this purpose. The huge variety of different malts, as well as many adjuncts, the possibility of using, among others, fruits, more than 260 varieties of hops, and spices such as hot peppers, tea, coffee, as well as many others, make it possible for an ingenious brewer to obtain a product with unprecedented characteristics.

However, one of the most important components of beer – yeast – remains virtually unchanged. Nearly all of the currently available strains of brewer's yeast belong to two closely related species: *Saccharomyces cerevisiae* and *S. pastorianus*. Individual strains often differ significantly in the

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degree of sugar utilization, production of volatile compounds, as well as enzymatic activities, among other things. However, there is no denying that a huge biodiversity of other yeast species is left untapped. Yeast, as the organisms conducting the alcoholic fermentation process, exerts a decisive influence on the quality characteristics of the finished product. Currently available studies indicate that individual strains of non-*Saccharomyces* yeast may for example be characterized by a more intense ability to release glycosidically bound volatile compounds. In conjunction with a different profile of volatile compounds synthesis, they may allow to obtain unique beers. However, a factor that eliminates a significant portion of non -*Saccharomyces* yeasts is their low alcohol resistance, slow fermentation rates, and inability to utilize sugars found in the wort. One way to solve this problem is to conduct mixed fermentations, by inoculating the wort simultaneously with the yeast strain of the interest, and the *S. cerevisiae* strain that will complete the fermentation. However, this solution has its own problems, because, among other things, it greatly complicates the process of inoculating the yeast, and performing subsequent fermentations using recovered yeast slurry [24].

The aim of this article is to present the current state of knowledge and determine the usefulness in the brewing industry of selected yeast species from outside the *Saccharomyces* genus.

BRETTANOMYCES SPP.

Microorganisms of this genus were first isolated from beer in the United Kingdom in 1903 by Hjelte Claussen. The sensory characteristics of beers obtained using those yeast strains were typical for a significant portion of beers produced in the Britain at the time, as reflected in the genus name *Brettanomyces*, meaning "British Brewing Fungus". In the literature, species from this genus are often referred to using the name of their anamorphic form, *Dekkera*. They are characterized by a high degree of adaption to conduct a fermentation under harsh environmental conditions and show high survival rates. For this reason, they can often be a part of the undesirable microflora in the beer, wine, or biofuel industries. Yeast of this genus are also a part of the native microflora of spontaneously fermented lambic and gueuze beers, where they impart distinctive sensory characteristics. The wort used in production of those beers contains significant amounts of dextrins, which can be broken down by these microorganisms. Hence, *Brettanomyces* yeast species are detected in significant quantities during the aging of these beers. The species detected in the highest quantities at the ageing stage are *B. bruxellensis*, *B. anomalus* and *B. custersianus*. The currently available literature regarding the use of these yeast in the brewing industry focuses mainly on the first two species [4, 12, 43].

Yeast from *Brettanomyces* spp., similarly to *S. cerevisiae* exhibit the Crabtree effect, whereby aerobic respiration is repressed in the presence of fermentable sugars. Literature sources reports that *B. bruxellensis* and *B. anomalus* strains can metabolize most of mono-, di-,tri-saccharides, as well as dextrins. The ability to use dextrins, which is rare among brewer's yeasts, is attributed to intracellular and extracellular α-glucosidase activity. These enzymes allow these organisms to utilize polysaccharides, from maltotetraoses to maltoheptaoses, which typically constitute the residual sugar content of beer, when fermented with *S. cerevisiae*. Thus, they can be used to produce highly attenuated beers with higher alcohol content [22, 30].

Literature data indicates that they can produce up to 15% of ethanol. Unlike *S. cerevisiae*, they produce little or no glycerol, an ingredient that is quantitatively the third fermentation product of *S. cerevisiae*, after CO_2 and ethanol. The rate of fermentation itself is also slower than in *S. cerevisiae*. When oxygen is present in the environment, they can produce significant levels of acetic acid, but the degree of this compound production depends strongly on the strain. Their high resistance to unfavorable environmental conditions is combined with significant resistance to low pH levels. Depending on the literature, they can survive in pH equal to 3, or even 2.3. They can grow at moderate temperatures of 19-35°C. This information is confirmed by the study of Tyrawa et al. [48], where conducting wort fermentations at 28°C allowed the tested *B. bruxellensis* strains to achieve full attenuation. Fermentations conducted at 15°C were characterized by a slower process rate, and a lower degree of attenuation. At that temperature, it was the control strain *S. cerevisiae* US-05 that achieved fuller attenuation. The results indicate that fermentations which use *Brettanomyces* strains should be carried out at higher temperatures, but the exact range is strongly dependent on the strain applied [12, 21, 30, 38, 48].

Beers obtained with *Brettanomyces* yeast have distinctive sensory characteristics. This is due in part to their ability to produce a wide range of phenolic compounds (POF+). In the brewing community, the aromas of these compounds are typically associated with beers made with this yeast. Among these compounds, 4-vinylguaiacol – 4VG (an aroma described as clove-like), and 4-vinylphenol – 4VP (phenolic, medicinal) are most often listed, and are considered as most important. They have a low sensory threshold of 0.2–0.4 mg/L, and are formed by decarboxylation of hydroxycinnamic acids, 4-VG from ferulic acid and 4-VP from p-coumaric acid, respectively. Since these compounds are extracted from the malt during the mashing process, it is not possible to remove the precursors of these reactions. They are highly undesirable in most beer styles, except for a few, such as hefeweizen or lambic. The literature reports that all strains of *B. bruxellensis* and *B. anomalus* exhibit, to varying degrees, the enzymatic activities required to produce these compounds. The only strain known so far that does not produce these off-flavors was found by Colomer et al. [45]. Tyrawa et al. [48] report that the final content of these compounds in fermented beverages is probably not dependent on fermentation temperature. Although lower fermentation temperatures limit the production of these compounds, by the time fermentation is complete, the levels of volatile phenols in beers fermented at lower temperatures equalize to those found in beers fermented at higher temperatures [12, 28, 31, 45, 47, 48].

The literature sources often attribute significant activity of the β-glucosidase enzyme to species of *Brettanomyces* yeast. During hopping, odorless precursors of volatile compounds pass from the hops into the wort. These precursors can be cleaved by the action of this enzyme, releasing a volatile

compound. Lafontaine et al. [27] report that the largest fraction of glycosides in hops are bound linalool (floral, coriander aroma) and α-terpineol (lilac, pine). For this reason, there has been considerable interest in recent years in β-glucosidase activities among brewer's yeast. Daenen et al. [15] report, that species of *Saccharomyces* genus currently used in brewing have a low capacity to degrade such compounds. The results presented by Colomer et al. [45] add to the knowledge of these enzymatic activities among *Brettanomyces* spp. The authors report, that this trait is strongly strain-dependent among *B. bruxellensis*, and some strains may not exhibit such activities at all. Interestingly, in this study, most of the *B. bruxellensis* strains isolated from beers had reduced enzymatic activity, compared to those isolated, for example, from wines. The strains of other species assessed in the study – *B. anomalus*, *B. custersianus*, *B. naardenesis* – showed high enzymatic activity. However, it was a single strain of *B. bruxellensis* that showed the highest ability to release glycosidically bound volatile compounds. Interestingly, the authors report that among *B. bruxellensis* strains tested, two of them had a very high ability to biotransform geraniol to β-citroneol. Levels of this compound in post-fermentation beers exceeded its sensory threshold and were comparable to those found in dry-hopped beers. Concurrently, these were the strains with the lowest levels of β-glucosidase activity. Daenen et al. [15] also did not detect uniformly high enzymatic activity in *Brettanomyces* spp., except for one strain of *B. custersii*. That strain showed significantly higher activity than any of *Brettanomyces* spp., *S. cerevisiae* and *S. pastorianus* strains tested. Recent scientific reports somewhat confirm the literature data. Indeed, yeasts of *Brettanomyces* spp. can exhibit very high levels of β-glucosidase activity, but high expression of this enzyme is relatively uncommon among individual strains [15, 26, 27, 42, 44].

Unfortunately, the current state of knowledge does not allow to present a complete characterization of volatile compound synthesis profile of these yeast. Crauwels et al. [14] report that yeast of this genus can synthesize significant amounts of acetic acid esters, with low acetates content which may be due to theirs high esterase activity. These assumptions are consistent with the results obtained by Tyrawa et al. [48]. In that study, most *Brettanomyces* strains produced higher amounts of ethyl decanoate, ethyl capronate and ethyl caprylate than *S. cerevisiae*. The latter two compounds are found in significant amounts in lambic and gueuze beers and are suspected to be responsible for the fruity and vinous character of these beers. They are also typical for this yeast. Most of these beers were also characterized by a diacetyl content above the perceptible threshold. Yeasts from the *Brettanomyces* genus impart distinctive sensory characteristics to beverages made with them, largely due to their volatile phenol content. As a result, they have been commercially available for years, to be used for the production of beers such as lambic, gueuze, or wild beers. Beers made with these yeasts can also be found on the market [11, 14, 48].

TORULASPORA DELBRUECKII

Torulaspora delbrueckii yeast has found use in the wine industry, where in 2003 those yeasts became the first commercially available non-*Saccharomyces* wine culture. They are often used in mixed fermentations, where they impart fruity aromas to wines. Studies report that in wine fermentations, this yeast allows to obtain a clean profile of volatile compounds, as well as low volatile acidity levels. There are reports that they may have been domesticated by humans as early as 4000 years ago. Over the years, the species has undergone many changes in classification. In earlier literature sources, it was classified as *Saccharomyces rosei* or *S. delbrueckii* [5, 33].

The literature reports, that yeast strains within this species are characterized by high variability in their ability to assimilate specific carbon sources. In a study by Michel et al. [32] of the 10 strains tested, all of them metabolized glucose, fructose, and sucrose, while maltose and maltotriose were consumed by only one strain. Similar results were obtained by van Breda et al. [5]. In a study by Canonico et al. [7], 8 of the 28 strains examined metabolized maltose. Equally diverse is their fermentation rate capacity, where some authors report that they may have a higher fermentation rate than *S. cerevisiae*, or much slower one, as reported by Canonico et al. [7]. In that study, pure cultures failed to achieve full attenuation, and produced about 50% less ethanol during fermentation than the control *S. cerevisiae* strain. In a study by Michel et al. [33], most strains grew well in a 5% ethanol environment, while a concentration of 10% was lethal to them. In this study, the only maltose-fermenting strain produced 4% of alcohol from 12°P wort. In contrast, Drosou et al. [17] investigated the utilization of sugars using different media that contained only one of each tested sugar. They found, that assessed *T. delbrueckii* strains produced alcohol levels not dissimilar to *S. cerevisiae* control strains, even in a medium that contained only maltose. The strains evaluated by van Breda et al. [5] in wine fermentations produced 8–13% of alcohol. In these studies, *T. delbrueckii* strains also produced higher amounts of glycerol than *S. cerevisiae*. The reports of these authors clearly indicate that the fermentation capacities of *T. delbrueckii* strains are highly strain dependent. In a study by Silva-Sousa et al. [46] the examined strains developed best at temperatures in the range of 25–30°C, but some strains showed good growth at 15°C. A temperature of 37°C inhibited the growth of most strains. Literature sources also report that, unlike yeast of the *Brettanomyces* genus, *T. delbrueckii* strains do not show production of phenolic aromas [5, 7, 17, 20, 46].

Despite many problems with the variability of the fermentation characteristics of *T. delbrueckii* strains, yeasts of this species are of interest to researchers because of their ability to impart interesting sensory characteristics to wines and beers. Canonico et al. [7] report that beers made with *T. delbrueckii* were characterized by fruity and citrus notes, and fullness of flavor. The beers contained lower concentrations of secondary metabolites formed during the fermentation process, compared to *S. cerevisiae*, with the exception of acetaldehyde. In a follow-up to this study, Canonico et al. [8] report, that mixed fermentations with *S. cerevisiae* allow to obtain higher levels of higher alcohols, ethyl acetate and isoamyl acetate. Similar results were obtained by Michel et al. [33], where flavors in beers were described as honey and pear, and also, depending on the strain, additionally plum or citrus. In a study by Einfalt [18] beers made with the addition of sorghum,

fermented with *T. delbrueckii* were preferred to those made with *Metschnikowia pulcherrima*, mainly due to a sweeter flavor that may have resulted from the lower attenuation levels found. The presence of β-glucosidase activity is an ambiguous issue. Despite the failure to detect such activities among the 5 strains evaluated by Escribano et al. [19], other authors such as Azzolini et al. [2] and Maturano et al. [29], have found it to be higher than in *S. cerevisiae*. An interesting feature of this yeast is its high ability to biotransform terpenoids derived from hops. King et al. [26] report, that *T. delbrueckii* showed the ability to produce geraniol from linalool, which was then converted to α-terpineol. There are also reports that they can synthesize some of the terpenes *de novo*. These activities may be responsible for the characteristic aroma of beers obtained using those yeast. The relatively high proportion of maltose-fermenting strains, the interesting sensory characteristics of products made with their application, as well as the significant production of ethanol and resistance to that compound make this yeast species an interesting candidate for beer production. Unfortunately, there are no commercially available strains of *T. delbrueckii* aimed for brewing applications [2, 7, 8, 18, 19, 26, 29].

LACHANCEA THERMOTOLERANS

Lachancea thermotolerans, formerly known as *Kluyveromyces thermotolerans* has attracted the interest of researchers in the wine industry for its ability to significantly lower the pH of wine, resulting in a pleasant acidity, thanks to the production of significant amounts of lactic acid. Production of this compound takes place at the beginning of the fermentation process, and due to the consumption of sugars in the process, its synthesis comes at the expense of ethanol. Therefore, when using strains characterized by a significant production of this compound, the resulting beers and wines are characterized by lower ethanol content. The production of lactic acid, as well as the interesting sensory characteristics impaired by this yeast, make them the subject of research in the fermentation-oriented industries. As of today, one of *L. thermotolerans* strains is commercially available. It's aimed to produce sour beers without the use of lactic acid bacteria, and it shows a high level of attenuation due to its ability to utilize maltose [34].

Literature data report that this yeast utilize glucose and sucrose. The ability to utilize maltose is a variable trait within the species. In a study by Domizio et al. [16] 3 of the evaluated strains utilized maltose to a similar extent as *S. cerevisiae*, but none of them utilized maltotriose. The strain tested by Callejo et al. [6] fermented maltose to a low degree, but again, did not utilize maltotriose. Nevertheless, in a study by Domizio et al. [16], beer obtained with *L. thermotolerans* was characterized by only 6–12% lower alcohol content, than one prepared with *S. cerevisiae*. A similar relationship was observed by Zdaniewicz et al. [50], where beers fermented with *L. thermotolerans* strain with low lactic acid production phenotype were characterized by lower alcohol levels (4.25–4.3%), and higher residual sugar content than those made with the *S. cerevisiae* control strain (5.22–5.37%). These results may confirm reports that they have a lower fermentation capacity than *S. cerevisiae*. *L. thermotolerans* strains show tolerance to up to 5–9% ethanol in the environment. Morata et al. [34] report, that species of this yeast has a similar temperature requirement to *S. cerevisiae*. Literature data indicate that *L. thermotolerans* exhibit higher levels of glycerol synthesis than *S. cerevisiae*, which is confirmed by studies by many authors, such as Domizio et al. [16], Zdaniewicz et al. [50] and Hranilovic et al. [25]. As mentioned, a unique feature of *L. thermotolerans* is the production of significant amounts of lactic acid. In sour beers made with lactic acid bacteria, the content of this compound is usually in the range of 3–6 g/L. In wine fermentations conducted by Hranilovic et al. [25], the strains produced 1.8 (±0.2) – 12.0 (±0.2) g/L of this compound. In the case of brewing, levels of lactic acid in beverages obtained by Domizio et al. [16], Zdaniewicz et al. [50], and Canonico et al. [9] were much lower, 0.1–0.25, 0.01 (±0.00) – 0.06 (±0.07) and 1.83 (±0.07) g/L, respectively. The authors' results indicate that the strains show significant differences in the production of this compound. So far, the strains of *L. thermotolerans* that have been examined did not show production of phenolic off-flavors [6, 9, 10, 16, 25, 34, 50].

In a study by Domizio et al. [16], aromas of the beers obtained with *L. thermotolerans* were described as fruity, floral, clove, melon, strawberry and sour. Unfortunately, the authors did not examine whether the aroma described as clove was due to the presence of volatile phenols. Similar fruity and spicy aromas, in the case of wines, were reported by Morata et al. [34]. Beers obtained by Zdaniewicz et al. [50] with *L. thermotolerans*, compared to *S. cerevisiae*, were characterized by a lower content of all analyzed esters except ethyl 2-methyloctanoate (higher content) and ethyl acetate (similar). The beers also differed significantly in the profile of higher alcohols. In contrast, in a study by Canonico et al. [9], beers obtained with *L. thermotolerans*, were characterized by a higher content of ethyl acetate. The aroma of beers produced with these yeasts may also be partly attributed to their enzymatic activities. Among the strains tested by Escribano et al. [19], 6% of *L. thermotolerans* strains exhibited β-glucosidase activity. Comitini et al. [13] also reported the detection of such activities among 2 of the 5 strains tested. In a study by Zdaniewicz et al. [50], the examined strain reduced the limonene, perillene, nerol and humulene present in the wort, and the previously absent citronellol, β-damascenone and nerolidol appeared in the beer. In addition, the concentrations of other terpenes were higher than in the beer produced with *S. cerevisiae* yeast. These activities, that result in the transformation of terpenes may be partly responsible for the aroma of beverages obtained with these yeast [13, 19, 50].

The interesting sensory characteristics of beers produced with this yeast species, combined with the possibility of using some of the strains to produce sour beers, or those with reduced alcohol content, mean that *L. thermotolerans* strains are currently being studied for their application in the brewing industry.

METSCHNIKOWIA PULCHERRIMA

The yeast from the *Metschnikowia pulcherrima* species were first isolated in 1884, by Ilya Metchnikoff. They were initially classified as *Monospora bicuspidata*, but their

classification has changed over the years. A characteristic feature of these microorganisms is the production of red dye, called pulcherrimin, which permeates into the substrate during their growth. Due to their broad antagonistic activity against molds, among others, they are used in natural plant protection products. At the same time, they do not produce mycotoxins or allergens, so they are not harmful to human health. These yeasts are often detected at the initial stages of wine fermentation, due to the fact that they constitute the native microbiota of fruits. Strains from this genus are characterized by the production of a wide range of extracellular enzymes, such as pectinases, proteases, β-glucanases, β-glucosidases, cellulases, cellobiases and amylases. Because of these activities, they are the subject of research, mainly in the wine industry, where they are used mainly in mixed fermentations. As of today, strains of *M. pulcherrima* are the least studied organisms among all those mentioned, especially in the case of brewing [36].

Literature data indicate that this yeast can consume glucose, sucrose, fructose, galactose and maltose as a carbon source. Abeln et al. [1] confirm the assimilation of maltose and maltotriose. In contrast, in fermentation trials conducted by Postigo et al. [37] and Rodríguez Madrera et al. [39], *M. pulcherrima* did not utilize these two sugars. In the literature data, it can be found that they have low fermentation capacity. In the case of wine fermentation, they produce about 4% of alcohol. However, in a few studies by other authors, higher values occur, as in study by Sadoudi et al. [41], where the *M. pulcherrima* strain allowed to produce a wine with 10.89 (±0.32) % of alcohol. So far, studies on their use in brewing are as inconclusive as those from winemaking. In studies by Postigo et al. [37] and Rodríguez Madrera et al. [39], the alcohol concentrations in beers after fermentation were 0.62 (±0.03) and 0.60 (±0.00)%, respectively. In those studies, they also had lower glycerol production than the control *S. cerevisiae* strain, despite reports that they can increase glycerol concentrations in wines. Different results were obtained by Einfalt [18], where fermenting wort with addition of sorghum, the *M. pulcherrima* strain allowed to produce a beer with 33.7 (±0.5) g/L ethanol, compared to *S. cerevisiae* 37.9 (±0.5) g/L. So far, this is the one of few available examples of such a high alcohol content in beverages obtained with this yeast. The fact that these yeasts are detected only at the initial stages of must fermentations is explained in the literature by their low resistance to the presence of ethanol in the environment. However, in a study by Barbosa et al. [3], 62 of the 65 assessed strains showed growth at alcohol concentration of 6%, while 4 strains expressed growth at a concentration of 9%. An important feature of these yeasts is the expression of aerobic metabolism. With the right degree of oxygenation, they can utilize more than 40% of the available sugars in respiratory processes, effectively reducing the amount of alcohol in the finished product. For this reason, they are being extensively studied in wine fermentations, as they could allow to obtain wines with lower alcohol content. In a study by González-Arenzan et al. [23], half of the studied strains had activities that condition the production of phenolic aromas. Similar results were obtained by Escribano et al. [1, 3, 18, 19, 23, 37, 39, 41].

As mentioned, the species *M. pulcherrima* has attracted the attention of researchers due to their broad spectrum of enzymatic activities. In a study by Escribano et al. [19], 63% of the strains showed β-glucosidase activity. A similarly high proportion is presented by Bedrinaña et al. [35] – 73% and Barbosa et al. [3] – 62 of 64 tested strains were found to possess this trait. Another group of compounds that in recent years have gathered the attention of researchers are the precursors of volatile sulfur compounds, found in both beer and wine. It is suspected that due to the β-lyase activity, they can be released into volatile forms, often characterized by a pleasant, fruity aroma and a very low sensory threshold. In a study by Barbosa et al. [3], all of the tested strains showed this activity, and 17 of them did so to a very high degree. In a study by Zott et al. [51], *M. pulcherrima* strains allowed the release of higher amounts of 3SH in wines, than the control *S. cerevisiae* strain. Einfalt [18] reports, that beers obtained with *M. pulcherrima* were characterized, compared to *S. cerevisiae*, by a lower content of 3-methylbutanolol, 2-phenylethyl alcohol, propanol, 2-methylbutanol, isoamyl acetate and 2-phenylethyl acetate, and a higher level of isobutanol. A similar, significant isobutanol content was observed by Postigo et al. [37], in sequential fermentations with *S. cerevisiae*, while the concentration of isoamyl acetate was higher than in the control sample. In this study, in sequential fermentations, beers obtained with *M. pulcherrima* were preferred over those obtained with *Hanseniaspora valbyensis*, *H. guilliermondii*, *Zygosaccharomyces bailii*, *Torulaspora delbrueckii* and *Wickerhamomyces anomalus*. In addition, in literature, there are many reports from the wine industry on the positive effects on the sensory characteristics when used in mixed fermentations with *S. cerevisiae*, such as those published by, among others, Varela et al. [49], Ruiz et al. [40] or Sadoudi et al. [41]. These reports indicate that, as in the case of winemaking, *M. pulcherrima* yeast may be of particular interest for use in mixed fermentations. Additionally, thanks to the ability to oxidize sugars they may find application in the production of alcohol-reduced beers [3, 19, 35, 37, 39–41, 49, 51].

CONCLUSIONS

In recent years, a number of researchers have undertaken a search for new brewing and wine yeast, among the non-*Saccharomyces* species. Although few of the existing microorganisms have been studied thoroughly so far, reports of their properties suggest that within the next few years, some of them may find application in the production of fermented beverages. The sensory qualities that are possible to obtain in beers thanks to their use already made some of the strains commercially available, as in case of *Brettanomyces* spp. and *Lachancea thermotolerans*. The relatively high fermentation capacity of *T. delbrueckii* and the broad spectrum of enzymatic activities of *M. pulcherrima* species make them an interesting candidate for the use in the brewing industry.

PODSUMOWANIE

W ostatnich latach wielu badaczy podjęło się szukania nowych drożdży piwowarskich i winiarskich wśród gatunków spoza rodzaju *Saccharomyces*. Mimo że, jak dotąd przebadano niewiele spośród istniejących mikroorganizmów,

doniesienia o ich właściwościach pozwalają sądzić, że w ciągu następnych lat część z nich może znaleźć zastosowanie w produkcji napojów fermentowanych. Możliwe do uzyskania z ich użyciem cechy sensoryczne sprawiają, że już dziś w przypadku piwowarstwa dostępne komercyjnie są szczepy *Brettanomyces* spp. oraz *L. thermotolerans*. Stosunkowo wysoka zdolność fermentacyjna *T. delbrueckii* oraz szerokie spektrum aktywności enzymatycznych *M. pulcherrima* sprawiają, że mogą one również znaleźć zastosowanie w przemyśle piwowarskim.

