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CONTENT

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EDITORIAL INTRODUCTION SPECIAL ISSUE "FOOD SCIENCE, FOOD TECHNOLOGY AND EQUIPMENT IN FOOD INDUSTRY"

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Significant progress in the field of food sciences and technology has been observed over the years. It applies to food engineering and nutrition as well as to the construction and exploration of food industry machinery. This is the best illustrated by the scope of selected papers published in this special issue. The scope can be divided into several areas of research interest. These include the research of raw materials and food products, the analysis of processes and processing equipment, and the study of consumer and nutrition preferences.

The first group of manuscripts regarding physical and process parameters in food processing and unit operations. One of them discribe the hydrodynamic effect in the CIP cleaning process enables the more effective removal of solid deposits from surfaces. This paper presents the impact of low-frequency pulsating flow on the effectiveness of cleaning a plate heat exchanger contaminated with milk deposits. Next one concerns research related to the attempt to use hydrojetting treatment in fish processing processes. Paper describes the researches which result are the supply pressure value definition of the water stream, necessary for the full intersection of the fish muscle flap. Next paper from this group presents the impact of heat treatment, i.e. micronization and roasting, on soybean seeds hardness and content of anti-nutritious substances. The last one paper concern to mathematical simulation of forces of normal contact pressure on the edges of double-edge knife during food materials cutting.

Five of the papers in this special issue concerns to chemical analysis of raw materials, products and nutrients. The first paper presents examinations of total phenolic content in honeys and honey powders from baltic sea region. Problems occurring during production are primarily related to the consistency of honey and a high content of monosaccharides and organic acids. Examinations shown that honey powders based on buckwheat honey were characterized by higher content of polyphenols and higher total acidity compared to honey powders based on rapeseed honey. Next paper presents near infra-red spectroscopy (NIR) for assessing nutrients in feeding materials and mixtures. The paper shown the results of comparative studies typical feed matrices performed by means of the NIR technique and standard methods, in compliance with the Commission Regulation (EU) No 152/2009. Next one, a very interesting paper compares the influence of different culinary treatments (frying, baking, and steaming) on the retention of compounds beneficial for consumers' health, such as n-3 fatty acids and fat-soluble vitamins (A, D3, and E). Applying of "twin fillet" approach enabled to avoid the influence of intraspecies variation on results obtained. Next paper presents the influence of heat treatment on the content of vitamin C in lemons, bilberries, apples, peppers and sweet potatoes. It was found that the process of freezing and cooking short-term vegetables

and fruits significantly affected the breakdown of vitamin C, and the content of ascorbic acid decreased from about 30% to 60%. The last one paper in this scope concern to effect of household cooking methods on nutritional value of cod and salmon.

The third thematic group of this special issue are papers on the scope of waste management in food industry and biodegradable packaging. The first paper in this section presents the research of the pelleting process of post-harvest hemp waste. During the research was determined the influence of potato pulp content in the mixture with hemp waste and the impact of the substrate mass flow on the device's power demand and on the density and kinetic strength of the obtained pellets. Next one, very interesting paper, describes the quality parameters of cereal products and by-products with the brewing industry processed by the extrusion method. The article also contains useful advice for optimizing this process. The third paper concern to recovering non-degraded meat from salmon backbones. It's an overview, which presents known and used in fish processing devices for recovery of non-degraded meat from salmon backbones after filleting. On the basis of this review the assumptions of scraping machine were formulated. The last one paper concern to nature based packaging materials - biodegradable material and technique of food containers that can be used for light meals (e.g. like a bowl for cereal and milk) molding. The prepared dish is aesthetic and ecological, after using it can be eaten with taste.

The last group of manuscripts are those from the scope of consumer preferences and nutrition. The first two papers relate to consumer preferences, and the three other manuscripts relate to dietary and nutritional awareness. The first paper presents an influence of advertisings on consumer's decisions on the example of diary products. The research showed, among others, that advertising is a factor that significantly affects consumer's nutrition and purchasing decisions, and is an important tool in shaping the right nutritional attitudes of the society and promoting positive changes in food consumption. The second one concern to preferences of the consumers of cold meat market in lights of a survey research in the region of Lublin (Poland). The conducted research showed that the factors differ significantly, simultaneously it allowed to indicate determinants describing the behavior of given consumer groups. Cold meats are consumed very often, there is also a large variety of them on the market, so decisions about the choice of those products can be difficult sometimes. Consumers want to get a product of specific features, therefore the producers who want to sell their goods try to meet the requirements. Three papers concern nutrition and nutritional awareness. The first of them concern to evaluation of the knowledge of mothers about the principles of children nutrition at an early school age. The knowledge of the majority of respondents about the fundamentals of children nourishing was assessed as considerably good. Young and better-educated women had the best knowledge about nutrition.It's stated that in spite of numerous educational programmes there is still a need to conduct parents' education about healthy eating habits for all family members. Next paper concern to evaluation of dietary practices of women over 60. In studied menus, many serious dietary mistakes, which can increase the risk of the development of such diseases like obesity, osteoporosis, and cardiovascular diseases were observed. In the diet of the all examined groups of women, an insufficient supply of vitamin D and of calcium with coexisting excess of phosphorus was stated. The last one paper describes the disease which is osteoporosis and characterizes disease risk factors. Diets used by the subjects were analyzed. The content of selected nutrients in diets was determined. The method of nutrition and the frequency of consumption of food products was evaluated based on a the author's questionnaire.

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AN ANALYSIS OF THE EFFICIENCY OF CLEANING A HEAT EXCHANGER USING A CIP SYSTEM WITH LOW-FREQUENCY PULSATING FLOW

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Pulsating flow,
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Plate heat exchanger.

ABSTRACT

The paper determines the impact of pulsating flow on the efficiency of cleaning performed on the surface of heat exchanger plates. The tests were conducted on a laboratory CIP station for four low-frequency pulsation modes and for steady flow. The test results are represented graphically and followed by a broad analysis of the effect of pulsation at a specific frequency on the efficiency of cleaning individual exchanger plates and the entire heat exchanger. It has been proved that applying pulsating flow during CIP procedure with a frequency of 3.5÷7.0 mHz significantly (α=0.05) improves the cleaning efficiency and, at the same time, shortens the cleaning time, up to 25%.

1.Introduction

The Clean in Place (CIP) method is used for cleaning and disinfecting flow units and tanks in many food processing sectors. The basic principle of the method is that media (water, aqueous solutions of acids and alkalis) flow through equipment, causing deposits formed in the production process to dampen and, subsequently, be washed away and out of the unit. The end result depends on the following conditions of the process: the cleaning time, the temperature of the cleaning solution, the chemicals used, their working concentration in the solution, as well as on the flow velocity and turbulence. The impact exerted by individual factors on the effect of cleaning has been the subject of many studies and analyses. Numerous studies have proved that, for example, increased concentration of cleaning solutions or extended cleaning time do not enhance the cleanliness of the surface (Diakun, 2011). It has also been shown that the effect of cleaning is to a great extent determined by the velocity of the media flowing through the cleaned units, and, at the same time, by the turbulence and hydraulic wall shear stress (Lelievre et al., 2002; Piepiórka-Stepuk and Jakubowski, 2013; Absi and Azouani, 2018). Increasing the hydrodynamic effect in the cleaning process enables not only the effective removal of solid deposits but also a reduction of microorganisms at the cleaning stage (Blel et al., 2009).

The enhancement of the hydrodynamic effect in the CIP process has been investigated by many studies. The research allowed scholars to determine, for example, the impact of barbotage, ultrasound and ice-pigging (Chahine et al., 2015; Kyllonen et al., 2005; Maskooki et al., 2008; Popovic´ et al., 2010; Quarini, 2002). However, the introduction of pulsating flow to the cleaning process received the most attention. The essence of this solution is a local intensification of the hydrodynamic effect, caused by a temporary increase in flow velocity. Consequently, an increase in wall shear stress is observed, resulting from a high gradient of flow velocity accompanied by an increased amount of the cleaning agent transported to the layer of deposit to be

removed from the surface (Pérez-Herranz et al., 1999; Föste et al., 2013; Absi and Azouani, 2018). The hydrodynamic effect causes molecular ties in the deposit and the interphase ties established with the surface to weaken and break down, decreasing the adhesion of the deposit and enabling its removal (Farries and Patel 1993; Lelievre et al., 2002). The impact of oscillation on the effectiveness of cleaning mainly straight pipeline sections has been assessed under this method. The analysis led to determining, for example, the relationship between the effectiveness of cleaning and characteristic parameters of pulsation, such as pulsation frequency and amplitude (Augustin et al., 2010; Blel et al., 2009; Bode et al., 2007; Weidemann et al., 2014; Gillham et al., 2000). The research also focused on the effect of pulsation in the cleaning process, depending on the average steady flow velocity and the Reynolds number, as well as on the impact of selected flow characteristics (pulsating, oscillating) on the generated shear stress and the end result of cleaning (Celnik et al., 2005; Absi and Azouani, 2018). It was demonstrated that pulsation with a frequency of ≤2 Hz brings a 50% increase in the efficiency of removing protein deposits from the surface of a tube heat exchanger as compared to typical CIP cleaning and restores 100% of the exchanger's thermal conductivity (Gillham et al. 2000). Some papers concerning such solutions also propose that oscillating flow shortens the cleaning time, decreases the required amount of cleaning agents and reduces bacterial cells (Augusting et al., 2010; Blel et al., 2009; Gillham et al. 2000; Christian and Fryer, 2006).

An intensification of the hydrodynamic effect in the CIP process is undoubtedly beneficial for the end result of cleaning. Pulsating flow improves the heat and mass transfer characteristic at low constant Reynolds numbers (<2000) and increases the shear stress levels. Moreover, it may induce cavitation and thus damage and accelerate the degradation of construction materials. This paper examines the impact of low-frequency (1.5÷7.0 mHz) pulsating flow on the effectiveness of cleaning a plate heat exchanger contaminated with milk deposits. The cleaning effectiveness and the time needed to conduct the process were identified as part of the study. The kinetics of the cleaning process were determined on the basis of changes in pH and solution turbidity during the cleaning process. The study was compared to cleanliness results obtained following a standard CIP cleaning process.

2. Materials and methods

2.1. The construction of cleaning station

The study was conducted on a laboratory CIP station (Fig. 1).

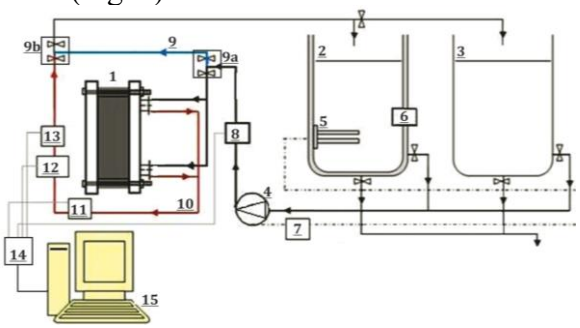

Figure 1. A scheme of laboratory CIP station: 1 – a plate heat exchanger, 2 – an insulated tank equipped with a heater, 3 – an auxiliary tank, 4 – a centrifugal pump, 6 – temperature sensor, 7 – inverter, 8 – flow rate meter, 9 – auxiliary pipeline – bypass, 9a and 9b – valves, 10 – the returning pipeline, 11 – meter pH, 12 – a conductivity meter, 13 – a turbidity meter, 14 – a measurement card, 15 – a computer

The subject of cleaning was a plate heat exchanger 1 containing 11 chevron plates with a total area of 0.378 m^2. The characteristic dimensions of the exchanger are shown in Table 1. Cleaning solutions were prepared in tanks 2 and 3, pumped through a centrifugal pump 4 and transported through a pipeline to the cleaned object 1. One tank was equipped with a heater 5 and a temperature sensor 6, which facilitated the heating and temperature control of the solutions. An inverter 7 was used to define the

flow conditions for the cleaning agent in the pipeline, controlled by measuring the volumetric flow rate 8.

Table 1. Main geometrical characteristics of the plate heat exchanger used to the research

Geometrical characteristics	Symbol	Unit	Value
Effective length of the plate	L_w	m	0.381
Effective width of the plate	L_s	m	0.11
Area of one plate	$A= L_w \cdot L_s$	m^2	0.042
Area of heat transfer	A_c	m^2	0.46
The largest distance between plates	b	m	0.008
Mean distance between the plate	c = (b/2)	m	0.004
The surface area of the transverse flow	$P_{str} = cL_s$	m^2	0.0005
Wetted	$Ob_c = 2c + 2L_s$	m	0.23
Total number of plates in heat exchanger	N_p	items	11
Number of channel in plate heat exchanger	$N_c = (N_p – 1)/2$	items	5
Hydraulic diameter of the channel	d_{ch}	m	0.009
Corrugation angle	β	°	60
Type of plates	Straight - flow		

Pulsation was generated by regularly switching valves 9a and 9b inside the unit, causing the cleaning liquid to flow through the subject of the study 1, and then through an auxiliary pipeline 9. The obtained flow characteristic is shown in Figure 2, including a division into periods of the liquid flowing through the heat exchanger (t) and downtime (2t) (the liquid flowing through an auxiliary pipeline), with the two periods equal to each other and in line with the study plan (Table 2).

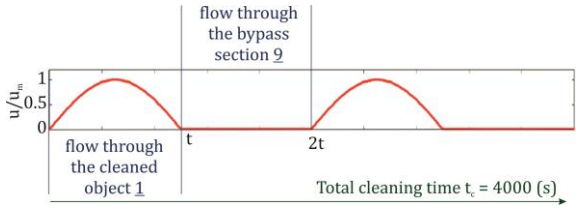

Figure 2. The pulsating flow model assumed in the study

The devices installed on a returning pipeline 10, returning the liquid from the cleaned object 1 to tank 2 or 3, included a pH meter 11, a conductivity meter 12 and a turbidity meter 13 monitoring cleaning liquid turbidity changes in accordance with the method presented by Piepiórka-Stepuk et al. (2017). The sensors were integrated with a computer measurement card 14 and computer analogue-to-digital converters 15, to enable registering the measured turbidity and pH.

2.2. Soiling procedure and cleaning process

Before cleaning started, the disassembled exchanger plates were heated in 90°C and covered in raw milk, in accordance with the methodology suggested by Piepiórka-Stepuk et al. (2016). Owing to the mechanism of producing milk deposits on hot surfaces, presented by Jeurninek et al. (1995) and Bansal and Chen (2005), whole, raw (unpasteurised) milk was used in the study. The contaminated plates were reassembled and cleaned in accordance with the study plan described in Table 2.

Table 2. Study plan

No.	Pulsation frequency f (mHz)	Period t (s)	Temperature T (°C)	Cleaning time t_c (s)	Flow rate in the pipeline u (m/s)
1	0	0	45	4000	2.5
2	1.5	600	45	4000	2.5
3	2.0	420	45	4000	2.5
4	3.5	300	45	4000	2.5
5	7.0	150	45	4000	2.5

The average flow velocity of the cleaning liquid between the plates of the tested heat exchanger (calculated on the basis of the flow rate measured at the operating distance DIN 40 mm) was u_c=0.623 (m/s) and the Reynolds number was *Re*=9348. The variable factors were the frequencies of starting and stopping the flow of the cleaning liquid through the cleaned object. To eliminate chemical effects related to the presence of active cleaning substances in cleaning, clean water at a temperature of 45°C was used. A constant volume of liquid was assumed in the tank and was the liquid replaced after a cleaning program was completed.

Changes in the turbidity and pH of the cleaning liquid were monitored during cleaning. The collected measurements served as a basis for defining the kinetics of cleaning and were analysed in the context of the intensity of washing residue out of units (Piepiórka-Stepuk et al., 2017; Piepiórka-Stepuk and Mierzejewska, 2017). A higher turbidity of the liquid meant a larger amount of residue washed off the exchanger surface. After the process was finished, the exchanger was disassembled and its cleanliness evaluated.

2.3. Cleanliness evaluation

The cleanliness of the plates was evaluated using the *Clean-Trace^{TM} Surface Protein Plus Test Swab* (Piepiórka-Stepuk, 2012). The method is based on the colour reaction of Cu^{2+} in protein complexes. The presence of protein residues causes colour change of indicators, which reflects the state of cleanness of the studied surface. The concentration of the coloured complex formed is proportional to the number of peptide bonds formed in the studied solution. The degree of cleanliness was evaluated on a scale from 0 to 5, with 0 meaning the initial contamination of the plates and 5 – the demanded cleanliness (no contamination).

All plates in the heat exchanger were examined. Samples were taken from five identical 5.0×5.0 cm areas on each of the plates. The obtained test results were used to calculate the general average cleanliness of each exchanger plate, as the arithmetic mean of all sampling areas on each plate, and the total cleanliness of the heat exchanger, as the arithmetic mean of all sampling areas in the entire exchanger.

2.4. Statistical analysis

The tests were repeated three times for each set of the factors defined in the study plan. The obtained results were averaged and presented in graphs (Figures 3÷4) as a distribution of the final cleanliness of individual exchanger plates after cleaning and the total cleanliness of the exchanger. Standard deviations were determined for the obtained results, taking the calculated average values into account. In order to verify the relevance of the impact exerted by the pulsation frequency on the final cleanliness of the exchanger, the Fisher-Snedecor test was conducted in Statistica 13 to verify a zero hypothesis H_0: ($\mu=\mu_0$) and an alternative hypothesis H_1: ($\mu\neq\mu_0$), while F^{crit}=2.3839. The Tukey's multiple comparison test was also conducted at the significance level of α=0.05. Additionally, the measurement of turbidity and pH of solutions during cleaning facilitated the determination of the cleaning kinetics (Figures 5÷8).

3. Results and discussions

3.1. Analysis of the cleaning effectiveness

Figure 3 presents the average cleanliness of individual exchanger plates after cleaning with different flow pulsation frequencies.

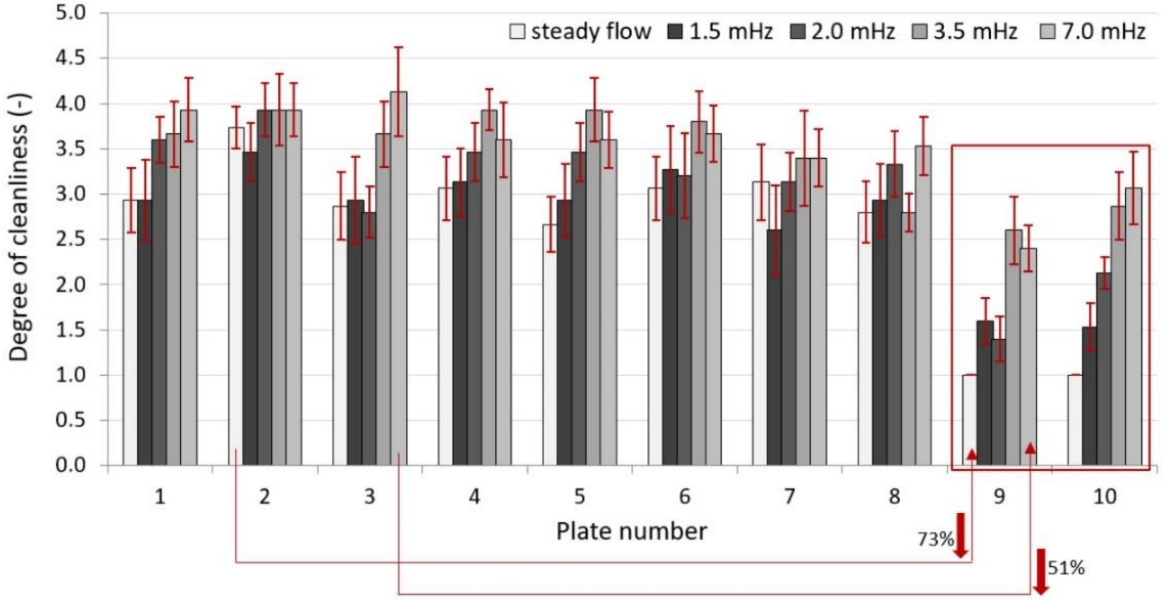

Figure 3. *The degree of cleanliness of individual heat exchanger plates under different flow conditions*

It was observed that introducing pulsation to the process in the analysed scope of frequency improves the end result of cleaning in comparison to the standard cleaning procedure. The best effect was observed for pulsating flow with a frequency of 3.5÷7.0 mHz.
It has also been shown that the first plates in the exchanger are cleaned the most efficiently. The lower cleanliness degree of the successive plates is connected to a lower flow rate in grooves formed by the plates. This is consistent with previous research on the distribution of flow velocity in individual exchanger sections (Tereda et al., 2007; Piepiórka-Stepuk and Diakun, 2014) and increased distribution of contamination and milk deposits (Jun and Puri, 2006; Georgiadis and Macchietto, 2000). As a result, the cleanliness of the last two exchanger plates for steady flow was lower by 73% than the best efficiency value obtained for these conditions (second plate). On the other hand, in the case of pulsating flow (f=7.0 mHz), the end result of cleaning the ninth plate (the least well cleaned) was only 50% lower as compared to the third plate (the cleanest).

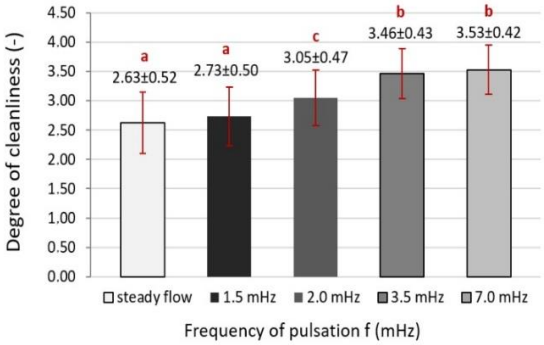

Figure 4. The degree of final cleanliness of the plate heat exchanger after cleaning with pulsation flow

Figure 4 presents the total final cleanliness of the heat exchanger. The Fisher test results for the analysed experimental results enabled the author to reject the zero hypothesis H_0: ($\mu=\mu_0$), which assumed an equal average cleanliness of

the plate heat exchanger after cleaning in different flow conditions, and assume the alternative hypothesis H_1: ($\mu \neq \mu_0$), with the F statistic value of F=28.5744, which fulfils the inequality ($F^{crit}<F$).

Increasingly higher pulsation frequency led to a higher cleaning efficiency. The lowest efficiency (of 2.6÷2.7) was observed for steady and pulsating flow with a frequency of 1.5 mHz. The Tukey's range test (Table 3) did not reveal any statistically significant differences between the two average values. However, they were significantly different from the remaining results in terms of statistics. A significantly higher degree of final cleanliness of the plate heat exchanger was achieved for pulsating flow with a frequency of 2.0 mHz. The best cleaning efficiency was achieved for pulsating flow with a frequency of 7.0 mHz and 3.5 mHz. No statistically significant differences were found between the two values. Finally, using pulsation in cleaning in this respect enabled a 30% improvement of cleaning efficiency in relation to steady flow. This is proved by the beneficial impact of pulsating flow on cleaning.

Table 3. The significance of the impact of temperature on the final clarity of the solution

Pulsation frequency f (mHz)		Tukey's HSD test; variable cleanliness of the plate heat exchanger; Approximate probability for post hoc tests; Error: Intergroup MS=0.88021, df=745				
		0.0	**1.5**	**2.0**	**3.5**	**7.0**
1.	**0.0**		0.86236	0.00101*	0.00002*	0.00002*
2.	**1.5**	0.86236		0.03133*	0.00002*	0.00002*
3.	**2.0**	0.00101*	0.03133*		0.00129*	0.00011*
4.	**3.5**	0.00002*	0.00002*	0.00129*		0.97271
5.	**7.0**	0.00002*	0.00002*	0.00011*	0.97271	

* *statistically different tests*

3.2. Analysis of the pH and turbidity characteristics

The characteristics obtained by monitoring the pH and turbidity of the liquid during the cleaning process are presented in Figures 5÷8.

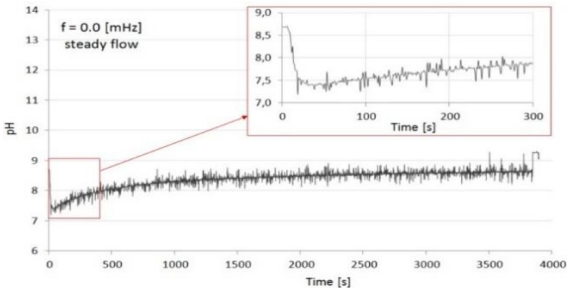

Figure 5. Changes in the pH of the cleaning solution during CIP cleaning with steady flow

During the first few minutes of the cleaning process, pH clearly dropped to a value close to 7.5 (Fig. 5). The change in reaction was caused by washing a large amount of milk deposits away from the exchanger (the pH of milk of about 6.5). Subsequently, pH slowly increased and stabilised at about 8.5, close to the pH of clean water used for washing. Changes of a similar nature occurred during pulsating cleaning (Fig. 6a, b, c, d).

Figures 7 and 8 show the characteristics of changes in the turbidity of the solution during the cleaning process. Initially, the turbidity of the solution clearly rises to about 220 NTU. As in the case of the pH value, this was caused by washing a large amount of milk deposits away from the exchanger In the next stage, the turbidity decreases and stabilises. The final turbidity value is different for each cleaning programme, which indicates variable cleaning conditions and the resulting amount of removed deposits.

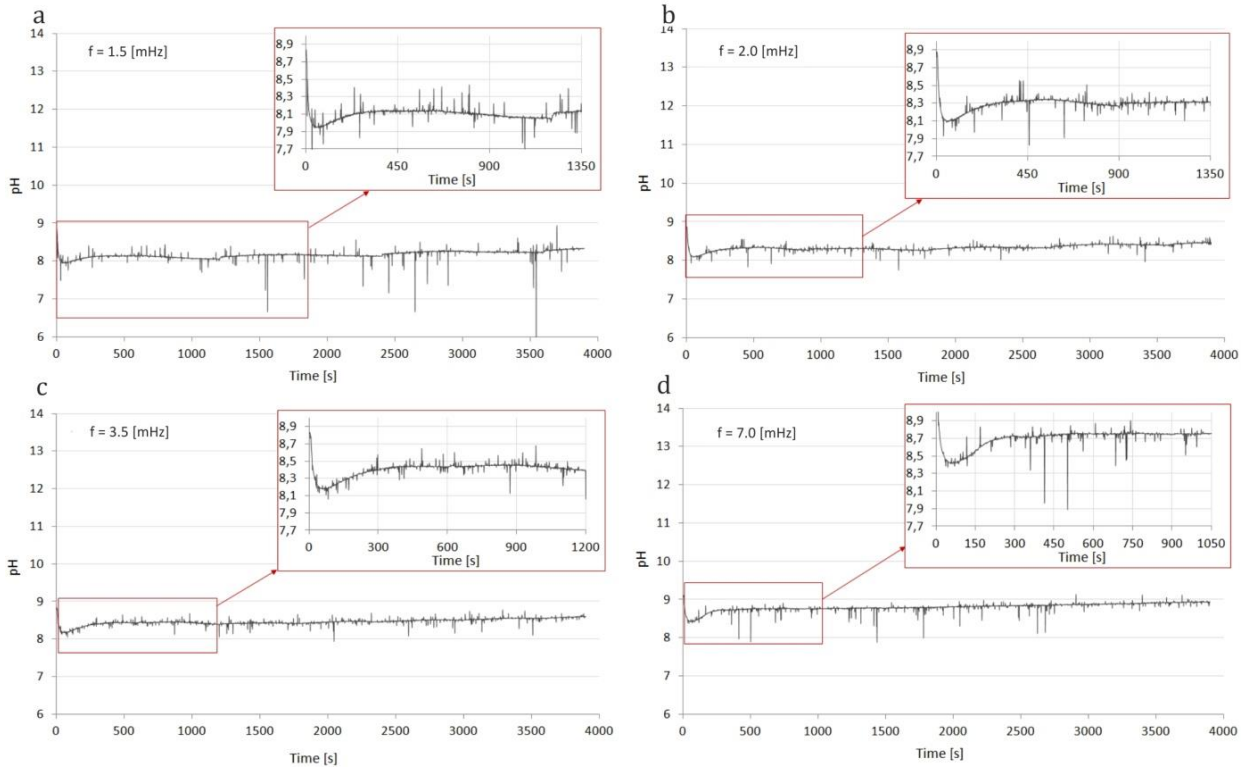

Figure 6. Changes in the pH of the cleaning solution during CIP cleaning with pulsating flow: a) f=1.5 mHz; b) f=2.0 mHz; c) f=3.5 mHz; d) f=7.0 mHz

In reference to the characteristic obtained in cleaning with steady flow, turbidity stabilises at about 12 NTU (Fig. 7). After about 20 minutes no changes in the turbidity of the cleaning solution are observed, which means that contamination is no longer intensely washed off the plate surface. However, during cleaning with pulsation flow, turbidity change curves have characteristic peaks. They indicate an increase in turbidity when the valves were switched. This is due to the turbulence of the liquid in the unit resulting from a temporary increase in pressure. Turbidity surges are regular and correspond to the pulsation period t used in the study plan (Fig. 8 a, b, c, d).

The obtained curves indicated that cleaning is the most efficient at a pulsation frequency of 7.0 mHz and 3.5 mHz (Fig. 8 a, b). This confirms the previous analyses. Under these conditions, the turbidity stabilised at about 21 NTU, which suggests that a larger amount of milk deposit was washed away, while during pulsation of f=7.0 mHz the stabilisation time was shorter (about 15 minutes).
In the remaining cleaning programs (Fig. 8 c, d) solution turbidity stabilised in an approximate time (about 20 minutes) and at a lower level (about 18 NTU).