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AMERICAN FOREIGN SUPPLIER VERIFICATION PROGRAM (FSVP) – REQUIREMENTS, BENEFITS OR BURDENS FOR INDIAN FOOD COMPANIES, AND DIFFICULTIES IN THE IMPLEMENTATION®

Amerykański Program Weryfikacji Dostawców Zagranicznych (FSVP) – wymagania, korzyści lub obciążenia dla indyjskich firm spożywczych oraz trudności we wdrożeniu®

Key words: India, FSVP, food safety, importer.

The purpose of this article was to present the American Foreign Supplier Verification Program (FSVP). An importer of food is required to develop, maintain, and follow a Foreign Supplier Verification Program (FSVP) to ensure that each food product it imports meets FDA food safety standards. Specifically, an importer's FSVP must provide adequate assurances that: (a) the importer's foreign suppliers produce food with the same level of public health protection as those required by FDA for domestically produced food; and (b) the importer's foreign suppliers produce food that is not adulterated or misbranded. The FSVP regulations apply to all FDA-regulated food imported or offered for import into the United States.

Słowa kluczowe: Indie, FSVP, bezpieczeństwo żywności, importer.

Celem artykułu było przedstawienie Amerykańskiego Programu Weryfikacji Dostawców Zagranicznych (FSVP). Importer żywności jest zobowiązany do opracowania, utrzymywania i przestrzegania Programu Weryfikacji Dostawców Zagranicznych (FSVP) w celu zapewnienia, że każda importowana żywność spełnia normy bezpieczeństwa żywności FDA. W szczególności FSVP importera musi zapewnić odpowiednie gwarancje, że: (a) zagraniczni dostawcy importera produkują żywność o takim samym poziomie ochrony zdrowia publicznego, jak wymagany przez FDA dla żywności produkowanej w kraju; oraz b) zagraniczni dostawcy importera produkują żywność, która nie jest zafałszowana ani błędnie oznakowana. Przepisy FSVP mają zastosowanie do całej żywności podlegającej przepisom FDA, importowanej lub oferowanej do importu do Stanów Zjednoczonych.

INTRODUCTION TO THE FOREIGN SUPPLIER VERIFICATION PROGRAM (FSVP)

Food standards are increasingly impacting developing countries' trade balance and economic development. Over the past two decades, both public and private standards have proliferated in global food supply chains. As the global food trade is increasing, the importance of uniform food standards for consumer protection is noticeable [29]. The most significant reform of food safety laws for developing countries in the history of the United States was the U.S. Food Safety Modernization Act (FSMA), which went into effect in September 2016 as it was signed into law by President Obama.

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Since then, the Food and Drug Administration (FDA) has been working to develop the rules that the act requires them to implement. The focus of this law is to prevent food safety issues in the U.S. food supply more effectively. The FSMA implementation is done through seven rules: (1) standards for produce safety; (2) preventive controls for human food; (3) preventive controls for food for animals; (4) a foreign supplier verification program; (5) accreditation of third-party auditors; (6) sanitary transportation of human and animal food; and (7) food protection against intentional adulteration [22, 23].

The Foreign Supplier Verification Program (FSVP) as a significant provision of FSMA [6]. The FSVP creates new requirements for importers of food for humans and animals into the United States. This regulation requires importers to perform risk-based activities to ensure that food imported into the United States was produced in accordance with applicable U.S. safety standards and that the food is not adulterated or allergen misbranded. The regulation includes standard requirements for larger importers as well as a modified set of procedures for importers who fall under the definition of "very small importer". Modified procedures can also be used when importing food products from certain small foreign suppliers. Importer refers to the owner or consignee of a food item offered for import into the United States. If that food does not have any U.S owner or consignee at the time of entry, then the U.S agent or representative of the foreign owner or consignee can be the importer, as confirmed in the signed statement of consent according to 21 CFR PART 1.500 [6]. The effectiveness of a food importer's FSVP is dependent on the calibre and knowledge of the Preventive Controls Qualified Individual (PCQI) it has chosen, the firm's hazard analysis, its food safety plans, the food safety programs of all its foreign suppliers, and the selection, implementation, and documentation of the appropriate levels of verification. For the last three years (2019–2022), the FDA has conducted 1645 FSVP inspections, of which 17 were found to comply with FSVP regulations equalling a compliance rate of 1% [1].

Regulations under the Foreign Supplier Verification Program are designed to ensure that imported food meets the same standards of quality as food made in the United States. Therefore, the process aims to enhance food safety by improving importers' responsibility for verifying foreign suppliers and compliance with GMPs. The FDA has released draft guidance for the Foreign Supplier Verification Program, which includes the most comprehensive set of requirements for importers to date [13]. The FSVP regulation applies to all food imported or offered into the United States. Apart from this, certain categories of imported food are not covered by the final rule which consists of certain juice, fish, and fishery products (because they are already subject to supplier verification requirements); food for research or evaluation; food for personal consumption; and alcoholic beverages and ingredients used in making alcoholic beverages, food that is transhipped through the U.S, food that is imported for processing and export, returned consignments, certain meat, poultry and egg products regulated by the FDA [7, 8].

THE FOREIGN SUPPLIER VERIFICATION PROGRAM (FSVP) – REQUIREMENTS

The FSVP rule is codified in 21 C.F.R.1, Subpart L, Sections 1.500–1.514 [6]. These regulations specify several requirements an importer must take when evaluating food and supplier for hazards and risks, including determining whom the FSVP importer is, conducting a hazard analysis of the food being imported, evaluating the foreign supplier, identifying and conducting verification activities on hazards requiring a preventive control, and re-evaluating food risks and the foreign supplier [4].

Suppliers play a significant role in the food industry sector. The quality of the final product is determined by many factors and one of them is raw materials and half-products used in the manufacturing process. Many authors emphasized the need to assess suppliers, including food importers [19, 30]. For the last 10 years, a considerable amount of research was carried out on supply chain management, especially: the selection of suppliers [5, 9, 31]. There is a similar requirement based on FSVP. The importers can only import foods from authorized foreign suppliers after assessing the risk the item poses and the supplier's track record. However, this does not preclude importers from temporarily importing food from unapproved suppliers as long as these products are subjected to sufficient verification procedures prior to importation. The FSVP mandates that importers develop, maintain, and follow an FSVP for each food imported into the United States from each foreign supplier of that food. This suggests that a separate FSVP would be necessary if an importer purchases a specific food from a different supplier. Similarly, if an importer purchases a variety of foods from a single supplier, a separate FSVP is required for each food [21]. If certain importers, who are also manufacturers or processors, comply with the supply-chain program requirements set forth in the preventive control rules, implement preventive controls for the hazards in the food in accordance with those rules or are exempt from those rules in certain specified situations, they are deemed to be in compliance with most FSVP requirements. Examples of such situations include those where the type of food (e.g. coffee beans) could not be consumed without the use of preventive control or when the customer will be significantly reducing or preventing identified hazards and they comply with disclosure and written assurance requirements. The risk must be re-evaluated at least every three years, or whenever new information about a potential hazard or the performance of a foreign supplier becomes available. If importers receive assurances that subsequent entities in the distribution chain are processing the food for food safety, they are not required to evaluate the food or conduct supplier verification activities. Importers must, however, disclose in the documents accompanying the food that the food has not been processed to control the identified hazard [21]. Importers will be required to document the hazards requiring controls of imported foods in order to proactively mitigate or eliminate them. An importer must also assess the vulnerability of the materials/products to food fraud and must produce documentation during a Food and Drug Administration inspection (FDA).

The frequent evaluation of the performance of importers' foreign suppliers is another important requirement of the FSVP rule. Foreign manufacturers' hazard analyses, entities in charge of hazard control (foreign manufacturers or their suppliers), food safety methods, processes, and practices, compliance with relevant regulations, and food safety history should all be included. Each facility would be required to implement a written food safety plan focused on hazard prevention. The regulation requires that certain activities must be completed by a "preventive controls qualified individual (PCQI)". Importers have an explicit responsibility to verify that their foreign suppliers have adequate preventive controls in place to ensure that the food they produce is safe. There are four types of preventive controls i.e., Process preventive controls, allergen preventive controls, sanitation preventive controls, supply chain preventive controls and other controls. An importer can rely on a third party to determine and perform appropriate supplier verification activities, so long as the importer reviews and assesses the relevant documentation. Annual on-site audits of the supplier's facility are required when there is a reasonable probability that exposure to a hazard controlled by the foreign supplier will result in serious adverse health consequences or death. An importer's verification activities may provide evidence that a foreign supplier has not provided the same level of public health protection as required under the Produce Safety and Preventive Controls rules. Taking appropriate corrective action by importers is the last requirement in meeting the FSVP requirements. The appropriate corrective measure will depend on the circumstances and may include discontinuing the use of the foreign supplier. According to the FSVP rule, importers must provide the name, email address, and unique facility identifier (UFI) for each line entry of food product offered for importation into the United States. The FDA has approved the data universal numbering system (DUNS) number as a valid UFI for the FSVP.

Although the FSVP proposed rule would not itself establish safety requirements for food manufacturing and processing, it would benefit the public health by helping to ensure that imported food is produced in a manner consistent with other applicable food safety regulations [6]. The research on the measurement of the effectiveness of FSMA FSVP implementation in food manufacturing companies is still very limited. Several authors have argued that increasing food standards, including FSVP, act as barriers to developing countries' integration in global markets and lead to the exclusion or reduced bargaining power of small farmers. On the other hand, there is evidence that standards can generate important benefits for poor rural households in developing countries, either in the form of contracts with processing or exporting companies, or as employees [29].

THE FOREIGN SUPPLIER VERIFICATION PROGRAM (FSVP) – BENEFIT OR BURDEN FOR INDIAN FOOD COMPANIES

Indian food regulatory model was a complex web of multiple ministries taking care of different food laws, standards setting and enforcement and even promotional bodies for different food commodities [29]. In 2006, the Government of India consolidated food regulations into a single act known as the ‚Food Safety and Standards Act' [10]. The FSSA covered the concept of food safety across the entire supply chain from manufacturing, storage, distribution. The FSSA consolidated the laws relating to food and established the Food Safety and Standards Authority of India (FSSAI) for laying down science-based standards for food regulating their manufacturing, storage, distribution, and sale to increase food safety [11, 28].

At the same time, the standards and conformity assessment are gaining increasing importance in relation to cross-border trade. Food safety and quality, a major agenda in international trade is, therefore, receiving increased attention in the Asia-Pacific region - especially in developing countries like India. Henson and Olale, 2011 analysed the E.U. and U.S. data for food products border rejections from 2002-2008 [17]. The study analysed four groups of products against some causes of rejections. From the data, in the United States, filthy/ unsanitary conditions are the highest cause of rejections in fish and fishery products followed by microbial contaminants, while pesticide residues are a major cause of rejections in fruits and vegetables, labelling issues in nuts and seeds and microbial contaminants followed by labelling in herbs and spices. Some food manufacturing entities, especially exporting countries food governing bodies are not alert to producing healthy and safe food. Due to the lack of knowledge and awareness, it is very difficult for consumers to distinguish between healthy food and unhealthy food. A food production company may try to reduce production costs by mixing low-quality materials with the high-quality ones [24]. However, the expansion of food safety standards, including FSVP, has introduced new complexity in trade policy dialogues and efforts to expand global trade in agricultural products. A loss of competitiveness due to the significant costs required to comply with these standards has arisen concern among exporting firms, particularly those in developing countries [20].

In addition, for developing countries, it is difficult to comply with the food safety standards in developed countries as they are subject to change over time in response to emerging problems, advances in scientific knowledge, consumer concerns, political pressure, etc. The majority of food exporting industries show less interest in implementing these standards if the compliance comes at a large expense. However, a well-coordinated food safety management may generate international competitiveness and awareness in the global arena [24].

The implementation of food safety requirements in India has become a significant task in recent years. However, in comparison to other countries, such as the U.S., the U.K., the E.U., and Japan, food safety requirements and inspections in the Indian food chain are still not rigorous enough [2, 3, 15]. So, it is essential that all the importing countries have some kind of risk-based verification program/ activities to ensure that the food imported into their countries has been produced in a manner that meets their food safety requirements. FSMA applies to both domestic as well as imported food hence foreign food producers will have to adhere to the same safety standards as U.S. domestic farmers and food companies. Of these, three rules of significance to food exporters are the U.S.

are Preventive Controls for Human Foods (PCHF), Foreign Supplier Verification Program (FSVP) and Accredited Third-Party Certification [25]. Rejection of consignments of food exports from India to the U.S. in 2019 especially that of basmati rice, marine products, spices and fruits and vegetables, were mostly on grounds of contamination. The U.S. rejected a total of 1674 consignments compared to 1939 rejections the year before [27].

India is one of the largest producers of many crops and food grains such as rice, wheat, pulses, oilseeds, coffee, jute, sugarcane, tea, tobacco, groundnuts, dairy products, fruits, etc. Given these advantages, India is now exporting fresh and processed food products to a number of developed and developing country markets including the United States, the European Union, Vietnam and the Middle Eastern countries [14]. India's exports of fresh fruits and vegetables to the U.S. stood at 3,018 MT valuing 8.61 million USD in 2019–20 as against 2,541 MT valuing 7.97 million USD in 2018-19 [25]. During 2021–22, the U.S. was the largest importer of Indian agricultural products at US$ 5.7 billion with a share of 11.5% of the total exports [18].

Multinational food corporations now account for a growing portion of the global food market. Food companies are keen to keep their reputation by offering safe and high quality food. Many of these companies have built food processing factories in developing countries where food safety regulations might be less stringent than in developed countries and where the ability of the government to conduct proper monitoring may be limited [12]. In India, the food industry is regulated by numerous legislatures which monitor the permits, licensing, and sanitation issues. The government also runs the Food Safety and Standards Authority of India (FSSAI) to monitor and regulate food processing, manufacturing, storage and market distribution. Despite a monitoring body to ensure safe food, public awareness must prevail.

Food standards do not necessarily lead to new barriers to trade but can also enhance developing countries' participation in high-value global food markets and generate benefits for the poor [29]. The benefit of FSMA FSVP is higher than the efforts, financial and time expenditures associated with the installation of inspection devices. The FSVP implementation can be viewed as both an opportunity to ensure food safety and defence against harm to a company's reputation that may emerge from recall efforts. We all know that prevention is better than cure, FSVP, one of the requirements as per FSMA rule is also focused on this by verifying that imported products comply with the same activity level of health protection concerning food safety as stated by FDA regulatory food requirements. Besides, the benefits will come back to consumers and the nation in general [24].

DIFFICULTIES IN THE IMPLEMENTATION OF FSVP

The number of border detentions is an explicit indicator of the ongoing difficulties that exporters in developing countries face in meeting food safety standards in industrialized countries. Indeed, the ultimate risk for exporters is that their consignments will be turned back at the border, necessitating the destruction of the implicated products or the incurring of additional transportation costs to bring the products home or divert them to an alternative market [16]. Access to food export markets will be based on their ability to satisfy the regulatory requirements of importing nations [24]. Building the faith and confidence of importers and consumers in the integrity of their food systems is essential to creating and maintaining demand for their food goods in international markets. Such food safety measures are crucial because the agricultural output is the core of the economies of the majority of developing nations. In India, international standards, guidelines, and recommendations are increasingly used to guide domestic as well as international tradeIf the FSVP importer obtains the foreign supplier's safety plan, unless the imported food is exempt or subject to modified requirements, a thorough evaluation of each imported food item (or type of food) is required. The FSVP also requires the importer to spend additional time analysing the food safety plan of its foreign supplier. Some importers lack the technical knowledge required for such analyses, as well as the time required for review which is very common in developing countries [24]. A Preventive Control Qualified Individual should perform the FSVP verification activities, as some importers are having difficulty finding qualified employees in an already competitive labor market. Hiring a Qualified Individual as a consultant imposes a financial burden on the importer and will most likely not encourage the degree of involvement between the importer and its FSVP that is desirable [26].

Sampling and testing of food samples is another FSVP difficulty facing the food exporters, especially small/ medium scale exporters, but this activity is already costing the food processor tens of thousands of dollars prior to the FSVP implementation. In addition, the HACCP system was created in large part due to the fact that sampling and testing are not reliable methods for guaranteeing the safety of food. Next difficulty is the implementation of food safety system based on HACCP principles. Food safety has been fervently discussed throughout the world. Priority for food safety addresses issues in enhancing food safety systems in terms of exporting countries, contribution to consumers' health and protection and advancement on food regulations and standards. Not all food industrial companies are able to follow demands presented by international bodies [24]. Next are the verification issues. An onsite audit, the recommended FSVP verification method, also comes at a high expense to the importer [26]. The FDA does not allow relying on foreign suppliers' own self-audit as an appropriate verification activity. The FDA accept third-party analyses, evaluations, and activities for meeting FSVP requirements. So if the importer doesn't have local auditing staff based in his manufacturing country, hiring a professional third party might be a good compliance solution [13].

CONCLUSIONS

The Foreign Supplier Verification Program (FSVP) regulations are intended to ensure imported foods meet the same quality levels of food produced in the U.S. The FSVP process aims to improve food safety by increasing the importers' responsibility for verifying foreign suppliers and their good manufacturing practice compliance. The U.S. Food and Drug Administration Food Safety Modernization Act (FSMA) on Foreign Supplier Verification Programs

(FSVP) for Importers of Food for Humans and Animals requires that importers perform certain risk-based activities to verify that food imported into the U.S. has been produced in a manner that meets applicable U.S. safety standards. The FSVP certification allows foreign (non-U.S) suppliers to obtain certification following an audit. The FSVP program is mandatory and applicable to importers of food to the U.S. The compliance is equal to a passport for food products' entry into the U.S. market. Under the FSVP, U.S. importers are required to monitor their foreign suppliers' compliance with FDA requirements. There are difficulties in the implementation of FSVP in India. However, the benefit of FSMA FSVP is higher than the efforts, financial, and time expenditures.

WNIOSKI

Przepisy Programu Weryfikacji Dostawców Zagranicznych (FSVP) mają na celu zapewnienie, że importowana żywność spełnia ten sam poziom jakości, co żywność produkowana w USA. Proces FSVP ma na celu poprawę bezpieczeństwa żywności poprzez zwiększenie odpowiedzialności importerów za weryfikację dostawców zagranicznych i przestrzeganie przez nich dobrych praktyk produkcyjnych. Amerykańska Ustawa o modernizacji bezpieczeństwa żywności (FSMA) Agencji ds. Żywności i Leków w sprawie Programów Weryfikacji Zagranicznych Dostawców (FSVP) dla importerów żywności dla ludzi i zwierząt wymaga, aby importerzy wykonywali określone działania oparte na ryzyku w celu sprawdzenia czy żywność importowana do USA została wyprodukowana w sposób, który spełnia obowiązujące amerykańskie standardy bezpieczeństwa. Certyfikacja FSVP umożliwia zagranicznym dostawcom (spoza USA) uzyskanie certyfikatu po audycie. Program FSVP jest obowiązkowy i dotyczy importerów żywności do USA. Zgodność jest równoznaczna z paszportem na wejście produktów spożywczych na rynek USA. W ramach FSVP importerzy amerykańscy są zobowiązani do monitorowania zgodności swoich zagranicznych dostawców z wymaganiami FDA. Istnieją trudności we wdrażaniu FSVP w Indiach. Jednak korzyści płynące z FSMA FSVP są większe niż wysiłki, koszty finansowe i czasowe.

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MODELE BIZNESOWE W BRANŻACH SPOŻYWCZYCH Z ANALIZĄ PORÓWNAWCZĄ DOTYCZĄCĄ MOŻLIWOŚCI ZASTOSOWANIA MODELU FRANCZYZY PRODUKCYJNEJ W BRANŻY PIEKARSKO-CUKIERNICZEJ®

Business models in food industries with a comparative analysis on the possibility of using the production franchise model in the bakery and confectionery industry®

Słowa kluczowe: model biznesowy, franczyza produkcyjna, przemysł spożywczy, branża piekarsko-cukiernicza.

W literaturze przedmiotu jest niewiele opracowań dotyczących modeli biznesu w przemyśle spożywczym. Modele biznesu w branży piekarsko-cukierniczej, a także ich typologia to nierozpoznana naukowo dziedzina. Świadczy o tym brak publikacji podejmujących problem typologii w odniesieniu do przedsiębiorstw branży piekarsko-cukierniczej. W artykule wskazano na aktualnie stosowane modele biznesowe w branżach spożywczych z analizą porównawczą dotyczącą możliwości zastosowania modelu franczyzy produkcyjnej w branży piekarsko-cukierniczej.

Key words: business model, production franchise, food industry, bakery and confectionery industry.

There are few studies in the literature on business models in the food industry. Business models in the baking and confectionery industry, as well as their typology, is a scientifically unrecognized field. This is evidenced by the lack of publications addressing the problem of typology in relation to enterprises in the baking and confectionery industry. The article indicates the currently used business models in the food industry with a comparative analysis of the possibility of using the production franchise model in the bakery and confectionery industry.

INTRODUCTION

Sposób funkcjonowania przedsiębiorstwa kojarzy się przede wszystkim z jego strategią rozwojui strategiami konkurowania. W ostatnich latach pojawiła się nowa koncepcja dotycząca zasadi sposobów działania przedsiębiorstw – koncepcja „modelu biznesowego". Problematyka modeli stała się popularna zarówno w przedsiębiorstwach jak i wśród teoretyków zarządzania. Rośnie liczba publikacji na ten temat, aczkolwiek pogłębionych opracowań jest niewiele [14] Modele biznesu w branży piekarsko-cukierniczej, a także ich typologia to nierozpoznana naukowo dziedzina. Świadczy o tym brak publikacji podejmujących tę problematykę w odniesieniu do przedsiębiorstw branży piekarsko-cukierniczej. Analizowane firmy w wyniku przeprowadzonych badań ankietowych nie stosują żadnych modeli biznesowych w działalności, zatem badania przeprowadzono w zakresie strategii jakie firmy obierają. Informację tę skorelowano z odpowiedziami w zakresie możliwości zastosowania franczyzy produkcyjnej. Jak wynika z przeprowadzonych analiz niewiele firm, bo zaledwie 62%, działa w oparciu o obraną strategię. Blisko ponad 38% niestety nie posiada żadnej strategii rynkowej i funkcjonuje na zasadzie „jestem na rynku bo jestem, uda się to się uda".

Celem artykułu jest wskazanie na aktualnie stosowane modele biznesowe w branżach spożywczych z analizą porównawczą dotyczącą możliwości zastosowania modelu franczyzy produkcyjnej w branży piekarsko-cukierniczej.

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DEFINICJA MODELU BIZNESU

Model biznesowy jako pojęcie w naukach o zarządzaniu funkcjonuje zaledwie od około 20 lat. Krótka historia tego terminu sprawia, że nie doczekało się ono jeszcze jednolitej i spójnej definicji. Wydaje się wręcz, że każdy autor podejmujący problematykę modelu biznesowego posiada własną interpretację tego zagadnienia. Co więcej, również w praktyce gospodarczej model biznesowy jest używany w dowolny sposób, najczęściej w celu opisania podejścia przedsiębiorstwa do wykonywania działalności gospodarczej i osiągania zysków. Ten stan rzeczy powoduje pewien chaos interpretacyjny, który utrudnia eksplorację istoty modelu biznesowego i jego wpływu na wyniki finansowe osiągane przez przedsiębiorstwo [26].

W dorobku nauk zarządzania próby usystematyzowania modeli biznesowych dopiero są podejmowane [1]. Przegląd różnych definicji modeli biznesu wskazuje, że są one bardzo podobne. Nie zmienia to jednak faktu, że brakuje jednej, ogólnie przyjętej definicji [30]. Autorzy koncepcji wzorcowych i twórcy pierwszych referencyjnych modeli biznesowych to: P. Timmers, M. Rappa, L. Applegate, czy C. Zott. i R. Amit, a w dalszej kolejności Y. Pigneur, A. Osterwalder, S. Klein, C. L. Tucci, J. Gordijn, O. Petrovic, Ch. Kittl, P. Stähler, A. Patel. Za autorów najbardziej popularnych – najczęściej cytowanych – koncepcji uważa się: L. Applegate'a, A. Osterwaldera oraz P. Rappa'ego i R. Amitta oraz C.Zotta, a w dalszej kolejności: P. Timmersa, J. Margrett'ę, A.N. Afuah'a, A.J. Slywotzky'ego, D.J. Morrisona, B. Andelmana, G. Hamela, H. Chesbrough'a, R.S Rosenblooma, T.W. Mallone'a i P. Weilla, G.S. Yipa, J.C. Lindera, S. Cantrella, M. Dubboson – Torbay, F. Betza, czy M. W. Johnsona, H. Kagermanna. Wśród autorów polskich zajmujących się tą problematyką modeli należy wspomnieć przede wszystkim Zespół SGH w składzie: T. Gołębiowski, T.M. Dudzik, M. Lewandowska i M. Witek- Hajduk, A. Jabłoński a także K. Obłój, S. Gregorczyk oraz J. Niemczyk i J. Drzewiecki, dostarczających opisów porównawczych dostępnych koncepcji w tym zakresie. Powstały również polskie opracowania dotyczące przeglądu modeli w branży informatycznej [m.in.: D. Nojszewski, T. Sierotowicz]. Ciekawe ujęcie modeli biznesowych przedstawił również R. Krupski, przyjmując, jako główne kryterium klasyfikacji przedsiębiorstw stopień ich wirtualizacji. Modele przedstawione w jego koncepcji odnoszą się jednak do specyficznych form przedsiębiorstw, jakimi są tzw. fraktale i organizacje wirtualne.