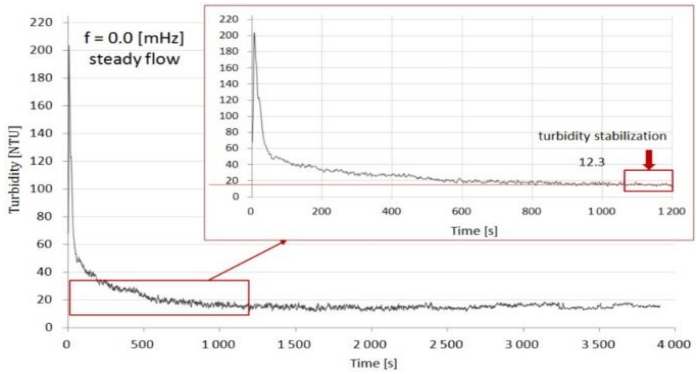

Figure 7. Changes in the turbidity of the cleaning solution during CIP cleaning with steady flow

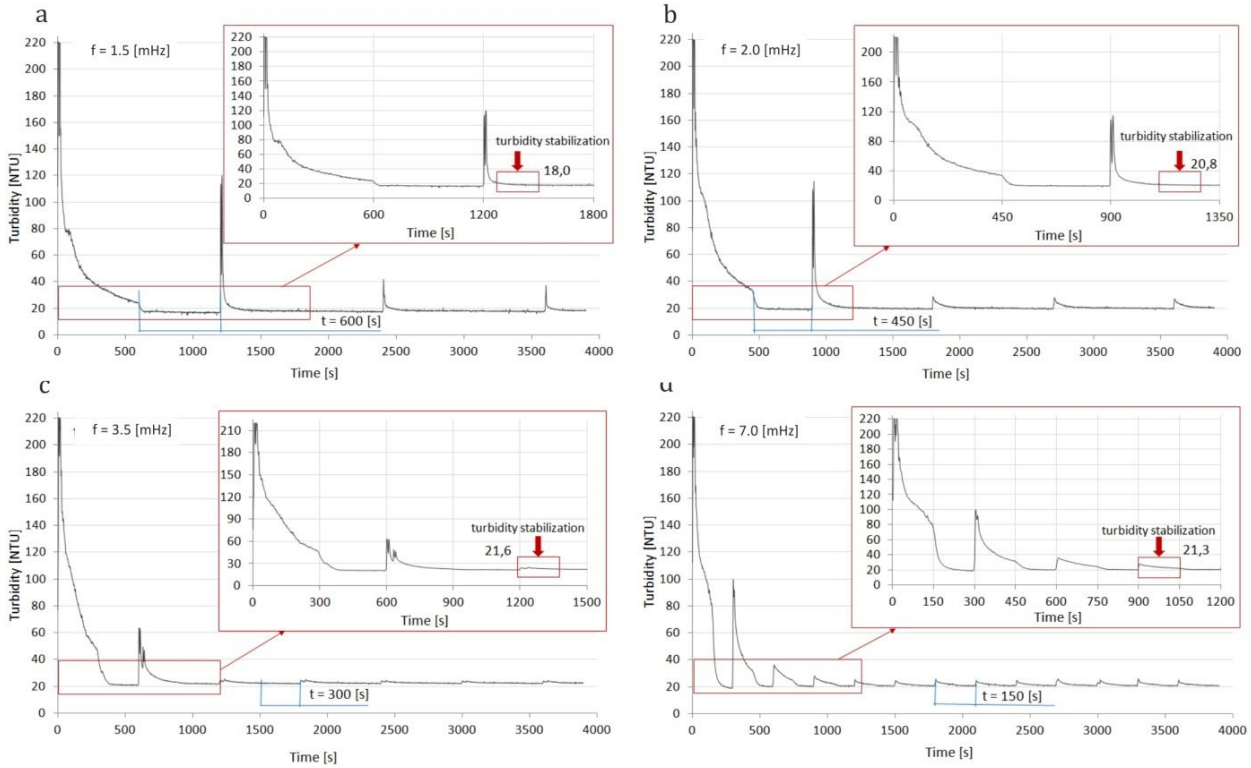

Figure 8. Changes in the turbidity of the cleaning solution during CIP cleaning with pulsating flow: a) f=1.5 mHz; b) f=2.0 mHz; c) f=3.5 mHz; d) f=7.0 mHz

4. Conclusions

The experimental results demonstrated in this paper and by other scholars indicate a considerable potential of CIP cleaning using pulsating flow. Applying this solution during a standard CIP procedure enhances the hydrodynamic effect of the liquid on the walls of the cleaned components, eventually improving the final efficiency of cleaning. The described study revealed that the final cleaning efficiency improved by 30% after introducing low-frequency pulsation (f=7.0 mHz). The conducted analysis also proved that the cleaning efficiency increases with each consecutive plate in the heat exchanger. Finally, it appears that higher pulsation frequencies caused higher cleaning efficiency in the conducted analysis.

Introducing pulsation to CIP may bring other quantifiable benefits, e.g. shorten the cleaning time. For the assumed characteristic of pulsating flow with a frequency of f=7.0 mHz, the cleaning time was shorter by about 25%. This may contribute to decreasing energy consumption during the cleaning process. Further research is needed in this field.

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DETERMINING THE SUPPLY PRESSURE DEPENDING ON THE FEED SPEED AND THE DIAMETER OF THE NOZZLE

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ABSTRACT

The constant development of fish processing machines is dictated by the need to automate production while achieving efficiency at a level similar to manual processing. Currently used machining tools make it difficult, and sometimes impossible, to selectively cut or separate various fish components such as bones, meats, skins, and scales. In addition, the smooth performance of even simple displacement of these tools during operation is difficult and sometimes impossible. It is difficult, therefore, to mechanize operations such as cutting a portion of a product with a complex shape. Therefore, it is necessary to look for alternative cutting tools that will allow bypassing such restrictions. One of the tools allowing for, for example, selective cutting of the raw material is a high-pressure water jet. In connection with the above, work was carried out to implement this technology for fish processing. The research was carried out on the muscle flakes of rainbow trout. The work included determining the value of the supply pressure necessary for full cutting of the raw material, for 6 water nozzle diameters and 3 values of the feed speed. During the tests, it was observed that a water stream supplied with pressure occurring in the water supply system (0.4 MPa) is able to cut through the soft muscle tissue. To achieve a total cut of all parts of the muscle for nozzles with a diameter of (0.174 mm) water pressure of (7MPa) is necessary, and for nozzles with a diameter of (0.95 mm), at least (2MPa) is sufficient. The tests also allowed to determine the degree of impact of the feed speed and nozzle diameter on the smoothness of the cut surface.

1.Introduction

The processing of fish and other hydrobiots for various commercial forms (carcasses, muscle flap and fish fillets) is based mainly on the processes of separating edible parts from parts of various usability. One of the most common operations during pre-treatment of fish is cutting, which can be carried out by machine or by hand

For over a hundred years are conducted research related to the development and modernization of machinery, equipment and vending machines for processing marine and freshwater fish.

In the first stage, these works concern morphometric measurements and fish orientation in processing machines (Dutkiewicz et al., 2011a; Dutkiewicz et al., 2012; Wieliczko, Bil., 2013), mechanization of fish processing operations (Dutkiewicz Dowgiałło, 2002; Dutkiewicz, 2004), or automation by introducing mechatronic elements or appropriate control elements (Dutkiewicz, Bil, 2009; Dutkiewicz, Bil, 2010; Dutkiewicz et al., 2011b).

The general purpose of these works is to increase the machine processing capability and the safety and hygiene of the product. As a

result, many machining units are so modern that human intervention in the technological process is not necessary. Nevertheless, these devices still generate higher raw material losses than manual processing mainly due to the specification of the machining tools used.

Currently, in the fish processing industry, cutting processes are most often carried out using circular knives with a smooth or serrated cutting edge. They are used for the operation of heading, cutting off fins, cutting the abdomen, portioning muscle flap, fillets and others. These knives have a large side surface which results in the formation of high friction forces when processing sticky materials. At the same time, manipulating such knives during their work is difficult and sometimes even impossible. As a result, the cutting surface made with their use is flat which generates raw material losses up abov 4% (Majewski 2005; Dutkiewicz, Bil, 2009). In addition, the morphological diversity of fish occurring even within the same species makes it impossible to construct a device or machine for their treatment with technological efficiency similar to the manual processing. Therefore, processing of more expensive fish, ie salmon, halibut, perch, zander, etc., is still carried out by hand. However, due to the hard working conditions - reduced temperature, high humidity, high noise, etc. - and the nuisance of physical work, it is necessary to mechanize and automatization of fish processing. In order to break the technological barrier, it is necessary to look for alternative machining tools that will allow the creation of new ways machine treatment of marine and freshwater fish. One of the alternative cutting tools that can replace traditional knives in fish processing is high-pressure water jet, also called hydro-jetting treatment technology.

The research carried out so far at the Faculty of Mechanical Engineering at Koszalin University of Technology has shown that hydro jetting technology can replace traditional machining tools with increasing technological efficiency. At the same time, it allows to selectively cut tissues, which in the case of fish processing gives great opportunities. However, due to the heterogeneity of the processed material, it is necessary to select the machining parameters for each group of processed raw materials.

This paper presents the method of determining the value of the supply pressure needed for the full intersection of the muscular flap depending on the diameter of the water jet and cutting speed.

2. Materials and methods

2.1. Materials

The low interest of machine manufacturers in the area of freshwater fish processing makes that there are few small-sized machines enabling the mechanization of processing in small production plants. And machines available on the market for processing marine fish are beyond financial reach. Therefore, a rainbow trout representing a species of freshwater spindle fish was selected as the research material.

The raw material used for the research was obtained in fresh form directly from the grower. In the first stage, the carcasses were sorted into three dimensional groups based on measurements of total length L_c and total weight after gutting m_c. First dimensional groups included fish with a total length of (L_c <300 mm) and a mass of (m_c <320 g). The total length of the carcasses assigned to the second group was in the range (300 < L_c < 340 mm), and their weight was in the range of (320 < m_c < 420 g). The third group included only carcasses whose overall length was (L_c > 340 mm and total mass was m_c > 420 g). In the next step, two samples were cut from each fish in the form of a skinned muscle flap Figure 1. The samples were cut using a fillet knife in such a way that minimum muscle tissue remained at the spine.

Figure 1. Sample in the form of skinless muscle flap

2.2. Test stand

The research was carried out using a research stand, own design, in the form of a cross table Figure 2. The table construction allows for automated movement of the head in two mutually perpendicular directions. The head movement was realized by means of two stepper motors, whose characteristics allowed for smooth regulation of the feed speed in the range of (0 ÷ 50 mm / s). The regulation could be made independently in two directions. In addition, the stand is equipped with a handle allowing manual adjustment of the angle of inclination of the stream with respect to the vertical in the range of (0 ÷ 90°).

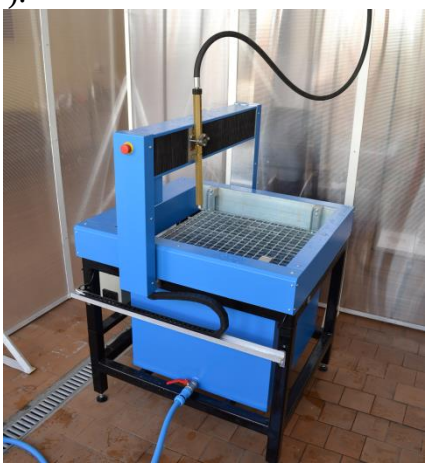

Figure 2. Machining table

To create pressure in the system, the mobile pressure unit of 500/15a was used, allowing for a smooth change of the supply pressure (p_z) in the range of (0.4–50 MPa) with a maximum capacity of (15 L/min).

The shape of the water stream was obtained by passing it through sapphire nozzles embedded in a stainless steel fitting Figure 3 with the diameter of the hole forming the stream successively: (d_d = 0.175; 0.25; 0.35; 0.45; 0.65; 0.95 mm).

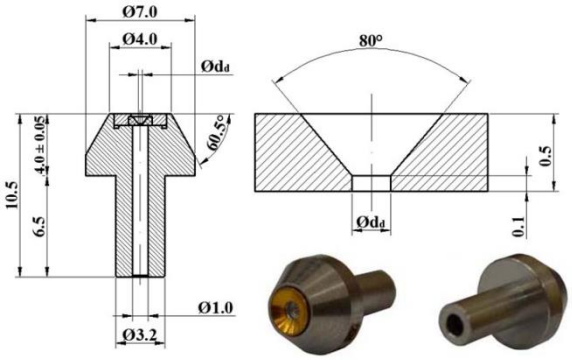

Figure 3. Nozzle geometry

The diameter of the forming hole was chosen in such a way that the change between neighboring nozzles caused a twofold increase in the jet power.

During the tests, a minimum value of the supply pressure was determined which allows full cut of the muscle flap. The pressure values were determined for six diameters of the jet forming holes and three feed speeds (v_d = 5; 25; 50 mm/s). Therefore, the remaining processing parameters were taken as fixed input parameters:

- distance of the nozzle from the raw material (l_d = 15 mm),
- spray angle of the stream against the vertical ($\alpha = 0^{o)}$,
- type of cutting medium: drinking water, at a temperature of (3-4°C), drawn directly from the water supply system.

3.Results and discussions

The conducted research allowed to determine the minimum values of the supply pressure at which the water stream has enough energy to cut the muscle flap of the rainbow trout. The obtained results are presented in the form of diagrams in Figure 4 and Figure 5. Using the markers with smaller dimensions, mark the supply pressure values needed to cut the individual areas of the sample. Use larger size markers, which are additionally connected by straight lines, the values of the supply pressure were indicated, with the use of stream of water always cuts the sample.

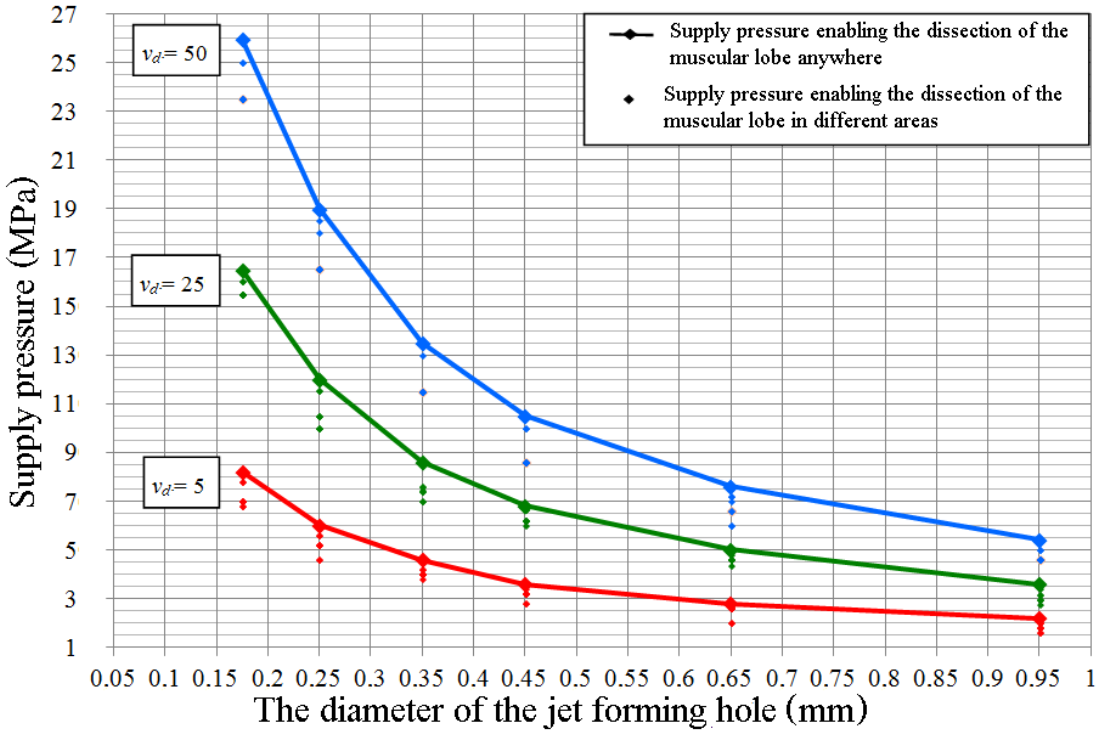

Figure 4. Graph of supply pressure (p_z MPa) needed for a full muscle cut depending on the nozzle diameter (d_d mm) for individual feed speed (v_d mm/s)

Analyzing the results in terms of the diameter of the hole forming the water jet, it can be concluded that the nature of the change in the supply pressure necessary to cut the muscle is close to the hyperbolic course. Regardless of the feed rate used, the lowest pressure values where the full muscle cuts were obtained, each time was noted for a water nozzle with a hole diameter (d_d = 0.95 mm). For feed speed (v_d = 5 mm/s) full muscle cut was obtained by feeding the jet with pressure of approx. (2.2 MPa). In turn, clear incisions of muscle tissue were noted already at approx. (0.4 MPa), pressure occurring in the water supply system. The reduction of nozzle hole diameter from (d_d = 0.95 mm) to (d_d = 0.175 mm) caused that the water stream for the same feed speed had sufficient energy to cut the muscle only when it was fed with pressure of about (8.2 MPa). This gives more than three and a half times the pressure increase by more than five times reducing the diameter of the water stream. However, it should be noted that as the feed speed increases, this proportions are change. For example, for the highest applied feed speed (v_d = 50 mm/s), the same change in the diameter of the water jet results in a nearly fivefold increase in the supply pressure from about (5.4 MPa) to about (26 MPa).

The character of the change in the supply pressure value for individual nozzle hole diameters, depending on the feed speed, is shown in Figure 5.

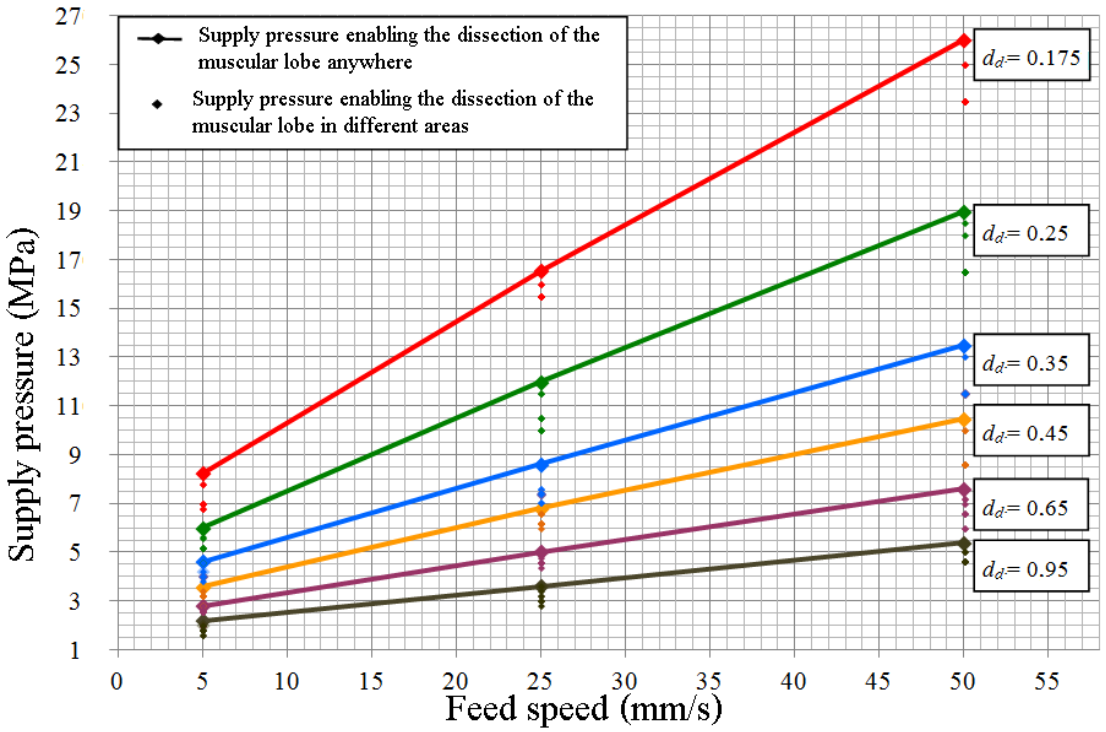

Figure 5. Graph of supply pressure (p_z MPa) needed for a full muscle cut depending on the feed speed (v_d mm/s) for individual nozzle diameter (d_d mm)

The tests show that using the lowest selected feed speed (v_d = 5 mm/s), feeding a water jet with a diameter (d_d = 0.95 mm) pressure approx. (2.2 MPa) it is enough for the full cut of the rainbow trout muscle. Increasing the feed speed to (v_d = 50 mm/s) results in the necessity of supplying the same stream with pressure of approx. (5.4 MPa). This results in almost two and a half times the increase in pressure with a tenfold increase in the feed speed. It should be noted, that reducing the diameter of the nozzle, resulted in a change of these proportions. For example, an increase in the feed speed from (v_d = 5 mm/s) do (v_d = 50 mm/s), for a water jet with diameter (d_d = 0.45 mm), gives almost a threefold increase in the supply pressure from approx. (3.6 MPa) to approx. (10 MPa), and for a nozzle with a hole (d_d = 0.45 mm), the increase is over three times from (8.2 MPa) to (26 MPa).

Analyzing the waveforms shown in Figure 4, it can be seen that reducing the diameter of the water nozzle hole has a gentler effect on changing the supply pressure for (v_d = 5 mm/s) than in the case of (v_d = 50 mm/s). This is due to the strength heterogeneity of the muscle, associated with the presence of intermuscular tissue located in the region of the tail.

By analyzing the effects of the cut, it can be observed that the tissue forms thin fibers along the edges of the muscle segments, whose water-jet cutting strength is much higher than the strength of the muscle itself. In effect, to cut the muscle flap around the tail, using a feed speed equal to (v_d = 50 mm/s), a water jet with small diameters, it was necessary to supply the installation with much higher pressure than when using the same speed for nozzles with large diameter of the forming hole. Similar relationships called selective influence of the stream on the tissue were observed and used at the turn of the 80-90 years in neurosurgery.

The next relations that could be observed during the research were the influence of the feed speed and the diameter of the nozzle hole to the smoothness of the cut edge. The effect of cutting the muscle for various values of the feed

speed and diameter of the water jet is shown in Figure 6.

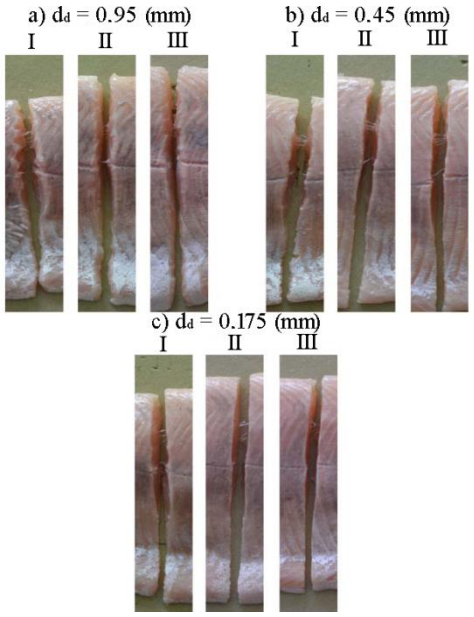

Figure 6. Effect of cutting the muscle using a different diameter of the nozzle hole for feed speed: I – (v_d = 5 mm/s); II – (v_d = 25 mm/s); III – (v_d = 50 mm/s)

Analyzing the cutting effect due to the hole diameter of the water jet , it can be observed that it significantly affects the smoothness of the cutting edge. It can be clearly seen that when using a nozzle with a hole diameter of (d_d = 0.95 mm), the water jet leaves the edge strongly jagged. The reduction of the nozzle hole diameter from (d_d = 0.95 mm) to (d_d = 0.45 mm) results in partial smoothing of the cutting edge. The best effect in this respect was obtained using a nozzle with a hole (d_d = 0.175 mm). At the same time, when analyzing the above-mentioned effects in terms of the feed rate used, a similar relationship can be observed. Increasing the feed from (v_d = 5 mm/s) to (v_d = 50 mm/s) using a nozzle with a hole (d_d = 0.95 mm) makes the cuted edge less ragged. If the feed is increased by using a nozzle with a hole (d_d = 0.45 mm), this effect is much more pronounced. The best result was obtained by increasing the feed rate during cutting with a jet diameter (d_d = 0.175 mm). It is clearly visible that when using a feed (v_d = 50 mm/s) and a nozzle with a hole diameter (d_d = 0.175 mm), the cut have almost completely smooth edge. It should be note, that the use of small diameters and high feed rates results in the necessity of feeding the system with higher pressure.

In addition, during the tests, it was observed that the water stream allows selective tissue cutting. An example of selective muscle cut-off with connective tissue is shown in Figure 7.

Figure 7. Selective cut of muscle with connective tissue

It can be observed that the soft muscle tissue has been rinsed from between the harder connective tissue. A similar effect was noted and widely described in the field of medical sciences (Hreha et al., 2010; Oertel et al., 2003a; Oertel et al., 2003b). The use of a small-diameter jet fed with relatively low pressure allowed cutting soft tissue (e.g., brain, kidneys, liver), leaving the inner vascular network intact, among others, for example, blood and nervous vessels.

4. Conclusions

The tests have shown that the water stream allows selective tissue cutting. Proper use of this property, through precise selection of machining parameters , can contribute to the increase in production efficiency. In addition, the precise selection of machining parameters will significantly reduce costs associated with the purchase and operation of pressure aggregates. In effect small-size machining machines using high-pressure water jets will become available even for small businesses.

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EXAMINATION OF TOTAL PHENOLIC CONTENT IN HONEYS AND HONEY POWDERS FROM BALTIC SEA REGION

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ABSTRACT

The paper presents the method of honey powders obtaining from buckwheat and rapeseed honey. The aim of the study was to determine an effect of bee honey type and the type of applied carrier substance on the quality of honey powders obtained. Fresh honey was subjected to alcoholic fermentation in order to reduce the content of monosaccharides contained in it, then the solutions were subjected to freeze drying, after an addition of selected carrier substance. The contents of vitamin C, polyphenolic compounds, dry matter and total acidity were evaluated in fresh honeys, post-fermentation solutions and honey powders.

The use of alcoholic fermentation of honeys resulted in the reduction in the content of monosaccharides, but it did not affect the content of bioactive components of honey, such as polyphenolic compounds, which allowed to obtain honey powders with enhanced health-promoting properties. The honey powder with the most desirable characteristics, excellent friability and granulation was the powder obtained from buckwheat honey with a 20% addition of maltodextrin as a carrier substance.

1. Introduction

The interest of consumers in convenient and functional foods is steadily growing. This is primarily linked to the new trends created by food producers as well as with the change of the lifestyle to a more health-promoting one [Adamczyk, 2010]. Due to the unfavorable physicochemical properties of honey, i.e., density and viscosity, it is not used on a large scale in the food, cosmetics and pharmaceutical industries. A solution to the problem may be the production of honey in the form of a powder, which would be an alternative to liquid honey (Kruszewski et al., 2014).

Obtaining the honey in the form of a dry powder is a very complicated operation. Problems occurring during production are primarily related to the consistency of honey and a high content of monosaccharides and organic acids in it. Problems occurring during production are primarily related to the consistency of honey and a high content of monosaccharides and organic acids in it (Suhag, Nanda, 2015). A feature of these substances is the low glass transition temperature, which combined with the usually higher drying temperature, prevents the material from drying into a powder and causes the drying chamber sticking with it or material burning, which results in undesirable gummy and sticky form (Jedlińska et al., 2012).

Carrier substances, which include mainly maltodextrins, starch and gum Arabic, are used in order to increase the glass transition temperature, which would allow to dry the honey and obtain a powder. Another way of an effective honey powders obtaining is modification of the drying parameters or

reduction of monosaccharides content in honey. This is possible due to the dilution of honey and subjecting it to alcoholic fermentation process (Samborska et al., 2011).

Several methods are known for powders producing based on honey, which are constantly modified and improved in order to obtain powders with the highest honey content, with a characteristic taste and aroma and properties as close as possible to the properties of the initial product. Also the preservation of nutritional value of the material that was subjected to drying, which mainly includes the content of vitamins and polyphenols, is an important aspect (Jedlińska et al., 2014). The choice of the method and parameters for honey powders production depends on their subsequent use (Samborska et al., 2011). Dried honey can be a substitute for sucrose in products used on an industrial scale, e.g. in bars, candies, breakfast cereals, bread, it can be a component of supplements or nutraceuticals (Jedlińska et al., 2012). For these reasons, the aim of this study was to obtain honey powders from two types of bee honey: buckwheat and rapeseed, and the use of various carriers. An effect of honey type on the quality of obtained honey powders as well as the influence of the carrier used during production on obtained powders quality was determined.

2. Materials and methods

The basic materials used in the study were two types of nectar honey - buckwheat honey and rapeseed honey, from the Regional Beekeeping Association in Koszalin (Jeżyce Apiary, Zachodniopomorskie Voivodeship). Non-brewed meads were obtained from the honey, and then honey powders were produced by freeze drying.

In order to obtain honey powders, buckwheat and rapeseed honeys were fermented using *Saccharomyces cerevisiae* Turbo Jäst yeast strain. The batch was prepared in the initial stage. For this purpose, 400 g of honey were collected and diluted with water to obtain a 20% general extract. The honey broth was inoculated with *Saccharomyces cerevisiae* Turbo Jäst yeast in an amount of 0.5 g per 2 L of the batch. Alcoholic fermentation of honey was carried out in anaerobic conditions at the temperature of 22°C for 14 days. During batch fermentation in the bioreactor, additional portions of honey were added to it in the amount of 200 g after 5, 9 and 14 days of fermentation. After two weeks of fermentation, the post-fermentation solutions were immobilized on the carriers and freeze-dried to obtain honey powders. Six different mixtures were prepared from the post-fermentation solution of buckwheat and rapeseed honey, and their composition depended on the type and amount of the carrier added. Three honey solutions with 20% and 10% addition of the following carriers were prepared: maltodextrin, inulin, tapioca flour and the combination of two types of carriers with the following composition: 15% maltodextrin and 5% guar gum; 15% inulin and 5% guar gum; 15% tapioca flour and 5% guar gum. The prepared mixtures were homogenized for 5 minutes in a ULTRATURRAX T25 Basic homogenizer at 16000 rpm. Then the samples were frozen and freeze-dried in the Alpha 1-2 LDPLUS laboratory lyophilizer from Christ company for 24h, pressure 63 Pa, safety pressure 103 Pa.

The content of vitamin C (PN-A-04019:1998 Determination of vitamin C content), total acidity (PN-88/A-77626 Bee honey), total content of compounds polyphenolic compounds (AOAC International, 1974), dry matter content using a moisture analyzer at 105˚C, were determined in buckwheat and rapeseed honey, post-fermentation solutions and honey powders.

3. Results and discussions

Due to the unfavorable physicochemical properties of bee honey, its use in the food industry is significantly reduced (Cui et al., 2008). This is related to the high density and viscosity of the honey, which to a high degree impedes standard technological processes, including dosing (Jedlińska et al., 2014). During

dispensing, the product sticks to the walls of tanks and pipes, which causes large losses (Jedlińska et al., 2012). Honey powders obtained by drying with the use of carrier substances would be an alternative to fresh honey (Jedlińska et al., 2012). In the United States, honey powders are produced on a large scale and used as an additive to dietary supplements, spices, teas, instant beverages and as a substitute for sucrose in bread (Ahalya, 2011).

Fresh honeys and honeys after alcoholic fermentation were analyzed for L-ascorbic acid content, total acidity, total polyphenol content and dry matter content (Table 1).

Tabel 1. Evaluation of particular components content in fresh honeys and after alcoholic fermentation

Properties	Honey		Post-fermentation solution	
	Buckwheat	Rapeseed	Buckwheat	Rapeseed
Dry matter content (% (m/m))	88.65	87.9	17.8	16.1
Total acidity (mval/dm^3)	17	35	19	42
Vitamin C content (mg/100 g)	19.39	48.09	1.24	1.24
Polyphenols content (mg/ml)	0.24	0.72	0.39	1.09

The analysis of vitamin C content in fresh bee honey showed that the honey type significantly affects vitamin C content. Buckwheat honey is characterized by a higher content of vitamin C compared to rapeseed honey. The content of L-ascorbic acid in fresh buckwheat honey was 48.09 mg/100 g of the examined sample, while in the case of fresh rapeseed honey it was 19.39 mg/100 g. Kędzia and Hołderna-Kędzia (1998) determined the content of vitamin C in fresh honeys at a minimum level of 22 mg/kg, but this value may increase more than five-fold in the case of buckwheat honeys, which are characterized by the highest content of vitamin C among all bee honeys. The content of vitamin C in honeys that were subjected to alcoholic fermentation is lower compared to fresh honeys. According to Czyżycki et al. (1998), a normal phenomenon during alcoholic fermentation is the loss of vitamins, especially vitamin C, which is due to the fact that Saccharomyces cerevisiae yeasts used during the fermentation of fresh bee honey do not assimilate vitamin C, which results in such a high decrease of this vitamin content in the product. In turn, the type of honey that was subjected to alcoholic fermentation has no effect on the subsequent content of vitamin C in it.

The total acidity of fresh buckwheat honey is higher compared to the total acidity of fresh rapeseed honey. The total acidity of fresh buckwheat honey was 3.5 ml 1 M NaOH/100 g honey, i.e., 35 mval/kg. This result is consistent with the values given in PN-88/A-77626 (1989), which determines the total acidity of buckwheat honey at 48.5 mval/kg. Conducting the study on the acidity of various types of honeys, Popek (2003) showed that the total acidity of buckwheat honey is 24.6 m/kg. According to Rybak-Chmielewska (1986), the highest total acidity among honey varieties is attributed to buckwheat honey, while the lowest to rapeseed honey and acacia honey. The average value of total acidity assumed for rapeseed honey is 17.7 mval/kg, and for acacia honey 22.9 mval/kg (according to PN-88/A-77626 (1989)). The total acidity of fresh rapeseed honey presented in Table 1 was 17 mval/kg. A similar result was obtained by Popek (2003), who showed in his study that the total acidity of fresh rapeseed honey is 14.9 mval/kg.

Alcoholic fermentation of fresh honeys affect their later total acidity, which after the process increased significantly from 35 mval/kg to 42 mval/kg in the case of buckwheat honey, whereas in the case of rapeseed honey this value increased from 17 mval/kg to 19 mval/kg. A similar relationship between the alcoholic fermentation of fresh honey and the increase in its total acidity was obtained by Kruszewski et al. (2014). The authors showed in their study that the total acidity of post-fermentation solution of buckwheat honey was higher compared to the total acidity determined for fresh honey. This value increased from 50 mval/kg to 340 mval/kg. An increase in total acidity in bee honeys indicates the alcoholic fermentation processes taking place and this is a normal and common phenomenon (Wojtacki, 1982).

Honey contains many active constituents and antioxidants such as polyphenols. Polyphenols are phytochemicals, a generic term for the several thousand plant-based molecules with antioxidant properties (Hossen et al. 2017). The content of polyphenolic compounds was determined in fresh bee honeys and after alcoholic fermentation. It was found that the content of polyphenolic compounds in post-fermentation honeys is significantly higher compared to fresh honeys. In the case of buckwheat honey, this content increased by 0.37 mg/ml, while in the case of rapeseed honey by 0.15 mg/ml. A similar relationship was demonstrated in the study conducted by Kruszewski et al. (2014), where the polyphenols content in the fermented bee honey was 0.74 mg/ml and was almost twice as high as in the case of fresh honey. According to Zujko et al. (2005), the content of polyphenolic compounds in fresh buckwheat honey was at the level of 0.95 ± 0.46 mg/ml, and according to Majewska et al. (2012) at the level of 0.049 ± 0.16 mg/ml. The differences may result primarily from different places of honey origin, as well as different collection time. In addition, buckwheat honey contained a higher amount of polyphenols compared to rapeseed honey. The content of polyphenolic compounds in bee honey is closely related to the honey species. There is a greater number of these compounds in dark honey compared to light honey (Wesołowska et al., 2014; Kędzia and Hołderna-Kędzia, 2008). Gheldof et al. (2002) indicate the highest content of polyphenols in buckwheat honey (0.46 ± 0.80 mg/ml based on gallic acid) compared to other types of honey. The lowest content of polyphenols is at the level of 0.27 ± 0.40 mg/ml calculated as gallic acid and refers to light honey - acacia and rapeseed ones (Kędzia and Hołderna-Kędzia, 2008).

The content of dry matter in fresh buckwheat and rapeseed honey was on a similar level and amounted to: 87.9% for buckwheat honey and 88.65% for rapeseed honey. Polish Standard PN-88/A-77626 (1989) clearly indicates that the water content in fresh bee honey should not exceed 20%, which means that the minimum content of dry matter in fresh honey should be 80%.

The first stage in honey powders production was the preparation of a broth with a high content of bioactive components of bee honey, such as the content of vitamin C or polyphenolic compounds. For this purpose, the honey broth was diluted with water to obtain a 20% extract. Then, during the fermentation, honey was added to the prepared batch in three portions. The first portion of honey was added at the batch preparation stage, other after 7 and 12 days after batch inoculation with the starter culture. Three times repeated addition of bee honey to the batch was caused not only by an increase in the content of bioactive compounds but also by reduction in the content of monosaccharides in order to facilitate the freeze drying process as well as to obtain honey powders of the desired quality (Jedlińska et al., 2012). The main component of the dry matter in honey is sugar, the content of which mainly affects the high dry matter result (Bornus, 1989). Therefore, the content of dry matter in fermented honeys was 17-18% for both types of honey.

The post-fermentation solutions of bee honeys - buckwheat and rapeseed ones, were

immobilized using the following carrier substances: inulin, tapioca, maltodextrin and guar gum. Such prepared solutions were freeze-dried and ground to obtain homogeneous honey powders, which were subjected to physicochemical analysis. It was demonstrated that the best emulsifying properties, high solubility and low viscosity, i.e., features that facilitate the drying process and by which the powders of the desired quality are obtained, are obtained in the case of inulin and maltodextrin. Their application allowed to obtain honey powders with the highest content of dry matter (Figure 1).

Similar results were obtained by Nurhadi et al. (2012) who, after an addition of maltodextrin as a carrier substance, received honey powders with the highest dry matter content, which amounted to 97.7%. Adding maltodextrin, Jedlińska et al. (2012) obtained honey powders in which the water content was 2 and 4.6%, which as a result determines a dry matter content of 98 and 95.4%.

Figure 2 and 3 present honey powders obtained from buckwheat honey. Most powders were characterized by good flowability, small particle size and white or slightly cream color.

The variety of bee honey and the type and amount of the addition of high molecular weight carrier substances have a major impact on the quality of the honey powders obtained. Obtained honey powders based on buckwheat honey were characterized by good friability, they did not clump and their particles were of similar size. In turn, honey powders from rapeseed honey did not obtain the desired friability, they were sticky and easily clumped.

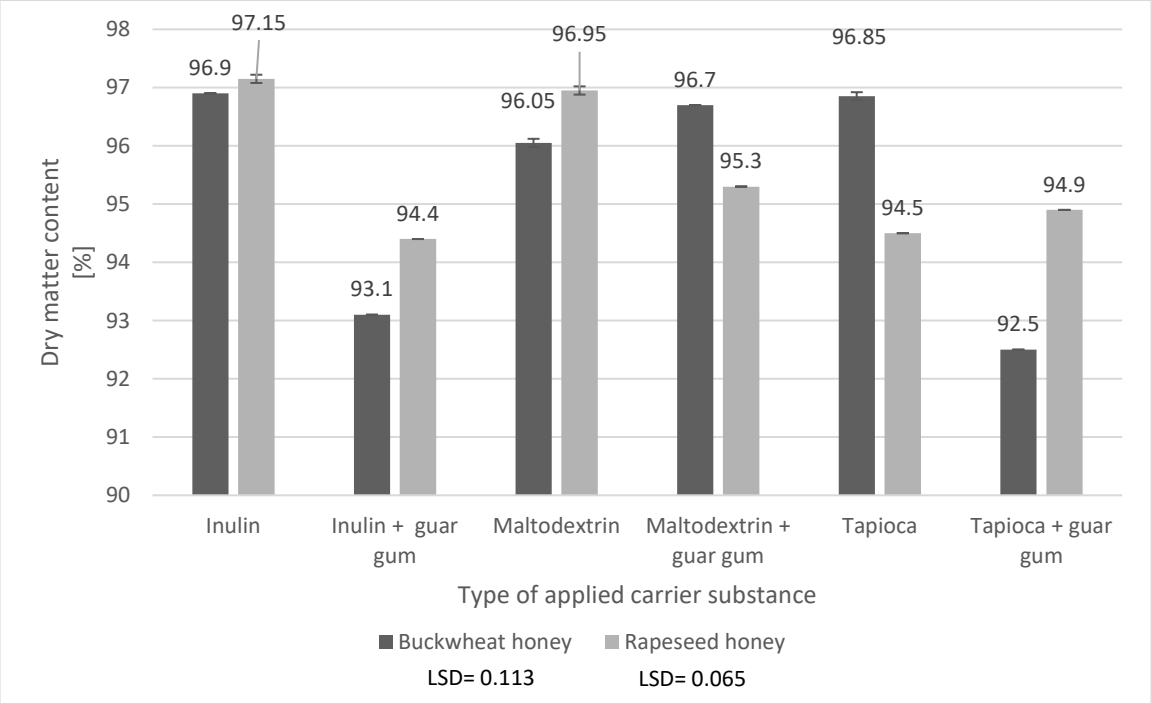

Figure 1. Dry matter content in honey powders from buckwheat and rapeseed honey

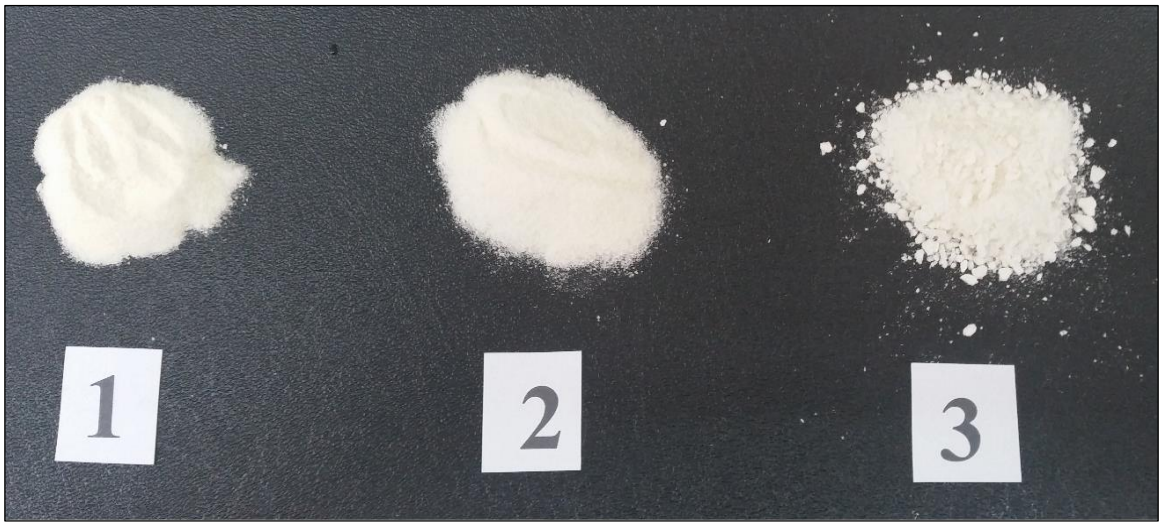

Figure 2. Honey powders obtained by freeze drying, where 1 - addition of maltodextrin 2 - addition of inulin, 3 - addition of tapioca as a carrier substance

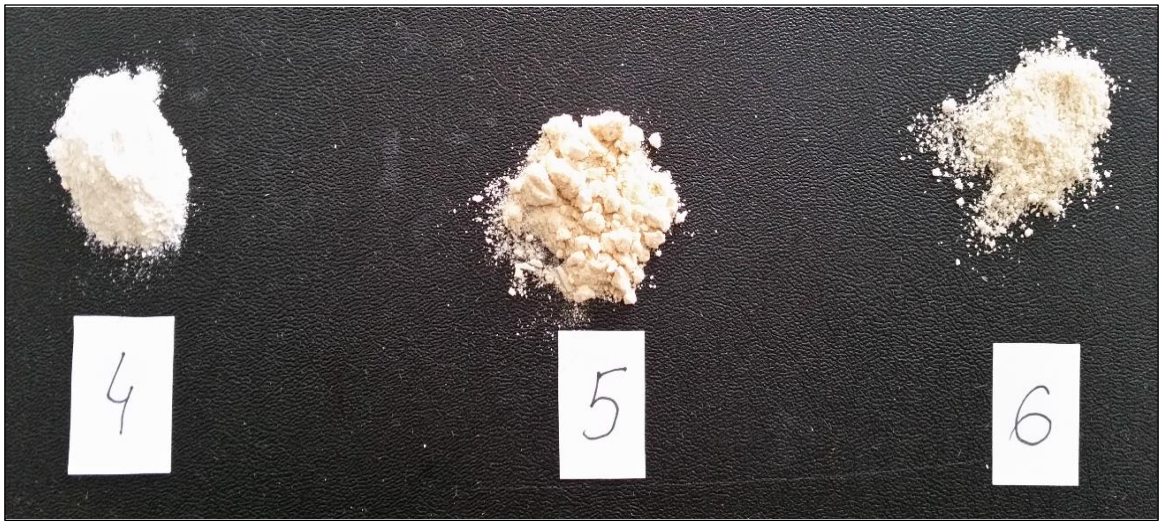

Figure 3. Honey powders obtained by freeze-drying, where 4 - addition of maltodextrin and guar gum, 5 - addition of inulin and guar gum, 6 - addition of tapioca and guar gum as a carrier substance

The best friability and lack of adverse clumping phenomenon were noted in the case of droughts obtained using maltodextrin, inulin and maltodextrin with the addition of guar gum. These powders had the most desirable form, they did not stick together and had the correct white or slightly creamy color. The best structure and size of the particles were determined for honey powders obtained using maltodextrin and maltodextrin with the addition of guar gum. Honey powders with 20% addition of a carrier substance were characterized by very good physicochemical properties. The particles of these powders were similar in size, did not clump and had a white color. An addition of 10% of the carrier also made it possible to obtain honey powders, but they tended to agglomerate easily. The particles differed in size and the resulting drought was of a yellow color, more

like the color of honey and characterized by a more intense honey scent.

The content of vitamin C in all tested honey powders was 1.24 mg/100 g and was the same as in post-fermentation solutions of bee honeys. In turn, the content of polyphenolic compounds in honey powders decreased compared to post-fermentation solutions, but it was still comparable to the content of these compounds in fresh honey. The addition of the carrier substance affected polyphenols content in the examined powders (Figure 4).

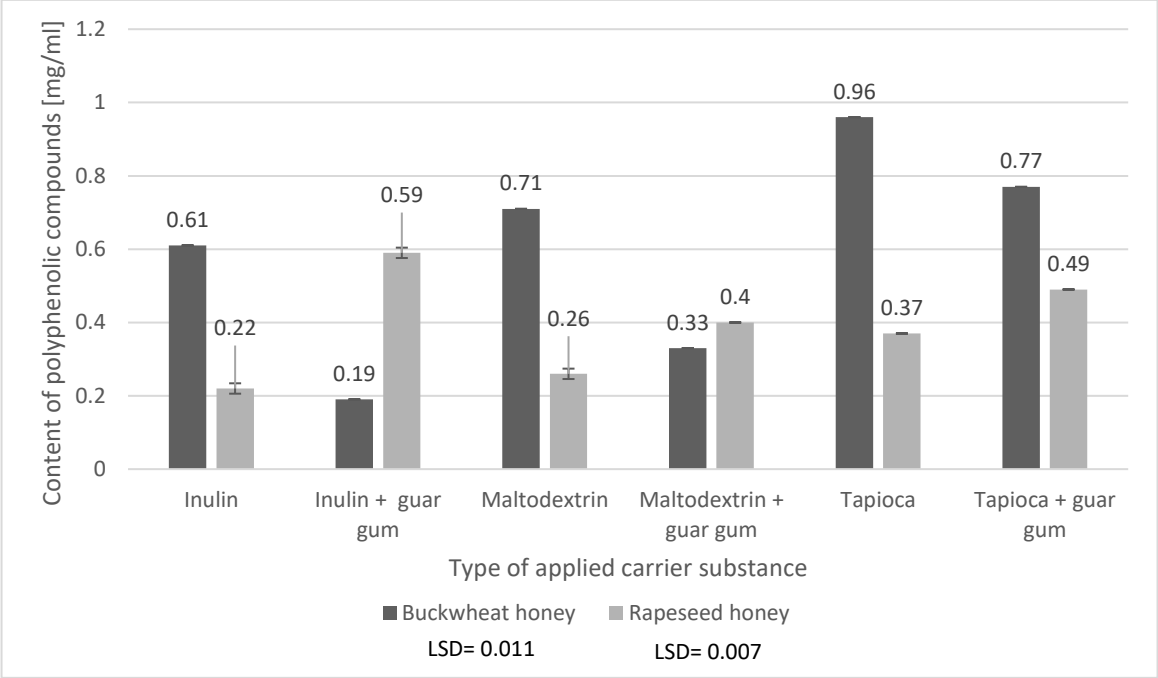

Figure 4. The content of polyphenolic compounds in honey powders from buckwheat honey and rapeseed honey

The largest reduction in polyphenols content was observed in honey powders with inulin as the carrier substance. In the case of honey powders obtained from buckwheat honey, this drop amounted to 44.04%, while in the case of honey powders based on rapeseed honey 43.59%. The smallest decrease in polyphenol compounds content was observed in honey powders with the addition of tapioca as a carrier substance - in buckwheat honey powders, the decrease was 11.93% and in the case of rapeseed honey powders 5.13%. Similar results were obtained by Kruszewski et al. (2014), who showed a reduction in polyphenols content by about 30%. It was found comparing the content of polyphenolic compounds in the obtained honey powders with the content of polyphenols in fresh honeys, that the concentration of polyphenols is at an even level and in some cases even higher. Wintersteen et al. (2005) showed that despite contact of the product with hot air during the drying process, the concentration of polyphenolic compounds in the dried product did not change.

Figure 5 presents the results of tests on the total acidity of obtained honey powders from buckwheat honey and rapeseed honey.

It can be concluded from the study that the type of carrier substance affects total acidity result of honey powders obtained by freeze-drying, causing its lowering. The highest total acidity was observed in honey powders obtained from buckwheat honey, which were enriched with maltodextrin with the addition of guar gum. Their total acidity was 5 mval/dm3. In turn, the lowest total acidity was observed in honey

powders from rapeseed honey enriched with maltodextrin with the addition of guar gum – 1.6 mval/dm3. The freeze-drying process of post-fermentation solutions of buckwheat and rapeseed honey affected the reduction of total acidity. A similar effect of product drying on the decrease in its acidity was proved in the study by Pobereźny and Wszelaczyńska (2013), while Kruszewski et al. (2014) showed that the total acidity of honey powders obtained by post-fermentation solutions drying decreased by almost 34%. Powders obtained from buckwheat honey were characterized by higher total acidity compared to powders from rapeseed honey, which was related to the higher total acidity of post-fermentation solutions of buckwheat honey compared to rapeseed honey post-fermentation solutions. Higher acidity has a beneficial effect on the quality of dried product due to the inhibition of development of unfavorable bacterial flora and putrid bacteria in it (Targoński and Stój, 2005).

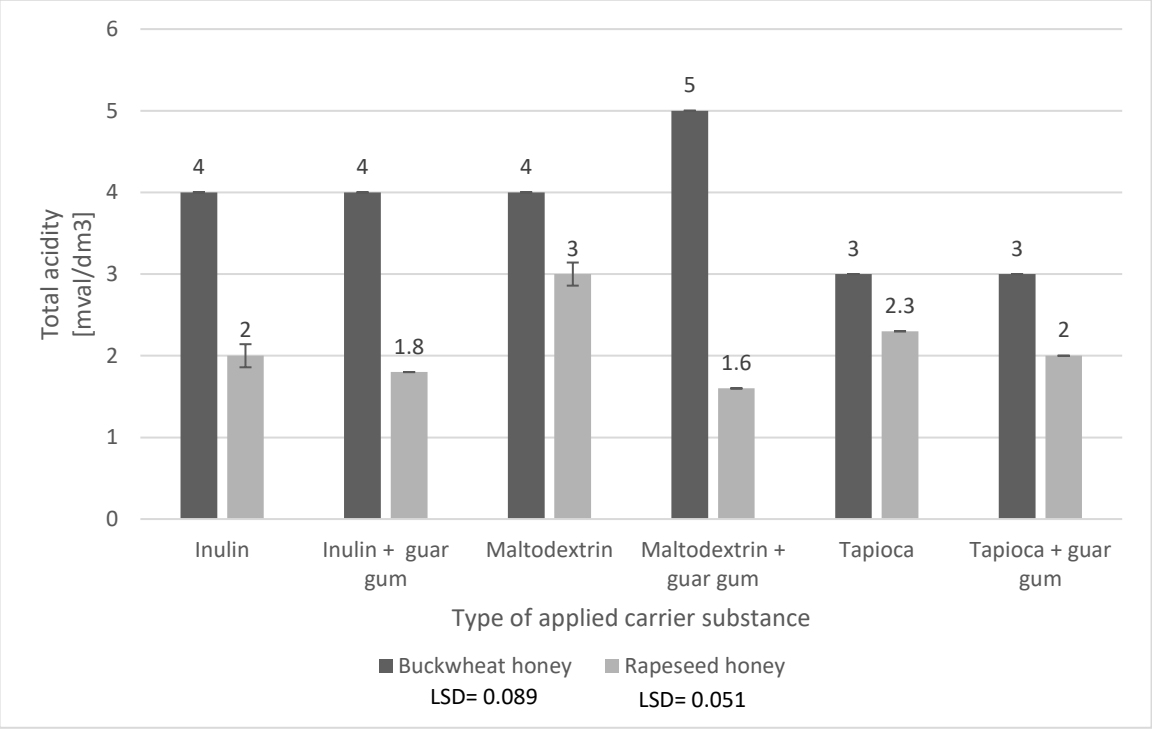

Figure 5. Total acidity of honey powders obtained from buckwheat honey and rapeseed honey

4. Conclusions

Use alcoholic fermentation of bee honeys does not reduce the content of bioactive components in honey, such as polyphenols, thanks to which it was possible to obtain honey powders with improved health-promoting properties.

Honey powder with the most desirable characteristics, excellent friability and granulation was the powder obtained on the basis of buckwheat honey with 20% addition of maltodextrin as a carrier substance.

Honey powders based on buckwheat honey were characterized by higher content of polyphenols and higher total acidity compared to honey powders based on rapeseed honey.

Honey powders contained a higher content of polyphenolic compounds and greater total acidity than fresh bee honey used in their production.

Type of honey, freeze-drying of post-fermentation honey solutions and the type of carrier substance do not affect the content of L-ascorbic acid in the obtained honey powders, which was low.

Addition of inulin and maltodextrin as carrier substances enabled to obtain honey powders with the highest dry matter content.

Honey powders with 20% addition of carrier substance were characterized by better properties compared to honey powders with 10% addition of carrier substance.

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THE INFLUENCE OF ADVERTISINGS ON CONSUMER'S DECISIONS ON THE EXAMPLE OF DIARY PRODUCTS

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ABSTRACT

Food advertising usually refers to human emotions, affecting health and safety; it also influences shaping the nutritional attitudes of the society. This trend also appears on the market of dairy products, which plays an important health role in the human diet. In recent years, dairy fermented beverages and probiotic milk drinks have become a very dynamically growing segment of the food market. The introduction of these products to the market resulted in increased expenditures of competing companies on their advertising.

Therefore, the aim of the work was to examine the impact of advertising on consumer nutrition decisions in the field of dairy products, in particular products enriched with probiotic bacterial strains, included in the functional food group. The research was carried out using a questionnaire specially developed for this purpose, among respondents over 18 years of age. The collected data was presented by means of graphs and then subjected to basic statistical analysis adequate to the nature of the variables.

The research showed, among others, that although the attitude of buyers to advertising is diverse, it is, however, a factor that significantly affects consumers' decisions and is an important source of information for them on the market of dairy products enriched with substances positively affecting the digestive system. This information indicates the positive role of food advertising, shaping the right nutritional attitudes of the society and promoting positive changes in food consumption.

1. Introduction

The functioning of both consumers and producers in the modern world is dominated by many trends; the most important are mass culture and consumerism, which significantly affect all market participants. On the one hand, buyers strive to satisfy their needs, and, consequently, constantly face the dilemma of choosing the right product that meets their expectations. This is not easy as the free market economy, currently existing in most national systems, is characterized by a large variety of commonly available products. However, the other side of the market should not be forgotten, namely - producers, brokers, sellers - who, in order to survive on the market and generate profits, must maintain current and acquire new buyers of their products/services.

Consumer behavior on the market, as well as the process of making purchasing decisions (i.e. actions in which people choose, buy, evaluate and consume a product or service to meet their

needs or desires. (Guolla, 2011)) is determined by many factors, variables and external stimuli, that reach the awareness of buyers. On the one hand, these are the factors lying on the producers/sellers' side, such as: price, assortment, quality, brand, etc., which allow the development of long-term relationships with clients, which in turn - in today's competitive and changing business environment, where the strength of retailers and the level of customer demand is constantly growing - it is necessary for the success or even survival of the company (Thapa 2011; Giovanis et al. 2013). Nevertheless, interpersonal factors lying on the consumers' side are also important, among which, cultural factors (e.g. culture, subculture and social class of buyers), social (e.g. reference groups, family, social role and status, society as a whole), psychological (e.g. personal motivation, perception, acquiring knowledge, as well as beliefs and attitudes), personal (e.g. age, sex, family life cycle, professional status, way of life, perception of yourself and personality) and economic (e.g. level of income allocated for expenses, savings and assets, creditworthiness, debt, attitude to spending and saving money) should be mentioned (Moschis 1976; Kotler 2005; Stoma et al. 2017).

Regarding food products, several studies have been carried out in the last three decades about making consumers' decision of buying food products, and in particular the identification of predictors and correlations between them. It is even more complicated due to the fact that different scientific disciplines elucidate the subject from different perspectives (health sciences, nutrition, food and technology, psychology, marketing and management). Therefore, attempts are made to make an interdisciplinary review. According to Symmank et al. (2017), biological, psychological and product-related factors deserve special attention in this area. Food trends as well as consumers' awareness of healthy eating and their knowledge of the impact of purchased and consumed products on health, well-being and broadly understood quality of life, must not be forgotten either (Asp 1999).

The impact of the above-mentioned variables/factors on consumer attitudes takes place through mutual relationships and relationships between them. It is important, however, that many consumer decision-making behaviors may be different for different people because customers can use different approaches to making choices, not just mathematical modeling (Swait and Adamowicz 2001). In addition, the purchase decisions of customers in most cases depend on both rational and emotional factors.

A significant part of these factors is of direct character, an example of which may be one of the most common forms of promotion, which is advertising It should be mentioned that it is no longer just a factor that accompanies the act of buying and selling. It is a comprehensive phenomenon, fulfilling many important functions, including: informative, communicative, persuasive and stimulating, competitive, consolidating, and even culture-forming, educational and economic. It reaches both mass and anonymous receivers as an impersonal and paid message. However, it has the greatest impact on the buyers in a psychological way, increasing the awareness of the product in the minds of current and potential customers.

Advertising plays a special role on the market of food products, on which it refers mainly to human emotions, especially in the aspect of health, safety and quality of life. Often, it also influences shaping the nutritional attitudes of the society. It should be emphasized that the food market belongs to the group of sectors with the highest outlays allocated for this type of promotion (Świątkowska 2009). This is also evident in the dynamically developing segment of dairy products, including dairy

fermented beverages and probiotic milk beverages, which play an important health role in human diet. As a result of the introduction of these products on the market, competing companies - in order to highlight their offer and, consequently, increase demand - have been forced to use marketing activities on a wider scale, including the use of appropriate promotional tools. It should be added, that in today's times of uncertainty, organizations and industries seriously come at advertising their products and services (Hassan 2015).

Various media and means of information transfer are used in advertising activities. They are different in terms of the ability to reach potential clients with the message; they also differ in cost, as well as the power of expression. The decision on the selection of media and advertising means depends on many factors, including the nature of the target group, product characteristics, nature of the message, intentions and goals of the advertising campaign and the amount of available funds. This is an extremely important issue because properly selected and designed advertising affects its effectiveness.

Depending on the means used, different types of advertisements can be distinguished: TV, radio, press, internet, cinema, postal, external (e.g. signboards, websites, billboards, advertising columns, etc.), ambient media. While most of them are widely known to the public, the specificity of ambient media often makes it a bit incomprehensible. Ambient media are in fact non-standard means of advertising messages, which are mainly based on customer's surprise. Therefore, they occur mainly in such places and at such time that the client does not expect. The use of ambient messages allows to reach the customer more precisely and effectively because through selective action it enables establishing a personal relationship with the receiver.

A common feature of most ads is communicating with receivers through the media, which have become a kind of bridge that allows to reach the selected market segment with the message. They also enable shaping awareness of the existence of a product or brand by creating needs and willingness to satisfy them; they also often change the way of consumers thinking, mainly due to being based on emotions (Mirabi et al. 2015). Today's advertising has to meet the expectations of both buyers and clients. Therefore, it must be original and properly prepared in accordance with rapidly changing trends in this market area (globalization, technology development, modern forms of communication, etc.); it should also be moderate, both in content, manner of transmission and intensity.