Poniżej przedstawiono wybrane definicje. Model biznesowy *jest to plan, który tworzy przedsiębiorstwo w celu wygenerowania przychodu i maksymalizacji zysku operacyjnego. Określa relacje pomiędzy uczestnikami rynku, informuje, jak przedsiębiorstwa działają, tj. w jaki sposób tworzą wartość dla klientów, towary i usługi oraz z czego czerpią zyski*[11]. Jak podaje Timmers, *model biznesowy to struktura produktu, usługi i przepływu informacji, zawierająca wyszczególnienie tzw. aktorów biznesowych wraz z ich rolami i opisem potencjalnych korzyści jakie odnoszą* [24]. *Innymi słowy, jest to definicja źródeł przychodów*. Armit i Zott określają model biznesowy jako *zawartość, strukturę i kierowanie transakcjami zaprojektowany w taki sposób, aby tworzyć wartość poprzez wykorzystywanie szans biznesowych* [28]. Według Portera model biznesowy jest *opisem działalności przedsiębiorstwa, które zapewniają mu zyski. Sprowadza się do określenia roli organizacji w łańcuchu wartości, w jakim działa. W kompleksowym ujęciu chodzi o metodę przyjętą przez firmę, przez realizację, której będzie ona powiększać i wykorzystywać zasoby tak, aby oferować klientom większą wartość od konkurencji. Dzięki temu przedsiębiorstwo osiągnie wyższe zyski, a może nawet uzyska i utrzyma trwałą przewagę konkurencyjną* [20].

MODEL BIZNESU A STRATEGIA PRZEDSIĘBIORSTWA

Analiza definicji i przykładów opisujących koncepcję i strukturę modelu biznesu wskazuje na trudności rozróżnienia pojęć „model biznesowy" oraz „strategia". Dotyczy to zwłaszcza przypadków, gdy model biznesowy jest definiowany i opisywany szczegółowo, a definicja obejmuje także wątki związane ze sposobem konkurowania. Trudność ta jest dostrzegana przez autorów zajmujących się problematyką modeli biznesowych. Oczywiście i w tym przypadku nie ma jednolitości poglądów co do relacji między obu pojęciami. Część autorów utożsamia oba pojęcia lub traktuje strategię jako element modelu biznesowego. Z przeglądu literatury wynika jednak, że częstszy jest pogląd, iż rozróżnianie tych pojęć jest zasadne [20]. Dość często spotykany w literaturze jest pogląd, według którego model biznesu jest rozumiany jako system ukazujący sposób powiązania poszczególnych elementów, natomiast strategia określa sposób konkurowania. Model biznesu określa ogólne założenia, na postawie których formułuje się strategię konkurowania [24]. Funkcją modelu biznesu jest określenie, jakie zmiany w biznesie (produktowe, technologiczne) należy wprowadzić, zaś funkcją strategii jest ustalenie, jak to uczynić[20]. Według H. Chesbrougha i R.S. Rosenblooma na rozróżnienie modelu biznesu i strategii biznesu pozwalają trzy aspekty [4]:

- w strategii biznesu w centrum uwagi pozostaje utrzymanie przewagi konkurencyjnej, podczas gdy w modelu biznesowym kwestia ta nie ma aż takiego znaczenia,
- w modelu biznesowym często abstrahuje się od kwestii finansowania danego przedsięwzięcia gospodarczego przyjmując, że dostępne są wewnętrzne lub zewnętrzne źródła finansowania. Natomiast w planowaniu i realizacji strategii kwestie finansowania pozostają bardzo istotne,
- w koncepcji modelu biznesowego zakłada się, że zasoby wiedzy (jakimi dysponuje przedsiębiorstwo, jego klienci i inne podmioty rynkowe) są ograniczone z uwagi na ograniczenia poznawcze i to, że wiedza traci walor obiektywności pod wpływem wcześniejszych sukcesów firmy. W przypadku strategii przyjmuje się założenie o konieczności dokonywania wieloaspektowych analiz poprzedzających podejmowanie decyzji, co wymaga dużej wiedzy o warunkach działania [14].

D.J. Teece [23] twierdzi natomiast, że model biznesowy jest koncepcją bardziej ogólną niż strategia biznesowa. Integracja analizy strategicznej i modelu biznesowego jest wymagana do utrzymania przewagi konkurencyjnej wynikającej z zaprojektowania nowego modelu biznesowego. Według autora strategia zawiera się w idei modelu biznesowego.

Casadesus-Masanell, J.E. Ricart [2] wskazują, że model biznesowy odwołuje się do logiki działania przedsiębiorstwa i do tego, jak ono kreuje wartość dla interesariuszy (stakeholders). Strategia odnosi się do wyboru modelu biznesowego, dzięki któremu przedsiębiorstwo będzie skutecznie konkurowało na rynku. Taktyka odnosi się do pozostałych wyborów otwartych dla przedsiębiorstwa z racji wybranego modelu biznesowego. Strategia jest zatem pojęciem nadrzędnym w stosunku do modelu biznesowego. Ch. Zott, R. Amit [29] podają w swojej publikacji, że istnieją dwie zasadnicze różnice pomiędzy strategią a modelem biznesowym:

- strategia koncentruje się bardziej na osiągnięciu przewagi konkurencyjnej, a model biznesowy na kreowaniu wartości dla wszystkich interesariuszy,
- model biznesowy stawia w centrum zainteresowania tworzenie wartości dla klienta, co jest w mniejszym stopniu przedmiotem zainteresowania zarządzania strategicznego. Zatem model biznesowy jest pojęciem komplementarnym w stosunku do strategii.

M. Jabłoński [16] twierdzi, że model biznesu jest to zbiór pewnych zasobów, ich konfiguracji wraz ze wzajemnymi interfejsami, które umożliwiają osiąganie przez przedsiębiorstwo zysków. Strategia natomiast nadaje rytm zmian modelu biznesu. W konkluzji strategia jest nadrzędna względem modelu biznesowego i wyznacza kierunki jego zmiany. M. Duczkowska-Piasecka, M. Poniatowska-Jaksch, K. Duczkowska-Małysz [9] publikują, że strategia i model biznesu nie są tożsame, ale wzajemnie od siebie zależą. Kierunek zależności jest taki, że to model biznesu kształtuje strategię, a nie odwrotnie, gdyż strategia, aby była realna, musi opierać się na zdolnościach, zasobach i dotychczasowej pozycji przedsiębiorstwa, a cele długoterminowe muszą być możliwe do zrealizowania. W konsekwencji model biznesu jest pojęciem szerszym od strategii. C.M. DaSilva, P. Trkman [6] zaznaczają, że model biznesowy różni się od strategii z dwóch powodów:

- strategia kształtuje rozwój umiejętności, które mogą zmienić model biznesowy w przyszłości,
- strategia odzwierciedla to, czym przedsiębiorstwo chce się stać, podczas gdy model biznesowy opisuje, czym przedsiębiorstwo w rzeczywistości jest w danym momencie. Zatem w ich ocenie to strategia kształtuje postać modelu biznesowego.

Autor T. Doligalski [8] opisuje, że model biznesu przedstawia to, czym przedsiębiorstwo jest, natomiast strategia opisuje to, co przedsiębiorstwo chce osiągnąć i jak zamierza to zrobić. W strategii istnieje wymiar czasowy oraz pewien kierunek zmian, podczas gdy model biznesu jest obrazem organizacji uchwyconym w wybranym momencie.

Przedstawiony kontekst jest niezbędny do określenia miejsca i roli modelu biznesowego w strategii i zarządzaniu strategicznym. Analiza literatury przedmiotu nie dostarcza jednolitego poglądu na temat różnicy, miejsca i roli modelu biznesowego oraz strategii. Wręcz przeciwnie, występujące w literaturze przedmiotu poglądy na ten temat często wzajemnie się wykluczają. Rozpiętość poglądów na to zagadnienie jest bardzo szeroka, począwszy od twierdzenia, że strategia jest nadrzędnym pojęciem względem modelu biznesowego, a kończąc na przeciwległym krańcu poglądów, w którym model biznesowy determinuje strategię. W całej tej przestrzeni można znaleźć wiele poglądów pośrednich. Przedstawione zestawienie poglądów na temat relacji pomiędzy modelem biznesowym a strategią i zarządzaniem strategicznym nie pozwala na rozstrzygnięcie tej kwestii. Rozpiętość poglądów jest bardzo duża, co wynika w dużej mierze ze stosunkowo młodego wieku koncepcji modelu biznesowego. Przedstawiony stan wiedzy na ten temat wymaga zatem pewnej syntezy [26].

Podsumowując, wydaje się, że pojęcie modelu biznesowego na trwałe zakorzeniło się w naukach o zarządzaniu przedsiębiorstwem. Coraz częściej istota modelu biznesowego jest przedstawiania w kontekście systemowego podejścia do zarządzania przedsiębiorstwem. W modelu biznesowym wyraża się sposób prowadzenia przez przedsiębiorstwo działalności i osiągania przewagi konkurencyjnej nad innymi podmiotami działającymi na rynku. W takim ujęciu model biznesowy jest integralną częścią strategii przedsiębiorstwa i jest kreowany w ramach procesu zarządzania strategicznego. Strategia jest zatem nadrzędnym pojęciem względem modelu biznesowego. Dobrze zaprojektowany model biznesowy jest natomiast sposobem osiągnięcia celów strategicznych przedsiębiorstwa [26].

ANALIZA MODELI BIZNESU POLSKICH PRZEDSIĘBIORSTW W BRANŻY PIEKARSKO-CUKIERNICZEJ

W literaturze przedmiotu jest niewiele opracowań dotyczących modeli biznesu w przemyśle spożywczym [27]. Modele biznesu w branży piekarsko-cukierniczej, a także ich typologia to nierozpoznana naukowo dziedzina. Świadczy o tym brak publikacji podejmujących problem typologii w odniesieniu do przedsiębiorstw branży piekarsko-cukierniczej [13] Próbę klasyfikacji modeli biznesu w branży spożywczej podjęła autorka licznych publikacji nt. modeli biznesu prof. M.K. Witek-Hajduk. Według M.K. Witek-Hajduk w grupie przedsiębiorstw przemysłu spożywczego najwięcej jest firm realizujących modele biznesu tj. „Gracz Rynkowy" (62% przedsiębiorstw z tej branży) i „Tradycjonalista" (22%). Nieliczne firmy stosują model „Dystrybutor" oraz model „Specjalista".

Mimo znaczącego wzrostu popularności modeli biznesowych, niewielu autorów podjęło próbę opisania modeli branżowych, nie wspominając już o braku pogłębionych analiz w tym zakresie. Dodatkowo, istniejące klasyfikacje modeli biznesu znacznie różnią się od siebie, co jest rezultatem przyjęcia przez ich autorów różnych definicji pojęcia, a także odmiennego podejścia w określaniu jego elementów składowych [30].

TYPOLOGIA MODELI BIZNESU ZAWIERAJĄCA ELEMENTY FRANCZYZY

Po wnikliwym przeglądzie literatury poniżej przedstawiono modele biznesu, które zawierają elementy wspólne dla modelu biznesu z wykorzystaniem franczyzy produkcyjnej (Tabela 2).

Table 1. Features of business models in the food industry

Tabela 1. Cechy modeli biznesowych w branży spożywczej

MODEL BIZNESU	CECHY MODELU
Gracz rynkowy	*Elementy konstytuujące:* – źródłem wartości dla klienta są zarówno korzyści materialne jak emocjonalne związane z produktem, – dysponowanie istotnymi unikatowymi zasobami: kompetencje menadżerskie, zaawansowana technologia, marka, maszyny, urządzenia i infrastruktura, zasoby finansowe, wiedza na temat rynku, – koncentracja na działaniach tj.: projektowanie, wytwarzanie, marketing i sprzedaż (przy czym wybrane operacje w ramach tych działań mogą być zlecane na zewnątrz outsourcing / offshoring), – relacje partnerskie z uczestnikami łańcucha dostaw, – podstawowymi źródłami przychodów są: sprzedaż wytworzonych dóbr materialnych lub świadczonych usług oraz inne niż sprzedaż formy udostępniania produktu. *Elementy oceniające:* – wysoki stopień opanowania kluczowych czynników sukcesu w danej dziedzinie, – model sprzyja tworzeniu przewagi z tytułu dyferencjacji lub przewagi zintegrowanej (kosztowej i z tytułu dyferencjacji), – duża zdolność do tworzenia aliansów strategicznych, – przedsiębiorstwo realizuje autonomiczną strategię rynkową, – znaczne możliwości modyfikacji modelu. *Czynniki wyboru, zakres zastosowania, sugerowane kierunki zmia-ny modeli biznesu:* Podstawowymi czynnikami wyboru tego modelu są: oczekiwana znaczna przewaga konkurencyjna, a zwłaszcza w warunkach polskich – zdolności do uzyskania przewagi wyróżniającej. Typowymi źródłami przewagi są: innowacyjność i wysoka jakość wykonania produktu, obecność w asortymencie produktów flagowych, które osiągnęły sukces rynkowy, siła marki, przywództwo w segmencie, niskie koszty. Model skuteczny w firmach o silnej pozycji na rynku. Przewaga konkurencyjna jest przesłanką różnych form zaangażowania firmy na rynkach zagranicznych. Przydatność modelu wydaje się większa dla firm relatywnie dużych, dysponujących wystarczająco dużymi zasobami do tworzenia i utrzymywania przewag konkurencyjnych także w przypadku ekspansji międzynarodowej. W przypadku trudności realizacji strategii firmy przy wykorzystaniu tego modelu Integrator lub Specjalista.
Tradycjonalista	*Elementy konstytuujące:* – źródłem wartości dla klienta są korzyści materialne związane z produktem oraz relacja korzyści do kosztów, – istotne są zasoby finansowe, ponadto brak unikatowych zasobów / kompetencji, – realizowanie następujących działań w ramach łańcucha wartości: projektowanie, wytwarzanie dóbr/usług i ich sprzedaż, co oznacza, że jego wewnętrzny łańcuch wartości jest relatywnie długi, – dominują relacje transakcyjne z uczestnikami łańcucha dostaw, – pasywna rola w łańcuchu tworzenia wartości dla ostatecznego nabywcy /użytkownika, – źródłem przychodów jest przede wszystkim sprzedaż wytworzonych dóbr materialnych lub świadczonych usług. *Elementy oceniające:* – niski stopień opanowania kluczowych czynników sukcesu w danej dziedzinie (branży), czego efektem są ograniczone możliwości uzyskania wyraźnej przewagi konkurencyjnej i silnego, wyrazistego pozycjonowania oferty; model sprzyja(w warunkach polskich) tworzeniu przewagi kosztowej,w mniejszym stopniu – przewagi z tytułu dyferencjacji, – słaba do silnej pozycja przetargowa w relacjach z dostawcami i odbiorcami (zależnie od wielkości firmy i stopnia opanowania kluczowych czynników sukcesu), – ograniczona zdolność do tworzenia aliansów strategicznych, – przedsiębiorstwo jest zdolne realizować autonomiczną strategię rynkową lub prowadzi ją we współpracy z pośrednikami handlowymi (co może grozić przejęciem inicjatywy przez silnego, aktywnego pośrednika handlowego) w przypadku niewystarczających kompetencji marketingowych firmy, – ograniczone możliwości wprowadzania zmian modelu biznesowego, – umiarkowane możliwości przechwytywania wartości w ramach łańcucha wartości. *Czynniki wyboru, zakres zastosowania, sugerowane kierunki zmiany modeli biznesu* Podstawowymi czynnikami wyboru tego modelu biznesowego są: oczekiwana zadowalająca kosztowa przewaga konkurencyjna przedsiębiorstwa wynikająca bądź z tytułu lokalizacji (dostępu do tanich czynników produkcji) lub korzyści skali i/lub elementy przewagi z tytułu dyferencjacji. Typowymi źródłami zysku w opisywanym modelu są: niskie koszty, jakość wykonania produktu (efekt doświadczenia w danej dziedzinie i sprawdzonych relacji z dostawcami). Model ten wydaje się być bardziej skuteczny na rynkach branżowych, które nie przyciągają silnych konkurentów. Jego przydatność wydaje się większa dla firm relatywnie dużych w skali branży, co umożliwia wykorzystanie wystarczająco dużych przewag.

MODEL BIZNESU	CECHY MODELU
Dystrybutor	*Elementy konstytuujące:* – źródłem wartości dla klienta jest wartość dostarczana klientom na poszczególnych etapach cyklu transakcyjnego oraz korzystna relacja korzyści do kosztów, – wyróżniające zasoby/kompetencje to przede wszystkim wiedza na temat rynku (tak nabywcach, jak i dostawcach), – koncentrowanie działań na sprzedaży, co oznacza, że jego wewnętrzny łańcuch wartości jest bardzo krótki, – dominują relacje transakcyjne z uczestnikami łańcucha dostaw, – podstawowym źródłem przychodów jest pośrednictwo handlowe. *Elementy oceniające:* – niski do wysokiego stopień opanowania kluczowych czynników sukcesu w obszarze operacji handlowych i logistycznych, co rzutuje na możliwości pozycjonowania oferty i firmy, – rodzaj przewagi konkurencyjnej uzyskiwanej dzięki przyjęciu tego modelu zależy od charakteru przewagi konkurencyjnej dostawców, model sprzyjać może tworzeniu przewagi kosztowej lub tytułu dyferencjacji, – słaba do silnej pozycja przetargowa, – zdolność do tworzenia aliansów strategicznych, – przedsiębiorstwo prowadzi strategię rynkową we współpracy z dostawcami (producentami) lub realizuje strategię autonomiczną, – umiarkowane możliwości zmiany modelu biznesu, – umiarkowane możliwości przechwytywania wartości w ramach łańcucha wartości. *Czynniki wyboru, zakres zastosowania, sugerowane kierunki zmia-ny modeli biznesu:* Podstawowymi czynnikami wyboru tego modelu są: możliwość uzyskania przewagi konkurencyjnej związanej z lokalizacją firmy lub wyróżniającą obsługą klienta. Typowymi źródłami przewagi są: niskie koszty, jakość obsługi klienta, a także siła marki. Przydatność modelu wydaje się większa dla firm relatywnie dużych w skali branży, co umożliwia wykorzystanie odpowiednio dużych zasobów do uzyskania przewag konkurencyjnych. Model skuteczny zarówno w firmach o ugruntowanej pozycji na rynku krajowym, a także dla niszowych firm o zasięgu lokalnym. Model umożliwia różne formy zaangażowania na rynkach zagranicznych.
Specjalista	*Elementy konstytuujące:* – źródłem wartości dla klienta są tak korzyści materialne, jak i emocjonalne produktu oraz wartość dostarczana klientom na poszczególnych etapach cyklu transakcyjnego, a także relacje tworzone z ostatecznym nabywcą produktu, – unikatowymi zasobami są: kompetencje menedżerskie, zaawansowane technologie, marka, wiedza na temat rynku, – koncentrowanie na realizowaniu następujących działań: projektowanie oraz marketing, wytwarzanie dóbr materialnych lub świadczenie usług może realizować w całości lub częściowo samodzielnie albo zlecać na zewnątrz kontrolując te działania, – relacje z odbiorcami mają charakter partnerski, – podstawowym źródłem przychodów jest sprzedaż wytworzonych dóbr materialnych lub świadczonych usług. *Elementy oceniające:* – wysoki stopień opanowania wybranych, unikatowych kluczowych czynników sukcesu, czego efektem są możliwości uzyskania wyraźnej przewagi konkurencyjnej, – model sprzyja tworzeniu przewagi z tytułu dyferencjacji, – brak zdolności do tworzenia aliansów strategicznych – firma może być jedynie atrakcyjnym członkiem aliansu, – ograniczenie możliwości zmiany modelu biznesu (efekt głębokiej specjalizacji). *Czynniki wyboru, zakres zastosowania, sugerowane kierunki zmiany modeli biznesu:* Podstawowymi czynnikami wyboru tego modelu są: oczekiwane zdolności do uzyskania przez firmę przewagi z tytułu dyferencjacji a także przewaga kosztowa. Typowymi źródłami przewagi konkurencyjnej są: unikatowość, innowacyjność i jakość wykonania produktu, funkcji realizowanych przez firmę, siła marki oraz niskie koszty. Przewaga konkurencyjna stanowi przesłankę ekspansji międzynarodowej. Model może być skuteczny w branżach o intensywnej konkurencji, a jego skuteczność jest uzależniona od stopnia opanowania wybranych kluczowych czynników sukcesu. Wielkość firmy nie ma decydującego znaczenia dla skuteczności modelu. Ewentualne kierunki zmiany modelu to przejście do modelu Integrator lub Gracz Rynkowy.

Source: [13]

Źródło: [13]

Table 2. Business models with elements in common with the production franchise business model

Tabela 2. Modele biznesu zawierające elementy wspólne z modelem biznesu franczyzy produkcyjnej

NAZWA MODELU BIZNESU	OPIS / CECHY WSPÓLNE
Otwarty model biznesu (open innovarion business)	Tworzenie wartości poprzez współpracę z partnerami eko-systemu: firmy poszukują nowych sposobów współpracy z dostawcami, klientami czy producentami dóbr, w celu zwiększenia zakresu swojej działalności.
Franczyza	Franczyzodawca udziela licencji na korzystanie z nazwy i oferowanie usług lokalnym podmiotom (korzysta on z marki, know-how i innego wsparcia).
Nowe rynki (breakthrough markets)	Inwestowanie w nowo otwierających się rynkach w celu tworzenia monopolistycznej pozycji. Utrzymywanie pozycji na rynkach dzięki intensywnej dystrybucji oraz odpowiedniej polityce cenowej i efektywności operacyjnej.
Gwarantowana dostępność (G-F-C)	Firma gwarantuje ciągłą dostępność produktu lub usługi, w efekcie czego nie ma okresów przestoju. Firma wykorzystuje doświadczenie i efekty skali.
Sprzedaż produktów wysokiej jakości (Quality selling)	Firma oferuje wysokiej jakości i/lub unikatowe produkty, zapewnia wysoką jakość usług przy i posprzedażnych.

Source: The own study

Źródło: Opracowanie własne

Franczyza produkcyjna jest modelem pochłaniającym cechy wspólne ww. poszczególnych modeli.