Opponents of advertisement claim that it is an unnecessary cost to the consumers, raising the price of the purchased product/service. However, as the examples of modern enterprises show, the percentage share of advertising in production costs is not too high. Moreover, if the impact of advertising on consumer purchasing decisions and, consequently, the increase in demand, is visible, then the scale of production can be increased, which, in turn, reduces unit production costs, and finally reduces the price of the product/service.

To sum up, it should be stated that advertising as one of the promotion strategies is an important tool in building brand, company or product awareness in the minds of potential customers, and consequently in making decisions about the purchase of a product. Producers create an emotional relationship with clients, among others, due to advertising, which is considered a powerful tool for informing and influencing consumer behavior (Latif and Abideen, 2011).

Promotion and its various forms and tools, including advertising, are used where there is market and competition. As Belch ~~and Belch~~ (1999) believe, advertising is not just a matter of existence in economies where the dictatorship

has destroyed the forms of the market economy (e.g. in a centrally controlled economy, supported by a totalitarian system of power). This is due to the fact that such economies have been distorted by irrational use of resources or their waste. In such conditions, advertising would be tactless and even ironic, due to the lack of goods in stores. On the other hand, it should be remembered that advertising of a brand, product or enterprise is not a guarantee of their success.

As already mentioned, advertising is widely used in the case of food products, including milk and milk products. This is because contemporary consumers are paying more and more attention to the health-promoting properties of food, including dairy products. Milk contains many the ingredients that are needed by the body for life, development, as well as mental and physical activity. Building and energy materials that can be found in milk are: proteins, lipids and carbohydrates. Substances that have regulatory functions include vitamins, hormones and minerals. Milk also abounds in elements of the immune system, which provide protection against pathogens. In addition, some specific milk components, such as whey proteins, unsaturated fatty acids, calcium or vitamin B2, have a multidirectional effect on the human body, reducing the risk of many diseases of affluence (Brodziak et al. 2017). It should be added that high biological value of milk components is associated with their large diversity, versatility and digestibility and assimilation, which has fundamental importance for human nutrition. The addition of milk may increase or supplement the nutritional value of other food products. Therefore, milk and its products should be a part of the daily human diet. Its amount recommended for consumption depends on age, performed work, physiological condition and health (Żelazna 2003). Unfortunately, it is also one of the more allergenic products (Stoma et al. 2016).

Dairy products are included in the human diet mainly due to their properties, which are conditioned by microorganisms with the ability to ferment milk, e.g. from the genus *Lactobacillus sp., Leuconostoc sp., Pedicoccus sp., Bifidobacterium sp.* as well as *Streptococcus thermophilius* and *Lactococcus sp*. Currently, fermented dairy products are divided into three groups (Niedźwiedzka, Deptuła 2006):

1. yogurts and kefirs, as well as acydophilic milk resulting from the fermentation carried out by lactic bacteria;
2. products containing live bacteria to which, in addition to bacterial strains causing lactic fermentation, intestinal bacterial cultures are used;
3. products created exclusively on the basis of fermentation processes of probiotic bacteria.

In Poland, the following types of fermented milk beverages are produced in the largest quantities: yoghurts (natural, flavored), kefir, buttermilk, acidophilus milk and other products containing probiotic microflora. Among the products containing additional microflora, next-generation fermented milk drinks are becoming more and more popular, namely the ones containing probiotic microflora and prebiotics (Stankiewicz 2009).

The term probiotics is defined as live microorganisms that, when present in the right amount, have a beneficial effect on the health of the host. This effect varies depending on the strain used in the product. Among the most frequently mentioned beneficial functions of the use of probiotic strains are the following (Woźniak-Kosek 2004):

- stimulation of the immune system,
- maintaining the balance of bacterial flora in the digestive system,
- prevention of intestinal infections,
- alleviation of lactose intolerance,
- correcting disturbances of the intestinal flora,
- inhibiting the development of tumors,

- lowering cholesterol.

In compliance with the expectations of today's - mostly conscious and educated – consumers, looking for products that have a beneficial effect on their health and considering so many health-promoting properties of milk, and especially its products enriched with probiotic microflora, producers should properly promote milk and dairy products as elements of a proper lifestyle that ensures good health, well-being and affects the right quality of life (Brodziak et al. 2017).

Therefore, the aim of this work was to examine the impact of advertising on consumers' nutritional decisions in the field of dairy products, in particular products enriched with probiotic bacterial strains, included in the functional food group (Zdybel et al. 2015), whose share in the dairy market in the last the time has increased significantly. The research focused on respondents' attitudes to advertising and the influence it might have had their decisions regarding the purchase of this type of products.

2. Materials and methods

The research was conducted in a group of people over 18 years of age. The size of the examined group was 250 people. The method of gathering information was a targeted direct interview in three age groups, taking into account the gender of respondents and their place of residence. Due to the fact that the data was obtained by collecting population samples, they can be considered as descriptive research based on the method of data collection, and more specifically - questionnaire survey.

The research was carried out using a measurement tool specially developed for this study, in the form of an original questionnaire. The 14 questions included in the questionnaire were closed and respondents were asked to mark one correct answer among several available options. The questionnaire, except for the metric questions, allowing to make the socio-demographic characteristics of the respondents (due to different grouping variables, including gender, age or place of residence), included questions mainly about:

- speaking to consumers of particular forms of advertising,
- attitudes to advertising of food products,
- the impact of advertising on the choice of food products,
- factors affecting the purchase of probiotic products.

The collected data was presented by means of charts, and then it was subjected to basic statistical analysis adequate to the nature of the variables.

3. Results and discussions

The article focuses on the analysis of answers to selected questions regarding food products, in particular dairy probiotic products. In addition, one of the grouping variables, that is gender, was used in further research. That is why the analysis of consumer's preferences in the field of reception of advertising messages and their impact on purchasing decisions, depending on their gender, is presented below.

First of all, the respondents were asked a question - which of the contemporary forms of advertising food products appeal to consumers the most. Respondents had a choice of 6 most common advertising media, namely: television, radio, press, internet, leaflets and billboards. The obtained data is presented in Fig. 1.

As it appears from the information provided in Figure 1, the TV commercial was the most popular among both sexes; about 69.8% of women and 69.2% of men indicated this form of advertising, as the one most appealing to consumers in relation to food products. In the next place, in both cases there were leaflets (9.3% of women and 15.4% of men). Radio advertising was marked by 7.7% of men and 4.7% of women, press ads were chosen by 7% of women and 3.8% of men, while billboards were indicated by 4.7% of women and 3.8% of men. In the case of online advertisements, it has appeared that 4.7% of women pay special

attention to this form, while for men it has not been considered at all.

The preference to choose TV commercials as the form of advertising that speaks most to buyers of food products is not surprising. The number of TV commercials broadcast, their creativity and the type of message contained in them, causes the buyers to remember some of them, and the information placed in them is taken into account when making purchase decisions.

The fact that television advertising is considered as one of the most effective media, that has an impact on consumer purchasing decisions, has already been confirmed in many studies (Ansari, Joloudar, 2011; Hassan 2015). Ansari and Jolouldar (2011), using regression analysis, concluded that TV commercials have a positive impact on customers. It also turned out that the customer's interest in the product, the desire to buy, and finally the satisfaction with the purchased product, increases due to the TV commercial. According to Hassan (2015), television is considered the most effective medium because it can reach the maximum number of recipients at effective costs.

In the next question, the respondents were asked to express their attitude to television commercials about food products (Fig. 2).

The data presented in Fig. 2 indicate the indifferent or even negative attitude of respondents (especially men) to television advertisements of food products. 50% of men decided that advertising of food products displayed on television is annoying. For 38.5% of male respondents they are indifferent, and only 11.5% of men like watching food products on TV. The structure of women's answers looks a bit different. The largest number of women surveyed - 39.5%, expressed indifferent attitude towards television advertising of food products, and 27.9% - negative. It is worth emphasizing that in contrast to men, almost 1/3 of surveyed women (32.6%) like watching TV advertisements of food products. This may be due to the fact that the majority of advertising messages is targeted at women, which in turn may be determined by their dominant role in the decision-making process of buying food products. This is even more important as Khan et al. (2012) argue that positive consumer response to a given advertisement increases the likelihood of its positive evaluation. In addition, as shown by other studies, respondents of both sexes show a much more positive attitude towards advertising when they currently have, use or consume a given product (Hassan 2015). The structure of respondents' answers to the next question regarding the impact of advertising on shopping of food products was similar for both sexes, as presented in Figure 3.

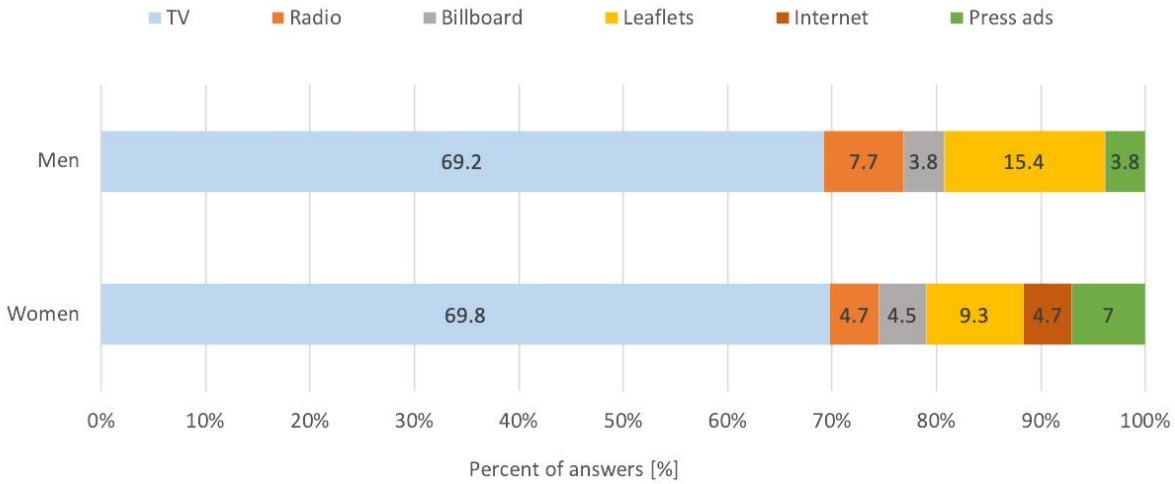

Figure 1. Structure of forms of advertising of food products most appealing to consumers depending on gender.

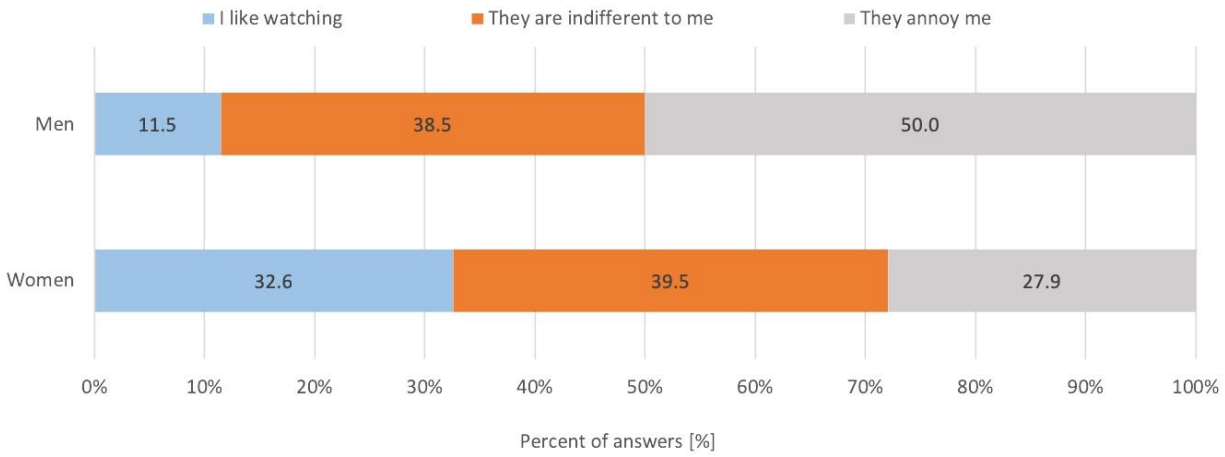

Figure 2. Structure of the respondents' attitude to TV commercials regarding food products depending on gender.

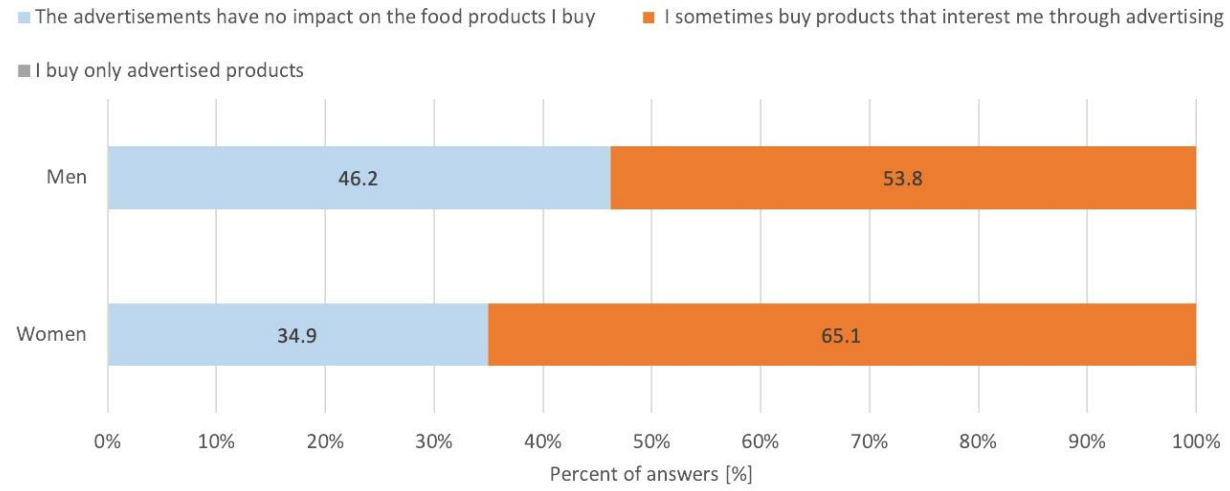

Figure 3. The structure of the impact of advertising on food products purchased by respondents depending on gender.

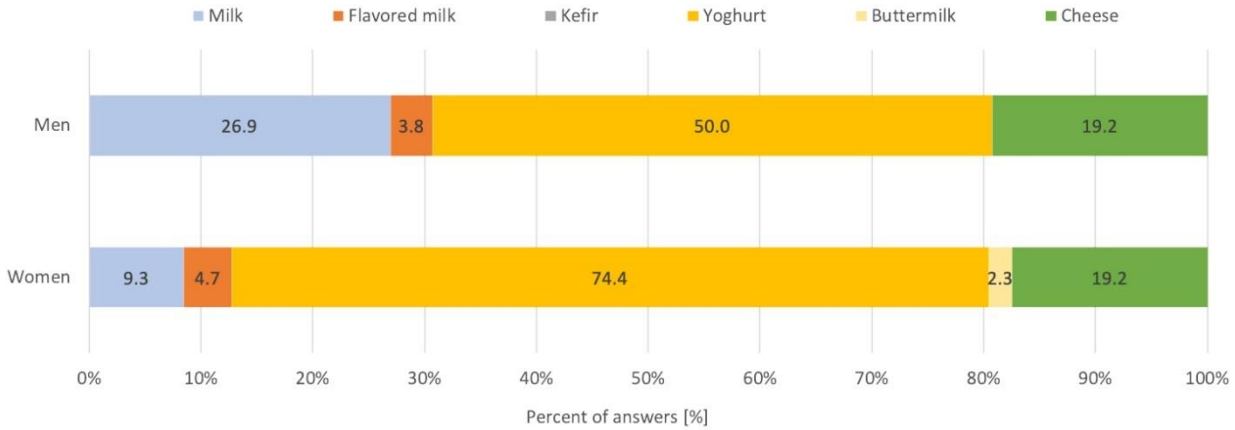

Figure 4. The structure of the type of dairy products purchased by respondents under the influence of advertising depending on gender.

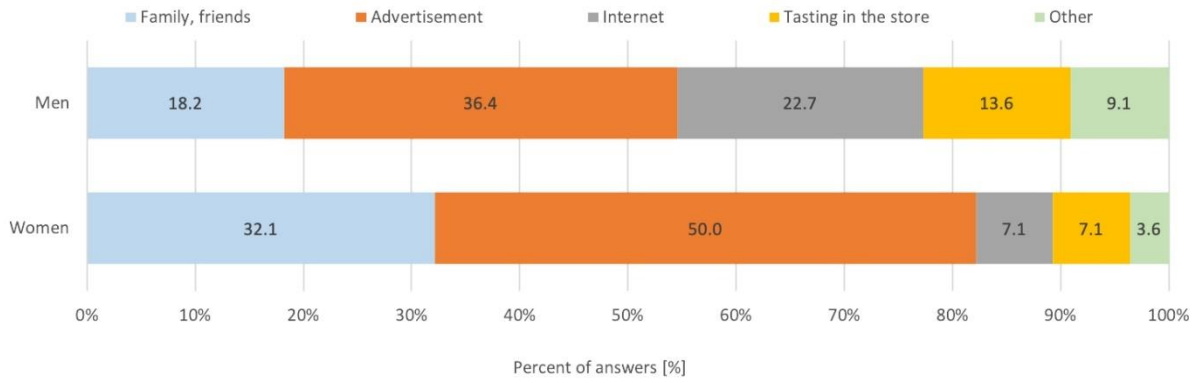

Figure 5. The structure of sources of information on the existence of probiotic products to consumers depending on gender.

Consumers have agreed that they sometimes buy products that interest them through advertising. This response was provided by 65.1% of women and 53.8% of men. The remaining part of the respondents, that is 34.9% of women and 46.2% of men said that the advertisements have no impact on the food products they buy. None of the respondents replied that they were buying only advertised products.

Respondents to a large extent (over half of men and almost 2/3 of women) admit buying products that interested them through advertising, which means that they are aware of the impact of advertising on their decisions. Tests carried out by Hassan (2015) also showed that women more often purchase products seen on television commercials and admit that TV commercials have increased the frequency of their purchase. It also turns out that over a dozen or so years, consumer awareness of the impact of advertising on their purchasing decisions has increased (in relation to both genders) (Jeżewska-Zychowicz 2002).

In the next question, the respondents were asked to assess the reliability of advertising of food products. The structure of the answer to this question was also quite similar - the respondents of both sexes had similar opinions. Both men and women most often responded that there is a lot of truth in the advertising of food products (51.2% women and 50% men). In turn, 44.2% of women and 46.2% of men had a completely different opinion, claiming that advertisements of food products are untrue and inadequate to the quality of the advertised product. A small proportion of respondents, as only 4.7% of women and 3.8% of men, considered advertising food products as a very reliable source of information.

The results obtained show that a relatively large proportion of respondents consider food advertising as unreliable. It can be concluded that advertisements usually contain information about the benefits of the product and the benefits of its use or consumption, and its disadvantages and possible negative impact on health or quality of life are not taken into account, which may cause the buyer post-purchase dissonance. Similar results were also obtained in the study by Hassan (2015), in which respondents reported that the quality of the product is often not as it is shown in the advertisement.

This is all more important because advertising and other marketing messages, especially those dealing with food and nutrition issues, can have a significant and measurable impact on cognition, emotions and consumer behavior. Some of them affect consumers in a positive way, promoting a healthy lifestyle or discouraging unhealthy food; others have a negative impact on consumers' behavior and shopping decisions. The specific effects often depend on the content and manner of such communication in combination with the consumer's characteristics. Therefore, it is

important to adapt communication to target receivers and test intended and unintended consequences (Pechmann, Catlin 2016).

The following part presents the analysis of information obtained from respondents regarding advertising and purchase decisions in relation to dairy products, in particular probiotic products. Therefore, in the next question, respondents were asked to express their opinion on dairy products most frequently bought under the influence of advertising (Fig. 4).

As can be seen from the information presented in Figure 4, most consumers, under the influence of advertising, buy yoghurts. In the case of women, this answer was given by nearly 3/4 of the respondents, namely 74.4%. In turn, 50% of men marked this answer. In the next place, among the products purchased under the influence of advertising, by the surveyed male, there was milk (26.9%) and cheese (19.2%). A small part of men, because only 3.8%, said that under the influence of advertising they buy flavored milk. Other products (buttermilk, kefir) were not indicated by the surveyed men as those purchased under the influence of advertising.

In the case of women, the structure of dairy products purchased under the influence of advertising was similar to that of men, however with a different size of indications. Also, among female respondents, in the next place after yoghurts, there were milk and cheese, but with much less support than male respondents (9,3%). Some of the ladies, 4.7%, also buy flavored milk under the influence of the advertising, and 2.3% butter milk. None of the surveyed women buy kefir under the influence of advertising.

From the analysis of the data presented in Figure 4, it turns out that advertisements to the largest extent influence the purchase of yoghurt. This is probably the result of a significant number of advertisements of these articles as well as a wide range of products available on the market and the constant turning out of new products from this area.

The next questions included in the questionnaire used in the research concerned probiotic products. The first of them was aimed at showing the number of people buying dairy products enriched with substances positively affecting the digestive system. As it turned out, the preferences and, consequently, decisions and purchase of probiotic products by respondents of both sexes is different. The majority, as much as 65.1%, of women declare buying dairy products enriched with substances positively affecting the digestive system. In turn, in the case of men, this tendency is reversed; only 38.5% of the respondents buy such products. Dairy products that positively affect the digestive system are more often bought by women, probably due to their greater interest in healthy nutrition, trends and new products in this area as well as greater awareness and knowledge about the beneficial effects of dairy products enriched with probiotic microflora.

When asked about the source of information on the existence of probiotic products for consumers buying them, the majority of both women and men pointed to advertising (Fig. 5).

As can be seen from the information presented in Figure 5, for 50% of women and 36.4% of men surveyed, advertising is the basic source of information on the existence of products containing probiotics. In the next place, in the case of women, there were family and friends (32.1%); whereas, men - as a source of information quite important for them - in 22.7% indicated the answer "the Internet". 7.1% of women said that the source of such information for them is the Internet and tastings in stores, and 3.6% of them indicated the answer "other". In turn, men, in 18.2% of cases, indicated that the source of information on the existence of probiotic products is family and friends, and 13.6% of them considered tastings in stores as a source. The remaining part of the surveyed men gave the answer "other".

Respondents in most cases (half of women and over 1/3 of men), as the main source of information on the existence of products enriched with probiotic microflora on the market, indicated advertising. It may result from the fact that, as already mentioned, on the

modern, highly competitive market, companies wanting to promote this type of products spend a lot of money on their advertising and ensure that it is original, often surprising, although not always 100% reliable. This is also manifested by the frequent occurrence of various types of ads for probiotic products, especially yoghurts.

4. Conclusions

The paper attempts to illustrate the impact of various forms of advertising on consumers' nutritional decisions. The study method adopted a questionnaire containing questions about advertising and identifying the socio-demographic profile of the consumer.

The conducted research and the analysis of the information obtained as a result of it allowed to state that the form of advertising that is the most popular and appealing to the consumers is television advertising, and this statement also applies to television ads for food products. Respondents for the most part admitted that sometimes they buy food products the advertising of which is interesting. This allows to draw a conclusion about a certain awareness of consumers about the mechanisms of the impact of advertising.

The analysis of the obtained data also allowed to state unequivocally that the dairy product most frequently purchased under the influence of advertising by consumers is yogurt. This is due to the significant share of advertisements of this product in the total number of advertisements for dairy products, as well as the variety of yoghurts available on the market that can satisfy the diverse requirements of individual consumers.

Research has also shown that advertising is the basic source of information about the emergence of dairy products enriched with substances positively affecting the digestive system. This information is extremely important as it points to the positive role of food advertising in shaping the right nutritional attitudes of the society.

The conducted analysis confirms the thesis that advertising is a factor that significantly affects consumers' decisions. Other researchers who considered different products came to a similar conclusion (Latif and Abideen 2012; Uddin et al. 2014; Mirabi et al. 2015, Lopez et al. 2015). This statement was also true in relation to the decision to buy food products, in particular dairy products, which is also confirmed by the results obtained by Hassan (2015), who conducted research on the impact of TV advertising on consumer purchasing decisions on UHT milk. The conducted research shows the power of food advertising, which aims to improve the automatic eating behavior, thus has a much more impact on the purchase decisions made than the brand preferences (Harris et al. 2009).

Although the attitudes of buyers to advertising are diverse, it is considered by consumers as a valuable source of information about products appearing on the market, of course, if the content contained therein is reliable and substantive on the one hand, and on the other - attractive and eye-catching. In addition, the content of dairy products presented in advertisements popularizes knowledge about proper dietary attitudes among the society and promotes positive changes in food consumption, and the ads themselves are positively connected with consumer purchasing intentions.

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IMPACT OF HEAT TREATMENT ON THE HARDNESS AND CONTENT OF ANTI-NUTRITIOUS SUBSTANCES IN SOYBEAN SEEDS

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ABSTRACT

Soybean has a high content of anti-nutritious substances and, therefore, it should be subject to heat treatment in order to reduce harmful compounds and to increase its digestibility. Soybean seeds are used in animal nutrition as a component of compound fodder, and in dietetic food as a substitute for meat. In recent years, various soybean-based dishes gained on popularity. The process of high-intensity infrared processing (micronization) in 50 seconds raises the temperature of the raw material to 90°C. At this temperature starch gelatinization takes place, thanks to which the digestibility of seeds raises. Most often, in the production of fodder and soybean-based food, after heat treatment the reduction of average diameter or flaking process is implemented for which hardness, fragility, and seeds moisture content are among important parameters. In the present study the research was carried out on the impact of heat treatment, i.e. micronization and roasting, on soybean seeds hardness and content of anti-nutritious substances.

1. Introduction

Soybean is considered to be one of the most valuable and profitable plants, used as food for humans and fodder for animals. Soybean seeds for fodder purposes are used in the form of pellets, for oil industry – for oil production, and also for pharmaceutical purposes. Considering the world trade soybean is on the first place among all the leguminous plants. Among the multitude of varieties soybean (*Glycine max*) has the greatest economic value (Palacios,*et al*., 2004). On a global scale, the United States of America are the largest supplier of soybean and its products, as in total they provide over 60% of the entire export. On average, composition of soybean includes up to 40% of protein with an excellent amino acid sequence and up to 20% of fat with high amounts of essential fatty acids (EFA). Residual soybean meal, which is a good, high protein component of fodder mixtures as well as oil used in nutrition are of high importance when it comes to commodity market. In addition, soybeanseeds are a rich source of lecithin, mineral salts, as well as vitamins. However, from the perspective of nutritional usability, there are also some undesirable substances in soybean seeds. One can mention here, for instance, protease

inhibitors, lectins, goitrogenic factors, and compounds acting as antivitamins. Undesired action of protease inhibitors is based on partial inactivation of the enzymes found in the digestive system of animals. Lectins are second anti-nutritious component, which has the ability to agglutinate red blood cells of animals and humans. Raw soybean flour contains approximately 3% of lectin (Tharanathan, *et al.*, 2003). Also, a group of compounds was discovered that act as antivitamins. Their work principle boils down to counteracting by an antivitamin the essential effects of particular vitamin. By replacing vitamins, these compounds create inactive enzymatic complex, which contributes to suppressing certain biological activities. Until now, antivitamins A and D were discovered in soybean. The seeds intended for human consumption as well as husbandry animal consumption have to be previously subject to appropriate heat treatment. Use of higher temperature increases digestibility and assimilability of nutrients (Grela, 1996, Grochowicz, 1996). Soybean husk has the highest content of anti-nutritious substances. Therefore, in many cases soybean husking is implemented followed by separation of husks from seeds. This process contributes to the reduction of harmful substances (Panasiewicz, *et al.*, 2017). Among many thermal processes that are used in processing raw materials of plant origin one can identify: expansion, extrusion as a barothermic process, micronization, and roasting. As the outcome of thermal treatment, both physical and chemical changes occur that result in an increased level of absorption of the finished product. Seeds of leguminous plants are subjected to heat treatment in order to acquire certain organoleptic characteristics, in particular with regards to external appearance, colour, smell, and taste, as well as chemical composition. Implementation of any heat treatment usually leads also to changes in the physical properties, mainly moisture content in the seeds and their hardness. This is due to defining an appropriate temperature and duration time of the process, or is associated with previously carried out initial treatment of the raw material subject to heating (Grzesińska, 2005, Bijok, 2001).

The aim of the study was to determine the impact of micronization process and roasting in a convection oven on the content of anti-nutritious substances and hardness of soybean seeds. The raw material that was used for the research consisted of soybean (*Glycine max*) of Merlin variety. The seeds came from an organic cultivation, without GMOs.

2. Materials and methods

The characteristics of the test material are presented in Table 1. The soyabeans were bought at local market in Poland.

Acquired soybean seeds of "Merlin" variety had low initial moisture content, which amounted to 4.48%. Therefore, appropriate moistening of soybean seeds was necessary. For this reason, a process of conditioning was carried out for the period of 24 hours at the temperature of 7°C and with prior addition of appropriate amount of water.

Table 1. Physical properties of the test material

Soybean - a control sample	
Variety	Merlin
Average dimensions: - length, mm - width, mm - thickness, mm	 6.8 7.6 5.7
Angle of repose,	14
chute angle,	24.7
Bulk density, $kg \cdot m^{-3}$	753.72
Shaken density, $kg \cdot m^{-3}$	765.48
Moisture content	4.48
Mass of 1000 seeds, g	139.05
Mass of husks, %	1.46

The seeds were moistened to the moisture content equal to 11.5% and 19% respectively.

Then, during the first stage, soybean seeds were subject to roasting in a convective oven at the temperature of 200°C for the period of 90, 120, and 150 seconds respectively. The drier Pol-Eko model SLW-53-STD was used for roasting process. On each occasion a sample of 150g ±2g was measured, which was then spread on a metal plate so that a single layer of material was formed. When the scheduled time elapsed, the sample was removed from the oven and its temperature was measured.

During the second stage of the experiment soybean seeds were subject to infrared radiation (micronization). The micronizer of own construction with ceramic heaters was used for the study. Similarly, samples of 150g ±2g were prepared and spread on a paper base forming a single layer of material, and then treated with infrared radiators. The distance between heater and sample was 100mm. Processing time was equal to 60, 90, and 120 seconds respectively. Temperature of processing, measured on the surface by thermocouple of the base, was equal to 130°C.

Soybean seeds heat-treated in this way were tested in terms of hardness using Instron 4302 instrument and the moisture content was determined in accordance to the applicable standards (PN-EN ISO 712:2012). The hardness was determined by crushing test. The test consisted in placing soyabean seed between working platens of the measuring head, and then carrying out the crushing test at the constant speed of 50 $mm \bullet min^{-1}$ until the structure of the sample cracked or was destroyed. The maximum strength measured on the apparatus was taken as the "hardness". The test of hardness was carried out in 10 replications.

In the samples subject to thermal treatment amount of trypsin inhibitors was determined and urease activity was examined as the indicators of anti-nutritional substances. The research was performed in accordance to the methodology determined by Hamerstrand *et al.* (1981).

3.Results and discussions

The level of urease activity and amount of trypsin inhibitors as the indicators of anti-nutritional substances contained in soybean seeds are shown in table 2. The amount of trypsin inhibitors and the level of urease activity changed depending on the type and duration of the heat treatment. Soyabean seeds subject to micronization for 90 seconds contained the same amount of trypsin inhibitors and level of urease activity as the seeds not subject to thermal treatment. Reduction of anti-nutritious substances of over 16% in the case of micronization was observed after the processing time of 120 seconds. At the same time, subjecting to a higher temperature during roasting (200°C) for the period of 120 seconds resulted in reduction of anti-nutritious substances by about 70%, while extending this process by further 30 seconds resulted in reduction of additional 2% of anti-nutritious substances. In the research carried out by Pour-El, *et al.* (1981) an acceptable low activity of trypsin inhibitor in soybean seeds was obtained after a microwave treatment. According to the authors of the report, moisture content in seeds after the treatment might by an additional indicator of inactivation of trypsin inhibitor.

Table 2. The amount of trypsin inhibitors and level of urease activity in soybean seeds after heat treatment

Type of treatment	**Urease activity [mg N /g min]**	**Trypsin inhibitors [mg/g]**
Control sample	9.04	23.4
Roasting at 200°C, time: 120s	1.66	7.2
Roasting at 200°C, time: 150 s	1.08	6.8
Micronization, time: 90 s	9.04	23.4
Micronization, time: 120 s	6.73	19.6

Process of heating seeds entails also changes in grain structure. The mean values of seeds hardness decreased with the extension of the duration of micronization process for the control sample with the moisture content equal to 11.5%. The highest average hardness value of 253.87N ±22.17 was recorded for the control sample (not subject to heating), while the lowest was determined for the sample subject to micronization for the period of 120 seconds. It equaled to 229.14N ±20.39 (Fig. 1). In turn, for the soybean seeds with the moisture content of 19% an inverse relationship was observed. Seeds not subject to the heat treatment had the hardness of 109.19N±12.28, while those subject to micronization for the period of 120 seconds had the hardness of 115.6N±20.61, and extending the processing time by 30 seconds resulted in increasing hardness to 118.3N±17.94. In the research carried out by Jae-YeunSong *et al*. (2003) soybean seeds were subject to blanching at the temperature of 80, 90 and 100°C respectively for the period between 10 and 20 minutes. In this study a dependency was observed between the extension of processing times and the decrease of soybean seeds hardness.

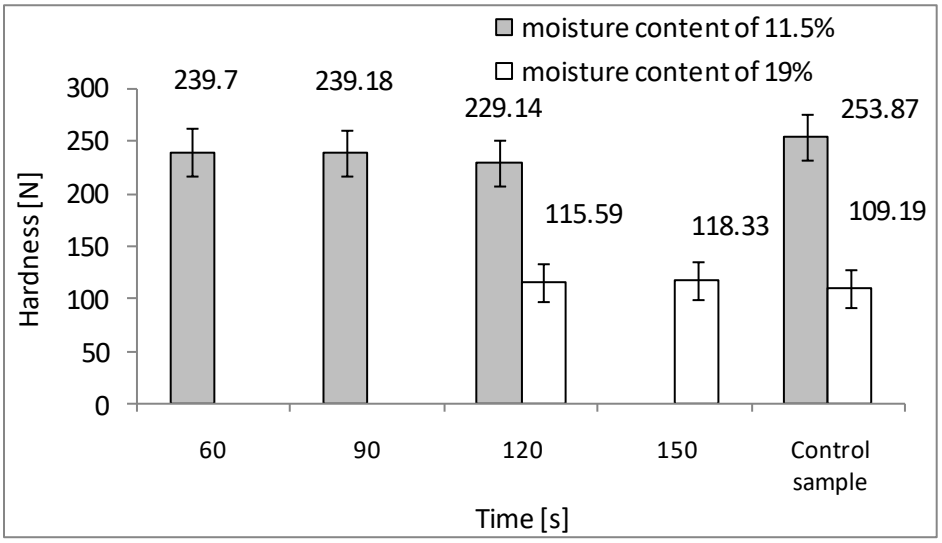

Figure 1. Changes of soybean seeds hardness in relation to the time of micronization treatment for the initial moisture content of 11.5% and 19% respectively

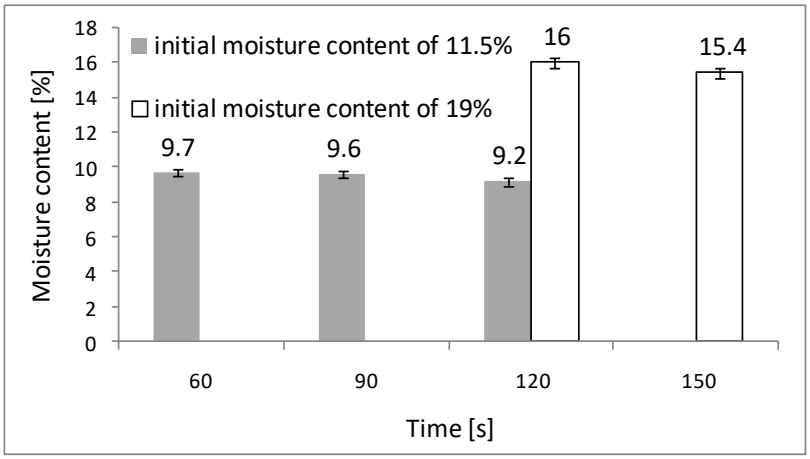

Figure 2..Changes in the soybean seeds moisture content after micronization process

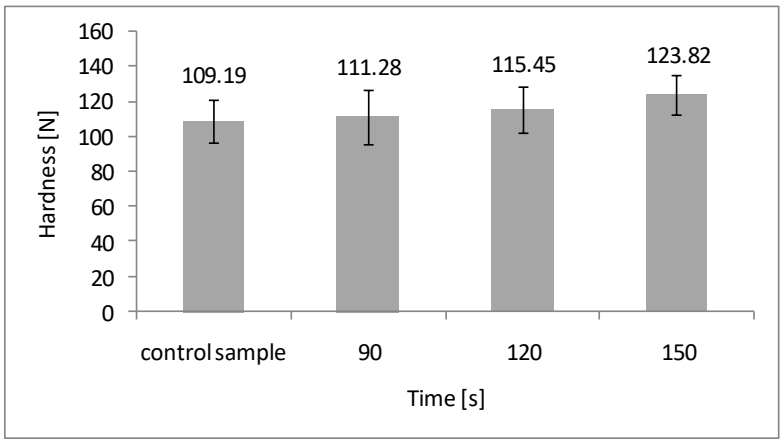

Figure 3..Changes in soybean seeds hardness after roasting for the sample with the moisture content equal to 19%.

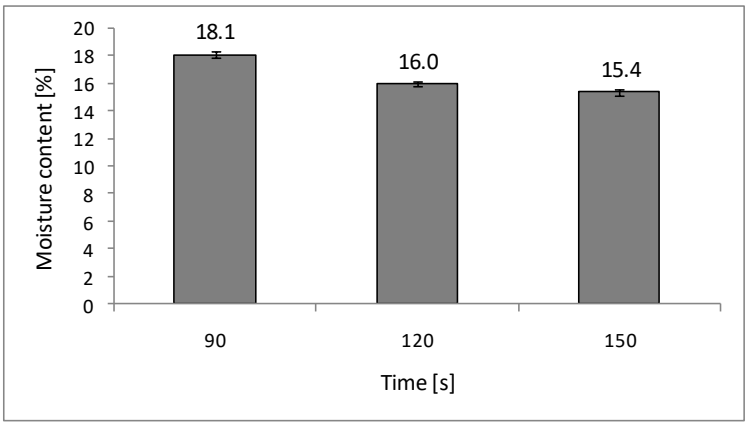

Figure 4..Change in soybean seeds moisture content after roasting

In the course of further research moisture content after heat treatment was determined in soybean seeds. As shown by previous research, although treatment with the use of infrared radiators reduces moisture content in the seeds, this decrease does not affect the hardness of the seeds. Seeds with higher moisture content (19%) were characterised by increasing hardness with extension of the micronization time, while those with the moisture content of 11.5% - by decreasing hardness with the prolongation of the treatment time.

Hardness increasing with the extension of the processing time was observedduring roasting soybean seeds at 200°C. The highest hardness was observed in the case of seeds roasted for 150 seconds. It was equal to 123.8N ±11.07 and increased by more than 13% when compared with the control sample (Fig. 3).

Similarly as in the case of micronization, moisture content of these seeds decreased with lengthening of the duration of the process. After 150 seconds the moisture contentamounted to 15.4% for the seeds with the initial moisture content of 19% (Fig 4).

According to the studies of various authors (Lee,*et al.,* 2009) micronization process in 50 seconds raises the temperature of the raw material to 90°C. At this temperature starch gelatinization takes place, thanks to which the digestibility of seeds increases. In the production of soybean-based fodder and food,

most often after heat treatment the reduction of average diameter or flaking process is implemented during which hardness, fragility, and seeds moisture content are among important parameters (Dziki, *et al.*, 2009).

Many of studies conducted until today focused on the digestibility and reduction of anti-nutritional substances resulting from microwave treatment or roasting of soybean seeds. The results obtained allow to confirm beneficial effects of these processes on soybean seeds (Dakwa *et al.* 2005, Lee *et al.* 2009, Kato *et al.* 1981).

4. Conclusions

The research carried out allows formulating the following conclusions:

1) micronization process performed for the period shorter than 120 seconds does not result in inactivation of anti-nutritious substances in soybean seeds. Prolongation of the processing time to 150 seconds results in the decrease of anti-nutritious substances by 16%.

2) heat treatment of seeds at 200°C for 120 seconds results in reduction of trypsin inhibitors by about 70%.

3) hardness of soybean seeds after micronization depends on the initial moisture content. By extending processing time to 150 seconds the hardness of seeds with the initial moisture content of 11.5% decreases. In the case of soybean seeds with the initial moisture content of 19% prolongation of processing time results in the increased hardness of soybean seeds.

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INVESTIGATION OF PELLETING PROCESS OF HEMP WASTE WITH POTATO PULP

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ABSTRACT
The aim of the research was to assess the usefulness of post-harvest hemp waste as a raw material used to produce fuel pellets. Research on the pelleting process was carried out on the SS-4 station, whose main element is the P-300 pelletizer with a flat rotary die with a hole diameter of 8 mm and a hole length of 28 mm. During the research, the influence of potato pulp content (10, 15 and 20%) in the mixture with hemp waste and the impact of the substrate mass flow (10, 30 and 50 $kg \cdot h^{-1}$) on the device's power demand and on the density and kinetic durability of the obtained pellets (by Holmen method) was tested. On the basis of the conducted tests, it was found that along with the increase in the content of potato pulp in a mixture with hemp waste, the moisture content of the thickened material increased, which had a significant impact on the pelletizer's demand for power and quality of the obtained pellets (its density and kinetic durability).

1. Introduction

According to Rehman et al., (2013), energy is one of the most important commodities in today's world to ensure socioeconomic development of the country.

Bajwa et al (2018) claims that, use of densified agricultural residues for energy production can reduce dependence on fossil fuels and help mitigate the environmental and economic security threats that they pose in an uncertain geopolitical scenario. As with most energy production, attention must be given to choosing the correct feedstocks and processes in each case to assure economic viability.

A big source of energy from biomass is the agricultural-food industry which generates huge amounts of post-production waste e.g. buckwheat hulls obtained during the production process of groats (Obidziński 2014a; Obidzinski 2016), fruit pomace left over from juicing facilities (Nawirska and Uklańska 2008), industrial tomato post-production waste (Celma et al., 2012), rapeseed pomace obtained in rapeseed oil production (Stahl and Berghel 2011), herbal waste (Obidziński et al., 2017) and other plant waste. These types of waste are only utilised to a small extent and they often constitute a serious problem to particular processing plants.

One of the waste materials produced in agriculture are hemp harl. Schluttenhofer and Yuana (2017) estimates that the weight gain of green hemp on average is 14.5 $t \cdot h^{-1}$ dry matter, of which about 70-75% are by-products of the processing of hemp, i.e. hemp harl, which according to Prade (2012) are usually left in the field as an organic fertilizer.

On the other hand, the harl, which in the straw is from 60 to 80%, after being separated from the fibers, served once as a bedding for animals. Today, we do not treat them as waste, but as a valuable source of raw material in the construction of hempen houses, hemp pellets with a calorific value of 19.8 $MJ \cdot kg^{-1}$, very durable furniture boards (Mankowski and Kolodzej 2008), or as a substrate in greenhouse crops and as a bedding (Mankowski and Kolodziej 2008).

According to Thomsen and co-authors (2005) and Thygesen (2005, 2006), the cannabis stem consists of 75% of the shives. These are the soft parts of the plant remaining after the separation of long fibers, composed of 40% cellulose, making them an excellent raw material for the paper production.

According to Kolarikova et al. (2014), uniqueness of hemp consists in its ability to yield about 10–15 t ha-1 in 100–120 days which is more than other energy crops. Mańkowski and Kołodzej (2008) state that hemp mortars show energy properties comparable to wood materials during combustion, which makes it another way to use them to produce fuel granules (Prade et al., 2011) or fuel briquette (Mankowski and Kolodzej, 2008, Kolarikova et al. 2015).

Otherwise industrial hemp has been used for production of biodiesel (Rehman et al., 2013), bioethanol (Tutt and Olt, 2011) and biogas (Prade et al., 2011).

According to Thygesen (2005a) and Tajvidi and Motie (2010) hemp fibres have also gained interest for use in composite materials due to concern about how the high production and disposal of synthetic fibres affects the environment.

However, the undoubted disadvantage of crumbled and dried hemp harl is their low bulk density, which means they take up a lot of storage space, and are stored in the open air prone to wind and precipitation. In addition, the shredded hemp harl are a material with low compaction susceptibility, as confirmed by the authors' preliminary research. Therefore, in order to increase their susceptibility to compaction and improve the process conditions, binder material should be added to them during the granulation process. Such a material may be a potato pulp, which consists mainly of raw fiber, starch and mineral residues and is a post-production waste produced in the production of potato starch.

The pulp consists mainly of the skin and the pulp and due to the high humidity (about 87%) and the rich chemical composition - contains starch (4.8%), vegetable fiber (4.9%) and protein (0.5%)) - is unstable and prone to microflora infection (Mayer and Hillebrandt 1997).

Potato pulp has been used in agriculture while feeding sows and fattening pigs, but it is not very popular among animal breeders due to its low nutritional value. New ways to use potato pulp are sought, for example as an addition to wheat bread (Kaack et al. 2006), low-calorie sausages (Kaack and Pedersen 2005) and a solid fuel component from waste (Obidziński 2012, Obidziński 2014).

In most cases, the introduction of binder additives or other types of biomass waste increases the kinetic strength of the obtained pellets and decreases the energy consumption of the pelleting process.

The aim of the research was to assess the usefulness of post-harvest waste in hemp as a raw material used to produce fuel pellets. The specific objective of the research was to determine the impact of potato pulp content (in terms of its use as a binder) in a mixture with ordinary hemp waste for the demand for pelletizer power and the quality of the obtained pellets.

2. Materials and methods

Hemp harl from Podlaskie Konopie and potato pulp from Pepees Łomża (a waste produced in the production of potato starch) were used as raw materials for the research.

The tests of the pelleting process of the investigated mixture of hemp waste with potato pulp, were carried out on a SS-4 work stand,

presented in papers (Obidziński 2014, Obidzinski 2014a, Obidziński i in. 2016), whose main component is a P-300 pellet mill with a flat matrix with a hole diameter of 8 mm and a hole length of 28 mm, cooperating with a system of two compacting rolls.

The pellet mill is driven by an electric motor whose torque is transmitted through a bevel gear to the shaft on which a flat rotating matrix is mounted; the matrix cooperates with a stationary system of two bearing-supported densification rolls which force the densified material through the matrix openings. Feeding the densified raw material evenly to the working system of the pellet mill is possible owing to the vibrating feeder which passes the material to the working system of the pellet mill through the inlet. Pellets leave the working system through the outlet. The SS-4 stand was equipped with a universal meter for measuring the electric power demand of the device, and with a Spider 8 recorder connected to a computer. Signals from the universal meter were transmitted to the Spider 8 recorder in the form of binary files which were further processed using the Microsoft Excel software (Obidziński 2014, Obidzinski 2014a, Obidziński i in. 2016).

During the research, the influence of the content of potato pulp (10, 15 and 20%) in the mixture with hemp waste on the device demand for power as well as the density and kinetic durability of the obtained pellets were determined.

The pelleting process was tested at a mass flow rate of 50 $kg \cdot h^{-1}$, at the rotational speed of the die 170 rpm and at the working gap between the densifying rolls and the die of 0.4 mm.

24 hours after pellets had left the working system, kinetic durability of the obtained pellets was determined using Holmen's test, pursuant to PN-EN 15210-1: 2010, and the recommendations given in papers (Obidziński 2014, Obidziński i Dołżyńska 2017). Kinetic durability of the obtained pellets is expressed as the ratio between the mass of pellets remaining in Holmen's chamber to the initial sample mass. It is calculated as the mean value of five replications.

Determination of the moisture content of the hemp waste, potato pulp, and a mixture of hemp waste and potato pulp) was performed pursuant to PN-EN 14774-1:2010, by means of a WPE 300S scale-dryer with an accuracy of 0.01%. Each time, moisture content of five samples was determined. The average values thus obtained were adopted as the final results of moisture content determination.

Density of the obtained pellets was determined 24 hours after the process. It consisted in measuring the diameter and length of 15 randomly chosen pellets (with an accuracy of ± 0.02 mm) and then weighing them on a WPS 360 laboratory balance (with an accuracy of ± 0.001 g). Density of pellets ρ_g was calculated as the pellets' mass to volume ratio.

3. Results and discussions

Table 1 presents the results of testing the process of hemp harl pelleting with potato pulp depending on the content of the pulp in the mixture and the mass flow rate of the mixture supplied to the pelletizer's working system.

Table 1 and Figure 1 show the results of the research: the influence of material and process factors (moisture content of mixture and mass flow of compacted material) on the pelletizer's demand for power.

On the basis of the tests carried out (Table 1 and Fig. 1), it can be stated that during the pelleting process of a mixture of hemp harl and potato pulp, the pelletizer's demand for power increases with the increase of the mass flow of the raw material.

Increasing the mass flow rate of the mixture from 10 $kg \cdot h^{-1}$ to 50 $kg \cdot h^{-1}$ with a 10% addition of potato pulp to the mix results in an increase in the pelletizer's demand for power from 1.36 kW to 1.72 kW. When densifying the mixture with the addition of 15% potato pulp, increasing the mass flow rate of the mixture

from 10 kg·h^{-1} to 50 kg·h^{-1} increases the demand of the granulator for power from 1.10 kW to 1.65 kW, while using a 20% additive potato pulp in the mix, increasing the mass flow rate of the mixture to the pelletizer's working system from 10 kg·h^{-1} to 50 kg·h^{-1} increases the demand of the pelletizer for power from 0.80 kW to 0.85 kW.

At the same time, the results of the study allowed to conclude that the increase in the content of potato pulp from 10 to 20% resulted in a significant decrease in the pelletizer's demand for power, at each of the studied mass flow rates of the compacted mixture. For example, an increase in the amount of potato pulp from 10 to 20% (at a mass flow rate of 10 kg·h^{-1}) causes a decrease in the pelletizer's demand for power from 1.36 kW to 0.80 kW, a decrease in the pelletizer's demand for power from 1.70 kW up to 0.81 kW (at a mass flow rate of 30 kg·h^{-1}) and a decrease from 1.72 to 0.85 kW (at a mass flow rate of 50 kg·h^{-1}).

Table 1. The results of pelleting of hemp harl with potato pulp

Mass flow rate of the raw material [kg·h^{-1}]	Potato pulp content in the mixture [%]	Average pelletizer's demand for power [kW]	Pellets bulk density [kg·m^{-3}]	Pellets kinetic durability [%]
10	10	1.36	783.08	99.45
30	10	1.70	767.64	98.4
50	10	1.72	691.09	98.1
10	15	1.10	666.18	98.65
30	15	1.45	542.78	98.44
50	15	1.65	613.55	97.99
10	20	0.80	541.97	98.11
30	20	0.81	534.18	97.98
50	20	0.85	463.62	96.42

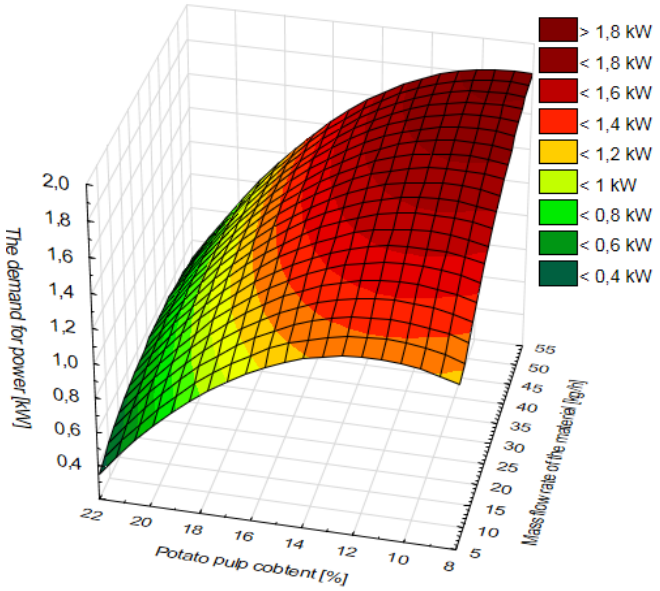

Figure 1. The dependence of the pelletizer`s demand for power from the mass flow rate and the content of the potato pulp in a mixture with hemp harl

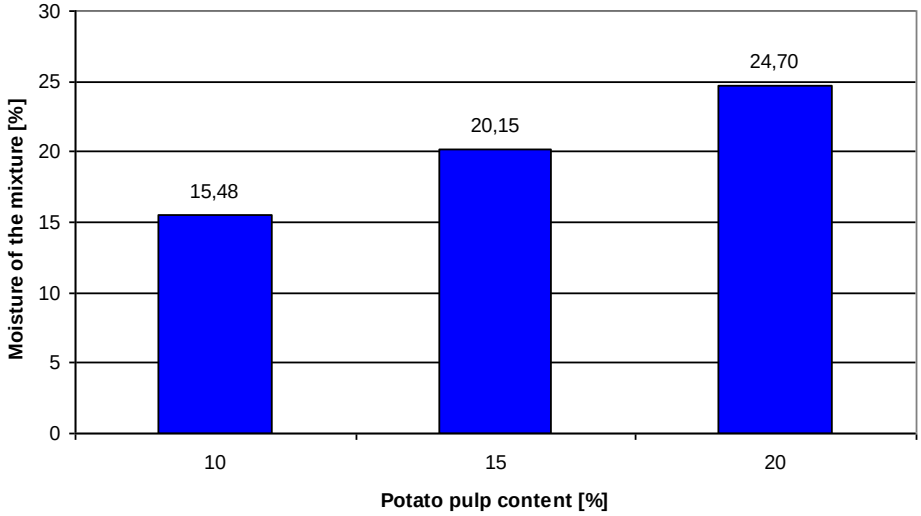

Figure 2. Moisture content of compacted mixtures depending on the percentage of potato pulp

The observed decrease in the pelletizer`s demand for power was caused by a significant increase in the moisture content of the compacted mixture (Fig. 2) caused by an increase in the content of potato pulp from 10 to 20% in the compacted mixtures.

Hemp harl is a material with a low moisture content of 8.56%. This level of moisture content is insufficient to be subjected to the pelleting process. Therefore, before the pelleting process, the increase of their moisture content by adding water or a high moisture component is necessary. Such a supplement may be the potato pulp, as shown by the author's previous research (Obidziński 2012; Obidziński 2012, Obidziński 2013, Obidziński 2014a).

The moisture content of the mixture increased from 15.48% (with a 10% potato pulp content in the compacted mixture) to 24.70% (with a 20% potato pulp content in the compacted mixture). The increase in the content of the pulp in the thickened mixture caused the formation of increasing amounts of binder (in the form of viscous liquid formed from starch and moisture) during the pelleting process. The growing content of the resulting viscous liquid caused the effect of "lubricating" the surface of the holes in the pelletizer`s matrix and the drop in the transfer resistance. Lowering the transfer resistance resulted in a reduction in the value of the pelletizer`s demand for power. This is confirmed by other author's studies made for the mixture of buckwheat hull and potato pulp (Obidziński 2014a).

Morey (Kaliyan and Morey 2009) also confirmed that an addition of binder (lignosulphonate) during the pelleting process reduces the power demand.

It is also confirmed by Mediavilla et al. (Mediavilla et al. 2012) who claim that an addition of maize starch or lignosulphonate (in dosages of 2.5, 5.0 and 7.0 wt. % (d.b.) of dry additive) increased the stability of the process and reduced power demand during the pelleting process of poplar.

The effect of the potato pulp content z_w in the mixture with hemp harl and the mass flow of the mixture through the operating system Q_s on the pelletizer`s power demand N_g obtained during compaction in the working system "flat die - compacting rollers" is described by the following relationship:

$$N_g = 0{,}12 + 0{,}31 Q_s + 0{,}18 z_w - 0{,}0002 Q_s^2 - 0{,}001 z_w Q_s - 0{,}008 z_w^2 \quad \text{[kW]} \quad (1)$$

where:

z_w – content of the pulp in a mixture with hemp harl [%],

Q_s – mass flow rate of the compacted mixture [kg·h^{-1}].

Table 1 and Figure 3 show the results of research on the impact of material factors (moisture content of mixture) and process (raw material mass flow) on the pellets bulk density of a mixture of hemp harl and potato pulp.

The research (Table 1 and Figure 4) shows that increasing the mass flow of the raw material contributes to the drop in the pellets bulk density. Increasing the mass flow rate of the mixture from 10 to 50 kg·h^{-1} (at 10% addition of potato pulp to the mix) results in a drop in the bulk density of the pellets from 783,08 kg·m^{-3} to 691,09 kg·m^{-3}. When the mixture was mixed with the addition of 15% potato pulp, the bulk density of the pellets dropped from 666,18 kg·m^{-3} to 613,55 kg·m^{-3}, while using a 20% addition of potato pulp in the mixture, increasing the mass flow rate of the mixture from 10 to 50 kg·h^{-1} causes the bulk density of the pellets to drop from 541,97 kg·m^{-3} to 463,62 kg·m^{-3}.

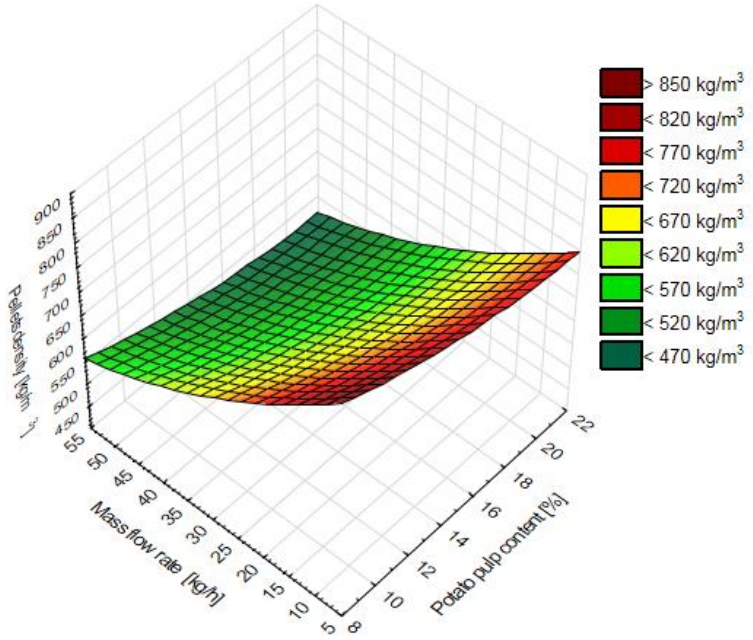

Figure 4. The dependence of pellets bulk density on the mass flow rate and content of potato pulp in a mixture with hemp harl

At the same time, research shows that the increase in potato pulp content from 10 to 20% also affected the drop in bulk density of the pellets, at each of the studied mass flow rates of the compacted mixture. Increasing the content of potato pulp from 10 to 20% (at a mass flow rate of the mixture with 10 kg·h^{-1}) causes a drop in pellets density from 783,08 kg·m^{-3} to 541,97 kg·m^{-3}, density drop from 776,64 kg·m^{-3} up to 534,18 kg / m3 (with a mass flow rate of 30 kg·h^{-1}) and a decrease from 691,09 kg·m^{-3} to 463,62 kg·m^{-3} (at a mass flow rate of 50 kg·h^{-1}).

The effect of the content of potato pulp in mixtures with hemp harl and the mass flow of the mixture through the working system $\boldsymbol{Q_s}$ on the pellets bulk density $\boldsymbol{\rho_g}$ obtained during compaction of the mixture in the working system of a "flat die - compacting rollers" pelletizer is described by the following equation:

$$\boldsymbol{\rho_g} = 1253 - 4{,}13\boldsymbol{Q_s} + 51{,}74\boldsymbol{z_w} + 0{,}029\boldsymbol{Q_s}^2 + 0{,}034\,\boldsymbol{z_w}\,\boldsymbol{Q_s} + 0{,}91\,\boldsymbol{z_w}^2 [\mathrm{kg/m^3}] \quad (2)$$

The obtained results of the influence of the addition of the pulp to the mixture with hemp harl on the quality of the obtained pellets are confirmed by the studies of Celma and colleagues (2012) who concluded that the density, strength and kinetic durability of pellets from industrial tomato post-production waste (peels and seed cores) depend on the initial moisture content of the biomass, as well as on further actions connected with moisture reduction after densification and the storage time of the obtained pellets.