Warto w tym miejscu przedstawić specyfikę otwartego modelu biznesu (open innovation business), który jest najbardziej zbliżonym modelem do modelu biznesowego z wykorzystaniem franczyzy produkcyjnej w przedsiębiorstwach piekarsko-cukierniczych sektora małych i średnich przedsiębiorstw. A mianowicie, model otwartych innowacji w ostatnich latach zdobywa coraz większe zainteresowanie zarówno wśród naukowców, jak i praktyków. Został on po raz pierwszy wprowadzony do nauk o zarządzaniu w 2003 roku przez Chesbrougha [3]. Autor wskazuje, że paradygmat otwartych innowacji opiera się na dwustronnym przepływie wiedzy: od otoczenia do przedsiębiorstwa oraz od przedsiębiorstwa do otoczenia. Zmiana w podejściu do modeli innowacyjnych związana jest z ewolucją teorii wzrostu gospodarczego. Akcentuje się w nich coraz częściej znaczenie wiedzy oraz procesów uczenia się zachodzących między wieloma podmiotami gospodarczymi i interesariuszami zewnętrznymi. W konsekwencji aktualnie opisywane modele innowacyjności, zarówno na mikro-, mezo-, jak i makro poziomie, przypisują decydujące znaczenie wymianie wiedzy w różnych formach interakcji grupowej. Kluczowym elementem jest intensyfikacja działań zmierzających w kierunku pogłębienia współpracy między podmiotami i współdzielenia wiedzy. Koncepcja otwartych innowacji, wpisując się w ten nurt rozważań, stwarza (podmiotom, branżom, regionom) możliwości komercjalizacji zaimplementowanych w otoczeniu innowacyjnych rozwiązań, wpływających pośrednio lub bezpośrednio na kształtowanie ich przewagi konkurencyjnej [12]. Stanisławski [22] wskazuje na przesłanki stosowania otwartych innowacji jako strategii działania podmiotów gospodarczych. Pierwsza z nich jest związana z konstatacją, że o przewadze rynkowej decyduje częściej szybkość wprowadzania nowych rozwiązań, a nie prowadzenie zamkniętej działalności B+R (będące najczęściej długim proce-sem). Kolejna dotyczy znacznej dynamiki zmian zachodzących w otoczeniu, która jest wynikiem postępu technologicznego i znacząco wpływa na zmianę gustów, upodobań i potrzeb klientów. Trzecia przesłanka związana jest ze spostrzeżeniem, że przedsiębiorstwom nie opłaca się zatrzymywać „niewykorzystanej wiedzy", którą można komercjalizować przez licencje, umowy czy też istniejące sieci partnerskiej współpracy [12]. Koncepcja otwartych innowacji może być stosowana we wszystkich sektorach i branżach. Dotychczasowe badania wskazują jednak, że w zdecydowanie w większym wymiarze jest ona wykorzystywana w sektorach zaawansowanych technologii [7]. Związane jest to z występowaniem w nich stosunkowo krótkiego cyklu

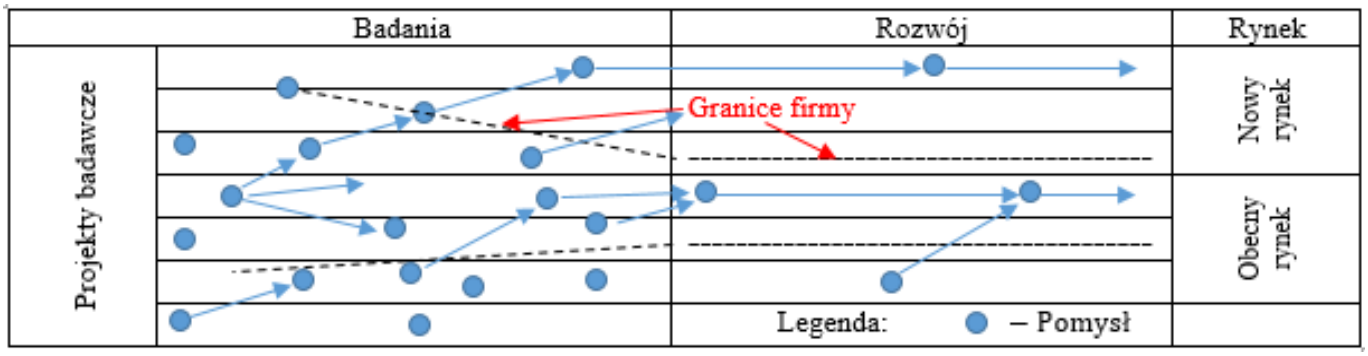


Fig. 1. Model of open approach in innovation processes.

Rys. 1. Model otwartego podejścia w procesach innowacyjnych.

Source: [13]

Źródło: [13]

życia technologii i krótkimi cyklami życia produktów. Podobne wnioski wynikają z badań Lichtenthaler i Ernst [17] oraz van de Vrande i in.[25]. Huston i Sakkab[15] twierdzą jednak, że nie ma jednoznacznych dowodów, że model otwartych innowacji nie może być wykorzystywany w sektorach tradycyjnych i dojrzałych. Wdrażanie innowacji wymaga bowiem zdolności do poszukiwania, wchłaniania i wykorzystywania wiedzy zewnętrznej lub wymiany wiedzy generowanej wewnętrznie. W ten nurt rozważań teoretycznych i empirycznych wpisuje się koncepcja otwartych innowacji. Jej paradygmat opiera się na założeniu, że podmioty gospodarcze mogą i powinny wykorzystywać zarówno zewnętrzne, jak i wewnętrzne pomysły w swych procesach innowacyjnych [13].

Model otwartych innowacji oznacza zatem, że granice firmy są tylko formalnymi ramami przepływu wiedzy między przedsiębiorstwem a jego otoczeniem.

W konsekwencji innowacyjne projekty mogą być uruchamiane zarówno ze źródeł wewnętrznych, jak i zewnętrznych, a nowości mogą być wprowadzane do procesu na różnych jego etapach. Podmioty stosujące model otwartych innowacji rozwijają pomysły, których nie są autorami, jak i udostępniają własne pomysły innym jednostkom [13]. Jednocześnie przedsiębiorstwo nie rezygnuje całkowicie z ochrony zdobytych przez siebie praw własności przemysłowej, ale stara się opracować najefektywniejszy sposób zarządzania nimi (np. przez licencje, w postaci start-up lub scedowanie części praw na współpracujące firmy. Dochodzi w ten sposób do maksymalizacji wartości płynącej z pomysłów pojawiających się zarówno w przedsiębiorstwie, jak i poza nim. Otwarte podejście w działalności innowacyjnej pozwala także na wcześniejsze odrzucenie tych projektów, które nie mają szans na odniesienie sukcesu rynkowego. Niezbędnym warunkiem wykorzystania modelu otwartych innowacji jest powszechna współpraca w sieci [13]. Tendencje coraz większej otwartości procesów innowacyjnych realizowanych w przedsiębiorstwach skłaniają do postawienia pytania o możliwość i zakres stosowania otwartych modeli innowacji w gospodarce żywnościowej. Badania empiryczne dotyczące tego zagadnienia są w światowej literaturze przedmiotu relatywnie nieliczne [21].

Dahlander i Gann [5] przewidują niski stopień otwartości w sektorach niskiej techniki (do którego należy branża piekarsko-cukiernicza). Sarkar i Costa [21] twierdzą, że może to szczególnie dotyczyć małych i średnich przedsiębiorstw działających w sektorze gospodarki żywnościowej. Zdaniem Huston i Sakkab [14] nie ma jednak jednoznacznych dowodów, że model otwartych innowacji nie może być wykorzystywany w sektorach tradycyjnych i dojrzałych [13]. Otwartość działalności innowacyjnej przemysłu spożywczego rozpatrywano w aspekcie porównawczym z branżami niskiej techniki. W opracowaniu wykorzystano dziedzinowe podejście klasyfikacji przetwórstwa przemysłowego i usług według intensywności prac B+R. Doboru działów do badań dokonano przy zastosowaniu Polskiej Klasyfikacji Działalności (PKD) 2007, kompatybilnej ze Statystyczną Klasyfikacją Działalności Gospodarczej Unii Europejskiej (NACE Rev. 2). Zgodnie z przyjętym kryterium do sektora niskiej techniki zalicza się: produkcję artykułów spożywczych, produkcję napojów, produkcję wyrobów tytoniowych, produkcję wyrobów tekstylnych, produkcję odzieży, produkcję skór i wyrobów ze skóry wyprawionych, produkcję drewna i wyrobów z drewna, produkcję papieru i wyrobów z papieru, poligrafię, produkcję mebli oraz pozostałą produkcję wyrobów [19]. Zakres współpracy określono, biorąc pod uwagę udział przedsiębiorstw aktywnych innowacyjnie współpracujących z innymi podmiotami w zakresie działalności innowacyjnej oraz odsetek przedsiębiorstw współpracujących z innymi podmiotami w zakresie działalności innowacyjnej w ramach inicjatywy klastrowej. Zakres czasowy analizy obejmował lata 2010–2012. Poziom współpracy przedsiębiorstw spożywczych aktywnych innowacyjnie wskazuje, że co trzeci z nich korzysta z możliwości opracowywania nowych rozwiązań z innymi podmiotami (27,2%.) wszystkich przedsiębiorstw spożywczych. Przedstawione dane wskazują, że polskie przedsiębiorstwa przemysłu spożywczego stosują strategię otwartych innowacji w relatywnie ograniczonym zakresie [12]. Przyjmując, że paradygmat otwartych innowacji zakłada powiązania sieciowe umożliwiające przepływy wiedzy, ważne jest także określenie stopnia współpracy przedsiębiorstw w ramach inicjatywy klastrowej. Warto w tym miejscu nadmienić, że inicjatywa klastrowa rozumiana jest *jako powiązania kooperacyjne zawiązane w sposób formalny na podstawie listu intencyjnego, umowy stowarzyszeniowej, umowy o utworzeniu konsorcjum itp*.[10] Nie należy jej zatem utożsamiać z klastrem, który zgodnie z powszechnie przyjmowaną definicją Portera [18], jest bliską geograficznie grupą powiązanych przedsiębiorstw i instytucji, połączoną podobieństwami i wzajemnie się uzupełniającymi. Z danych Głównego Urzędu Statystycznego wynika, że tylko 5,5% przedsiębiorstw wskazało taką współpracę. Był to jeden z najniższych wyników wśród branż sektora niskiej techniki. Podkreślić jednocześnie należy, że w poprzednim okresie (lata 2009–2011) odsetek przedsiębiorstw przemysłu spożywczego współpracujących w ramach inicjatywy klastrowej był ok. 4-krotnie wyższy. Wskazuje to na spontaniczny charakter podejmowania inicjatyw klastrowych, wynikający najczęściej z możliwości ich finansowego wsparcia. Z punktu widzenia wdrażania otwartych innowacji w przedsiębiorstwach przemysłu spożywczego jest to zjawisko niekorzystne [13]. Skłonność do podejmowania kooperacji poszczególnych branż z innymi podmiotami, co jest jedną z podstawowych cech otwartych innowacji, nie była statystycznie istotnie skorelowana z poziomem ich innowacyjności. Szczególnie wyraźne wahania dotyczyły tych branż niskiej techniki, których poziom aktywności w zakresie współpracy nie przekraczał 26%. Przekroczenie tej granicy ewidentnie wskazuje na pozytywny wpływ zewnętrznej wiedzy na poziom innowacyjności poszczególnych branż. Zaliczają się do tej grupy przedsiębiorstwa produkujące artykuły spożywcze (w tym piekarniczo-cukiernicze). Można na tej podstawie sformułować tezę, że wyższy poziom współpracy z podmiotami zewnętrznymi, co jest głównym paradygmatem otwartych innowacji, jest czynnikiem usprawniającym proces innowacyjny w tych branżach [12].

Na Rysunku 2 zaprezentowano zależność pomiędzy procentową ilością przedsiębiorstw innowacyjnych a przedsiębiorstwami współpracującymi w zakresie działalności innowacyjnej.

Dla przedsiębiorstw współpracujących w 30% w zakresie działalności innowacyjnej teoretycznie ilość przedsiębiorstw innowacyjnych wynosi 55%.

$$\hat{y}\,(50) = 1{,}6427 \cdot 50 + 5{,}9255 = 55{,}2\% \qquad (1)$$

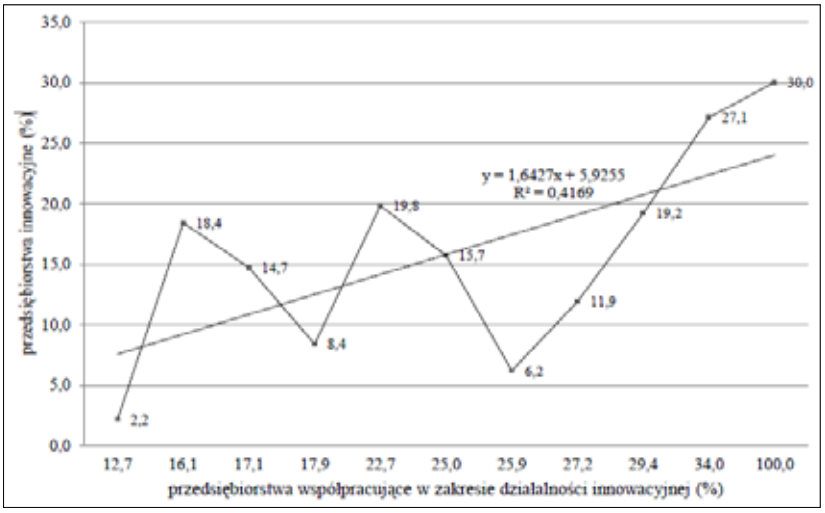


Fig. 2. Tendency to cooperate and the level of innovation.
Rys. 2. Skłonność do podejmowania kooperacji a poziom innowacji.
Source: [12]
Źródło: [12]

Współczynnik determinacji liniowej $R^2 = 0{,}4169 \cdot 100 =$ = 41,69% świadczy o tym, że zmiany ilości przedsiębiorstw innowacyjnych w 41,69% można tłumaczyć zmianami w zakresie działalności innowacyjnej. Wzrost przedsiębiorstw współpracujących w zakresie działalności innowacyjnej o 1% wiąże się ze wzrostem ilości przedsiębiorstw innowacyjnych 1,64%. Współczesne uwarunkowania gospodarcze wymagają działań innowacyjnych prowadzonych także w przedsiębiorstwach zajmujących się produkcją artykułów spożywczych, przy zaangażowaniu jak największej liczby interesariuszy. Powoduje to coraz częstsze przechodzenie od zamkniętych (tradycyjnych) modeli innowacji w kierunku nowego paradygmatu otwartych innowacji. Zakres współpracy podmiotów produkujących artykuły spożywcze z innymi organizacjami, będący podstawą koncepcji otwartych innowacji, wskazuje, że częściej stosują one modele zamkniętych innowacji. Podobne wnioski wynikają z analizy aktywności przedsiębiorstw omawianej branży związanej ze współpracą w ramach inicjatywy klastrowej.

W porównaniu z innymi branżami niskiej techniki podobny do przedsiębiorstw przemysłu spożywczego poziom odnotowano wśród producentów skór i wyrobów skórzanych, wyrobów tekstylnych i mebli. Zdecydowanie wyższy zakres kooperacji występował wśród producentów wyrobów tytoniowych. Najniższą otwartością procesów innowacyjnych cechowała się natomiast branża odzieżowa. Stopień współpracy przedsiębiorstw a poziom ich innowacyjności nie był statystycznie istotny. Oznacza to, że wpływ otwartych modeli innowacji na innowacyjność podmiotów gospodarczych zależy od branży i indywidualnych strategii przyjętych przez przedsiębiorstwa [12].

SPOSOBY WERYFIKACJI INFORMACJI STANOWIĄCYCH PODSTAWĘ BADAŃ

Informacje z badań porównywane były m.in. z informacjami prasowymi, danymi podanymiw Internecie oraz publikacjach naukowych. Bardzo cenne okazały się wyniki rozmów bezpośrednich i kontakty osobiste w ramach różnych struktur organizacyjnych nawiązane z fachowcami z branży,a także obserwacje zachowania i reagowania osób zbliżonych do kierownictwa. Próbę zakładów piekarsko-cukierniczych wyłoniono w następstwie zastosowania procedury losowej. Badaniami objąć można było tylko te zakłady, których kierownictwo zaakceptowało pomysł badania. Na szczęście jednak przypadki odmów udziału w badaniach były nieliczne, a przy tym rozkład ich okazał się losowy ze względu na szereg cech charakteryzujących zakłady.

Część empiryczna opracowana została na podstawie wyników badań przeprowadzonych wśród przedstawicieli kadry kierowniczej przedsiębiorstw oraz klientów firm z branży piekarsko-cukierniczej. Badania realizowane były metodą ankietową. Przeprowadzono je w 2018 roku, objęto ogółem 200 przedsiębiorstw, to jest firmy z sektora małych i średnich przedsiębiorstw z uwzględnieniem podziału na: małe (zatrudniające od 10–50 pracowników) oraz średnie (zatrudniające powyżej 50 pracowników nie przekraczając ilości 250 osób).

Wyniki badań opracowane zostały z wykorzystaniem programu PS IMAGO PRO 4, PS IMAGO 4, IBM SPSS Statistics. Przyjęcie wyżej wymienionych założeń dotyczących liczności próby i okresu badań, pozwoliło na wykorzystanie metod statystycznych, niezbędnych do merytorycznej oceny.

Wśród przedsiębiorstw minimalna liczebność próby wyliczona została według wzoru:

$$N_{min.} = \frac{N_p\,[\alpha^2 f(1-f)]}{N_p\,e^2 + \alpha^2 f(1-f)} \qquad (2)$$

gdzie: $N_{min.}$ – minimalna liczebność próby;
N_p – wielkość populacji, z której brana jest próba (13034 przedsiębiorstw według PKD 10.71.Z – stan na dzień 30.06.2015 r.);
α – poziom ufności dla wyników odczytany z tablic dystrybuanty rozkładu normalnego wynosi 1,96;
f – wielkość frakcji; ponieważ nie jest znana wielkość frakcji, w populacji przyjęto dla f wartość 0,5;
e – założony błąd maksymalny na poziomie 7%, czyli 0,07

Ostatecznie przebadano 200 firm, z których do dalszych badań i analiz zakwalifikowano 181 przedsiębiorstw.

OCENA STOSOWANYCH MODELI BIZNESOWYCH W BRANŻY PIEKARSKO-CUKIERNICZEJ

Badane firmy piekarsko-cukiernicze nie stosują teoretycznie żadnych modeli biznesowych. Nie znają również pojęcia modelu biznesowego. Firmy branży piekarsko-cukierniczej chętnie definiują własne cele strategiczne. Jak wynika z przeprowadzonych badań zaledwie 62% działa w oparciu o obraną

Table 3. Strategies chosen by bakery and confectionery companies

Tabela 3. Strategie obierane przez firmy piekarsko-cukiernicze

Statystyka	Wykorzystania niszy rynkowej	Wykorzystania nisz produktów	Marki (budowanie świadomości marki)	Prędkości (budowanie silnej pozycji przedsiębiorstwa)	Poprzez innowacje	Wykorzystania nisz kooperacyjnych	Brak strategii
Liczba badanych firm	33	15	18	14	30	2	69
Odsetek firm (%)	18,23	8,29	9,94	7,73	16,57	1,1	38,14
Przeciwni franczyzie (%)	74	61	65	69	65	0	65
Za franczyzą (%)	26	39	35	31	35	100	35

Source: The own study

Źródło: Badania własne

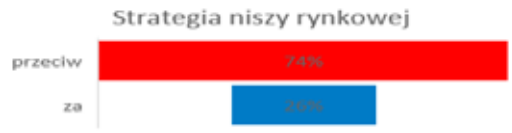
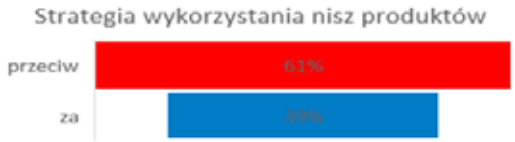
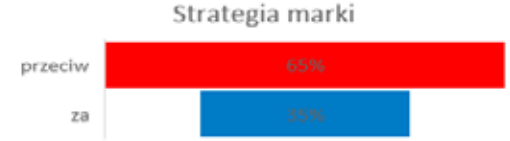
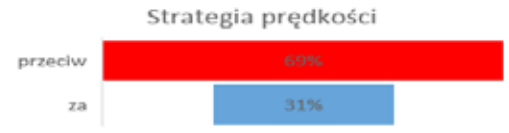
strategię. Blisko 38% niestety nie posiada żadnej strategii rynkowej. Badania opisują również analizę i ocenę stosowanych strategii z perspektywy wykorzystania modelu franczyzy produkcyjnej. Obrana strategia ma wpływ na decyzję o zastosowaniu franczyzy produkcyjnej.

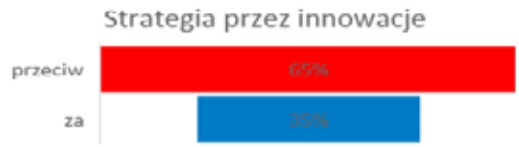
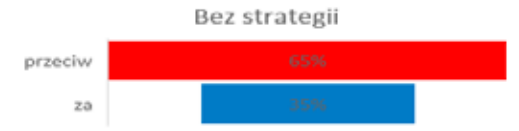
Poniżej przedstawiono różne strategie przyjęte przez firmy w branży piekarsko-cukierniczej. Ponieważ badane firmy nie stosują żadnych modeli biznesowych w działalności, badania przeprowadzono w zakresie strategii jakie firmy obierają. Informację tę skorelowano z odpowiedziami w zakresie możliwości zastosowania franczyzy produkcyjnej.

Firmy branży piekarsko-cukierniczej powinny zdefiniować własne cele strategiczne. Jak wynika z przeprowadzonych badań niewiele firm, bo blisko 62% skłonne jest działać lub próbuje podejmować działania w oparciu o możliwą do zaakceptowania ich zdaniem strategię. Blisko ponad 38% niestety nie posiada żadnej strategii rynkowej. Firmy raczej obserwują i naśladują konkurencję. Zamiast stosować strategię nastawioną na rozwój i ekspansję dążą do utrzymania „status quo", co wywołuje wrażenie stagnacji. Jak wynika z poniższej tabeli obrana strategia może mieć wpływ na decyzję o zastosowaniu franczyzy produkcyjnej, zatem możliwość wykorzystania franczyzy produkcyjnej zależy od obranej (przyjmowanej do realizacji) strategii firm. Faktem jest, że wiele firm teoretycznie zakłada strategie a realizacja jest nieadekwatna do założeń. Wiele firm przyznaje się do braku strategii działania.

Table 4. Various theoretically possible strategies of companies in the bakery and confectionery industry

Tabela 4. Różne teoretycznie możliwe strategie firm w branży piekarsko-cukierniczej

Strategia firmy	
	Skupienie działalności firmy na specyfice i potrzebach klientów określonego obszaru geograficznego
	Strategia dla jednorodnej określonej grupy osób. Dobór grupy produktów i koncepcja ich sprzedaży.
	Sposób budowy tożsamości marki ściśle skorelowany z zadaniami, jakie wyznacza sobie firma, jej strukturą, kulturą organizacyjną. Strategia pozwala wychwycić mocne strony marki, jej unikatowość w porównaniu z konkurencją, dostosowanie do klienta. Strategia polega na budowaniu świadomości marki.
	Strategia polegająca na budowaniu szybkiej silnej pozycji przedsiębiorstwa – lidera w danym obszarze.

Strategia firmy	
	Strategia polegająca na zastosowaniu po raz pierwszy w nowych lub zmodyfikowanych wyrobach zmian w celu uzyskania efektów technicznych, ekonomicznych lub społecznych. Doskonalenie przedsiębiorstwa dzięki zapewnie-niu potencjału ciągłych zmian – produktu, klientów lub regionów.
	Decyzje dotyczące łączenia podmiotów w celu zapewnienia możliwości konkurowania z dużymi organizacjami.
	Utrzymanie dotychczasowego stanu bez zmian.

Source: Own study

Źródło: Opracowanie własne

PODSUMOWANIE

Te przedsiębiorstwa, które obrały strategię i działają w oparciu o strategię nisz kooperacyjnych, w 100% opowiadają się za zastosowaniem franczyzy produkcyjnej. Inaczej wygląda sytuacja gdy skupienie działalności firmy polega na ukierunkowaniu specyfiki i potrzeb klientów określonego obszaru geograficznego (strategia niszy rynkowej). Aż 74% spośród firm, które zadeklarowały stosowanie ww. strategii opowiada się przeciwko zastosowaniu franczyzy produkcyjnej w ich firmach. Strategia tychże przedsiębiorstw opiera się na skupieniu działalności na specyfice i potrzebach klientów określonego obszaru geograficznego (głównie piekarnie -cukiernie regionalne rozprowadzające swoje produkty na obszarze gminy). 26% opowiedziałoby się za chęcią przystąpienia do franczyzy (kwalifikowane jako franczyzobiorcy). Są to głównie małe zakłady piekarsko-cukiernicze, które mają problemy finansowe, problemy związane z produkcją, zatrudnieniem wykwalifikowanych czeladników, firmy o obniżonej innowacyjności, nie posiadające pomysłu na rozwój.

Wśród przedsiębiorstw, które skłonne są postawić na strategię wykorzystania nisz produktów (dobierają wyselekcjonowane produkty i prowadzą koncepcję ich sprzedaży) 61% firm piekarsko-cukierniczych jest przeciwnych zastosowaniu franczyzy produkcyjnej. 39% chciałoby zastosować franczyzę. Tego typu przedsiębiorstwa kwalifikowane byłyby nie jako biorcy ale jako dawcy systemu. Jak wynika z przeprowadzonych badań firmy te oferują wysoko jakościowe produkty o doskonałych walorach smakowych. Wśród 35% badanych firm, które prowadzą strategię marki – a tym samym budują świadomość marki, należy dostrzec potencjalnych franczyzodawców. Firmy z branży piekarsko-cukierniczej działając w oparciu o ww. strategie budują świadomość swojej marki. Ich produkty stają się rozpoznawane na terenie całego kraju jak również za granicą. Oferowane produkty cieszą się popularnością wśród konsumentów. Ograniczeniem rozwoju stają się ograniczone możliwości produkcyjne w zakresie zwiększenia sprzedaży (duże koszty rozbudowy zakładów produkcyjnych). Podobne wnioski można wysnuć wobec firm – zwolenników zastosowania franczyzy i stosujących strategię prędkości (31%) oraz strategię innowacji (35%). Wśród wszystkich badanych przedsiębiorstw piekarsko-cukierniczych, 38% nie posiada żadnej strategii – funkcjonuje na zasadzie „jestem na rynku bo jestem, uda się to się uda", 35% opowiada się za chęcią zastosowania franczyzy. Są to potencjalni franczyzobiorcy. Nie posiadają oni atutów prowadzenia działalności, którymi mogliby pochwalić się dzieląc się doświadczeniami z innymi firmami. Oczekują one wsparcia zarówno pod względem marketingu swoich produktów, ale przede wszystkim uszlachetnienia procesu produkcyjnego, eliminacji marnotrawstwa, wdrożenia nowych sprawdzonych przepisów na sukces.