According to Artemio et al (2018) and many numerous studies, moisture content is a property that should be considered with caution, since water has a crucial role in the pelleting process (Samuelsson et al., 2009).

Whittaker and Shield (2017) confirmed a positive correlation between moisture content and pellet durability. They claims that moisture content is one of the most important physical characteristic of pellets. Higher moisture content can reduce friction by lubricating the biomass (Nielsen et al. 2009), and increase the extent at which pellets 'relax' after formation thereby leading to a decrease in durability (Adapa, et al. 2011).

According to Carone et al. (2011), water is not compressible, however, limiting the final density of the pellet.

Figure 4 shows an example view of the pellets obtained from a mixture of hemp harl with potato pulp (obtained at a mass stream of 30 $kg \cdot h^{-1}$ raw material with different content of a potato pulp).

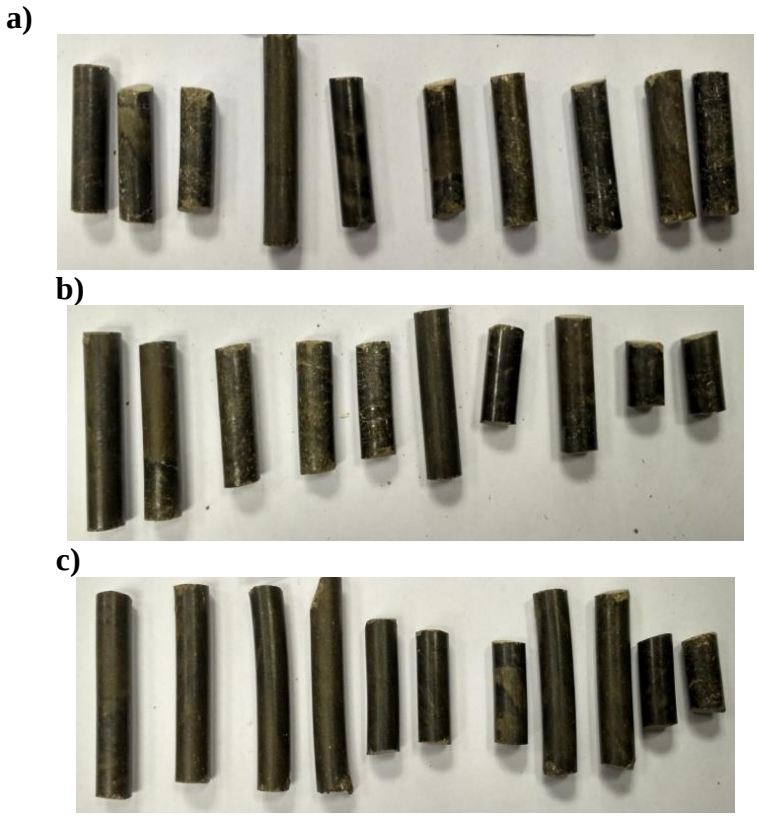

Figure 4. View of pellets hemp harl mixed with potato pulp (obtained with a mass stream of 30 $kg \cdot h^{-1}$ raw material), with pulp content of: a) 10%, b) 15%, c) 20%

The presented drawings show that the best quality is characterized by pellets obtained from a mixture with a content of 10% pulp. Its surface is the most shiny and smooth.

Table 1 and Figure 5 show the results of research on the impact of material factors (content of potato pulp) and process (mass flow

of raw material) on the kinetic durability of the pellets.

The conducted tests (table 1 and figure 5) allowed to state that the increase in potato pulp content from 10 to 20% slightly decrease the kinetic durability of the pellets, at each of the studied mass flow rates of the compacted mixture. Increasing the content of potato pulp from 10 to 20% (at a mass mix flow rate of 10 $kg \cdot h^{-1}$) causes a decrease in the kinetic durability of the pellets from 99,45 to 98,11%, decrease in the kinetic durability of the pellets from 98,40 to 97,98%, (at a mass flow rate of 30 $kg \cdot h^{-1}$) and a decrease from 98,10 to 96,42% (at a mass flow rate of 50 $kg \cdot h^{-1}$).

Increasing the mass flow rate of the mixture from 10 to 50 $kg \cdot h^{-1}$ also affected a slight decrease in the kinetic durability of the pellets, with each of the tested potato pulp additives to the mixture with hemp harl. For example, increasing the mass flow rate of the mix from 10 to 50 $kg \cdot h^{-1}$ (at a 10% addition of potato pulp to the mixture) caused a decrease in the kinetic durability of the pellets from 99.45 to 98.10%, decrease in the kinetic durability of the pellets from 98,65 to 97,99% (with a 15% addition of potato pulp to the mixture) and a decrease of 98,11 to 96,42% (with a 20% addition of potato pulp to the mixture).

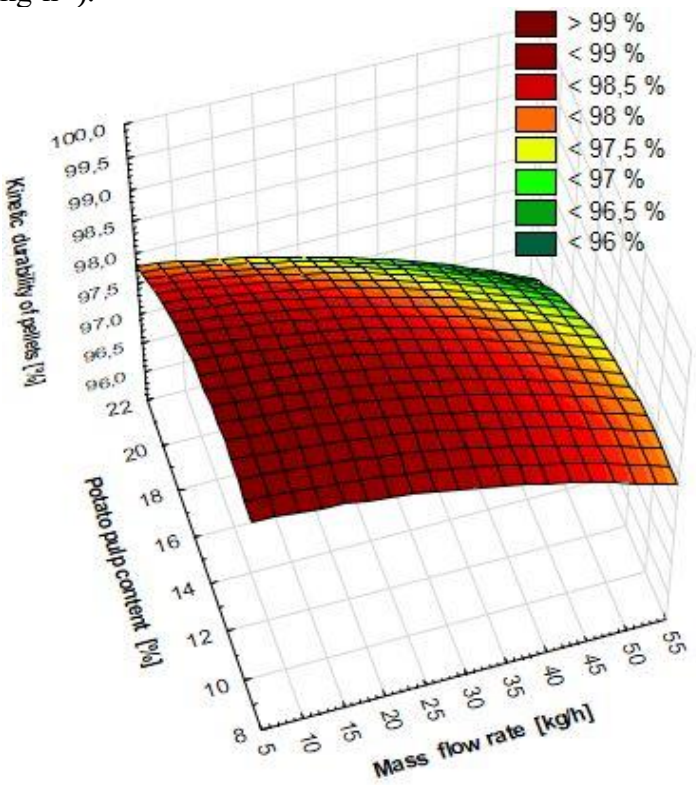

Figure 5. Dependence of kinetic durability of pellets on mass flow rate and content of potato pulp in a mixture with hemp harl

Obtained results of the influence of the addition of potato pulp as a binder in combination with other ingredients are confirmed by other studies of the author.

In the paper (Obidziński 2014) he discovered that increasing the potato pulp content in a mixture with oat bran from 15 to 25% resulted in reducing the value of the kinetic durability of the pellets by approx. 31%, from 95.78% to 65.90%. In the another papers (Obidzinski 2014a, Obidzinski i in. 2016) concluded that increasing the pulp content in a mixture with buckwheat hulls from 15 to 25 % caused a reduction of the density and the kinetic durability of the pellets.

This is confirmed also by Stahl i Berghel (2011), who stated that with the increase in the post-production content of turnip debris produced in the production of turnip oil in a thickened mixture with sawdust, the energy consumption of the pelleting process drops, but also the mechanical strength and the density of the obtained pellets decreases.

Miranda et al. (2012), who densified olive pomace waste obtained in the process of olive oil production, concluded that adding Pyrenean oak waste to olive pomace enables more effective densification of the mixture and increases kinetic durability of the obtained pellets.

According to Garcia-Maraver et al. (2015), different biomass feedstocks produce pellets with varying physical and mechanical properties. The wood from olive trees and the pumice from oil pressing have favorable mechanical properties when pressed on their own. Olive leaf pellets, however, require binders to produce pellets with even marginal strength and durability.

The research (Table 1 and Fig. 6) shows that the highest kinetic durability is found in pellets with 10% potato pulp in a mixture with hemp harl.

The effect of the content of potato pulp in mixture with hemp harl and the mass flow of the mixture through the working system $\boldsymbol{Q_s}$ on the kinetic durability of the $\boldsymbol{P_{dx}}$ pellets obtained during compaction of the mixture in the working system of the "flat die - compacting rollers" pelletizer are described by the following equation:

$$\boldsymbol{P_{dx}} = 97{,}83 + 0{,}005\boldsymbol{Q_s} + 0{,}25\boldsymbol{z_w} - 0{,}0004\boldsymbol{Q_s}^2 - 0{,}001\ \boldsymbol{z_w}\ \boldsymbol{Q_s} - 0{,}011\ \boldsymbol{z_w}^2 \quad [\%] \quad (3)$$

The obtained values of density and kinetic durability of pellets from a mixture of hemp waste and potato pulp allowed to conclude that at a pulp content of 20 % it is possible to obtain, at moderate power consumption, high quality pellets, which can be treated as full value solid biomass fuel. In relation to the values of kinetic durability (mechanical durability), pellets obtained from buckwheat hulls with a potato pulp content of up to 20 % meet the requirements of norms pertaining to wood pellets in European countries, as well as the requirements of the new ISO 17225 norm.

However, the obtained pellets are characterized by a high emission of hydrogen chloride (HCl), which causes high-temperature chloride corrosion and similar to NOx combustion when burning coal (with the addition of 20% potato pulp), as confirmed by the authors' research (Dołżyńska et al. 2018), which indicate that one should still look for solutions in the design of composite fuels, where one of the components would be hemp harl. This is also confirmed by the research of other authors (Szyszak-Bargłowicz i in. 2017) and Miranda at al. (2015), who claim that even though EN ISO 17225 standard enables the commercialization of pellets from different raw materials for different purposes and applications, the specifications to be considered are very demanding and, in certain cases, unattainable for some kinds of biomass, limiting their use to specific equipment, designed for this purpose.

4. Conclusions

Based on the research conducted on the pelleting of hemp harl with the addition of potato pulp, the following conclusions were made:

1. Hemp harl are a material characterized by low susceptibility to pelleting. To increase the susceptibility of harl to pelleting and obtain good quality granules it was necessary to use a binder (eg in the form of a ground potato pulp).
2. The addition of potato pulp to the hemp harl, contributed to improving the susceptibility of the mixture to pelleting and the desired quality of pellets.
3. Increasing the content of potato pulp from 10% to 20% in a mixture with hemp harl resulted in a decrease in the pelletizer's demand for power, drop in bulk density and

a slight decrease in the kinetic durability of the obtained pellets.

4. Increasing the mass flow rate of hemp harl mix with potato pulp from 10 to 50 $kg \cdot h^{-1}$ resulted in an increase in the pelletizer's demand for power, drop in bulk density and a slight decrease in the kinetic durability of the obtained pellets.
5. The best quality pellets with a kinetic durability of 99.45% (bulk density 783,08 $kg \cdot m^{-3}$) were obtained with the addition of 10% potato pulp for hemp harl and at a mass flow rate of 10 $kg \cdot h^{-1}$.

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NEAR INFRA-RED SPECTROSCOPY FOR ASSESSING NUTRIENTS IN FEEDING MATERIALS AND MIXTURES

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ABSTRACT
The present paper presents the results of comparative studies performed by means of the NIR technique and standard methods, in compliance with the Commission Regulation (EU) No 152/2009. The reliability of predicting the content of nutrients in typical feed matrices was confirmed. The ratio of mean values obtained by means of standard methods to predicted values was within the range of 0.95 to 1.00. Statistical parameters of the method were calculated following ISO 12099 (E), e.g. standard error of prediction, SEP, and bias. Participation in numerous proficiency testing rounds (Bipea in the years 2016-2018 and NIRS 2018) let us obtain an objective confirmation of the quality of the calibration software for the NIRS analyzer in case of testing model feed products and materials. Moreover, identification of feed matrices requiring developing new calibrations was performed.

1.Introduction

The nutritional value of feedingstuffs is defined by determining their chemical composition, mainly the content of crude basic nutrients: protein, fat, fiber and ash. The official feed control, in order to confirm compliance with the requirements, uses official methods published in the Commission Regulation (EC) No 152/2009. The results of test, obtained by authorized laboratories using the official methods, are reliable while assessing the market quality and safety of feedingstuffs. However, feed testing by the official methods may be often time-consuming and costly. An alternative may be provided by spectroscopy, a cheap, quick and simple to perform technique, which is becoming increasingly popular in feed manufacturing, e.g. to monitor feeding products' parameters in production lines. In Denmark NIR is effectively used in the official tests of feedingstuffs as a screening method by the reference laboratory of Danish Plant Directorate (Ellermann, 2006; Kolbuszewski, 2009). Some organizers of proficiency testing use this particular technique to perform the assessment of homogeneity of test materials. There are examples of creating a network of NIR analyzers which are coordinated by reference laboratories (or some other competent and well-equipped labs) supervising the functioning of each NIR analyzer in the network. Such a solution functions at the Centre of Agricultural Research in Wallonia, Gembloux in Belgium (http://cra.wallonie.be).

Performing a measurement within near infra-red spectrometry (NIR) consists of exposing a sample to electromagnetic radiation in the range of 770 nm to 2500 nm. Providing low energy, this does not have any harmful effect on the sample scanned. It is possible to determine the level of compounds containing characteristic functional groups, such as CH-, OH-, NH- , and it consists of absorbing the

radiation, which provokes vibration of chemical bonds in the compounds. The signal reflected or going through the sample, depending on the method of measurement, is modified in the apparatus, and after reaching the detector it contains the information about chemical compounds present in the tested material. The software of the apparatus will identify particular compounds and assess their quantity. It compares the spectrum of the studied sample with a mathematical model developed during the calibration process and on this basis it predicts the content of components in the sample (Aureli, *et al.* 2017*;* Ferreira, *et al.,* 2014; Siesler, *et al.,* 2006; Ozaki, *et al*., 2007; Worsz, 2012).

This is how the InfraXact 7500 spectrometer, by FOSS company, works, which uses a special halogen lamp as the source of light. The light is transmitted by the optical fiber to a Sample Presentation Unit. It reflects from the surface of the sample collecting information about its chemical composition. The reflected radiation is next transmitted to the spectrometer, where it meets the diffraction grating which splits it into individual waves. The rotation of the grating results in generating the spectrum within the range of 570 to 1848 nm. Next the light is shed on two detectors fixed inside the spectrometer. The signal is strengthened and transformed into its digital version. The DSP plate synchronizes the position of the grating with the signals from the detector and generates a spectrum which is sent to ISIScan software. The computer is connected with the apparatus by means of a USB cable. The ISIScan software processes the spectrum and generates the result of the analysis (www.foss.dk).

The calibration of NIR apparatuses consists of collecting a set of spectra of the samples (a calibration set) and analyzing their nutrients by means of reference methods. Next, multi-parameter calibration techniques (e.g. PCA, PCR, PLS) are used to refer different combinations of absorbance values to the composition of the sample (Burns, *et al*., 2008).

FOSS company has developed for its NIR spectrometers WinISI software which is used to create new calibrations on the basis of the collected absorbance spectra and the numeral values of the analyzed parameters ascribed to the former. It is possible to add more samples to the calibrations which have been validated and used in practice, in order to refine them. Then the process of validating a calibration model is repeated from the beginning, and the new software is sent to the apparatus by means of RINA or Mosaic. The continued expansion of calibration its increases the precision of measurements and contributes to both expanding the measurement range and including new types of samples (Nilsson, 2018).

Prior to the use, calibration equations are validated with the help of a test set representative for a population of samples which are to be analyzed. Scanning in the NIR apparatus and an analysis according to standard methods are both carried out. At least 20 samples are necessary to assess the bias, slope and standard error of prediction (SEP). Validation is performed for each type of samples, element/parameter, temperature and other agents which are known to be able to affect the measurement. Calibration is valid only for variabilities resulting from the type of a sample and the range and temperature use for calibration (EN ISO 12099:2017).

The assessment of calibration quality in laboratory practice may be also performed by comparing the results obtained from the NIR spectrometer with PT (proficiency testing) results. Since 2016 the National Laboratory of Feedingstuffs (NLF) has been participating in proficiency tests organized by the BIPEA, world renowned association from France. Each year there are 10 rounds which include two or three samples tested by both standard methods and NIRS. In 2018 NLF took part in proficiency testing organized by the International Analytical Group (IAG), Austrian Agency for Health and Food Safety (AGES) and Swiss Federal Centre of Excellence for

Agricultural Research (Agroscope). The PT included only those laboratories which had NIRS analyzers.

2.Materials and methods

2.1.Research in NIR tests

The analyses used the NIR InfraXact 7500 spectrometer, by FOSS, operating within the spectrum range of 570 nm to 1848 nm. Test materials were ground on the Retsch ZM200 mill with a sieve of 1 mm or Cemotec 1090 (FOSS) with the smallest working gap.

Samples were placed in a large sample cup and they were scanned with the use of calibration provided by FOSS such as „ground mixtures", „mixtures for poultry" and „feed materials". Calibrations made it possible to predict parameters, such as moisture, crude protein, crude fat, crude fiber, crude ash and starch.

2.2.Comparative studies in the laboratory, in compliance with ISO 12099:2017 (E)

More than 300 samples of feedingstuffs were taken and used in NIRS analyses in accordance with calibrations, as well as in the analyses with the use of standard methods in compliance with the Commission Regulation (EU) 152/2009. They were feed mixtures for poultry, pigs, rabbits, pet-food for dogs, and the following feed materials: wheat, barley, triticale, maize, soybean seeds, soybean meal, sunflower, rape-seed and DDGS. For selected groups of samples, including at least 20 cases, e.g. feed mixtures for poultry, wheat, maize the basic statistical parameters were calculated in accordance with EN ISO 12099:2017 (E) Animal feeding stuffs, cereals and milled cereal products – Guidelines for application of near infrared spectrometry. These included:

a) SEP – standard error of prediction is an expression of the bias corrected average difference between predicted and reference values predicted by a regression model when applied to a set of samples not included in the derivation of the model. In EN ISO 12099 (E) is also marked as s_{SEP} and it is calculated following the formula below (1):

$$s_{\mathrm{SEP}} = \sqrt{\frac{\sum_{i=1}^{n}\left(e_i - \bar{e}\right)^2}{n-1}} \qquad (1)$$

where:

n is the number of independent samples;
e_i is the residual of the i^{th} sample;
$\bar{e}$ is the bias

b) RMSEP – the root mean square error of prediction i san expression of the average difference between reference values and those predicted by a regression model when applied to a set of samples not included in the derivation of the model. RMSEP includes any bias in the predictions
c) the importance of bias
d) slope and intercept (the value of Y at X=0)

2.3.Reliability of result prediction using the NIRS method in proficiency testing (PT)

The reliability of predicting the results with the use of NIRS in proficiency testing (PT) organized by BIPEA (France), an internationally recognized PT organizer, was assessed. In PT BIPEA prediction of nutrients is performed by means of the NIRS method, and the reference values for the analyzed components are determined on the basis of the results of chemical analyses (standard ones). In the years 2016-2018 NLF participated in more than 25 rounds of PT. Test materials were provided by feed mixtures, pet-food for dogs, cereals and their derivatives, maize, high protein feed materials (soybean, rape-seed, sunflower meal). Number of participant varied from a dozen to more than a hundred laboratories.

A similar study was conducted in 2018 by a consortium including the International Analytical Group (IAG), Austrian Agency for Health and Food Safety (AGES) and Swiss Federal Centre of Excellence for Agricultural

Research (Agroscope). The participants of PT could be only laboratories equipped with NIRS analyzers. Each of them obtained 7 samples prepared by the organizer. They included feed mixtures for poultry, cattle and pigs, maize, wheat, barley and rape-seed. Each sample had to be scanned in 4 replications and the results were sent in an enclosed form.

Predicted results of analyzing moisture, total protein, crude fat, crude fiber, crude ash and starch were sent in case of both PT sessions. Each study was documented in a report (List of Reports from PTs Feedingstuffs; Report of NIRS Ringtest 2018).

3.Results and discussion

3.1.Correcting NIR calibration, following the data from NLF

More than 300 samples were scanned by the InfraXact apparatus and the predicted content of moisture, total protein, crude fat, crude fiber, crude ash and starch was determined. NIR makes it possible to predict accurately the results of a study if the content of components in the analyzed sample is similar to the content in the samples composing the calibration set. The market of feedingstuffs is constantly changing. Apart from traditional raw materials, such as cereals, maize, soybean and their products, new materials are being introduced. These are modified as a result of technological processing or changes in agro-technical technology. An important element leading to poor compliance of the samples is also weather alterations during the period of vegetation of plants which are later used in feed manufacturing. In the laboratories of the National Institute of Animal Production calibrations were verified and corrected, following chemical analyses performed by means of standard methods, which included a few hundred of feed mixtures and materials (Korol, 2016-2018).

Figures 1-4 present the assessment of bias for the NIR method, as well as its statistical reliability in compliance with ISO 12099 (E) for feed mixtures. In all the cases relevant bias of predicted results was statistically confirmed, and the bias was used in correcting the final results.

The results of predicting the content of basic nutrients in mixtures for poultry were assessed as satisfactory, with an exception of feed mixtures for laying hens (crude ash) (Fig. 4). Positive results were also recorded while predicting the content of nutrients in mixtures for pigs. In case of mixtures for rabbits and supplementing mixtures with a high content of minerals, predicted values of mainly crude ash were unsatisfactory. A negative assessment was also given to feed materials such as beet pulp and rapeseed. Satisfactory results of predicted components were confirmed for cereals, maize and soybean, as well as for their products (Fig. 5).

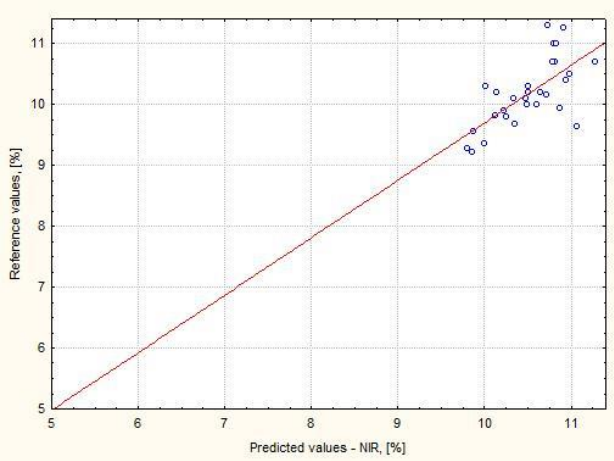

Figure 1. Evaluation of bias of the NIR method and its statistical significance for feed mixture; component predicted – moisture*

*calculated parameters according to the standards PN-EN ISO12099: reference mean value = 10.18 %, mean value predicted = 10.52%; bias = -0.33 %; the root mean square error RMSEP = 0.52; the standard error of prediction SEP = 0.40; enter the bias correction when it is greater than 0.06 – yes; ratio of average standard values to predicted = 0.97

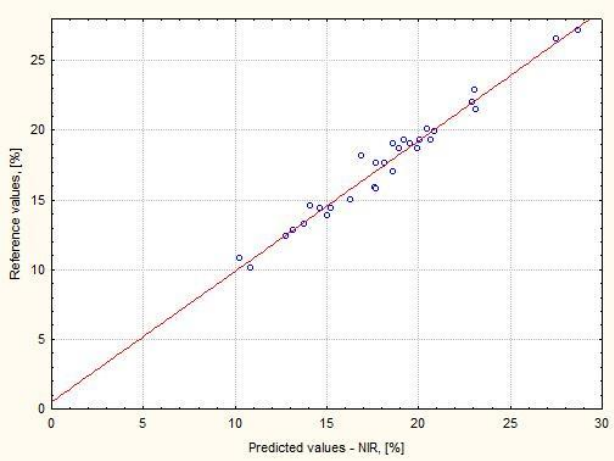

Figure 2. Evaluation of bias of the NIR method and its statistical significance for feed mixture; component predicted – protein*

* calculated parameters according to the standards PN-EN ISO12099: reference mean value = = 17.58 %, mean value predicted = 18.22 %; bias = -0.64 %; the root mean square error RMSEP = 0.98; the standard error of prediction SEP = 0.75; enter the bias correction when it is greater than 0.21 – yes; ratio of average standard values to predicted = 0.96

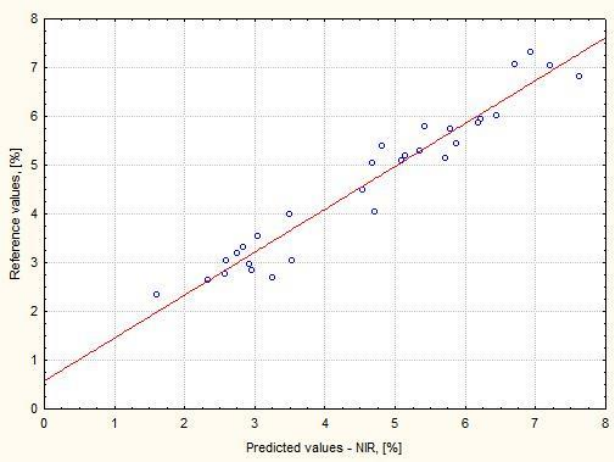

Figure 3. Evaluation of bias of the NIR method and its statistical significance for feed mixture; component predicted – fat*

* calculated parameters according to the standards PN-EN ISO12099: reference mean value = 4.63 %, mean value predicted = 4.62 %; bias = 0.02 %; the root mean square error RMSEP= 0.42; the standard error of prediction SEP = 0.43; enter the bias correction when it is greater than 0.07 – yes; ratio of average standard values to predicted = 1.00

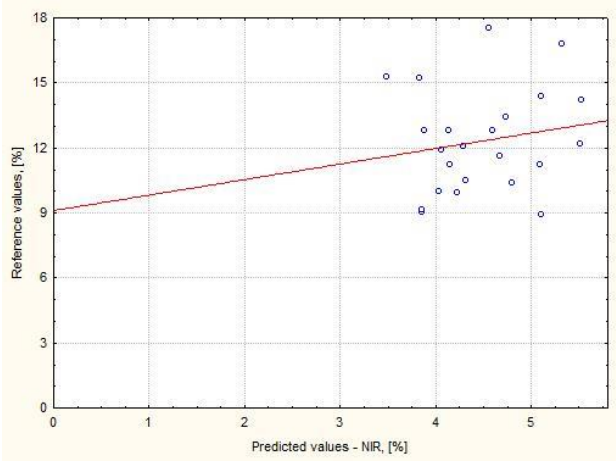

Figure 4. Evaluation of bias of the NIR method and its statistical significance for feed mixture; component predicted – ash*

*calculated parameters according to the standards PN-EN ISO12099: reference mean value = 12.32 %, mean value predicted = 4.48 %; bias = 7.83 %; the root mean square error RMSEP= 8.17; the standard error of prediction SEP= 2.38; enter the bias correction when it is greater than 2.44 – yes; ratio of average standard values to predicted = 2.75

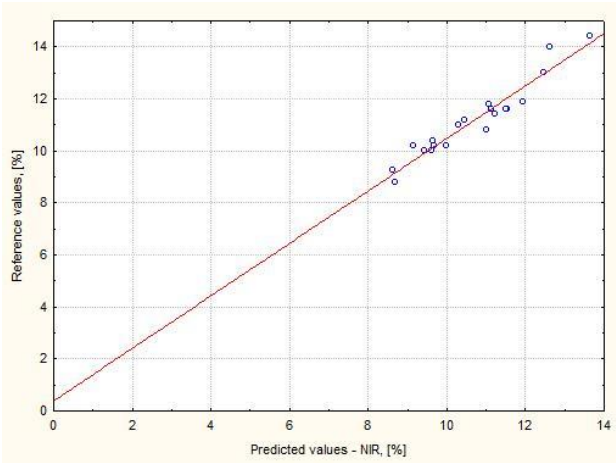

Figure 5. Evaluation of bias of the NIR method and its statistical significance for barley; component predicted – protein*

*calculated parameters according to the standards PN-EN ISO12099: reference mean value = 11.17 %, mean value predicted = 10.69 %; bias = 0.48 %; the root mean square error RMSEP= 0.61; the standard error of prediction

SEP= 0.39; enter the bias correction when it is greater than 0.77 – yes; ratio of average standard values to predicted = 1.04

The analyses made it possible to identify matrices requiring new calibrations. In case of the samples which did not comply with the calibration set used for the InfraXact instrument, a new individual set was created, e.g. for mixtures for laying hens, fodder yeast, beet pulp, guar flour. It is possible to develop new calibration from the beginning, with the help of WinISI software, to be later used in the NIR analyzer (Nilsson, 2018).

3.2.Assessing NIRS result prediction in PT

3.2.1.Proficiency testing organized by Bipea (France)

In the years 2016-2018 NLF participated in more than 25 rounds of proficiency tests organized by Bipea, France. A total of 40 samples of different feeding mixtures and materials prepared by the French organizer were tested. The results of selected PTs are presented in Tables 1-6.

Table 1. Results of determination of basic nutrients by the NIRS method in reference materials (compound feed) from proficiency tests – compound feed for rabbit

BIPEA, France, January 2016, Component	Assigned value	SDPA	Result NFL NIRS	z-score NFL NIRS	Result evaluation*	Permitted tolerances-Com. Reg. 939/2010*
Moisture,%	10.9	0.3	10.7	-0.67	S	S
Ash,%	7.0	0.2	6.95	-0.25	S	S
Protein,%	15.8	0.3	17.4	5.33	U	S
Fat.,%	3.8	0.5	4.8	2.00	S	S
Fibre.,%	16.7	0.7	13.2	-5.00	U	S
Starch, %	15.4	0.8	25.4	12.5	U	S

*S – satisfactory, U-unsatisfactory

Table 2. Results of the determination of basic nutrients by the NIRS method in reference materials (feed materials) from proficiency tests – beet pulp

BIPEA, France, January 2016, Component	Assigned value	SDPA	Result NFL NIRS	z-score NFL NIRS	Result evaluation*	Permitted tolerances-Com. Reg. 939/2010*
Moisture,%	10.5	0.3	10.8	1.00	S	S
Ash,%	5.4	0.3	5.8	1.33	S	S
Protein,%	7.4	0.2	17.1	48.5	U	U
Fat.,%	0.7	0.3	8.8	27.0	U	U
Fibre.,%	17.4	0.7	18.4	1.4	S	S

*S – satisfactory, U-unsatisfactory

Table 3. Results of determination of basic nutrients by the NIRS method in reference materials (compound feed) from proficiency tests – pet-food for dogs

BIPEA, France, May 2016 Component	Assigned value	SDPA	Result NFL NIRS	z-score NFL NIRS	Result evaluation*	Permitted tolerances-Com. Reg. 939/2010*
Moisture,%	8.3	0.3	8.6	1.00	S	S
Protein,%	23.3	0.4	23.1	-0.57	S	S
Fat.,%	15.4	0.4	16.2	1.60	S	S
Fibre.,%	2.7	0.4	2.7	0.00	S	S
Starch, %	35.2	0.8	35.2	0.00	S	S

*S – satisfactory

Table 4. Results of determination of basic nutrients by the NIRS method in reference materials (compound feed) from proficiency tests – compound feed for piglets

BIPEA, France, September 2016 Component	Assigned value	SDPA	Result NFL NIRS	z-score NFL NIRS	Result evaluation*	Permitted tolerances-Com. Reg. 939/2010*
Moisture,%	10.3	0.3	10.4	0.33	S	S
Ash,%	4.7	0.2	4.5	-1.00	S	S
Protein,%	17.7	0.3	17.6	-0.80	S	S
Fat.,%	3.6	0.5	3.8	0.24	S	S
Fibre.,%	3.7	0.4	3.2	-1.25	S	S
Starch, %	44.0	0.8	42.2	-2.40	D	S

*S – satisfactory, D- doubtful

Table 5. Results of determination of basic nutrients by the NIRS method in reference materials (compound feed) from proficiency tests – compound feed for poultry

BIPEA, France, January 2017 Component	Assigned value	SDPA	Result NFL NIRS	z-score NFL NIRS	Result evaluation*	Permitted tolerances-Com. Reg. 939/2010*
Moisture,%	9.2	0.3	9.8	2.00	S	S
Ash,%	4.7	0.2	5.2	2.50	D	S
Protein,%	17.4	0.3	17.4	0.00	S	S
Fat.,%	4.0	0.5	4.3	0.60	S	S
Fibre.,%	4.7	0.4	4.0	-1.75	S	S
Starch, %	44.0	0.8	41.8	0.40	S	S

*S – satisfactory, D- doubtful

Table 6. Results of determination of basic nutrients by the NIRS method in reference materials (compound feed) from proficiency tests – compound feed for turkey

BIPEA, France, February 2018 Component	Assigned value	SDPA	Result NFL NIRS	z-score NFL NIRS	Result evaluation*	Permitted tolerances-Com. Reg. 2017/2279*
Moisture,%	13.0	0.3	12.5	-1.67	S	S
Ash,%	6.1	0.2	5.0	-5.50	U	S
Protein,%	23.0	0.4	23.2	0.57	S	S
Fat.,%	4.5	0.5	4.2	-0.60	S	S
Fibre.,%	3.3	0.4	3.1	0.50	S	S
Starch, %	35.8	0.8	36.1	0.40	S	S

*S – satisfactory, U-unsatisfactory

The obtained indices (z-score) were assessed on the basis of test results and reference values, and the differences between prediction results for NIR and obtained standard methods were compared with accepted tolerances outlined in the Commission Regulation No 939/2010. The range of result prediction for NIRS included the following basic components of feed analyses: moisture, crude ash, total protein, crude fat, crude fiber and starch. While analyzing typical feed mixtures, satisfactory results were recorded for all analyzed components. In case of a mixture for rabbits or laying hens, which were of specific composition, NIRS results were correct to a lower degree, mainly in case of protein and moisture (Table 1). Unsatisfactory results were obtained for beet pulp. The data recorded provided another indication that new calibrations should be developed for the selected feeding materials, following collecting a set of required calibration samples with a possibly broad range of component content. The first stage in statistical processing of WinISI software will be scanning and performing analyses with the use of standard methods.

3.2.2.Proficiency testing organized by IAG, AGES and Agroscope (NIRS 2018)

Participation in PT provided us with another opportunity to assess reliability of predicted results with the use of the InfraXact apparatus. The number of participants ranged, depending on the matrix and the predicted parameter, from eight to more than twenty. All the results obtained by NLF were satisfactory (z-score<2). This proves the adequate matching of the calibration of the spectrometer to study the samples present on the European market. Figures 6-8 present the results of the predicted content of crude protein in a mixture for poultry, maize and wheat. Values obtained by NLF were similar to the value ascribed in the presented data.

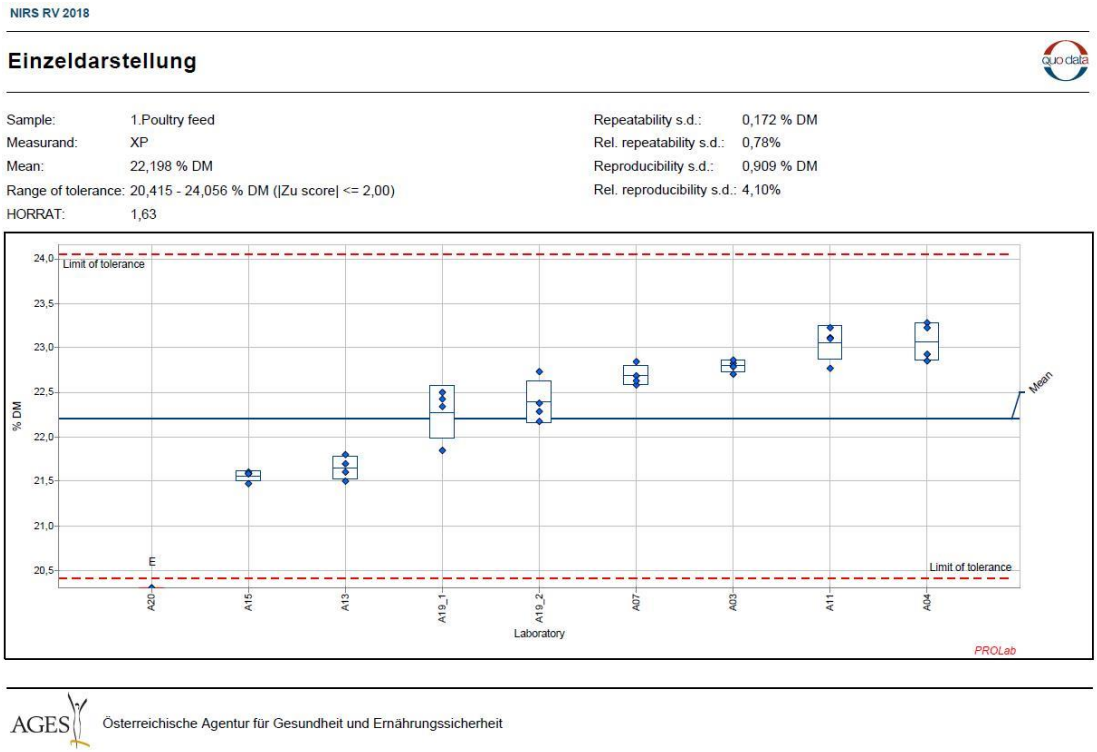

Figure 6. Scatter chart from the report PT NIRS 2018, product: compound feed for poultry, component predicted: protein; No NLF: A07

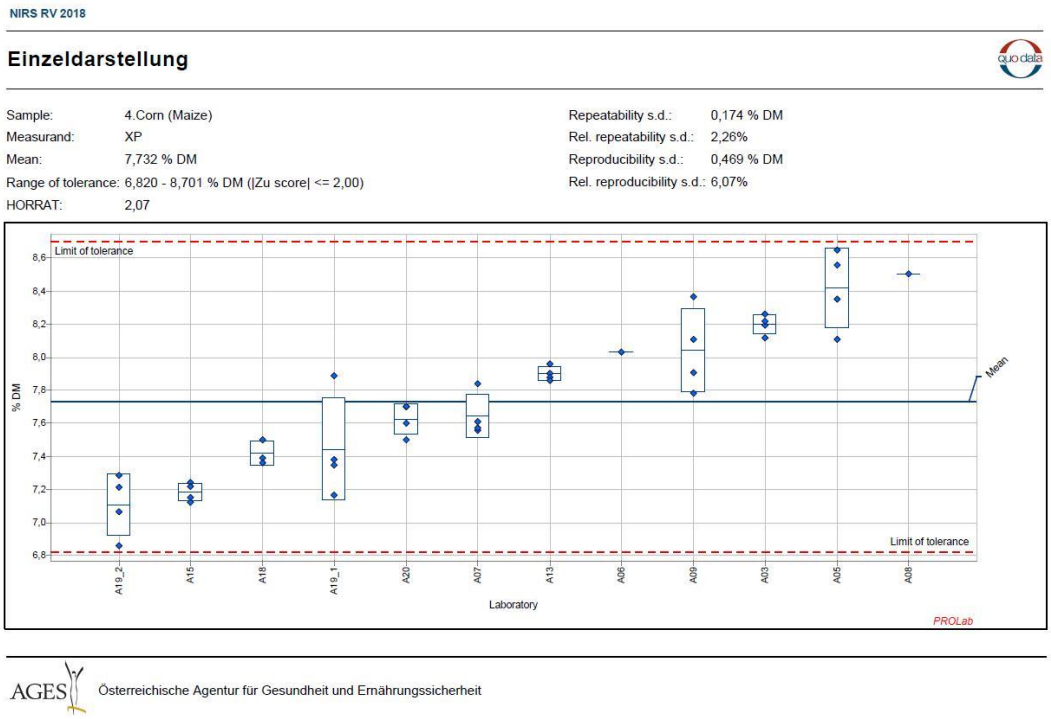

Figure 7. Scatter chart from the report PT NIRS 2018, product: maize, component predicted: protein; No NLF: A07

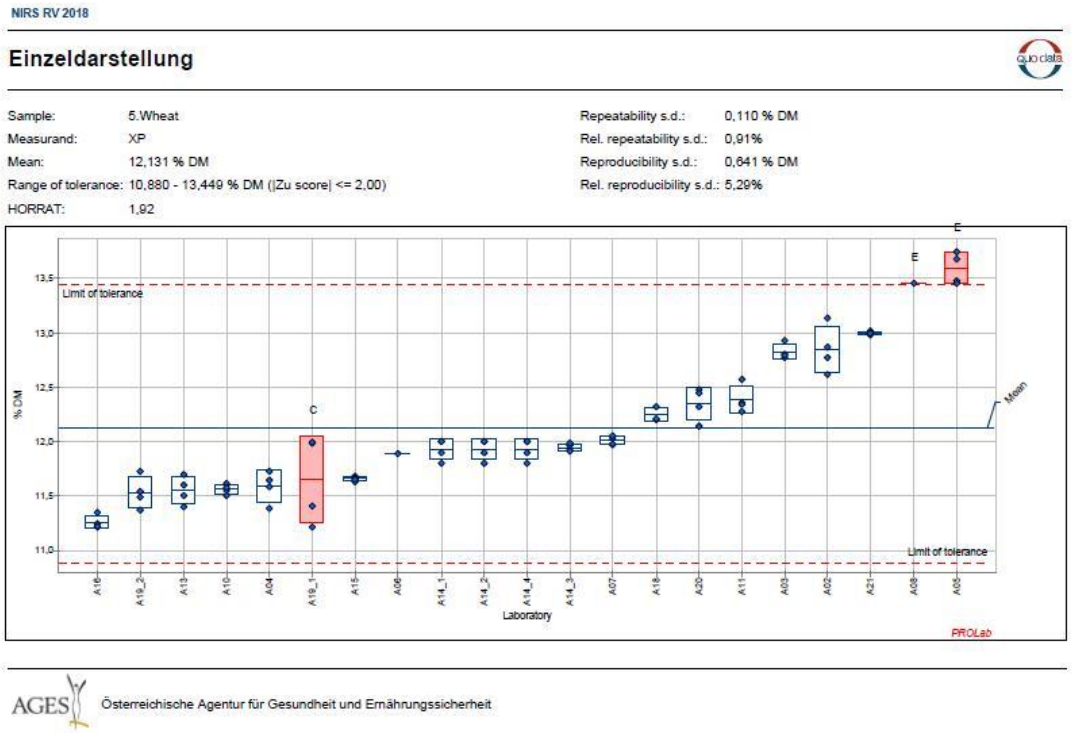

Figure 8. Scatter chart from the report PT NIRS 2018, product: wheat, component predicted: protein; No NLF: A07

4.Conclusions

The results of the analyses presented here confirm reliability of predicting the content of nutrients in feedingstuffs. NIR instruments are exceptionally useful in assessing the trading quality and they may contribute to higher safety and quality of feeds.

In comparative studies performed in NLF, in case of traditional feed mixtures and materials the ratio of mean values obtained by traditional methods to the predicted ones was between 0.95 and 1.00. Standard errors of prediction, SEP, and bias will provide an additional basis for correcting the values of predicted results.

Participation in proficiency testing let us find an objective confirmation of the quality of the NIRS analyzer's calibration software. For feed matrices commonly used in animal feeding the obtained results were satisfactory (z-score<2). Also, feed matrices or certain parameters were identified which required developing new calibrations, e.g. ash present in mixtures for laying hens, compound feed for rabbits or beet pulp.

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NATURE BASED PACKAGING MATERIALS - BIODEGRADABLE MATRIAL AND TECHNIQUE OF FOOD CONTAINERS THAT CAN BE USED FOR LIGHT MEALS (E.G. A BOWL FOR CEREAL AND MILK) MOLDING

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ABSTRACT

The aim of this article is to describe how to create a material and compile the technique of molding containers that can be used for light meals e.g. a bowl for cereal and milk. Primarily both the recipe of construction material was evolved and subsequently, a biodegradable bowl was shaped. All of this actions were handled experimentally. After that surface of the container was improved by finishing it with a coating that makes it tight, additionally, the final container was tested by examining the contact with milk resistance. Article also provides the information about materials of cereal-milling industry that were used as components of a biodegradable material in the designing part. The proportions were established experimentally, the bites of a cake and its properties were examined and eventually, a recipe for the future studies was chosen basing on the results of that analysis. Paper describes a technique of baking and improving the material to achieve the best parameters of the final product as well as a technique of shaping a container using a template and stamp were also formulated.

1. Introduction

Nowadays, polymer packaging waste creates a serious environmental problem and are subject of many research and analyses (Gupta *et al.* 2018, Michalska-Pożoga *et al.* 2017, Roohi *et al.* 2018). Products packaged with natural materials have become more and more noticeable in the food market (Popa *et al.* 2011). Such packagings, either partly or entirely made of natural polymer inter alia starch, cellulose, polynucleotides, polysaccharides or polypeptides are degradable and/or biodegradable. Both mentioned processes are limited by the European Standard 13193:2000 Packaging and the environment - Terminology. It defines the process of degradation as irreversible and leading to changes in the structure of material, thus also to the fragmentation and deterioration of its properties such as mechanical strength, consistency and molecular weight. By contrast, in terms of biodegradation, one can discern a degradation of a material that is caused by a contact with biological factors, especially by the influence of fungi, bacteria and their enzymes that significantly change chemical structure of a material. European

Standard EN 13432 determines that either the material or packaging may be called biodegradable if within 180 days the carbon in the material turned into carbon dioxide in a minimum of 90%. The initial stage of that process is the shortening of the length of polymer chains and the elimination of their fragments. This is followed by oxidation or hydrolysis. Typically, it is accompanied by decreasing in the degree of polymerization and molecular weight, and even depolymerization that is the dissociation into monomers (Leszczyński 2001). At the second stage, the present microorganisms slowly absorb organic compounds that were formed during the first stage. The effect of absorption and transportation of these substances into the cells of a microorganism is the oxidation of carbon into carbon dioxide as well as releasing of energy at the same time (Wróblewska-Krepsztul *et al.* 2018). Scheme of biodegradation with an description shows on figure 1. The biodegradable materials are polymers produced by the partial polymerization of raw vegetable materials. A prime example of that material is PET bottle, also called Plant Bottle, made of terephthalic acid and glycol, used in a proportion of 70% to 30% (Dean and Yu 2005, Vasilie 2018). The first of those components is made during the preparation and processing of crude oil, and glycol is a result of fermentation of vegetable polysaccharides and treatment of the resulting ethyl alcohol. Biodegradable polymers are i.a.: polymers isolated from plant and animal biomass (proteins, polysaccharides, lipids); polymers produced by the synthesis of the products of metabolism of microorganisms, as well as transgenic plants (polihydroxyalcanians); An interesting group of biodegradable materials are edible materials. As the name indicates, their components are the substances that a person can consume without any obstacles. These include m.in starch, pectin, collagen, gelatin and soy protein and soy nuts. Currently, this group of packaging materials has grown rapidly, because it combines both ecology and practicality.

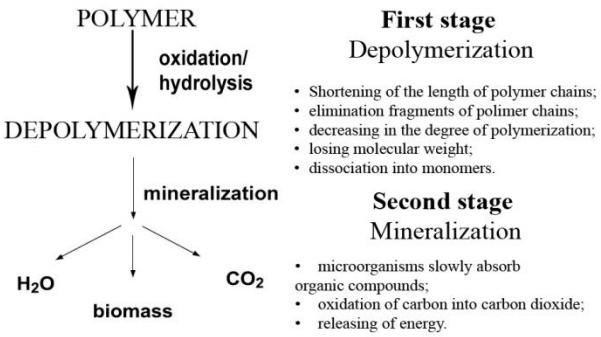

Figure 1. Scheme of polymer biodegradation

The biodegradable materials are also made from many other materials. Some of them are used in packaging production. One of such materials is polylactide – material made from treatment and fermentation of corn starch or sugar cane. Obtained this way lactic acid is polymerized. The structural features of material in comparison with petrol derivative polymers let reduce final mass of product even to 15%. By the current state of scientific knowledge and technology, the cons of this material is its low melting point and also weak resistance towards steam and oxygen (Łopacka and Półtorak 2014). The material is still fat resistant and also do not let pass through scent and aroma. Although there are conducted studies on increasing barrier capacity towards gases by using different chemical compounds for example deposition of silicon oxide, but lactidpolyacid (PLA) seems to have worse derivation attributes towards most of the factors than Polyethylene terephthalate. PLA has the biggest usage as component of other materials, mostly oil derivatives. When used it increases the renewable content in mixture and also increases the final price of packaging. The other way of using of polylactide is producing of film. Unfortunately it is very rigid and breakable and its usage makes much noise. That is why it is not used as independent packaging in food industry despite the fact that it is ecological. Nowadays it is used to producing rigid packaging of fresh food, not damp because of hygroscopic features of PLA. Material is compostable in industry conditions. In home conditions, in soil and salt

water process of biodegradation is relatively slow, but still fits in provided 180 days. In the picture (Fig. 2) is presented a clamshell made from polylactide.

Other material used in packaging biodegradable production is starch. It is crystal polysacharide with plant origin consisting from amylopectin polymers, which structure is highly branched and amylose line oriented. Proportions of these polymers in molecular structure are dependent from plant from which starch comes from and its possible genetic modification. It is the feature of all natural starches from f.e. potatoes, corn or tapioca (Łopacka and Półtorak 2014).

Figure 2. Clamshell packaging made from polylactide (PLA) (www.michigangreensafeproducts.com)

Nowadays it is possible to get starch in many ways and make many modifications in order to improve its solubility features or term plasticity. Because of the popularity and the origin starches are one of the cheapest and environment friendly polymers. Their con is very high water vulnerability and because of their crystal structure they have weak mechanic properties. It is also very difficult to process thermoplastic, because they are degraded in lower temperature than low melting point. That is why the starches should be modified by disrupting the structure with heating them in water and improve their properties using carboxylic acid, urea, alcohols for example glycerol and whole number of plastificators and other chemical substances. Then you can obtain modified starches by plastification and thermoplastic starches, which can be molded. In the further processing the starches are obtained by modification and they can be mixed with other biodegradable materials like polylactide, polyhydroxyalkanoates or aliphatic-aromatic polyesters, what makes possible to obtain bio substances with better mechanic proportions and less fragility. Depending on the proportions of different biodegradable materials is possible to produce disposable food packagings, dishes, rigid and flexible cutlery or coatings using particular method for particular type of packaging. By the opportunity of selecting the quantity of particular material the producers have wide range of possibility of producing the biomaterials with different functional characteristics (Żakowska 2012, Ching *et al.* 993). The natural origin of starch makes that the polymers are biodegradable. They can be composted in industrial environment.

The other popular material to produce packagings is cellulose. It belongs to polysaccharide group with plant origin. They consist of cellobiose- polymers with long and short crystal structural chains. Cellulose is insoluble in water and unmixable. That is why the production of the packagings with their unmodified form is problematic. It is chemically modified by esterification process to give it features making possible to processing. Then there are produced cellulose foils and other biomaterials like for example Biograde, mechanically and optically resembling polystyrene (Farmer 2016). Thermoplastic mixtures of cellulose and other biopolymers are biodegradable and renewable. The tend to be heat resistant in about 115ºC. The made from cellulose materials packagings are molded by injection molding and for rigid foils are also molded by extrusion. The good example of cellulose usage is cellophane – cellulose foil, which is produced from pulp of wood which has undergone number of chemical reactions. The pulp of wood is exposed to activity of carbon disulfide and alkalis and then it is conducted process of acidification and the pulp of is flushed. The natural origin of foil makes it compostable in home environment. The packagings made from cellophane are also used there, where the moisture transmission is a merit, because it has good barrier

for gases, aromas, oxygen or carbon dioxide, but it transmits steam. The material behaves well after folding. Thanks to its utility features it is ideal to fold and cook food. The problems with pollution of environment improves real quickly the branch of ecological packaging industry and new biodegradable materials will develop often.

One of the worth mentioning fact is every year consumer ecological awareness increases. One of the examples is France, where the resolution was adopted, whereby in January 2020 the resolution will apply, which will prohibit usage disposable packaging made completely from polymer material. Packaging producers of finished products will have to embody 50 % of biodegradable material of natural origin and in 2025 this proportion may increase and the containment of natural biopolymers will have to be at the level of 60%. It is cause because of actions of French government and increasing of ecological awareness. In July 2016 the French government prohibited giving the disposable bags made from artificial polymer material to clients in discount stores and supermarkets. At the beginning of 2017 such bags were also withdrawn from fruit and vegetables departments (www.sadyogrody.pl).

2. Matherials and methods

Present trends in world made the scientific centers and packaging industry to make new materials which could be used to producing disposal food packaging. In Koszalin University of Technology made an successful attempt of making natural and completely biodegradable material, and then made a form of bowl which could be used to consume f.e. cornflakes with milk. Initially to make the packaging the rice flour, rice syrup, oat bran and water were used. The more precise recipe is in the process of obtaining patent protection. The proportions of ingredients to make dough were estimated experimentally, which looked similar to bowl after baking in template made from thermosetting polymer clay. The vessel was hard and rigid, but also very brittle and desiccated quickly, what caused cracking of the surface and loosing of tightness. The molding of the vessel, which was made from the template from thermosetting polymer clay, was presented on Fig. 3, the figure 4 presents formed and baked vessel.

Figure 3. Initial forming of vessel-bowl in template made from thermosetting polymer clay

Figure 4. Formed and baked vessel-bowl

Because of fragility and rigidity and cracking of inside surface of vessel (Fig. 4 and 5) occurred couple of days after baking it was decided to modify the recipe. Also, the technology was slightly changed. By adding the wheat flour gluten chain structure of constructional material was reinforced, what made the vessel more flexible.

Figure 5. Vessel with cracked interior surface

It differed from previous examined in proportions and producing technology. After mixing flour with bran, starch which was contained in them were gelatinized. After draining into the part of the dough the gelatinized wheat flour was added and mixed in order to spreading the gluten into its structure. Then the dough was put into the template which was oiled with canola oil. After that it was squeezed oiled stamp and completely put into thermic chamber. After that time the vessel was taken out from the template and primarily formed vessel was baked for 60 minutes. Additionally, to prevent from moisture penetration and excessive desiccation external and internal surface of vessel was covered with refining layer made from gelatinized wheat flour and rice syrup. The effects are presented on the figure 6.

Figure 6. The effect of the research – the bowl-vessel made from modified natural materials

3. Results and discussions

3.1.Leakage test

One of the assumptions considering the created material was achieving the tightness of vessel that it will endure under the influence of milk for 15 minutes. In order to achieve that the resistance research was conducted and the vessel was treated with this liquid. The glass table was prepared, which was set between two benches, covered with white filter paper sheet and then examined vessels were put on them. The vessels were filled with 60 ml of cow milk with 2,8% fat (Fig. 7). The research were conducted for 15 minutes. Every 5 minutes condition of paper was checked from below and documented. After quarter of test with the fact that there was no stated any sign of leak, it was decided to conduct the test for 60 minutes. The effect is presented on picture 8.

Figure 7. Four bowls-vessels filled with milk during the resistance/leakage test. The vessels stands on the filter paper sheet lying on the glass table

As it is presented on picture 8 the leak is not indicated and the spots visible on photo resulted from the remains of canola oil used for oiling the template and stamp during the vessel forming.

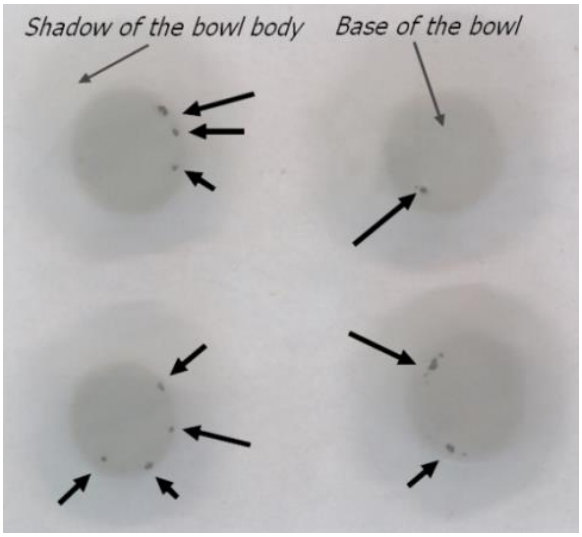

Figure 8. The filter paper used for leakage registration after 60 minutes of test. A view from the bottom side. There are some small marked spots (dark gray) came from residues of canola oil used for lubricating the stamp and template

4. Conclusions

A fully biodegradable packaging was created based on popular products from the grain and milling industry. The packaging created fully met the design assumptions made at the outset.

Because of the presented results it is possible to estimate that due to used materials the packaging is cheap, biodegradable and it is possible to eat on it. It has pleasant odor and taste. The vessel allows to eat from it flakes with milk, because it not disintegrates in 15 minutes and it resists contact with milk for longer than 60 minutes. It is very promisable and pleasing result. One notable fact is that after 60 minutes the test was stopped, but the state of vessels could suppose that they could resist the contact with milk at least 30 minutes longer.

One of the cons is the time-consuming and work-consuming production, but if the process would be transferred into the industry reality the idea have to be modified and improved, what would increase the production performance and give chances to exist such packaging on market.

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BY-PRODUCTS FROM BREWERY INDUSTRY AS THE ATTRACTIVE ADDITIVES TO THE EXTRUDED CEREALS FOOD

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ABSTRACT

The use of structure-forming raw materials allows the use of new components in extruded compounds. Although various components are widely used, the share of non-starch additives is rarely more than a dozen percent. The aim of the study was, therefore, to exceed the level of 30% of the brewers' spent grain - BSG (which is a by-product in the production of beer) and, using statistical analysis, to study the processing possibilities of this raw material. The general composition plan underlying the project was based on the following independent variables: process temperature, feed moisture content, participation of BSG (mixture with corn), and on dependent variables. The results show that it is possible to produce BSG extrudates above 30%, but only if the appropriate process conditions as outlined in the test are provided. To date BSG content in mainly extruded corn snack with additions of other ingredients improving the composition has been studied. A novelty in the applied research will be the performance results of extruded maize products and the share of nearly 40% BSG. Obtained results may help in future research on the creation of products with a high content of dietary fiber contained in by-products materials of the agri-food industry.

1.Introduction

Extrusion is currently one of the most popular and innovative raw plant processing methods in the food industry. The process owes its popularity to a number of factors, including a possibility to quickly obtain products that are ready to eat (RTE), to compose the content of the mixture and to quickly adjust extruder settings to the manufacture of new products (Mościcki *et al.,* 2012; Wu, 2015; Żelaziński *et al.,* 2016; Ekielski *et al.,* 2017; Li *et al.,* 2017). Therefore, the process enables easy expansion of the range of products offered by food processing plants, usually without the need to purchase new, costly technological lines. A new adaptive approach to the development of existing food industry plants may have an impact on reducing unit energy consumption of production lines (Wojdalski *et al.,* 2015; Borowski, 2019). Next to the starch and high-protein material, which are commonly used in the process of extrusion, the method can also be used for processing food waste, which then serves as new components of food products (Karkle *et al.,* 2012; Paraman *et al.,* 2015). These usually include by-products generated in the manufacture of well known, widely used foods, such as pomaceous fruit and vegetables (O'Shea *et al.,* 2012), which are usually rich in a number of valuable nutrients and antioxidants (Genevois *et al.,* 2016; Wijngaard *et al.,* 2009; Martins and Ferreira, 2017). Among them is

brewers' spent grain, i.e. a by-product generated in the production of wort in breweries, in which brewers' spent grains (BSG) constitutes as much as 31% of all waste products (Reinold, 1997; Townsley, 1979). BSG is a very interesting raw material, rich in dietary fibre, vitamins and micro elements (Eshak *et al.,* 2010; O'Neil *et al.,* 2010; Zhang *et al.,* 2011). When used as an ingredient of dietary products, BSG makes an interesting alternative to other natural products high in fibre, such as bran, prunes, pea, broccoli etc. Literature on the subject contains abundant information about the beneficial properties of the ingredient, such as cholesterol reduction, control of bacterial flora or reduced activity of digestive juices (McIntosh *et al.,* 1995; Mussatto *et al.,* 2006; Teixeira *et al.,* 2017). From the health point of view, the product can make an interesting and inexpensive ingredient of extruded products. As BSG contains only insignificant amounts of starch, it favours reduction of expansion indices while increasing the density of extruded products (Ainsworth *et al.,* 2007; Stojceska *et al.,* 2008; Makowska, Mildner-Szkudlarz, and Obuchowski, 2013; Nascimento *et al.,* 2017). Together with these parameters changes the texture (growth of hardness), which, in the opinion of some of the authors, make the primary barrier to application of large quantities of BSG in extruded mixtures (Ainsworth *et al.,* 2007; Ktenioudaki *et al.,* 2013). In literature, the share of brewers' spent grains rarely exceeds 30% of the overall content of the mixture (Stojceska *et al.,* 2008; Nascimento *et al.,* 2017;). Nevertheless, minding the large possibilities of shaping the conditions of extrusion process, it is difficult to confirm beyond any doubt that it is impossible to produce extrudates with a bigger share of the ingredient. Therefore, the aim of this study was to test the qualitative features of extruded products containing brewers' spent grains and to verify the processing capabilities (in various settings of the extrusion process) of the material with the use of statistical methods. To increase the range of research, the popular corn grits was used as a basic raw material (structure-forming material used in a blend with brewer's spent gain).