SUMMARY

Those enterprises that have chosen a strategy and operate on the basis of the cooperative niche strategy are 100% in favor of using the production franchise. The situation is different when the focus of the company's activity consists in targeting the specificity and needs of customers of a specific geographical area (market niche strategy). As many as 74% of the companies that declared the use of the above-mentioned strategy is against the use of manufacturing franchise in their companies. The strategy of these enterprises is based on focusing their activity on the specificity and needs of customers of a specific geographical area (mainly regional bakeries and confectioneries distributing their products in the area of the commune). 26% would be in favor of joining a franchise (qualified as franchisees). These are mainly small bakery and confectionery plants that have financial problems, problems related to production, employment of qualified apprentices, companies with reduced innovation and no idea for development.

Among the enterprises that are willing to bet on the strategy of using product niches (they select selected products and carry out the concept of their sale), 61% of bakery and confectionery companies are against the use of production franchise. 39% would like to use a franchise. Such enterprises would be classified not as recipients but as donors of the system. According to the conducted research, these companies offer high-quality products with excellent taste. Among the 35% of the surveyed companies that pursue a brand strategy – and thus build brand awareness, potential franchisors should be noticed. Companies from the baking and confectionery industry, acting on the basis of the above-mentioned strategies build brand awareness. Their products become recognized throughout the country as well as abroad. The offered products are popular among consumers. Development is limited by limited production capacity in terms of increasing sales (high costs of expansion of production plants). Similar conclusions can be drawn for companies that support the use of franchise and use the speed strategy (31%) and the innovation strategy (35%). Among all the surveyed bakery and confectionery enterprises, 38% do not have any strategy - they operate on the principle of „I am on the market because I am here, it will work out", 35% are in favor of using a franchise. These are potential franchisees. They do not have the advantages of running a business, which they could boast of by sharing their experiences with other companies. They expect support both in terms of marketing their products, but above all, to refine the production process, eliminate waste, and implement new proven recipes for success.

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FOOD SAFETY AND SUPERVISION IN IJHARS ACTIVITIES®

Bezpieczeństwo i nadzór nad żywnością w działalności IJHARS®

Key words: surveillance, food safety, notifications of non-compliance.

The article presents the results of research concerning the assess the scale and type of irregularities found during the inspections conducted by IJHARS in 2017-2021. The research material was the results published by IJHARS, i.e. Annual Reports for 2017–2021. Notifications by category were taken into account. Food and food contact materials were taken into account in the statements. In subsequent years, the number of reported irregularities increased. It was shown that in each year the group of most frequently reported irregularities included meat and meat preparations; fish and fish preparations; fruits, vegetables and their preparations; and dietary supplements. A slight upward trend was found for fish and fish preparations, whereas a downward trend was found for the others. Fats and oils were a significant item in 2021.

Słowa kluczowe: nadzór, bezpieczeństwo żywności, zgłoszenia niezgodności.

W artykule przedstawiono prezentację wyników badań dotyczących oceny skali i rodzaju nieprawidłowości stwierdzanych podczas kontroli prowadzonych przez IJHARS w latach 2017-2021. Materiał badawczy stanowiły wyniki publikowane przez IJHARS, tj. Raporty roczne za lata 2017–2021. Uwzględniono zgłoszenia z podziałem na kategorie. W zestawieniach brano pod uwagę żywność oraz materiały mające kontakt z żywnością. W kolejnych latach wzrastała liczba zgłaszanych nieprawidłowości. Wykazano, że w każdym roku w grupie najczęściej zgłaszanych nieprawidłowości było mięso i przetwory mięsne; ryby i przetwory rybne; owoce, warzywa i ich przetwory oraz suplementy diety. W przypadku ryb i ich przetworów stwierdzono nieznaczną tendencję wzrostową, natomiast spadkową dla pozostałych. W 2021 roku znaczącą pozycję stanowiły tłuszcze i oleje.

INTRODUCTION

Food safety is the totality of conditions that must be met. They include: additives and flavors used; levels of contaminants; pesticide residues; conditions of food irradiation; organoleptic characteristics, as well as the totality of measures that must be taken at all stages of food production or trade [11]. Before the introduction of the Law of 25 August 2006, the concept of quality of health was in force in Polish law. Since 2006, the concept of "health quality" has been replaced by an expanded concept, "food safety" [3]. As Szreniawska [2018] points out, to ensure food safety, the legislator has introduced official inspections. Several inspections are responsible for ensuring food safety in Poland, and the model they have created has been described as distributed [8]. The Agricultural and Food Quality Inspection (IJHARS) inspects the commercial quality of food in the producer and wholesale, including storage and transportation conditions. Commercial Inspection (IH), on the other hand, takes care of the commercial quality of food in retail. According to the Law on Commercial Quality of Agri-Food Articles of December 21, 2000, commercial quality is the characteristics of an agri-food article relating to its organoleptic, physicochemical and microbiological properties in terms of production technology, size or weight, as well as requirements resulting from the manner of production, packaging, presentation and labeling [10]. Importantly, IJHARS is required to provide the European Commission with information on the results of inspections at all stages of marketing. It is responsible for notifying the national point of contact under the RASFF network of the Rapid Alert System for Food and Feed Network (iRASFF system), as well as the actions taken regarding unsafe agri-food items.

The RASFF system is used for the rapid exchange of information on hazards detected in food, feed, and food contact materials [3, 4]. It is administered by the European Commission and was introduced by Council Decision No. 133/84/EEC of March 2, 1984 on a Community system for the rapid exchange of information on hazards arising from the use of consumer products. Currently, the system operates on the basis of Regulation (EC) No. 178/2002 of the European Parliament and of the Council of 28 January 2002 laying

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down the general principles and requirements of food law, establishing the European Food Safety Authority, and laying down procedures in matters of food safety. As of March 2021, networks such as the Rapid Alert System for Food and Feed (RASFF) network, the Administrative Assistance and Cooperation (AAC) systems network, and the Food Fraud Network (FFN) have been working together to enable efficient exchange of information between the competent authorities of member states and facilitate cooperation between them [6]. The European Commission is the administrator of the system.

The article presents the results of research concerning the assess the scale and type of irregularities found during the inspections conducted by IJHARS in 2017–2021.

MATERIAL AND METHODS

The research material consisted of results published by the Agricultural and Food Quality Inspection (IJHARS), i.e., Annual Reports for 2017–2021. Submissions by category were included. The food and materials in contact with food were taken into account in the statements. In the percentage structure, those with at least 2% were presented as separate categories. The others were given together as other. A polynomial trend line was drawn for the categories of reports occurring in each year, i.e., meat and meat preparations; fish and fish preparations; fruits, vegetables and their preparations; and dietary supplements. Calculations were performed using Statistica 13.3.

RESULT AND DISCUSSION

Inspections carried out by IJHARS from 2017 to 2021 showed that meat and meat preparations were the category most frequently reported. Their scale ranged from 26.1% in 2017 (Fig. 1) to 39.6% in 2018 (Fig. 2). In 2017, a high share of notifications was found for fish and fish preparations and dietary supplements /special-purpose products, with 15.9% each in both categories. Data from the 2017 RASFF Annual Report indicate that fish and fish products were the category most frequently reported [4]. Fruits, vegetables and their preparations were also a significant item in 2019. It was 14.2% (Fig. 3). This category was present in every year analyzed, with only 2.8% in 2018 (Fig. 2). Also, a relatively high number of irregularities for dietary supplements were reported. The highest number was found in 2017 and 2020, 15.9% and 14.8%, respectively (Fig. 1 and Fig. 4). In contrast, in 2021, reports of irregularities for the oils and fats category accounted for 18% (Fig. 5). For IJHARS, the definition of adulterated agri-food article found in the Law on Commercial Quality of Agri-Food Articles was decisive in qualifying irregularities [8]. According to Frąś et al. [1], the implementation of the idea of health-safe food cannot be done only by inspecting finished food products. Examination of food products at the end of the technological manufacturing or processing process is not and cannot be sufficient to

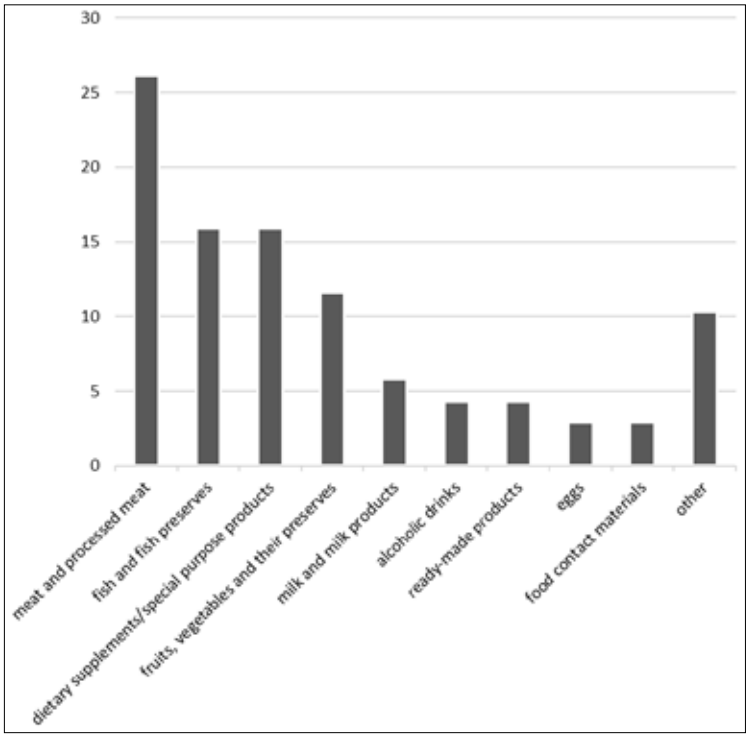

Fig. 1. IJHARS notifications in the AAC system by category in 2017 (%).

Rys. 1. Zgłoszenia IJHARS w systemie AAC z podziałem na kategorie w 2017 roku (%).

Source: The own study [12]

Źródło: opracowanie własne [12]

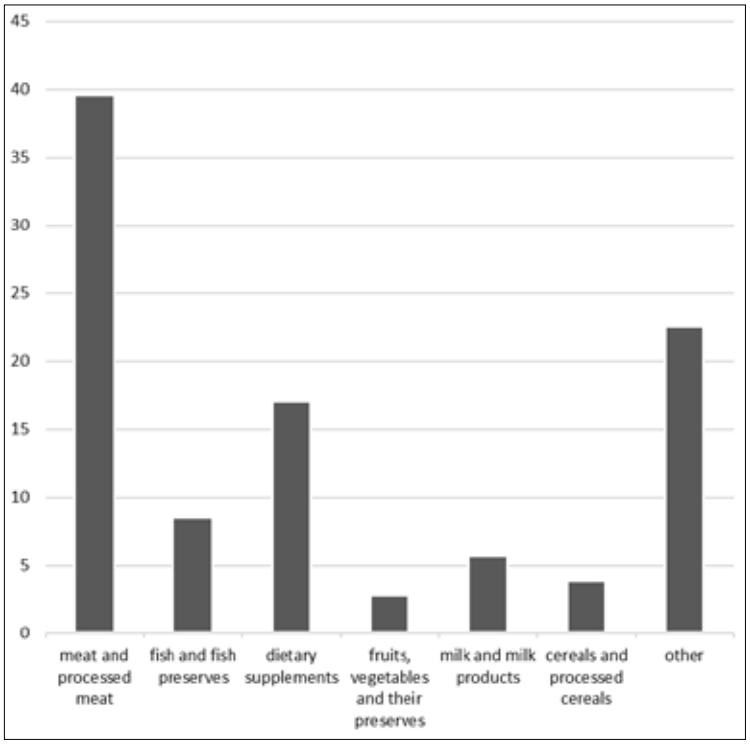

Fig. 2 JHARS notifications in the AAC system by category in 2018 (%).

Rys. 2. Zgłoszenia IJHARS w systemie AAC z podziałem na kategorie w 2018 roku (%).

Source: The own study [13]

Źródło: opracowanie własne [13]

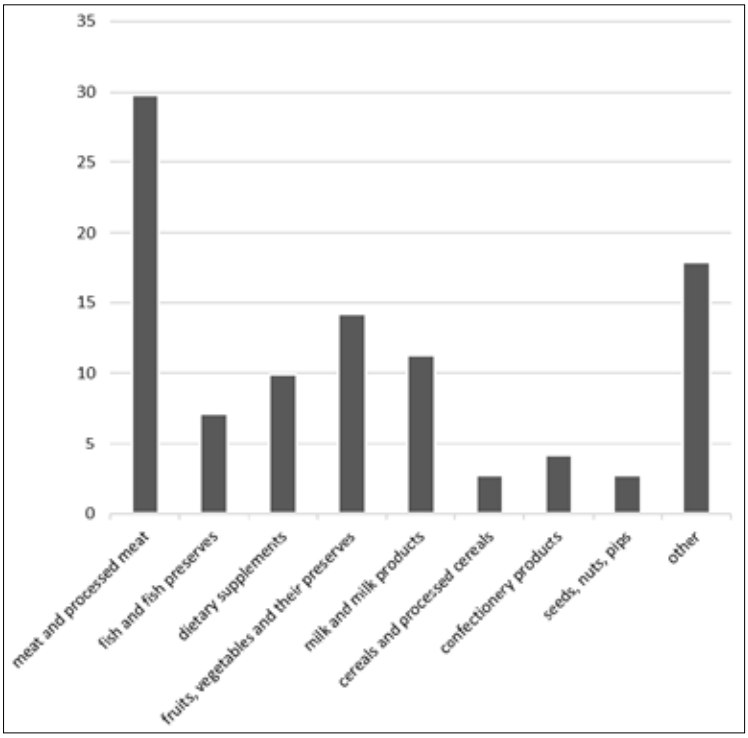

Fig. 3. IJHARS notifications in the AAC system by category in 2019 (%).

Rys. 3. Zgłoszenia IJHARS w systemie AAC z podziałem na kategorie w 2019 roku (%).

Source: The own study [14]

Źródło: opracowanie własne [14]

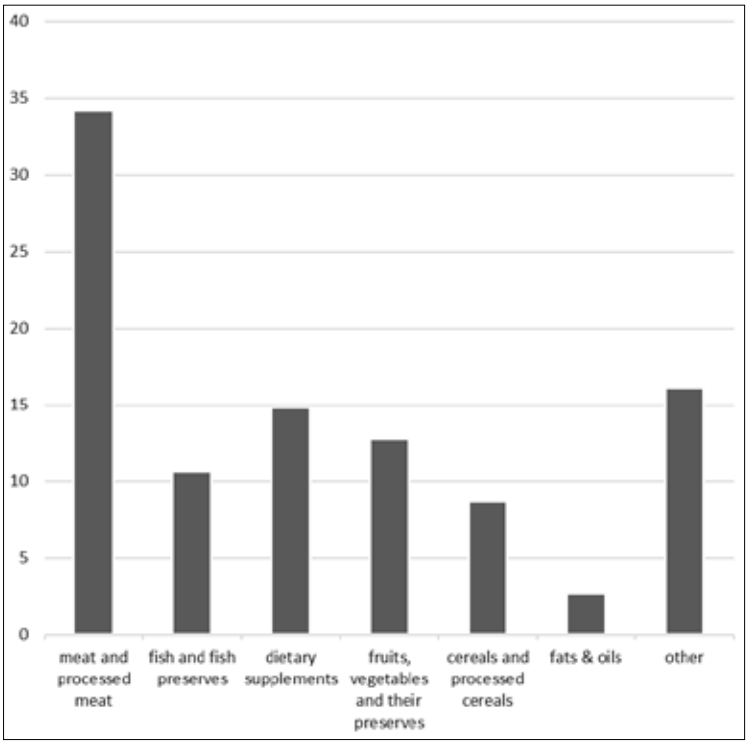

Fig. 4. IJHARS notifications in the iRASFF/ACC-FF system by category in 2020 (%).

Rys. 4. Zgłoszenia IJHARS w systemie iRASFF/ACC-FF z podziałem na kategorie w 2020 roku (%).

Source: The own study [15]

Źródło: opracowanie własne [15]

confirm the appropriate quality and to gain confidence that these products are nutritionally valuable and health safe. The quality management system in agribusiness should be built so that it can be easily programmed, managed, and verified the quality of the production and food produced. The requirements for the quality of manufactured food products are very high and industrial plants, which operate on the basis of quality management programs (GHP, GMP) and the principles of the HACPP system, can ensure the maximum level of safety of manufactured food. It should be noted that thanks to the responsible approach of producers, as well as the effective supervision provided by supervisory institutions, the marketed products are characterized by a high level of safety [2].

The trend analysis for the categories occurring in each year analyzed, i.e., meat and meat preparations; fish and fish preparations; fruits, vegetables and their preparations; and dietary supplements, showed an upward trend only for fruits, vegetables and their preparations. The Law on Commercial Quality [7] excludes health, sanitary, veterinary, and phytosanitary requirements for agri-food items specified in separate regulations from the Inspectorate's scope. However, this does not mean that IJHARS does not have any competencies related to food safety. They concern, for example, the conditions of storage and transport of agri-food articles, assessment of expiration dates or dates of minimum durability a from the point of view of adulteration. The increase in the number of notifications in subsequent years indicates an increase in the number of inspections, but also about the involvement of the Inspectorate. Similarly, as stated in the RASFF report, an increase in the number of notifications for each component of the warning and cooperation network was found in 2021 compared to previous years. This demonstrates the continued commitment of Member States' competent authorities, despite the challenging context of the Covid-19 pandemic, to detect and report noncompliance, whether or not it poses a health risk or is suspected of fraudulent practices [16]. In 2021, all members of the alert and cooperation network were active in the RASFF network, with Germany, Spain, and the Netherlands being the most active with 761,524 and 446 notifications, respectively, followed by Belgium (389), Italy (389) and Poland (335). In 2021, the number of non-compliance reports rose to 2290, and the majority were food-related issues (84%) [16]. In 2021, the most frequently reported product category was fruits and vegetables, accounting for 15% in the system. The second most frequently reported category was dietary foods, dietary supplements and fortified foods (10%), most of which were sold online. Meat and meat products were the third most frequently reported category (6%), with violations ranging from incomplete ingredient and traceability labels to missing or incomplete documentation [16].

CONCLUSIONS

The increasing number of reported irregularities found through inspections by IJHARS between 2017 and 2021 indicates a commitment to ensuring food safety. Providing such information to the iRASFF early warning system increases the credibility of control institutions in the food chain.

WNIOSKI

Zwiększająca się w latach 2017–2021 liczba zgłaszanych nieprawidłowości stwierdzanych w wyniku kontroli prowadzonych przez IJHARS wskazuje na zaangażowanie w zapewnienie bezpieczeństwa żywności. Przekazywanie takich informacji do systemu wczesnego ostrzegania iRASFF zwiększa wiarygodność instytucji kontrolujących w łańcuchu żywności.

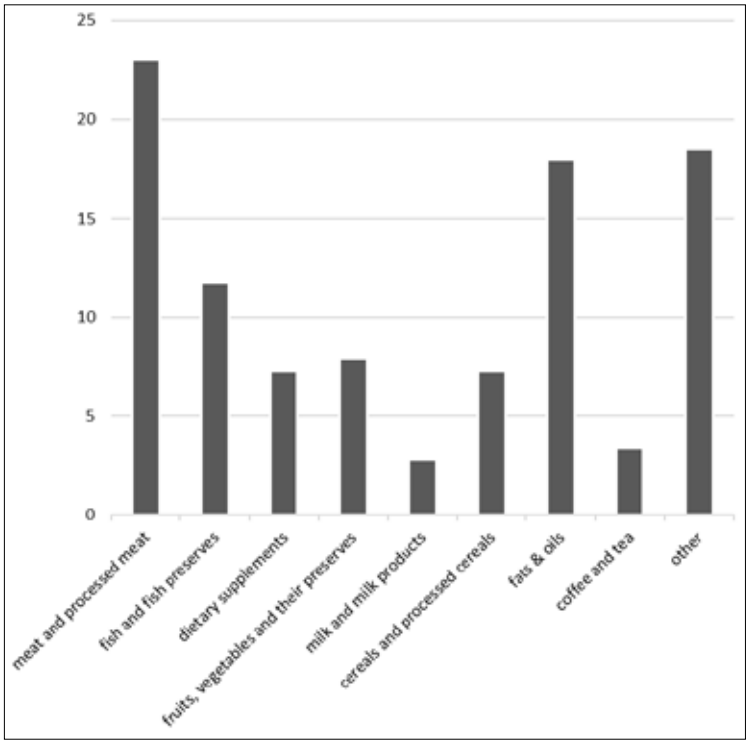

Fig. 5. IJHARS notifications in the iRASFF/ACC-FF system by category in 2021 (%).

Rys. 5. Zgłoszenia IJHARS w systemie iRASFF/ACC-FF z podziałem na kategorie w 2021 roku (%).

Source: The own study [16]

Źródło: opracowanie własne [16]

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SHAPING CROSS-DOCKING FACILITIES IN DAIRY SUPPLY CHAINS®

Kształtowanie obiektów typu cross-docking w łańcuchach dostaw branży mleczarskiej®

Key words: dairy industry, supply chain, cold chain, cross-docking, technical object, distribution logistics.

The article presents variants of shaping cross-docking facilities in which products from the dairy industry are served. Due to the type of goods, it is important to shorten the supply chain, as the products quickly turn sour or change consistency. The cross-docking method is defined as the distribution of goods, which eliminates the stage related to product storage in the supply chain. The goods go from suppliers to the facility, where they are properly consolidated and then directly shipped to a given recipient, in accordance with his order. The technical object aims to simplify the network of connections between them. Thanks to the cross-docking solution, it is possible to obtain shorter order fulfillment times and reduce the costs associated with the storage of goods. The use of appropriate technology in a cross-docking facility improves the flow of cargo, increases process safety and improves efficiency. Considering the dairy industry products, you should also pay attention to the rules and legal regulations that play a very important role in the transport of goods in order to maintain the cold chain.

Słowa kluczowe: branża mleczarska, łańcuch dostaw, łańcuch chłodniczy, cross-docking, obiekt techniczny, logistyka dystrybucji**.**

W artykule przedstawiono warianty kształtowania obiektów cross-dockingowych, w których obsługiwane są produkty z branży mleczarskiej. Ze względu na rodzaj towaru ważne jest skrócenie łańcucha dostaw, ponieważ produkty w niekontrolowanych warunach szybko kwaśnieją lub zmieniają konsystencję. Metoda cross-docking definiowana jest jako dystrybucja towaru, która eliminuje etap związany z magazynowaniem produktów w łańcuchu dostaw. Towar trafia od dostawców do obiektu, gdzie jest odpowiednio konsolidowany, a następnie bezpośrednio wysyłany do danego odbiorcy, zgodnie z jego zamówieniem. Obiekt techniczny ma na celu uproszczenie sieci połączeń między nimi. Dzięki rozwiązaniu cross-docking możliwe jest uzyskanie krótszych czasów realizacji zamówień oraz obniżenie kosztów związanych z magazynowaniem towaru. Zastosowanie odpowiedniej technologii w obiekcie cross-dockingowym poprawia przepływ ładunków, zwiększa bezpieczeństwo procesu i poprawia wydajność. Mając na uwadze produkty branży mleczarskiej należy również zwrócić uwagę na zasady i regulacje prawne, które odgrywają bardzo ważną rolę w transporcie towarów w celu utrzymania łańcucha chłodniczego.

INTRODUCTION

Supply chains should become more resistant to disruptions in the face of a dynamically changing market. To do this, they must be more intelligent, dynamic and equipped with the right information [27, 29]. However, recently there are many reasons why the supply chain has been in crisis. One example is the COVID-19 pandemic that started in March 2020. After the outbreak, a large number of factories suspended their production. As emphasized by the author [28], this resulted in a disproportion between supply and demand. There were delivery delays, logistical problems and restrictions related to international trade. In addition, global supply chains were shaken by Russia's invasion of Ukraine, which began in February 2022. According to [13] the main reasons for the disruptions were Ukraine's exclusion from transit and production problems. It should be emphasized that Ukraine is one of the four most important exporters of wheat in the world. The port blockade has resulted in the transport of grains to the most needy countries such as Ethiopia and Yemen.

The food industry is currently in a crisis. Many producers, in times of high prices of materials and raw materials, consider temporarily suspending production. It could also lead to a disruption of the supply chain and a shortage of products on store shelves [4]. On the other hand, there is a growing demand for products that are characterized by ever higher quality, are the freshest possible and available to the consumer at any

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time. Therefore, it forces a continuous shortening of supply chains. Cross-docking warehouses (transhipment terminals) stand in front of these requirements. The authors [2, 6] claim that these are facilities where the goods are picked up from the supplier and shipped directly to the recipient, skipping the warehousing stage. A properly shaped cross-docking facility shortens the time of handling goods, and thus the time of supply chain execution.

The authors [12, 19] emphasize that a cross-docking warehouse is irreplaceable where efficient transport of products in the shortest possible time is of key importance. Cross-docking devices are used when handling goods with a short shelf life or where fast delivery is important. The dairy industry seems to be susceptible to the implementation of the cross-docking concept. Modern warehouses with appropriately selected technology facilitate the handling of goods and simplify the network of connections in the supply chain, which is extremely important when reloading products from the dairy industry [33].

Supply chains are now evolving towards logistics systems that are more dynamic, more flexible, more customizable, more precise and more efficient. New digital technologies and automation are shaping a new concept of the supply chain. Elements that define the supply chain concept include, for example, the need to use technology to acquire and manage data. In the face of ever more voluminous and complex supply chains, information management has become an indispensable issue to be able to meet market demands. Another thing that is worth paying attention to is the greater integration of individual entities involved in the supply chain and process automation strategies to increase the precision and speed of execution. Effective supply chain management cannot be considered without taking into account the optimization of logistics processes of enterprises [3, 5, 30]. When transporting dairy products, it is very important to follow the rules of the „cold chain" terminology.

Taking into account the above, the authors divided the area of their work into 5 parts. The first part, which is in Chapter 2, provides an analysis of the literature on the legal regulations and rules that must be followed when transporting perishable goods. Chapter 3 presents the needs that contribute to the correct implementation of tasks in cross-docking technical facilities. The suppliers and recipients of the facility have been identified and the basic parameters determining the operation of the cross-docking facility have been described. The next Chapter 4 concerned the definition of design variants. Three variants of the object were presented. The next chapter dealt with the analysis of variants using the multi-criteria point method. The final part of the work presents a summary and conclusions are drawn from the research conducted in the field of shaping cross-docking facilities in the supply chain.

TRANSPORT AND STORAGE CONDITIONS FOR DAIRY PRODUCTS

Legal regulations concerning the transport of food and maintenance of the cold chain

The Polish legislator in the field of the transport of perishable products, including dairy products, derives its regulations from Community legal acts that have been implemented into the Polish legal system. The main act regulating the issue of transporting such means is the agreement on the international transport of perishable food products and on special means of transport for these transports (ATP) of September 1, 1970, which entered into force in Poland on May 15, 1984 (cf. U. 2015 item 667). Each carrier wishing to transport perishable foodstuffs is required to have a valid ATP certificate, which confirms that the means of transport meets the requirements of the ATP Agreement. The products of the dairy industry, as well as most of the perishable products, are susceptible to the development of microorganisms, e.g. bacteria and fungi, hence it is so important to observe the rules of transport hygiene and to maintain the efficiency of devices ensuring the control of the correct temperature of the transported products. In this regard, it is important that the products are transported at temperatures in accordance with the manufacturer's recommendation or the table contained in the ATP Agreement [1].

To maintain the freshness of dairy products and their desired quality, it is crucial to properly cool them and maintain a proper cold chain, because cooling is one of the most effective methods of extending the shelf life of the dairy industry [31]. By the cold chain, the authors [10, 26, 33] understand the proper organization of production, transport and storage in thermally controlled conditions, limiting the risk of product spoilage. The threats to the maintenance of the cold chain are, in particular, microbiological processes, physical changes and damage to the transported goods, chemical contamination and contamination, improper selection of the means of transport, packaging or containers, inadequate qualifications and training of the personnel, irregularities in the shipping documentation (in particular with regard to the desired temperature or type of transported food), damage to refrigeration equipment, which may also be caused by pests, i.e. rodents and insects [11].

Already at the production stage, it is important to ensure proper hygiene of both employees and production equipment, so that the product intended for the market meets the appropriate standards. For this purpose, modern dairy plants are equipped with systems monitoring the quality of products and their temperature. The response to the market requirements and the growing awareness of consumers is also the development of product packaging in the dairy industry [32]. A new trend on the market is the use of intelligent packaging equipped with an indicator that monitors specific parameters, including temperature - if the product reaches a temperature higher than recommended, the indicator permanently discolours to a certain color, thus informing the potential consumer that the product may have been stored at too high a temperature, which may translate into the quality and freshness of the product [15, 18].

Maintaining the cold chain is important because it affects the safety of the consumer who finally receives the product, so it is so important that the product is stored at the right temperature from the moment of production, as the authors [7, 24] claim. For the dairy industry, the temperature will most often be +6°C. As an exception, UHT sterilized milk can be stored under ambient conditions, ie approx. 25°C. Depending on the season, it will be necessary to either cool it down properly or warm it up properly so that the product does not freeze. However, short-term increases in storage and

transport temperature by a maximum of 3°C, resulting from the undertaken technical activities necessary to perform the transport service, are permissible [33].

A critical point in maintaining the cold chain is the reloading of cooled products, e.g. from a refrigerated trailer to the warehouse. In order to reduce the undesirable risk of temperature rise, modern warehouses are equipped with insulated airlocks – the door of the vehicle's trailer during unloading is surrounded as tightly as possible by a lock isolating the air supply from the outside [9]. This allows you to protect the goods against uncontrolled and undesirable temperature rise, and also has a positive effect on hygiene in contact with food.

Decision support in shaping logistics facilities in supply chains

There are many publications relating to decision support in various areas. The authors [23] presented decision support in the case of container reloading services at an intermodal railroad terminal. In another example, the authors [14] use fuzzy logic to support decisions in transport development planning. The authors [22] investigate the implementation of RFID in the supply chain. Among other things, in technical facilities. It is a very important element that can support the decision in shaping cross-docking facilities. It was the authors [16] who drew attention in their publication to the shaping of warehouse facilities.

Shaping cross-docking facilities should take into account, first of all, the purpose of the facility, which affects both the size and height of the building, the applied finishing standard and the internal transport solutions used. It is worth paying attention to the location and size of the plot. Much depends on the type of product to be stored in the hall. In the case of handling goods from the dairy industry, it is worth locating the technical facility as close to the collection points as possible. In this way, the product path is shortened, there is less likelihood of exposing the enterprise to loss [21, 25]. When it comes to products that are characterized by fast rotation, it is important to be close to the main communication routes.

Shaping cross-docking facilities requires the organization and distribution of appropriate work departments in different parts of the facility. When designing a facility, attention should be paid to a storage system that meets the required needs. They are: the best use of space, limiting the reloading of goods to a minimum, easy access to the stored product, the maximum possible rotation rate, maximum flexibility in product stacking and easy control of the number of stored goods. Technical requirements are important – if the type of stored products determines the need to maintain a constant temperature, this must be taken into account at the design stage.

The fast rotation of goods in the cross-docking facility means that it does not need to be equipped with racks, which in turn has an impact on the height of the hall. An ideal cross-dock facility is one in which as many docks as possible can appear in a small space. For such investments, the developer should provide additional equipment such as hydraulic ramps, ramps, bridges and comprehensive reloading systems. A maneuvering area of an appropriate size is also important, clearly larger than in the case of a standard logistics facility, as well as a large number of parking and parking spaces [16, 20].

DETERMINING THE NEEDS FOR THE IMPLEMENTATION OF TASKS IN CROSS-DOCKING TECHNICAL FACILITIES

Identification of suppliers and recipients

Goods from dairy cooperatives are delivered to the warehouse. The table 1 below lists the types of dairy products and specifies the requirements for their transport and storage.

Table 1. Storage and transport conditions for selected dairy products

Tabela 1. Warunki przechowywania i transportu wybranych produktów mlecznych

Product name	Storage and transport temperature
Butter	≤ 6°C
Fresh dairy products	≤ 6°C
Smoked cheese and yellow cheese	≤ 10°C
Pasteurized milk	≤ 6°C
UHT sterilized milk	≤ 25°C

Source: The own study

Źródło: Opracowanie własne

The logistic task of the facility, generally speaking, is related to the determination of the type of cargo that is delivered to the warehouse. Illustrates the inlet and outlet flow rates. The logistics task shows the number of vendors and customers that are served by the warehouse. The term also defines data on 24 hours of deliveries and collections. Accordingly, identifying all the information provides the basis for designing a logistics system.

The cross-docking warehouse is located in central Poland. The location is convenient due to the elements related to the local labor market, i.e. the available workforce and its costs. An equally important factor is the vicinity of modern road infrastructure, as well as the main communication arteries. Considering the dairy industry goods handled by the warehouse, the quality of deliveries is very important. Suppliers cooperating with the warehouse are three dairies located in the Mazowieckie Voivodeship. The recipients are the ten branches of the self-service wholesalers' networks. Branches are scattered all over Poland [17].

Suppliers ship pallet units of homogeneous goods. The base is a EUR 1 pallet with dimensions of 1200 x 800 [mm]. Road transport is delivered by units in refrigerated semi-trailers, which have a capacity of 33 [units]. Transporting loads on a pallet involves the risk of damage during transport. The units are secured with foam corners. Layers of cardboard boxes or packs are interleaved with cardboard spacers. The stretch film is used to wrap the whole thing to strengthen the structure. Thanks to this, the goods are stabilized, which reduces the risk of damage to the parcels. The weight of the unit does not exceed 700 [kg], and the height does not exceed 1.4 [m].

Taking into account the goods from the dairy industry handled in the cross-docking warehouse, presented in tab. 1, it was assumed that the temperature inside the object is 6. At the transhipment terminal, both deliveries and shipments take place at night, which minimizes the inadequate influence of high temperatures. They are implemented evenly over their time windows. Goods are received at the cross-docking warehouse from 22:00 to 4:00. However, shipments of goods from the warehouse are carried out from 24:00 to 6:00.

Assumptions determining the work of the cross-docking facility

A warehouse facility that is to function rationally requires the presentation and definition of the values of all parameters that directly affect the warehouse process being carried out [17, 20]. The table below presents the basic parameters that were used to design a cross-docking warehouse.

Table 2. Parameters determining the work of the cross-docking warehouse

Tabela 2. Parametry określające pracę magazynu cross-dockingowego

Parameter	Symbol	Value	Unit
Annual transhipment on entry	P_{wy}^{R}	611750	[jlp/year]
Number of working days	d_r	300	[days]
Impact factor at the entrance	φ_{we}	1,25	[-]
Exit damming coefficient	φ_{wy}	1,25	[-]
Vehicle filling at the entrance	Z_{ST}^{we}	30	[jlp/vehicle]
Filling the vehicle at the exit	Z_{ST}^{wy}	27	[jlp/vehicle]
Working time utilization factor	φ_t	0,90	[-]
Technical availability coefficient	φ_{gt}	0,95	[-]
Work area change factor	φ_{zo}	0,95	[-]
Non-mechanical equipment maintenance cost index	γ_W	0,10	[-]
Fixed elements maintenance cost index	γ_B	0,08	[-]
The index of costs of repairs and inspections of devices	γ_T	0,12	[-]
Index of costs of repairs and inspections of control devices	γ_S	0,30	[-]
Plant cost index	γ_{kz}	0,70	[-]
Equipment depreciation cost index	α_1	0,12	[-]
Capital interest rate	α_{2T}	0,02	[-]

Source: The own study

Źródło: Opracowanie własne

VARIANT DESIGN OF THE WAREHOUSE AND WAREHOUSE PROCESS

Choosing a unit storage method and product dispensing techniques is a very complex process. When designing the warehouse, attention was paid to factors such as [16, 25]: product storage period, quantity and type of goods, type of goods packaging, rules relating to goods storage, occupational health and safety, and technological layout in the facility.

The attention was paid to the conditions that enable the optimization of the use of warehouse space and efficient work. Correctly selected technology results in solving problems that result from improper management of the warehouse space. Based on the data presented in Chapter 3, three variants of the cross-docking warehouse have been designed. They differed from each other in the technology used. Each facility has the most popular shape of cross-docking facilities, referred to as "I".

Movement of loads is carried out by the multi-touch method, which consists in unloading at the entrance to the buffer areas and then the loads are transported to the exit to the buffer areas from where the loading of external transport vehicles takes place. Pages in the warehouse permanently assigned to deliveries and shipments.

In each variant, the loading docks at the entrance and exit in the warehouse are equipped with the DOBO system (docking before opening). These are the Hörman brand docks. Taking into account the usual docks, the driver of the vehicle must first leave the car, open the rear door one by one, and only then can he start maneuvering the car. The DOBO system works completely different. The truck drives up to the ramp with the door closed. Then, after docking, the dock gate seals are inflated. Only then are the car doors opened. They can also only be opened when transhipment has started. In this way, the goods remain safe in the trailer [34].

This method protects the reloaded goods against the influence of weather conditions. The cold chain is closed. There is greater safety and time savings associated with not having to leave the car for the driver. Reloading takes place in compliance with all hygiene requirements. This means that thanks to this solution it is impossible to get into the warehouse of pollutants or animals. There is also a saving in energy costs. As already mentioned, this limits the temperature exchange. Running the gate behind or in front of the loading dock helps to prevent the formation of thermal bridges. A diagram of the DOBO system operation is presented in the fig. 1 below. The width of the loading docks used is 3.5 [m].

Variant I – frame pallet racks

The first option proposed is interim storage of dairy products in inlet and outlet buffers using pallet frame racks. They are very universal, due to their versatility, i.e. access to all goods. Therefore, the FIFO principle (first in, first out) is maintained in the warehouse. They are characterized by relatively low purchase and operating costs. It is assumed that interim storage takes place on two levels. This is related to the most possible reduction of the volume that must be cooled in the facility due to the type of goods handled. Forklifts with front support for forks and a platform for the operator were used. The designed cross-docking facility for variant I is shown in Fig. 2.

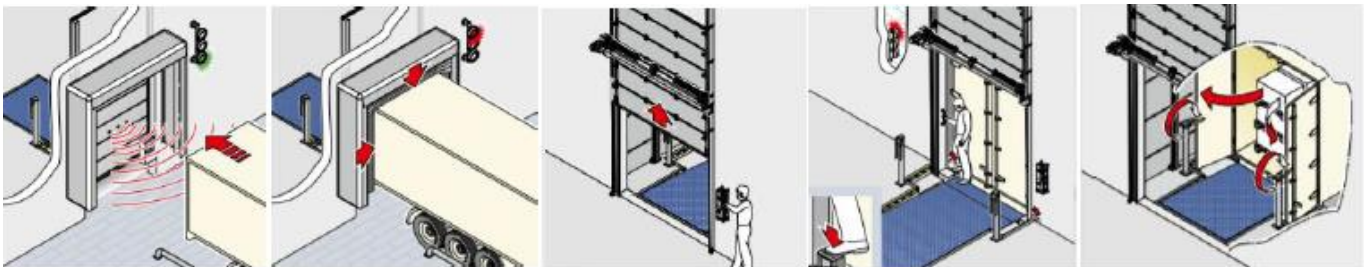

Fig. 1. Operation of loading docks with the DOBO system.
Rys. 1. Obsługa doków przeładunkowych z systemem DOBO.

Source: Own study based on [34]
Źródło: Opracowanie własne na podstawie [34]

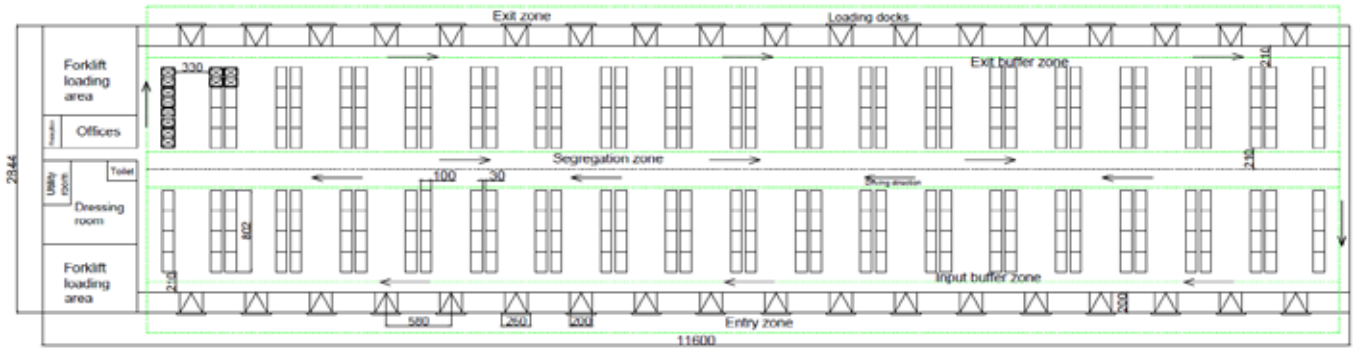

Fig. 2. Top view of the cross-docking terminal project for variant I.
Rys. 2. Widok z góry projektu terminala przeładunkowego dla wariantu I.

Source: Own study based on Auto CAD
Źródło: Opracowanie własne na podstawie Auto CAD

Variant II – flow and push-back racks

Another proposed variant uses buffering in flow and push-back racks. Flow racks were used for input buffers, while push-back racks were used for output buffers. Two types of racks are located opposite the loading dock. Interim storage in option II also takes place in two levels. The variant uses a forklift with front fork support with a platform for the operator and a telescopic mast, and a counterbalance stacker with a base mast.

Pallets are placed in the flow racks. They are built at a slight slant and contain belts with rollers. If necessary, it is possible to move the goods to the other side of the rack. Thanks to these racks, you save time when reloading products. The FIFO method is ideal for storage. The warehouse space is optimally used. The disadvantage of using flow racks is the high cost at the design stage.

In push-back racks, loading takes place by pushing a pallet with a trolley into the pallet socket. When using these racks, the storage and handling of pallets is used in the LIFO system (last in, first out).

The cross-docking warehouse with the technology described above is presented in Fig. 3.

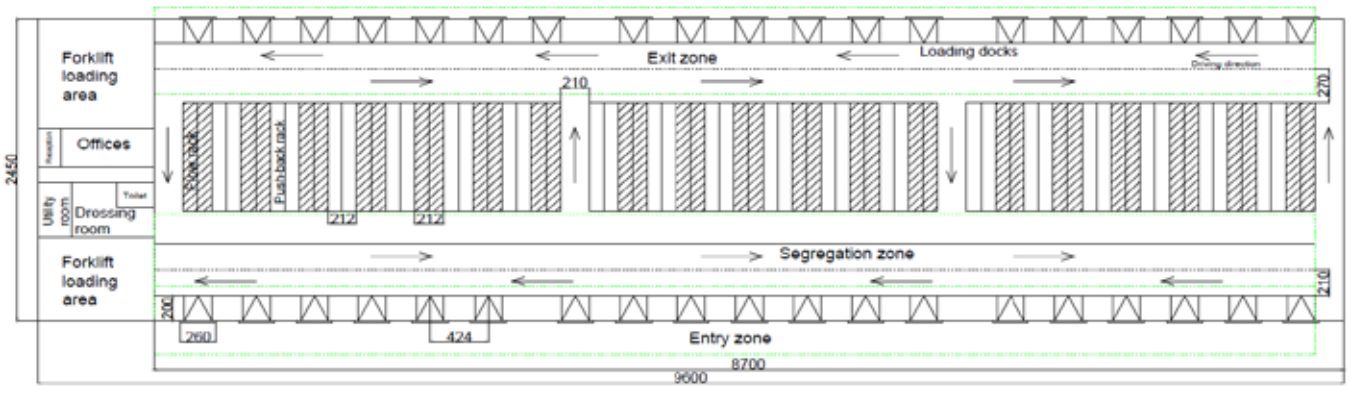

Fig. 3. Top view of the cross-docking terminal project for variant II.
Rys. 3. Widok z góry projektu terminala przeładunkowego dla wariantu II.

Source: Own study based on Auto CAD
Źródło: Opracowanie własne na podstawie Auto CAD

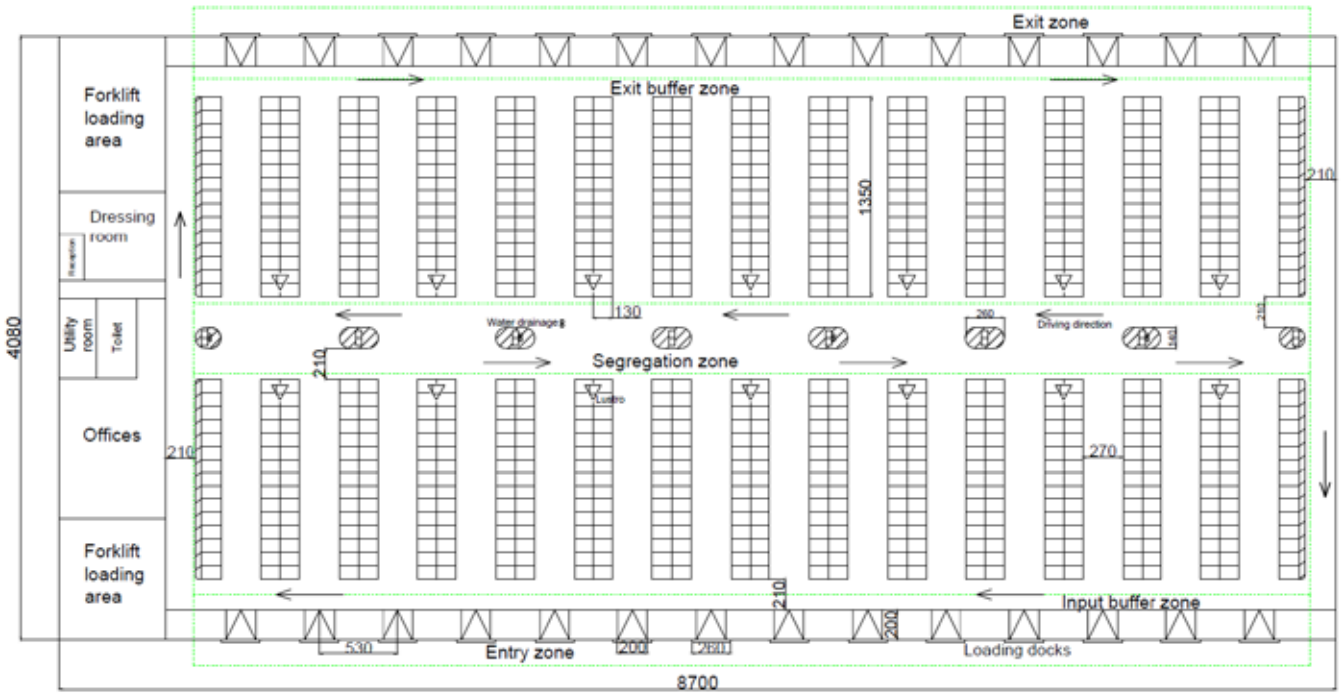

Fig. 4. Top view of the cross-docking terminal project for variant III.
Rys. 4. Widok z góry projektu terminala przeładunkowego dla wariantu III.

Source: Own study based on Auto CAD

Źródło: Opracowanie własne na podstawie Auto CAD

Variant III – buffering on the floor

The last option proposed is buffering the units on the floor. The devices used for this option are lifting trucks with an operator platform. The units are placed side by side on the floor, without the use of racks and without damming up. This is a temporary storage buffer that is used to temporarily store products that are to be sorted and released without being saved.

MULTI-CRITERIA EVALUATION OF VARIANTS WITH THE SCORING METHOD

For the evaluation of individual variants, the evaluation criteria were calculated and compiled. The first table shows the total costs and inputs for each of the options presented.

Table 3. Costs and outlays of individual variants of the cross-docking facility

Tabela 3. Koszty i nakłady dla poszczególnych wariantów obiektu cross-dockingowego

	Operating costs [zl/rok]	Investment outlays [zl]
Variant I	6 424 613,7	8 993 681
Variant II	7 019 144,1	10 370 150
Variant III	6 305 518,5	9 465 308

Source: The own study

Źródło: Opracowanie własne

The following table summarizes the number of employees and devices needed for each design variant.

Table 4. The required number of employees and devices for each variant

Tabela 4. Wymagana liczba pracowników i urządzeń dla każdego wariantu

	Employees [-]	Equipment [-]
Variant I	43	43
Variant II	41	41
Variant III	36	31

Source: The own study

Źródło: Opracowanie własne

The indicators and measures for each of the proposed design solutions of the cross-docking warehouse were also calculated. The results are shown in the table below.

Table 5. Selected measures for the assessment of design variants

Tabela 5. Wybrane mierniki i wskaźniki do oceny wariantów projektowych

	Surface meter [m^2/jlp]	Cubature meter [m^3/jlp]	Outlays for one pallet place [zl/jlp]	Cost for the unit to pass through the warehouse [zl/jlp]
Variant I	2,12	8,42	7666	10,47
Variant II	2,07	9,26	9002	11,44
Variant III	4,08	16,37	8936	10,27

Source: The own study

Źródło: Opracowanie własne

On the basis [8] of [15] and the assessment of design variants was started. By analyzing the above tables, the variants were assessed. For this purpose, one of the ranking methods was used - the scoring method. It consists in adding up the values of the standardized features for individual design variants based on the adopted criteria. The variants are ranked sequentially according to the decreasing value of the evaluation index. Thanks to this, it is possible to find the best solution objectively and to group the solutions into categories depending on the assessment.

Chapter 4 defines variants of a technical object. Then a set of goals and criteria was established. The individual goals were assigned the following weights:

- technical purpose $c = 1{:}w_1 = 0{,}3$;
- economic purpose $c = 2{:}w_2 = 0{,}6$;
- environmental purpose $c = 3{:}w_3 = 0{,}1$.

Then, the weights for the given criteria were determined on the basis of comparability, so that the weights of individual criteria were in the range [0; 1]. The sum of the weights for one target must be 1. It is presented in the table below.

Table 6. Assigning weights to individual goals and criteria

Tabela 6. Przypisywanie wag poszczególnym celom i kryteriom

Purpose	Purpose number	Purpose weight	Criterion	Criterion weight
Technical purpose	$c = 1$	0,3	Employees	0,5
			Equipment	0,5
			Sum	1
Economic purpose	$c = 2$	0,6	Operating costs	0,2
			Investment outlays	0,2
			Surface meter	0,1
			Cubature meter	0,1
			Outlays for one pallet place	0,2
			Cost for the unit to pass through the warehouse	0,2
			Sum	1
Environmental purpose	$c = 3$	0,1	Safety	0,5
			Accessibility of convenient access roads	0,5
Sum		**1**	**Sum**	**1**

Source: The own study
Źródło: Opracowanie własne

Due to the normalization of the ratings, the next step was to assign to each of the criteria whether it was a stimulant or a destimulant. Then, the values of evaluations of given decision variants were normalized. Before starting the selection of the variant, it was also necessary to determine the aggregated values of the evaluation indicators. As a result, it was possible to obtain a ranking of variants with the number of points. The steps described have been calculated and tabulated.

SUMMARY AND CONCLUSIONS

The aim of the article was to shape design variants for a cross-docking facility that served products from the dairy industry. It carries out activities such as unloading, loading, consolidation, which are carried out in the warehouse directly between external means of transport located in the reception and release docks, with the elimination of storage. This solution is used in the distribution network system. Cross docking is the optimization of storage and transport costs by shortening the supply chain.

Shortening the supply chain thanks to cross-docking facilities is a matter of ensuring the smooth functioning of logistics processes in them. This is due to the optimal organization of storage space and the use of appropriate storage systems. Since loads have to be transported as quickly as possible, the first step is to simplify your warehouse operations. Therefore, attention has been focused on shortening the routes that operators have to cover to an absolute minimum, or installing conveyor loops that will be responsible for the movement of loads in the technical facility.

In the case of high-turnover products, it is important to have direct access to them in a cross-docking facility. It is also important to optimally plan the loading docks in the warehouse. Their arrangement and communication with other areas of the facility should facilitate the effective collection and shipment of a large number of loads.

In variant I, interim storage was used in palet frame racks, which are located in the input and output buffering zone. The loads are stored in two levels. This resulted in the limitation of the cubature that needs to be cooled. The expenditure on this option turned out to be the lowest, and the maintenance costs were not much higher than in the case of variant III.

Variant II included the use of flow racks and push-back racks. Storage also takes place on two levels. However, the disadvantage of the variant is that the racks require a slope and the technical object, despite the more modern use of technology, turned out to be higher than in the case of variant I. The outlays and costs also proved to be the highest of all variants.

Variant III is a comparison of the two previous variants with the variant without the use of any shelves. Buffering takes place on the floor. This variant had the worst use of space and cubature. However, it had the lowest cost and relatively low outlay. This was due to the use of the simplest technologies.

When analyzing the conducted multi-criteria analysis using the point method, it can be noticed that variant III turned out to be the objectively best solution. It is related to the shortest time of activities performed in the terminal. This is very important for the supply chain. This also translates into a smaller number of workers and equipment needed, taking into account the other variants. Going further, it also reduces operating costs and the cost of passing one unit through a cross-docking facility. Variant III, despite the largest area, achieved low investment outlays. This was due to the lack of shelving and the low number of required devices.

Variant I was the second in the preferred order of choice. It was distinguished by the lowest expenditures. Its surface was much smaller than in variant III and the technology used was cheaper than in variant II. In variant I, the costs of cooling the

Table 7. Evaluation of individual variants

Tabela 7. Ocena poszczególnych wariantów

Purpose	Purpose weight	Criterion	Criterion weight	Normalization	Variant 1			Variant 2			Variant 3		
					Evaluation	Evaluation after normalization	Points	Evaluation	Evaluation after normalization	Points	Evaluation	Evaluation after normalization	Points
Technical	0,3	Number of employees	0,50	Destimulant	43	0,84	0,126	41	0,88	0,126	36	1,00	0,150
		Number of equipment	0,50	Destimulant	43	0,72	0,108	41	0,76	0,108	31	1,00	0,150
Economic	0,6	Operating costs	0,17	Destimulant	8993681	1,00	0,102	10370150	0,87	0,088	9465308	0,95	0,097
		Investment outlays	0,17	Destimulant	6424614	0,98	0,100	7019144	0,90	0,092	6305519	1,00	0,102
		Surface meter	0,16	Destimulant	2,12	0,98	0,094	2,07	1,00	0,096	4,08	0,51	0,049
		Cubature meter	0,16	Destimulant	8,42	1,00	0,096	9,26	0,91	0,087	16,37	0,51	0,049
		Outlays for one pallet place	0,17	Destimulant	7666	1,00	0,102	9002	0,85	0,087	8936	0,86	0,088
		Cost for the unit to pass through the warehouse	0,17	Destimulant	10,47	0,98	0,100	11,44	0,90	0,092	10,27	1,00	0,102
Environmental	0,1	Safety	0,50	Stimulator	1,00	0,92	0,045	1,91	1,51	0,087	1,1	1,00	0,050
		Accessibility of convenient access roads	0,50	Stimulator	3	1,00	0,050	3	1,00	0,050	3	1,00	0,003
SUM	**1**				**SUM**		**0,923**	**SUM**		**0,924**	**SUM**		**0,839**

Source: The own study

Źródło: Opracowanie własne

technical facility are lower than in variant III. On the other hand, the advantage of variant II is the low area and cubature index. This variant was the worst. This is due to the long cycle times which are caused by the high average stacking heights or picking up pallet load units from the racks. This option is the most time consuming from a supply chain point of view. As already mentioned, this variant required the greatest expenditure to use the racks used in it. It also used expensive counterbalanced trolleys as it was important to provide some tractive effort to service the push-back racks. Safety in the warehouse was also noted. It is related to the performance of specific activities.

PODSUMOWANIE I WNIOSKI

Celem artykułu było ukształtowanie wariantów projektowych dla obiektu cross-dockingowego, który obsługiwał produkty z branży mleczarskiej. Realizuje on czynności takie jak rozładunek, załadunek, konsolidacja, które są wykonywane w magazynie bezpośrednio pomiędzy zewnętrznymi środkami transportu zlokalizowanymi w dokach na wejściu i wyjściu, z wyeliminowaniem składowania. Rozwiązanie to stosowane jest w systemie sieci dystrybucji. Cross docking to optymalizacja kosztów magazynowania i transportu poprzez skrócenie łańcucha dostaw.

Skrócenie łańcucha dostaw dzięki obiektom cross-dockingowym to kwestia zapewnienia w nich sprawnego funkcjonowania procesów logistycznych. Wynika to z optymalnej organizacji przestrzeni magazynowej oraz zastosowania odpowiednich systemów składowania. Ponieważ produkty z branży mleczarskiej muszą być transportowane w jak najkrótszym czasie, pierwszym krokiem jest uproszczenie operacji magazynowych. Dlatego też zwrócono uwagę na skrócenie do absolutnego minimum tras, które muszą pokonywać operatorzy, czy też zaimplementowanie odpowiedniej technologii, która jest odpowiedzialna za przemieszczanie i obsługę ładunków w obiekcie technicznym. W przypadku produktów o wysokiej rotacji ważny jest bezpośredni dostęp do nich w obiekcie cross-dockingowym. Istotne jest również optymalne zaplanowanie doków przeładunkowych w magazynie. Ich rozmieszczenie i komunikacja z innymi obszarami obiektu powinny ułatwiać sprawne pobieranie i wysyłanie dużej liczby ładunków.

W wariancie I zastosowano składowanie tymczasowe w regałach ramowych paletowych, które znajdują się w strefie buforowania wejścia i wyjścia. Ładunki składowane są na dwóch poziomach. Spowodowało to ograniczenie kubatury wymagającej chłodzenia. Nakłady na ten wariant okazały się najniższe, a koszty utrzymania były niewiele wyższe niż w przypadku wariantu III.

W wariancie II zastosowano regały przepływowe i regały typu push-back. Składowanie również odbywa się na dwóch poziomach. Wadą wariantu jest jednak to, że regały wymagają nachylenia, a obiekt techniczny, mimo nowocześniejszego zastosowania technologii, okazał się wyższy niż w przypadku wariantu I. Nakłady i koszty również okazały się najwyższe ze wszystkich wariantów.

Wariant III to porównanie dwóch poprzednich wariantów z wariantem bez zastosowania jakichkolwiek regałów. Buforowanie odbywa się na posadzce. Wariant ten charakteryzował się najgorszym wykorzystaniem przestrzeni i kubatury. Miał jednak najniższy koszt i stosunkowo niskie nakłady. Wynikało to z zastosowania najprostszych technologii.

Skupiając uwagę na przeprowadzonej analizie wielokryterialnej metodą punktową można zauważyć, że obiektywnie najlepszym rozwiązaniem okazał się wariant III. Jest to związane z najkrótszym czasem wykonywania czynności w terminalu. Jest to bardzo istotne z punktu widzenia łańcucha dostaw produktów z branży mleczarskiej. Przekłada się to również na mniejszą liczbę potrzebnych pracowników i urządzeń, biorąc pod uwagę pozostałe warianty. Idąc dalej, zmniejsza to również koszty operacyjne oraz koszt przejścia jednej jednostki przez obiekt cross-dockingowy. Wariant III, mimo największej powierzchni, osiągnął niskie nakłady inwestycyjne. Wynikało to z braku regałów i małej liczby wymaganych urządzeń.

Wariant I stał drugi w preferowanej kolejności. Wyróżniał się najniższymi nakładami. Jego powierzchnia była znacznie mniejsza niż w wariancie III, a zastosowana technologia tańsza niż w wariancie II. W wariancie I koszty chłodzenia obiektu technicznego są niższe niż w wariancie III. Natomiast zaletą wariantu II jest niski wskaźnik powierzchni i kubatury. Ten wariant okazał się najgorszy.

Wynika to z długich czasów cykli, które wynikają z czynności układania oraz pobierania jednostek ładunkowych paletowych z regałów. Wariant ten jest najbardziej czasochłonny z punktu widzenia łańcucha dostaw produktów mlecznych. Jak już wspomniano, wariant ten wymagał największych nakładów na wykorzystanie zastosowanych w nim regałów. Wykorzystano w nim również drogie wózki z przeciwwagą, gdyż ważne było zapewnienie siły pociągowej do obsługi regałów push-back. W analizie zwrócono uwagę również na bezpieczeństwo w magazynie.

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NEEDS VS OPPORTUNITIES TO REVITALIZE LOCAL AGRIFOOD MARKETS, INCLUDING THE DEVELOPMENT OF ON-FARM PROCESSING®

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Key words: agri-food processing, local agri-food market, direct sales of agri-food products, agricultural retail trade, management.

After Poland's accession to the EU, there have been many unfavorable changes in production and the agri-food market, especially for the local market. Agricultural production is, so to speak, frozen in a large percentage of farms. In order to develop and support forms of direct sales of agricultural products - produced and processed on farms, liberalization of administrative and veterinary regulations and procedures would be required, especially with regard to regulations on the marketing of agricultural products at markets. In addition, to elaborate, the development of local agri-food markets will be conditioned by the necessary measures to increase the interest of large retail chains in commodity supplies from Polish agriculture and the repolonization of the agri-food industry operating in Poland in order to link it more closely to the domestic raw material base.

Słowa kluczowe: przetwórstwo rolno-żywnościowe, lokalny rynek rolno-żywnościowy, sprzedaż bezpośrednia produktów rolno-żywnościowych, rolniczy handel detaliczny, zarządzanie.

Po akcesji Polski do UE nastąpiło wiele niekorzystnych zmian w zakresie produkcji i rynku rolno-żywnościowego, zwłaszcza lokalnego. Produkcja rolna jest niejako zamrożona w dużym odsetku gospodarstw rolnych. W celu rozwinięcia i wsparcia form sprzedaży bezpośredniej produktów rolnych wytworzonych oraz przetworzonych w gospodarstwach rolnych wymagana byłaby liberalizacja przepisów i procedur administracyjno-weterynaryjnych, zwłaszcza w odniesieniu do przepisów dotyczących obrotu produktami rolnymi na targowiskach. Ponadto, w dłuższym okresie, rozwój lokalnych rynków rolno-żywnościowych uwarunkowany będzie niezbędnymi działaniami w zakresie zwiększenia zainteresowania wielkich sieci handlowych dostawami towarowymi z polskiego rolnictwa oraz repolonizacji funkcjonującego w Polsce przemysłu rolno-spożywczego w celu jego większego powiązania z krajową bazą surowcową.

INTRODUCTION

Today, local sales of agri-food products, especially those of animal origin, have largely disappeared in Poland. The Polish agri-food market, both wholesale and retail, is more than 90 percent controlled by large retail chains (mainly foreign). The monopolistic position of supermarkets is destroying the local agri-food market, while at the same time dictating price conditions, which is particularly acute for Polish consumers in the current economic crisis [1, 5].

These include unprocessed products (vegetables and fruits), which come partially from Polish agriculture, and processed products, coming mainly from non-agricultural agri-food processing.

The marketplace offers vegetable products, often also imported, and animal products, mostly coming from local, non-agricultural processing and still to a small extent from the processing of their own raw materials, carried out directly on the farms concerned.

The purpose of the article is to discuss the needs and possibilities of revitalizing local agri-food markets, through the implementation of on-farm systems of small-scale direct and retail sales of unprocessed and processed agri-food

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products, as well as the application of methods of activating small and medium-sized farms in the case of inclusion of the above farms in state intervention activities (e.g., purchase of products), as well as non-agricultural activities or at the interface of agricultural and non-agricultural activities. These activities would be aimed at strengthening farms economically and increasing expenditures to neutralize expenses related to high administrative and veterinary costs.

PRODUCTION AND COMMERCIAL ACTIVATION OF FARMS

To revive the local agri-food market in Poland and the activation of production and trade on farms is intended to contribute to four forms of small-scale direct sales:

The system (form) of direct sales of unprocessed products of animal origin, exclusively produced, on farms, implemented in Poland since 2016 [6]. This applies to the following products: carcasses and offal of poultry, lagomorphs, game, and products: milk, colostrum, cream, eggs, etc.;

It is assumed that the revival of the local market will be influenced by the currently implemented system (form) of production and trading activities of farms, namely agricultural retail trade – RHD. It is supported financially (investment-wise), starting this year, through grants from the Agency for the Restructuring and Modernization of Agriculture. RHD trade, which is basically an expanded version of the direct sales system, covers both products of plant and animal origin, unprocessed or processed, food, including prepared meals. Thus, it covers all agri-food products that can be produced and processed on farms, while allowing (unlike the direct sales system) the partial purchase of raw materials from outside the farm;

The system (form) of small-scale production and trading activity is the so-called MOL, (i.e., marginal, limited and local), which involves the processing of animal raw materials from its own production or from outside the farm [7]. The food obtained is sold to the final consumer or to a retailer. Processing in this form of business includes the cutting of fresh meat and the production of meat, fish, dairy, egg products and prepared meals;

The system (form) of small-scale activities carried out on farms, are the so-called direct deliveries of raw materials (grains, fruits, vegetables, herbs, mushrooms from own crops, etc.) to final consumers or to retail entities [8].

ADMINISTRATIVE-VETERINARY AND ECONOMIC-POLITICAL CONDITIONS FOR THE DEVELOPMENT OF LOCAL AGRI-FOOD MARKETS

The development of local agri-food markets is in the interest of the already small number of farms with sufficient potential to simultaneously operate a farm and carry out processing of the obtained crops or animal products. Carrying out these two functions on the farm is very difficult and requires a lot of labor, and thus an adequate number of people working. Carrying out these two intensive activities on the farm must be profitable in order to provide an alternative to the relatively profitable off-farm employment. In addition, it must be relatively easy in terms of compliance with regulations and official procedures, including inspections. Meanwhile, the administrative and veterinary regulations and procedures implemented in Poland under the EU's Common Agricultural Policy are excessively burdensome and discourage not only agri-food processing, but even animal husbandry. Official rigor even restricts traditional local trade, including markets. Hence, as much as ca. 80% of Polish farms are livestock-free, that is, they do not keep any livestock [1, 2].

The officially accepted systems of selling agricultural products directly from farms should not be the only acceptable form on the local market. There should be acquiescence to the operation of traditional small-scale marketing of agri-food products in this market. This is possible by the fact that administrative and veterinary (and hygiene) regulations are more liberal (simplified in the MOL system) than in the other systems under discussion [9]. Such differentiation of requirements, results from EU regulations [11, 12]. Therefore, the Polish side should apply to the European Commission for permission for at least temporary liberalization of overly stringent regulations limiting both the production activation of Polish farms and the development of implemented direct sales systems. It is also worth emphasizing that liberalization of some overly stringent regulations would be in line with the principle of freedom of management, declared in Polish legislation and commonly applied outside agriculture [3, 10].

The traditional and relatively widespread production activation of small farms, and the reconstruction of local markets would guarantee the background for the development of officially accepted direct sales systems (for RHD or MOL systems), in which the purchase of off-farm agri-food products is allowed. Such measures in Polish agricultural policy are necessary not only because of the need to shape appropriate health food safety, but also because of the safety of food security. The other aspect of food security is also important because of cyclical economic crises and threats of war crises in our geographic zone.

SUMMARY

Reconstruction of production (especially livestock) on farms smaller in area is not possible without state interventionism and implementation of comprehensive sector programs in the agri-food sector within the framework of Polish agricultural policy. The limited range of instruments of the Common Agricultural Policy does not allow this. This also applies to the agri-food market, deprived, among other things, of the possibility of carrying out intervention buying. The impact of the common agricultural policy on the agri-food sector is mainly reduced to subsidizing farms, according to the rigid scheme of the RDP program, with no non-financial impact on the market. It is necessary to supplement this instrumentarium within the framework of the currently declared Green Deal (for agriculture), favoring farms smaller in area [4]. At the same time, the extended instrumentarium is not envisaged in the approved Polish version of the strategic plan of the Common Agricultural Policy for 2023–2027. It should be recognized that in the absence of a broad instrumentarium, and

therefore in the absence of the possibility of comprehensive support for the restoration of agricultural production, there will be no significant production activation in the next EU financial perspective (2023–2027) on these farms, and in consequence the scope of the direct sales systems (forms) in question, despite tax breaks and investment subsidies, will be insignificant. As a result, insignificant will be the development of local agri-food markets and local agri-food processing on farms in the near term. All the more so since there is no political will to liberalize administrative and veterinary regulations and procedures, which significantly affect the reduction of production, especially animal production, on farms.

In summary, the important issue at present is the liberalization of administrative-veterinary regulations and procedures, especially with regard to regulations on the marketing of agricultural products at markets. In addition, in the longer term, the development of local agri-food markets will be conditioned by the necessary actions to increase the interest of large retail chains in the supply of commodities from Polish agriculture, as well as the repolonization of the agri-food industry operating in Poland in order to link it more closely to the domestic raw material base.

PODSUMOWANIE

Odbudowa produkcji (zwłaszcza zwierzęcej) w gospodarstwach rolnych mniejszych obszarowo nie jest możliwa bez interwencjonizmu państwowego oraz realizacji w ramach polskiej polityki rolnej kompleksowych programów branżowych w sektorze rolno-żywnościowym. Nie pozwala na to ograniczony wachlarz instrumentów wspólnej polityki rolnej. Odnosi się to również do rynku rolno-żywnościowego, pozbawionego między innymi możliwości realizacji skupu interwencyjnego. Oddziaływanie wspólnej polityki rolnej na sektor rolno-żywnościowy sprowadza się głównie do dofinansowania gospodarstw, według sztywnego schematu programu PROW, bez pozafinansowego oddziaływania na rynek. Niezbędne jest uzupełnienie tego instrumentarium w ramach deklarowanego obecnie Zielonego Ładu (dla rolnictwa), faworyzującego gospodarstwa rolne mniejsze obszarowo [4]. Przy czym, rozszerzonego instrumentarium nie przewiduje się w zatwierdzonej polskiej wersji planu strategicznego wspólnej polityki rolnej na lata 2023–2027 r. Uznać należy, że wobec braku szerokiego instrumentarium, a zatem wobec braku możliwości kompleksowego wspierania odbudowy produkcji rolnej, nie nastąpi w najbliższej perspektywie finansowej UE (2023–2027 r.) istotna aktywizacja produkcyjna w tych gospodarstwach, a tym samym zakres omawianych systemów (form) sprzedaży bezpośredniej, mimo ulg podatkowych i dofinansowania inwestycyjnego, będzie nieznaczny. W rezultacie, nieznaczny będzie rozwój lokalnych rynków rolno-żywnościowych i lokalnego przetwórstwa rolno-żywnościowego w gospodarstwach rolnych w najbliższym okresie. Tym bardziej, że nie widać woli politycznej do liberalizacji przepisów i procedur administracyjno-weterynaryjnych, które istotnie wpływają na ograniczenie produkcji, zwłaszcza zwierzęcej, w gospodarstwach rolnych.

Reasumując, kwestią istotną obecnie jest liberalizacja przepisów i procedur administracyjno-weterynaryjnych, zwłaszcza w odniesieniu do przepisów dotyczących obrotu produktami rolnymi na targowiskach. Ponadto, w dłuższym okresie, rozwój lokalnych rynków rolno-żywnościowych uwarunkowany będzie niezbędnymi działaniami w zakresie zwiększenia zainteresowania wielkich sieci handlowych dostawami towarowymi z polskiego rolnictwa oraz repolonizacji funkcjonującego w Polsce przemysłu rolno-spożywczego w celu jego większego powiązania z krajową bazą surowcową.

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EVALUATION OF THE ORGANIZATION AND IMPLEMENTATION OF CHILDREN'S NUTRITION IN CHILD CARE FACILITIES PARTICIPATING IN THE YELLOW PLATE PROGRAM IN 2018-2019®

Ocena organizacji i realizacji żywienia dzieci w placówkach oświaty uczestniczących w programie Żółty Talerz w latach 2018-2019®

Key words: organization of nutrition, evaluation of nutrition, children, child care facilities.

The aim of the study was to assess the organization and implementation of nutrition for children in child care facilities (n=303) participating in the Yellow Plate (ŻT) program in 2018-2019. The study was carried out in January 2019 throughout the country with the CAWI (Computer Assisted Web Interview) method. The survey included 42 questions, including questions about the child care facilities, children attending this institution, the organization and implementation of nutrition in the institution and the perception of the ŻT program. In total, 859 children ate meals in the surveyed facilities, including 426 receiving meals under the ŻT program. In 7 out of 10 institutions ŻT program was the only one aimed at supporting the child nutrition system. 4 out of 10 facilities had their own kitchen; however, in the case of 1/3, their equipment did not correspond to the current needs. Small household appliances, as well as refrigerators, cookers and convection ovens were indicated among the shortages. As part of the ŻT program, every 3rd child care facility received full funding for one meal, and every 5th facility received full funding for the cost of feeding a child; subsidy most often used to finance lunches. Children regularly reporting hunger were present in 41% of the child care facilities. At the same time, almost 3/4 of the facilities reported the lack of possibility for children to eat regular meals outside their facilities. Nearly 1/4 of the child care facilities, in addition to providing nutrition, also covered children with nutritional education in the form of various activities. The program was well appreciated by the institutions. In order to improve the organization and implementation of nutrition for children in care and educational institutions, it is necessary not only to educate employees on nutrition, but also to introduce a system of appropriate financial support, enabling the purchase of necessary kitchen equipment, as well as financing well-balanced meals for children in needs.

Słowa kluczowe: organizacja żywienia, ocena żywienia, dzieci, placówki oświaty.

Celem badania była ocena organizacji i realizacji żywienia dzieci w placówkach oświaty (n=303) uczestniczących w programie Żółty Talerz (ŻT) w latach 2018-2019. Badanie zostało zrealizowane w styczniu 2019 roku na terenie całego kraju z wykorzystaniem ankiety przeprowadzonej drogą internetową wypełnianej on-line metodą CAWI (ang. Computer Assisted Web Interview). Ankieta obejmowała 42 pytania, w tym pytania na temat: placówki oświaty, dzieci uczęszczających do tej placówki, organizacji i realizacji żywienia w placówce oraz postrzegania programu ŻT. Łącznie w badanych placówkach posiłki spożywało 859 dzieci, w tym 426 otrzymywało posiłki w ramach programu ŻT. W 7 na 10 placówek nie notowano innych niż ŻT programów mających na celu wsparcie systemu pomocy żywienia dzieci. 4 na 10 placówek dysponowało własną kuchnią; w przypadku 1/3 ich wyposażenie nie odpowiadało jednak bieżącym potrzebom. Wśród braków wskazywano drobny sprzęt AGD, jak również lodówki, kuchenki czy piece konwekcyjne. W ramach programu ŻT co 3 placówka otrzymywała pełne dofinansowanie jednego posiłku, natomiast co 5 - pełne finansowanie kosztów żywienia dziecka; dotacja najczęściej przeznaczona była na finasowanie obiadów. W 41% placówek były obecne dzieci regularnie zgłaszające uczucie głodu. Jednocześnie prawie 3/4 placówek raportowało brak możliwości spożywania przez dzieci regularnych posiłków poza ich placówką. Blisko 1/4 placówek oprócz realizacji żywienia objęła dzieci również edukacją żywieniową w formie różnorodnych działań. Program był dobrze oceniany przez placówki. W celu poprawy organizacji i realizacji żywienia dzieci w placówkach opiekuńczo-wychowawczych konieczna jest nie tylko edukacja żywieniowa pracowników, ale również system odpowiedniego wsparcia finansowego, umożliwiającego zakup niezbędnego wyposażenia kuchni, jak również finansowanie dobrze zbilansowanych posiłków potrzebującym dzieciom.

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INTRODUCTION

Many factors determine the health of a child and its proper growth and development, among which proper nutrition plays an important role. Parents and guardians are responsible for the child's nutrition to the greatest extent, and they should have optimal knowledge in this regard. The literature on the subject proves that parents and guardians do not always have the appropriate knowledge in this area [8] and even if they do, they are not always able to use it in everyday practice. The occurrence of many errors in the nutrition of children and adolescents is indicated by various authors of Polish studies [7]. The most frequently mentioned are too low consumption of vegetables and fruits, a small amount of groats, fish, milk and dairy products as well as whole grain products. On the other hand, excessive consumption of meat, wheat bread, sugar and sweets is indicated. The diet of an average child also includes sweetened drinks and highly processed products, fast food is common.

An unbalanced diet results in nutritional deficiencies and nutrient malnutrition as well as other health consequences. Obesity is a disease caused by an incorrect lifestyle, including an incorrect nutrition. This problem affects various age groups around the world, including Europe [13] and, unfortunately, also Poland [5,9,22]. However, other nutritional mistakes are noted in each age group, which result from the specificity of nutrition and various factors that determine them. The lack of knowledge of parents and guardians may has impact on the incorrect nutrition of children.

On the other hand, it is the lack of care for children on the part of parents and caregivers, including failure to provide them with basic physiological needs, which includes nutrition. According to the recommendations, proper nutrition should be tailored to the needs of the child, which depends on many factors such as: age, gender, physical activity and health status [15]. If parents and caregivers do not meet these basic needs of the child, government programs and non-governmental institutions come to the rescue.

The Yellow Plate (YP) Program [20] is just such a program. The purpose of YT is to support the children's nutrition system in the canteen or even at home. Currently, the 7th edition of this program has being implemented. At the beginning of its duration, i.e. since 2016, 9 million meals have already been financed for 10.250 children. The program is organized by the Kulczyk Foundation and implemented thanks to cooperation with diocesan Caritas, The Polish Red Cross, SOS Children's Villages and the Society of Children's Friends (Day Care Center, Day Support Centre, Caritas Community Center), as well as kindergartens and school canteens and school common rooms as well as out-of-school day care centers that support the children's nutrition system. However, even in such child care facilities, it is impossible to feed the child optimally because of the lack of financial resources. The aim of this program is to subsidize the equipment of child care facilities and nutrition for children.

The purpose of the study was to assess the organization and implementation of children's nutrition in child care facilities participating in the Yellow Plate program in 2018-2019.

MATERIAL AND METHODS

The study was carried out in January 2019 throughout the country among child care facilities participating in the Yellow Plate (YP) program (n=303). The aim of this program is to improve the quality of nutrition for children throughout Poland; currently, children from Ukraine also benefit from the YP program. Institute of Human Nutrition Sciences Warsaw University of Life Sciences (SGGW-WULS) is a contents partner of the YP program. Study was conducted using the CAWI (Computer Assisted Web Interview) method. The questionnaire included 42 questions on the child care facilities, enrolled children, organization and nutrition of children as well as the evaluation of the Yellow Plate program.

The part of the survey concerning the implementation of children's nutrition in the facility included the declared fact of the presence of selected products / groups of products as part of the meals offered in one full week of children's education / work of the facility. The products asked about in the survey were placed on the List of Yellow Plate Products [16] prepared by specialists from the SGGW-WULS. It includes products that are beneficial for children's nutrition and is recommended to people preparing meals for children covered by the Yellow Plate program. These data are not presented in this paper.

The study was voluntary, filling in the questionnaire was an expression of given consent to participate in the study.

RESEARCH RESULTS AND DISCCUSION

Characteristics of the child care facilities

The institutions participated in the study were from all over Poland; 2/3 of them (n=205, 68%) were located in cities and 1/3 in rural areas (n=98, 32%). Type / nature of the child care facility participating in the study is presented in Fig. 1. Almost half of the surveyed institutions were out-of-school day care centers; and every fifth was a kindergarten canteen; similar percentage of facilities was recorded in the case of school canteen. The smallest share was represented by school common rooms. In the other group (26%), the following answers were most frequently noted: Day Care Center, Day Support Center and Caritas Community Center.

In 7 out of 10 child care facilities (n=222, 73%), there were no programs other than the Yellow Plate, aimed at supporting the child nutrition system. However, every third child care facilities indicated such programs, including 'Vegetables and fruits at school', 'Glass of milk', 'Pajacyk', 'Keep fit', organized respectively by The Agency for Restructuring and Modernisation of Agriculture (ARMA), the Polish Humanitarian Action (PAH) and the Chief Sanitary Inspectorate, and Polish Federation of Food Industry Union of Employers (PFFI UE). Several institutions also indicated subsidies from the Municipal Office.

The methods of organizing meals in the child care facilities are presented in Fig. 2. It was noted that 4 out of 10 facilities had their own kitchen; every third of them used a catering.

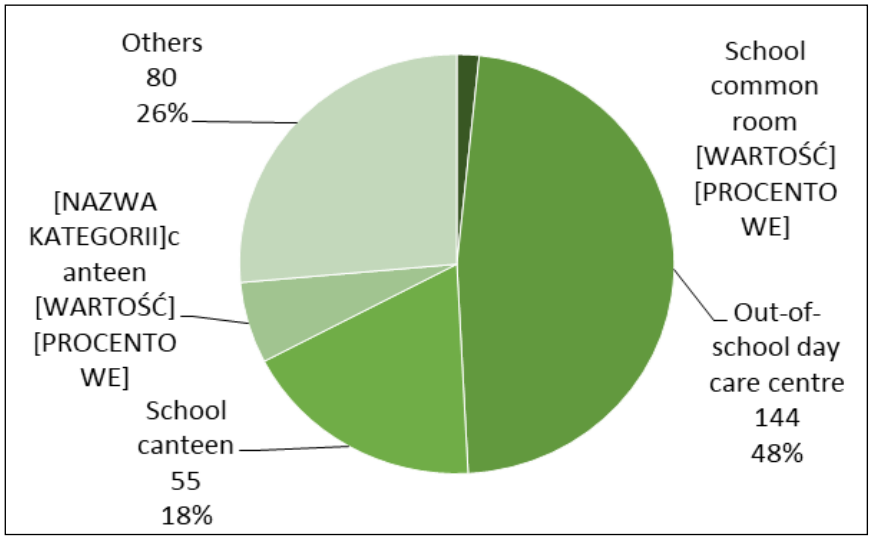

Fig. 1. Type / nature of the facility participating in the study (n, %).
Rys. 1. Rodzaj / charakter placówki biorącej udział w badaniu (n, %).
Source: The own study
Źródło: Badania własne

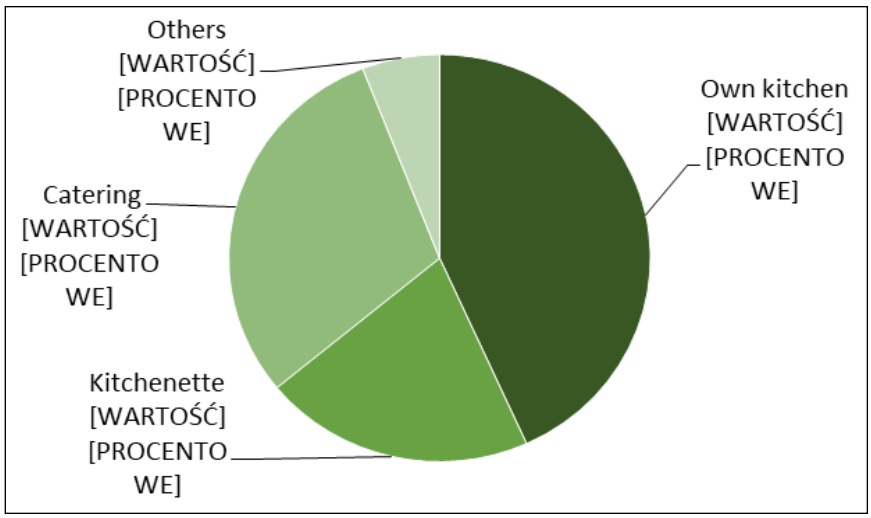

Fig. 2. The methods of organizing meals in the child care facilities (n, %).
Rys. 2. Sposób organizacji posiłków w placówce (n, %).
Source: The own study
Źródło: Badania własne

At this point, the child care facilities were additionally asked about the staff preparing meals. In the surveyed child care facilities, there were on average 2-3 such persons, in the case of using catering the number of staff was usually smaller. As other Polish studies on day care centers indicate, the type of kitchen determines the nutrition of children [12], which is closely related to the number of the staff employed and kitchen equipment. In the context of the organization of food, the kitchen equipment and the opinion of the facilities on whether it is sufficient for good organization of work were interesting. However, in the case of 1/3 (n=215, 71%), their equipment did not correspond to the current needs. Small household appliances, as well as refrigerators, cookers and convection ovens were indicated among the shortages. However, 90% (n=272) of the facilities indicated that they had a canteen or other place for children to eat meals. The average number of seats in the canteen was 38, the minimum was 5 and the maximum was 220. A place to eat meals preferably together with caregivers / parents is very important for a child. Shared meals promote a similar structure of food consumption [2], during which a child observes and imitates caregivers in terms of consumed products and beverages. Family eating is also correlated with a better structured diet [6]. All those involved in planning and preparing meals for children are indirectly their educators in this area. An employee of a canteen or community center is also such an educator. Cultivating the tradition of shared meals is also conducive to learn the food culture and is an opportunity to pass on knowledge about food and nutrition. Eating meals together at the table is currently an important recommendation included in the principles of proper nutrition [23].

Figure 3 presents the number of child care facilities offering individual meals as part of children's nutrition. It was noted that the largest number of facilities offered children lunch (69%), followed by afternoon tea (57%) as well as 5% of the respondents offered children a takeaway meal in the form of a packed lunch to take home. Children and young people should eat their first breakfast before going to school, and at school - at least 2 meals (snacks) [23]. It is worth making sure that all meals are prepared and eaten in the right conditions. Regular eating properly composed meals improves concentration and mood, has a positive effect on school and sports achievements, is important in the prevention of many diet-related diseases, including obesity. Lack of regular meals and skipping breakfast by Polish children is a big problem [17]. A combined higher meal frequency and daily breakfast consumption dietary pattern may prevent overweight and obesity in children [1].

The average cost of one child feeding in the surveyed facilities was PLN 6.21. Lunch was the most expensive and takeaway was the cheapest (Figure 4). The highest cost of lunch is due to the fact that, according to meal planning rules, it is the largest meal of the day in terms of portions. Dinner can consist of two courses, and its energy value should constitute 30-35% of the energy of the total diet. However, the cost of dinner depends on the choice of products and should not be related to its energy or nutritional value. Estimated by other authors [14], the costs of the proposed lunch sets varied; in the case of primary schools, they ranged from PLN 2.30 to PLN 7.70, and in the case of secondary schools - from PLN 2.80 to PLN 9.10 per set. As the authors indicate, if the financial possibilities do not allow for the preparation of more expensive sets, you can resign from them and provide meals in a given canteen using cheaper proposals.

As research shows, children often give up school lunches because of their taste and lack of attractiveness; parents because of their high costs [14]. The requirements for mass catering for children and youth in these educational units are regulated by law [21]. The price of the meal in the school canteens is established by the school manager. If the educational institution is not subsidized, the cost of lunch is usually higher. As part of the Yellow Plate program, every 3rd child care facility (n=90, 30%) received a full funding for one meal, and every 5th center (n=65, 21%) received funding for the cost of child full-board feeding. Half of the child care facilities (n=148, 49%) received co-financing for selected, various meals. The subvention from the Yellow Plate program was mostly used to finance lunches (63% of child care facilities, n=192), half of the child care facilities (49%, n=147) financed afternoon teas from this budget. Every third child care facility (29%, n=88) indicated that a hot meal financed by the Yellow Plate program is the only hot meal for children during the day.

Characteristics of children under care in facilities

In total, 859 children ate meals in the child care facilities, including 426 receiving meals under the Yellow Plate program (an average of 60 children/1 facility).

In the case of children benefiting from the assistance under the Yellow Plate program, the facilities reported the occurrence of family and behavioral problems. Parents' educational failure, single-parent families and unemployment, poverty or alcoholism were most often mentioned. Figure 5 shows the data.

Children regularly reporting hunger were present in 41% (n=125) of child care facilities. At the same time, almost 3/4 of child care facilities (n=224, 74%) reported the lack of possibility for children to eat regular meals outside their child care facility. Data from 2018-2020 indicate that 2.5% of the population in Poland were affected by undernourishment [4]. Almost 120,000 children in Poland go to school hungry, according to a Polish foundation called A Piece of Heaven [3]. Unbalanced and low calorie diet can affected students' ability to perform well in both educational and others activities. Malnutrition often is a problem in rural areas of Poland, where poverty levels are higher. Those living below the poverty line have limited access to well-balanced diet. As a rule, such a food is more expensive

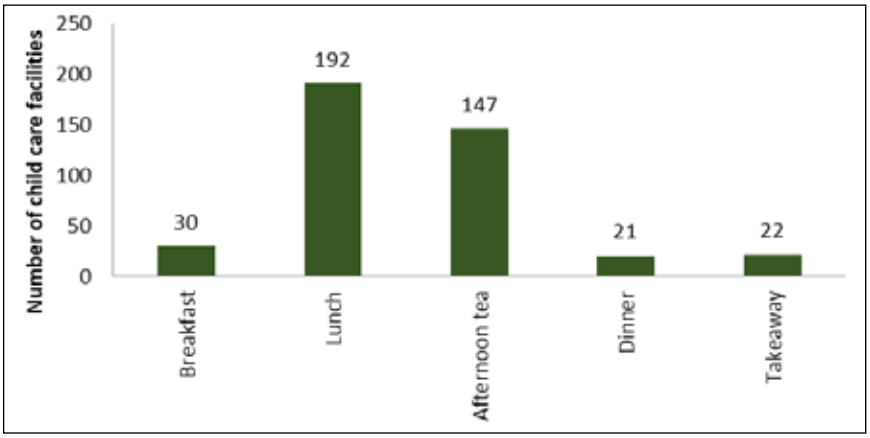

Fig. 3. Number of child care facilities offering individual meals as part of children's nutrition (multiple answers possible).
Rys. 3. Liczba placówek oferujących poszczególne posiłki w ramach żywienia dzieci (możliwa wielokrotność odpowiedzi).
Source: The own study
Źródło: Badania własne

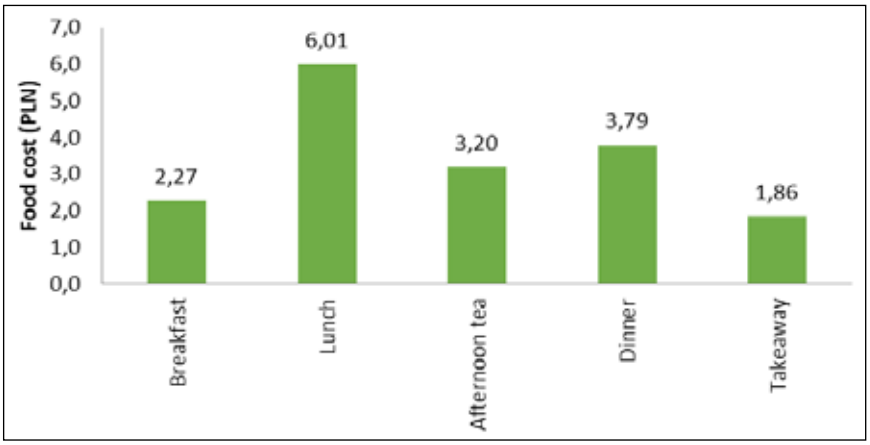

Fig. 4. Cost of the food (PLN/1 child).
Rys. 4. Koszt żywienia (PLN/1 dziecko).
Source: The own study
Źródło: Badania własne

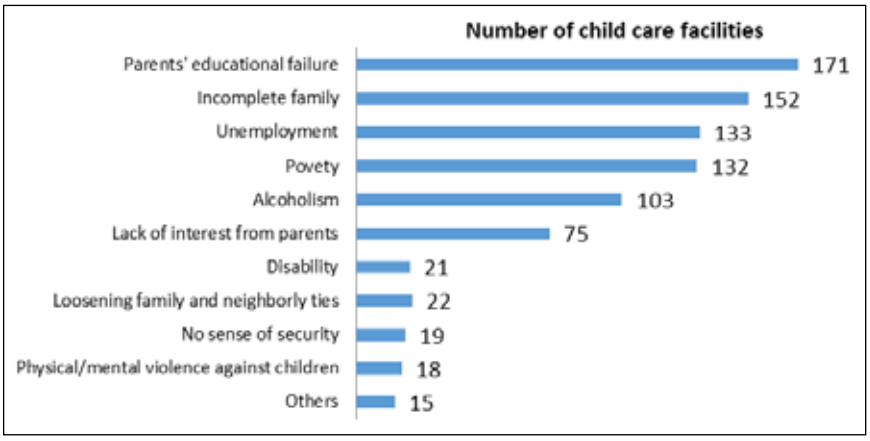

Fig. 5. Problems in children's families (multiple answers possible).
Rys. 5. Problemy występujące w rodzinach dzieci (możliwa wielokrotność odpowiedzi).
Source: The own study
Źródło: Badania własne

than a low-quality one. Much of the hunger in Poland is due to poverty. In our study, 44% of facilities indicated the poverty in families of children who attend to the child care facilities.

Nutritional education of children in the child care facilities

In the vast majority of facilities (97%, n=295), children not only had the opportunity to receive a meal, but also received nutritional education in the field of proper nutrition. Educational classes were held in various forms, as listed below (in order of frequency of answers, multiple answers possible):

- culinary workshops (88%, n=267),
- competitions and themed festivals (54%, n=163),
- educational trips (32%, n=97),
- organizing exhibitions, presentations, publishing newsletters (32%, n=97),
- setting up and running school gardens (9%, n=27).

The effectiveness of the implementation of nutritional education among children and staff of facilities has been demonstrated in many Polish studies [10,11,18,19].

The Yellow Plate program evaluation

The Yellow Plate program was well appreciated by the child care facilities. The vast majority (93%, n=281) described the program as real and effective help for children. A slightly smaller percentage of facilities (79%, n=238) appreciated the opportunity to increase children's knowledge and awareness of healthy eating. Almost 3/4 of the facilities (n=219) considered it important for some children to try products they had never eaten before for the first time. 35% (n=106) of child care facilities declared that the Yellow Plate program gave some children the opportunity to eat the only hot meal during the day. Thanks to the program, children had the opportunity to eat a varied, healthy meal, break the barrier of aversion to food products or dishes. In the opinion of the child care facilities, it was a "great adventure" for children and an opportunity to "play chef". It was also a learning of basic activities related to self-service, daily meal preparation, shopping planning, learning how to use small household appliances, etc. The meal provided as part of the program was an opportunity for integration and encouraged children to attend the facility more often. According to the assessment of some child care facilities the program provided a valuable financial support for children's parents.

Characteristics of people completing the survey – metric data

Data describing the persons completing the questionnaire is presented in Table 1.

The surveyed person most often held the position of a teacher in the child care facilities. The vast majority of the respondents were women. More than half of the people were between 31 and 50 years old. Most of the respondents had higher education. However, only every tenth person declared education related to nutrition, dietetics or nutrition organization. Among other positions mentioned were: educator, volunteer, cook, therapist. It is worth noting that the respondents often combined different roles, e.g. manager and teacher or teacher and pedagogue.

Table 1. Metric data

Tabela 1. Dane metryczne

Characteristic		%
Gender	Women (n=272) Men (n=31)	90 10
Age	18-30 years old (n=42) 31-50 years old (n=168) >50 years old (n=93)	14 55 31
Education	Secondary (n=46) High (n=256)	15 85
Education related to nutrition	Yes (n=36) No (n=267)	12 88
Position	Teacher (n=111) Manager (n=99) Administrative worker (n=58) Others (n=35)	37 33 19 11

Source: The own study

Źródło: Badania własne

CONCLUSIONS

In order to improve the organization and implementation of nutrition for children in child care facilities, it is necessary not only to educate employees in the field of nutrition, but also to create a system of financial support that would enable the purchase of necessary kitchen equipment, as well as financing well-balanced meals for children in need.

WNIOSKI

W celu poprawy organizacji i realizacji żywienia dzieci w placówkach opiekuńczo-wychowawczych konieczna jest nie tylko edukacja pracowników w zakresie żywienia, ale także stworzenie systemu wsparcia finansowego, który umożliwiłby zakup niezbędnego wyposażenia kuchni, a także finansowanie dobrze zbilansowanych posiłków dla potrzebujących dzieci.

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- **TABELE** – j.w.
- **WYKRESY** – jako bitmapy z rozszerzeniem – ***pdf*** (nie ma możliwości redagowania – muszą mieć ostateczną formę, wygląd i jak największą rozdzielczość).
- **RYSUNKI** – w programie COREL DRAW 9.0 z rozszerzeniem ***cdr*** (jest możliwość zmian i redagowania), albo jako bitmapy z rozszerzeniem – ***pdf*** (nie ma możliwości redagowania – muszą mieć ostateczną formę i wygląd).
- **ZDJĘCIA** – jako bitmapy z rozszerzeniem – ***pdf***, ***tif, psd*** lub ***jpg*** – z rozdzielczością 300 dpi (nie ma możliwości redagowania – muszą być profesjonalnie zeskanowane z jak największą rozdzielczością).

Z wyrazami szacunku
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