2. Materials and methods

2.1. Materials

The research material used in the study was extrudate obtained from corn grits (non-GMO, Polish local market) with an addition of brewer's spent grains (BSG) from laboratory production of wort. The BSG was obtained as waste from the production of 12.1º Blg wort from 3-5 EBC low colour Pilsen malt manufactured by Weyermann (Germany). Instrumentation: 50l Braumeister mash and boil kettle by Speidel (Germany). Before the feed material was added to the mixture, the brewer's spent grains had been dried in an FD-53 (producer: Binder, Germany) drier at 85°C until the moisture content equalled 10% (±0,2%). Then, the product was crushed with a 2 roller mill Maltmill (producer: Schmidling, USA). The parameters of the corn grits and the BSG are presented in Table 1. The percentage share of individual feed ingredients to be extruded is presented in Table 2.

2.2. Extrusion

A co-rotating twin-screw laboratory extruder EVOLUM 25 (producer: CLEXTRAL, Firminy, France) (27:1 length/diameter) was used in the testing process. The rotational speed of the screws was set at 350 rpm. The material was transported to the extruder's cylinder with a precise twin-screw feeder (accuracy: 0.01 $cm^3 \cdot min^{-1}$), at a feed rate of 6 $kg \cdot h^{-1}$ (the feeder had been calibrated before the tests). Five temperature levels were applied during the test. The temperature profile for the extruder cylinder equalled 60, 80, 110, 110, (113.2, 120, 130, 140, 146.8) °C, (starting from the feed section). A matrix with a round extrusion die (diameter: 2.5 mm) was mounted in the extruder head. Moisture content was controlled with the use of a water dispenser with accuracy of 0.01 $cm^3 \cdot min^{-1}$, providing the appropriate amounts of

water immediately to the feed section of the cylinder. The exact temperature range and feed moisture content used in the experimentation are presented in Table 2. Extrusion was performed with the use of a three-knife cutter mounted by the extrusion die, for samples of the average length of 7 mm (±1mm). The extrudates obtained were cooled (2 to 3 hours) in room temperature until moisture stability at the level of 10% (±0.5%).

Table.1. Typical composition of corn grits and BSG

Parameters of corn grits	
Moisture	13,2 %
Granulation	0,15 – 0,63 mm
Composition % d.m	
Starch	74 ±0.78
Total protein	8,3 ±0.45
Total fat	0,7 ±0.04
Ash insoluble [in 10% HCL]	0,10%
Parameters of BSG	
Dry mass (s.m.)%	21,5 (0,2)
Ash g·kg s.m^{-1}	57,6 (3,5)
Protein g·kg s.m^{-1}.	248,0 (8,0)
Dietary fiber g·kg s.m^{-1}	183,9 (14,7)
Sugar g·kg s.m^{-1}	11,6(0.5)

2.3. Experiment design

The tests were based on a Design of Experiments DOE, 2**(3), (nucleus plus star systems, number of input quantities: 3) general composition plan (Table 2) which sets forth interactions between individual factors such as the BSG, temperature and feed moisture. The plan consisted of 16 experimental runs, with 2 centre points and 14 non-centre points. In order to adjust the results obtained to experimental data, a regression model was used, encompassing a polynomial of degree 2 for dependent variables (Eq. 1).

$$Y = \beta_0 + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_i^2 + \sum_{i=1}^{2} \sum_{i=1}^{3} \beta_{ij} X_i X_j + \varepsilon \quad \text{(Eq. 1)}$$

In the model presented, Y - stands for the factor analysed, X – coded process variables (values), βo- constant coefficient, βi- linear coefficient, βii- quadratic coefficients, βij- interaction coefficients, ε - residual error, (Diamante *et al.,* 2012, Seth *et al.,* 2015). Significance of the factors tested in the model was established in an ANOVA test performed with the use of statistical software StatSoft, Inc. (2012), STATISTICA (data analysis software system, version 13.1.). Variables in the model were obtained by way of stepwise regression, with (β1, β2, β3) being the coefficients for independent variables (extrusion parameters) used in the experiment (results of the analysis are presented in Table 4). Significance was tested on several levels ($P \leq 0.001$, 0.01 and 0.05). Correlation between dependent variables was established based on the Pearson's correlation matrix computed. The results were presented in a graphic form on 3D response surface plots. Five tests were carried out.

Table 2. Coded levels for the response surface design

Variables	Levels				
	$-\alpha^*$	- 1	0	1	α
BSG addition [%], X_1	3.18	10	20	30	36.82
Temperature (°C), X_2	113.18	120	130	140	146.82
Feed moisture (%),X_3	10.61	13	15	14	17.55

α^*-1.5467

2.4. Expansion

A volumetric expansion index (VEI) was used in the tests, computed as a ratio of the radial and longitudinal expansion indices according to the (Alvarez-Martinezet *et al.*, 1988) method.

2.5. Textural measurement

Texture characteristics of extrudates were tested on the AXIS 500 (producer: Axis, Poland) device fitted with a dedicated head for the measurement of force (max 25 N) with accuracy of 0.01 N. The head, with a round spindle (diameter: 2 mm), moved at a speed of 0.02 mm $\cdot$ s^{-1}, with a displacement of 10 mm, which permitted full puncturing of the sample. The variable observed was the first max. peak force noted while the head was moving downwards (Ding *et. al.*, 2006). The force points so recorded were used as the determinants of product hardness. The data obtained was saved through the use of AXIS FM software (Poland).

2.6. Water absorption index (WAI) and Water solubility index (WSI)

The WAI and the WSI indices were determined in accordance with a method which is a common choice for quality tests, i.e. (Anderson *et al.*, 1969). First, 2.5 g of pre-milled samples were weighed out. Then, the samples were covered by distilled water (25 ml) and left for 20 minutes (every five minutes the samples were gently shaken). The so-prepared samples were centrifuged on a Rotofix 32A (producer: Hettich, Germany) laboratory centrifuge at a centrifugal force of 3000 $\cdot$ g for 10 minutes. The supernatant obtained was then decanted onto petri dishes of known weight and dried at 104°C for 24 hours. The samples were weighed on electronic scales (Radwag WPS 600/C) with accuracy of 0.001 g. WAI was established as ratio of the weight of a soaked sample to the weight of the original dry sample. WSI was established as a ratio of the weight of the dried supernatant to the weight of the original dry sample, expressed in %.

2.7. Water activity

The water activity (Aw) was determined using the AquaLab 4TE device (producer: Dekagon, USA). The tests were carried out after 6 days from extrusion. The samples were stored in closed bags made of polyethylene.

2.8. Colour

Colour tests were performed with a ColorFlex EZ spectrophotometer by HunterLab (producer: USA, Virginia). Colour description was based on a CIE Lab tristimulus model of colour perception (L*,a*,b*). Colour testing was performed on uncrumbled samples placed in a measuring vessel.

3. Results and discussions

Tables 3 and 4 show statistical surveys performed based on the results of the analysis of variance Anova. The results refer to the analysis of significance of all variables, with the preliminary model presenting the linear and quadratic effect of individual factors and interactions between them. In the next stage of the test, insignificant variables were removed by way of stepwise regression. As a result of the removal of insignificant variables, significance of the remaining variables in the model increased. The analyses so performed made a good background for selection of a

model that would suit best the empirical data, the results of which are presented in Table 5.

Table. 3. Analysis of variance (Anova) showing the linear, quadratic and interaction of the response variables (VEI, Force, WAI, WSI)

Source of variation		Source variables								
			VEI		Force		WAI		WSI	
		df	SS	F	SS	F	SS	F	SS	F
BSG addition	L	1	28.93	16534.94^{c}	25.72	529.68^{c}	0.012	0.38^{ns}	4130.07	503.99^{c}
	Q	1	6.79	0.74^{c}	8.61	177.23^{c}	1.45	46.66^{c}	357.72	43.65^{c}
Temperature	L	1	1.79	1733.30^{b}	1.39	28.55^{c}	0.18	5.88^{a}	162.54	19.83^{c}
	Q	1	1.023	231.95^{a}	0.26	5.26^{a}	0.012	0.40^{ns}	37.22	4.54^{a}
Moisture content	L	1	12.32	16.92^{c}	23.80	490.039^{c}	9.51	306.43^{c}	2235.61	272.81^{c}
	Q	1	1.44	52.19^{b}	4.53	93.24^{c}	2.015	64.95^{c}	184.36	22.50^{c}
Interaction 1vs2		1	0.44	1.28^{ns}	1.67	34.38^{c}	1.88	60.70^{c}	185.04	22.58^{c}
Interaction 1vs3		1	0.76	53.04^{a}	0.15	3.0004	0.18	5.74^{a}	24.97	3.047^{ns}
Interaction 2 vs3		1	0.031	219.61^{ns}	0.0045	0.09^{ns}	0.029	0.92^{ns}	326.20	39.81^{c}
Lack of fit		5	4.36	270.65^{c}	1.85	7.61^{ns}	2.49	16.03^{c}	418.67	10.22^{c}
Pure Error		33	5.24		1.60		1.024		270.43	
Total SS		47	61.29		73.92		17.94		8090.48	
Residual error		38	9.60		3.45		3.51		689.10	
R^2			0.84%		0.95%		0.80%		0.91%	
Adjusted R^2			0.81%		0.94%		0.76%		0.89%	

[a] Significant at P≤0.05
[b] Significant at P≤0.01
[c] Significant at P≤0.001
[ns] Not significant
L – linear, Q – square

Table. 4. Analysis of variance (Anova) showing the linear, quadratic and interaction of the response variables (Aw, L*, a*, b*).

Source of variation		Source variables								
			Aw		L*		a*		b*	
		df	SS	F	SS	F	SS	F	SS	F
BSG addition	L	1	0.017	562.13^{c}	291.93	1313.6^{c}	7.21	111588.6^{c}	70.09	277568.80^{c}
	Q	1	0.024	788.76^{c}	1.18	52.93^{c}	1.90	29371.40^{c}	2.17	8600.90^{c}
Temperature	L	1	0.00489	155.14^{c}	0.12	55.2^{c}	0.0014	22.50^{c}	0.07	275.20^{c}
	Q	1	0.00013	4.069^{ns}	0.94	42.16^{c}	0.50	7808.90^{c}	0.57	2245.50^{c}
Moisture content	L Q	1	0.24	7637.25^{c}	51.11	229.97^{c}	2.44	37809.30^{c}	21.13	83680.20^{c}
		1	0.00049	15.71^{c}	6.40	288.09^{c}	2.44	37667.30^{c}	10.10	40009.50^{c}
Interaction 1vs2		1	0.0016	53.017^{c}	0.083	37.28^{c}	0.007	108.30^{c}	0.023	92.80^{c}
Interaction 1vs3		1	0.0023	75.48^{c}	5.71	257.11^{c}	0.24	3743.50^{c}	5.95	23562.40^{c}
Interaction 2 vs3		1	0.0021	67.67^{c}	6.05	272.26^{c}	0.42	6558.80^{c}	5.76	22780.30^{c}
Lack of fit		5	0.032	203.87^{c}	21.96	197.62^{c}	2.0023	6194.80^{c}	8.42	6663.00^{c}
Pure Error		33	0.0010		0.0007		0.0021		0.0083	
Total SS		47	0.34		392.37		15.67		132.98	
Residual error		38	0.033		21.96		2.00		8.42	
R^2			0.90%		0.94%				0.94%	
Adjusted R^2			0.88%		0.93%				0.92%	

Table 5. Significant coefficients for the regression equations (1)* obtained for response surface

Coefficients	Estimated coefficients							
	VEI	Force	WAI	WSI	A_W	L*	a*	b*
B0	-31.86	9.74	-17.57 [c]	-304.87	-1.58 [c]	128.80 [c]	-1.86 [c]	41.26 [c]
β_1 (BSG addition)	-0.12 [c]	-0.50 [c]	0.33 [c]	1.076	-0.036 [c]	0.40 [c]	-0.0094 [b]	0.41 [c]
β_2 (Temperature)	0.55[a]	0.19	0.049 [c]	2.709	0.010 [c]	-1.19 [c]	0.18 [c]	-0.30[c]
β_3 (Moisture)	0.88	-2.34 [c]	1.96 [c]	25.003 [b]	0.17 [c]	-1.45 [c]	-0.009	-0.66 [c]
β_{11}	- 0.0053[c]	0.0059	-0.0023 [c]	0.038 [c]	0.00033 [c]	0.0022 [c]	-0.0027 [c]	0.003 [c]
β_{22}	- 0.0020[a]	-0.0010 [a]		0.012 [a]		0.002 [c]	-0.0014 [c]	-0.0015 [c]
β_{33}	-0.057 [b]	0.10 [c]	0.0071 [c]	0.646 [c]	-0.00077	-0.12 [c]	-0.074 [c]	-0.15 [c]
β_{12}		0.0026 [c]	-0.0028 [c]	-0.028 [c]	0.00008 [c]	-0.0006 [c]	0.00017 [c]	0.00031 [c]
β_{13}	0.018 [a]		0.0086 [a]		0.00099 [c]	-0.049 [c]	0.01 [c]	-0.05 [c]
B_{23}				-0.369 [c]	-0.00094 [c]	0.0502 [c]	0.013 [c]	0.05 [c]

[a] Significant at P≤0.05
[b] Significant at P≤0.01
[c] Significant at P≤0.001

3.1.VEI

When analysing variations of the volumetric expansion index (VEI) in a regression analysis (Table 5), it was observed that an increase in extrusion temperature had a positive linear and negative quadratic effect (at p≤0.05), while moisture content had a negative quadratic effect (at p≤0.01). The share of BSG, in turn, had a negative linear effect at the level of significance (p≤0.001). Figure 1A shows the impact of moisture content and temperature on changes in the VEI of products subjected to extrusion. The highest values of the parameter (7,60±0.27) were reported for feed moisture content of 13% and cylinder temperature of 140°C, while the lowest values were reported for moisture content of 15% and cylinder temperature of 120°C. A similar tendency of VEI variations was observed by Robin *et al.*, (2011), who found out that reduced feed moisture content led to a growth of pressure in the cylinder, thus enhancing the expansion of products, while a growth of expansion at higher temperatures was due to better gelatinisation of starch (Waramboi *et al.*, 2014). By increasing the share of BSG, quadratic VEI expansion declined significantly (p≤0.001) (Figure 1B), which was further confirmed by Nascimento *et al.*, (2017). As considerable amounts of raw fibre are introduced into the mixture together with BSG, the share of structure-forming starch, which is the main ingredient favouring the development of air bubbles in the product and growth of expansion, naturally decreases (Stojceska *et al.*, 2008). This finding is further confirmed by other authors, who also noticed that expansion coefficients decline as the ingredient is being added (Nascimento *et al.*, 2017). Despite the significant decline in the expansion index with maximum share of BSG, the minimum expansion in no case dropped below 4.53 (± 0.13). A result like this is frequent in literature devoted to extrusion including, in particular, extrusion of raw materials with low percentage share of starch and high moisture content (Kristiawan *et al.*, 2016). Lower expansion values can be compensated with a higher content of dietary fibre, which translates into a higher wholesomeness of the products (Stojceska,2011)

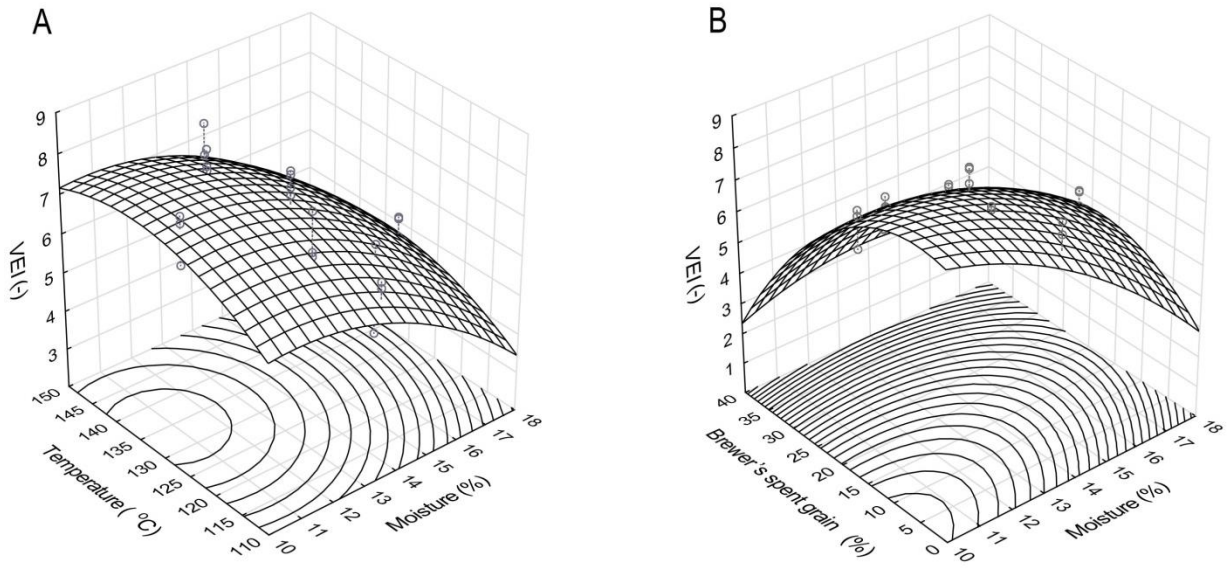

Figure 1. A) Effect of extrusion temperature and moisture content of the blend on the volumetric expansion index VEI. B) Effect of BSG addition and moisture content of the blend on the volume expansion index VEI

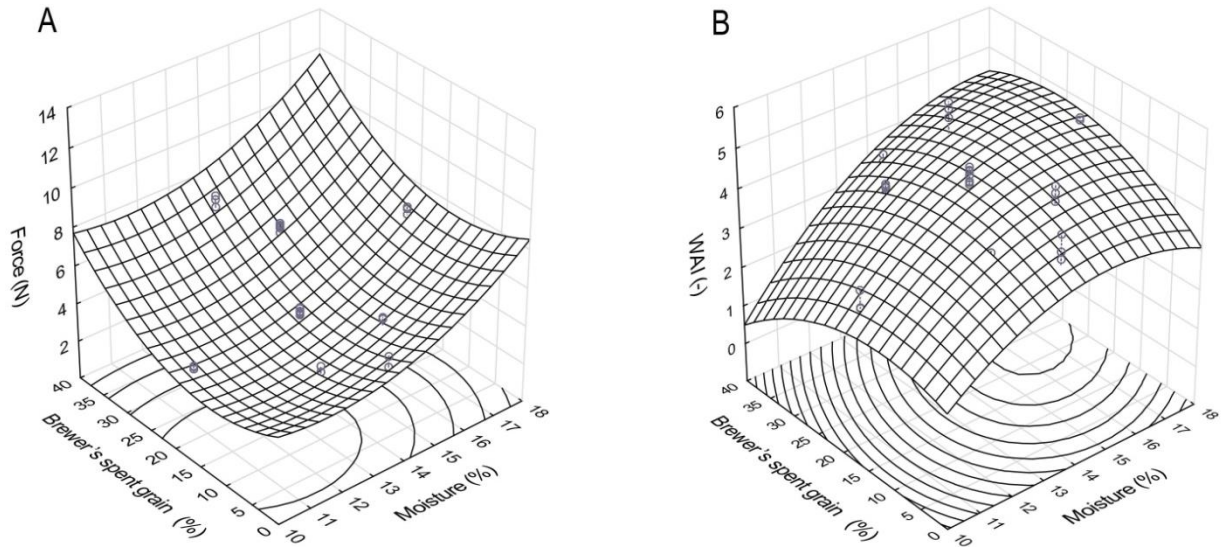

Figure 2. Effect of BSG addition and moisture content of the blend on: A) hardness B) Water absorptiontion index WAI

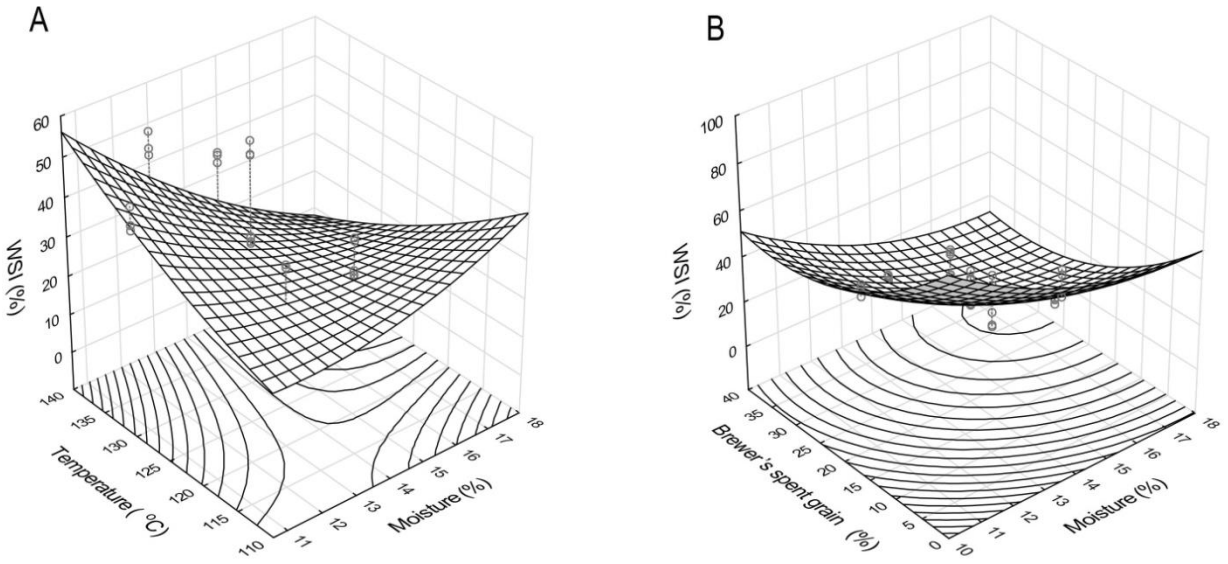

Figure 3. A.) Effect of extrusion temperature and moisture content of the blend on water solubility index WSI. B) Effect of BSG addition and moisture content of the blend on water solubility index WSI

3.2.Textural measurement

The most important parameters with a significant effect ($p \leq 0.001$) at changes in sample hardness were the share of BSG and feed moisture content. Additionally, findings show that process temperature affected (quadratic effect) hardness only at ($p \leq 0.05$). The impact of process variables on the hardness of extrudates is presented in Diagram 2A, which shows that by increasing the share of BSG and the feed moisture content, bigger product hardness is obtained. The reasons for growing product hardness in response to increasing feed moisture content lie in the rapid cooling of the extrudate and incomplete water evaporation right after the product leaves the extruder matrix, which, in effect, prevents the formation of the product's porous structure, as confirmed, among others, by Wójtowicz *et al.,* (2015). Finally, increased resistance of products with BSG is also attributable to dietary fibre contained in brewer's grains (Lue *et al.,* 1991; Stojceska *et al.,* 2008). Authors state that interaction between fibre and proteins leads to early disruption of gaseous cells and the subsequent formation of thicker and harder walls in the product. The phenomenon of texture upgrading in products together with a growing content of ingredients rich in dietary fibre was also noted by Mendonca *et al.,*(2000). The maximum hardness reported during the tests equalled (8.22 ±0.28), with the maximum share of BSG in the mixture of 36.82%, which was close to the adjacent values. Nevertheless, the model diagram shows that together with the increase of BSG grows hardness of the product, which may be among the principal factors restricting the application of the material in quantities exceeding 30% (especially for higher moisture content levels), as confirmed by results presented by Ainsworth *et al,.* (2007) and Ktenioudaki *et al., (*2013). However, where products high in BSG are to be used in the food coat processing sector, hardness can be helpful in further crushing procedures (Żelaziński *et al.,* 2017). Finally, it was also found that product hardness is negatively correlated with the VEI expansion index (Tab. 6).

3.3. WAI

When analysing the water absorption index (WAI) it was found out that all the three independent variables, both in the linear and in the quadratic function, were significant at

p≤0.001. The effect of the participation of BSG and of the feed moisture content is presented on Figure 2B, which shows that together with an increase in the share of BSG and moisture content grows the WAI, with the increase ranging from 2.65±0.15 to 5.12±0.11. This may be due to availability of the fibre contained in the brewer's grains, which shows water absorption properties (Lv *et al.,* 2017; Stojceska, 2011). Similar connections between WAI and fibre in the process of extrusion of rice and brewer's grain mixture were also reported by Nascimento *et al.,* (2017), while the growth of WAI accompanying the growth of moisture content was observed by Chakraborty *et al.(*2011) and Wójtowicz *et al. (*2015). In the tests performed, the lowest WAI values were reported for samples produced from raw material with moisture content of 10.61%. As proved by Sobukola *et al.,* (2013), who extruded pasta with the addition of BSG, low moisture content in the raw material enhances forces acting during the processing, as a result of which starch granules are destroyed, mostly mechanically, thus producing a low WAI. To sum up, the addition of BSG to extrudates can be beneficial to dietary products including both snacks and extruded pasta, as stated by Foschia *et al.,* (2015) and Wójtowicz and Mościcki, (2014).

3.4. WSI

The water solubility index (WSI) ranged from 15.60±0.21 to 59.58%±0.32. The most important factors with significant effect (at p≤0.001) on WSI were the share of BSG and the feed moisture content, with the process temperature having quadratic effect (at p≤0.05) (Tab. 5). Diagram 3A presents a significant effect of the increase in temperature on WSI in the initial range of moisture content in the raw material. This can be due to increased starch degradation when exposed to higher temperature, accompanied by increased action of shear forces, as cited by Sobukola *et al.,* (2013). Diagram 3A shows that WSI initially declines, up to the point when the feed moisture content of 15%, is reached, whereupon a slight increase of the index is observed. The shape of the diagram is consistent with the findings by Seth *et al.,* (2015), who studied yam and rice-based puff snacks. Furthermore, the authors explain such behaviours with a growth of resisting force in the matrix due to low moisture content, which leads to mechanical degradation of starch. Moisture content exceeding 15%, in turn, favours polysaccharide solubilisation in the food matrix, thus increasing the WSI. Finally, high WSI can also be attributable to high content of proteins and dietary fibre (Nascimento *et al.,* 2017). As the corn mixture tested and the BSG are both rich in such ingredients, they may enhance the test results obtained.

3.5. Water activity

Increasing of the share of BSG changed the activity of water (Aw) in the product (Figure 4A). The linear effect of the share of BSG and quadratic effect of moisture content were found out to be significant parameters of the model analysed (p≤0.001). When analysing the shape of the diagram it was concluded that a 20% addition of BSG reduced Aw (min. 0.10± 0.01), but further increase of BSG caused the growth of Aw to the maximum level (0.39± 0.02). A growth in feed moisture content caused significant increase in Aw. Therefore, it can be concluded that an addition of BSG beyond 20% will reduce the products' shelf life as better environment for the development of micro-organisms will be created (Banach *et al.,* 2014). Nevertheless, the Aw values obtained correspond to data observed by other authors for different food products (Gonzalez *et al.,* 2004). On the other hand, products with higher activity of water may develop specific sensory properties, such as reduced hardness and crispiness, lower splinter ability and impaired sound effects (Makowska *et al.,* 2015; Primo-Martin, 2008; Jakubczyk *et al.,* 2015).

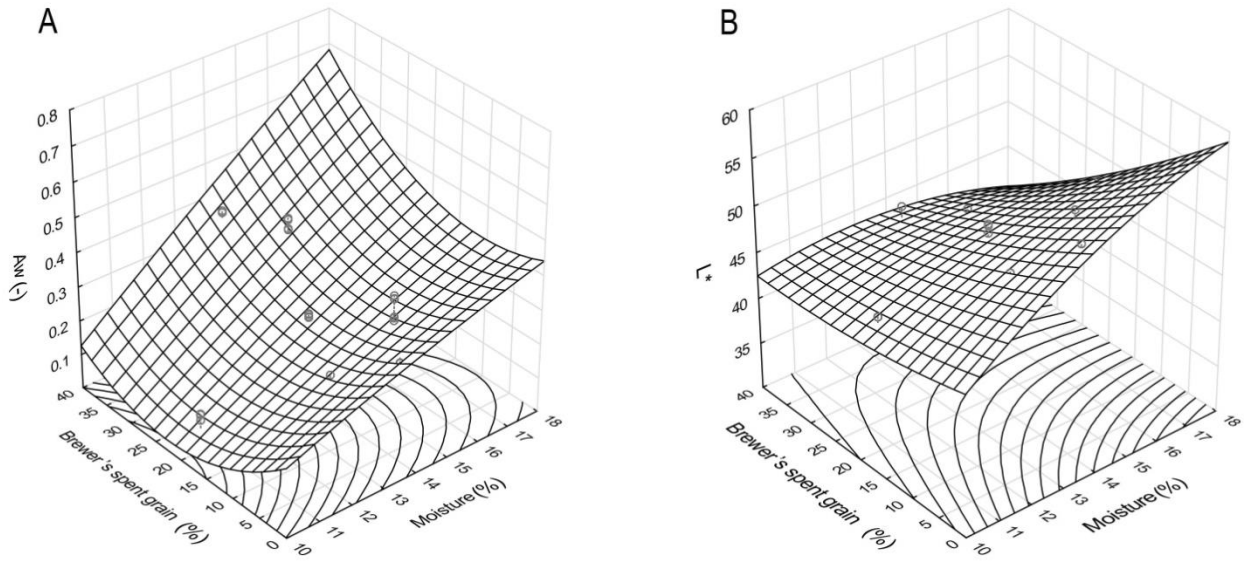

Figure 4. Effect of BSG addition and moisture content of the blend on: A). water activity in product Aw, B) colour space parameter L*.

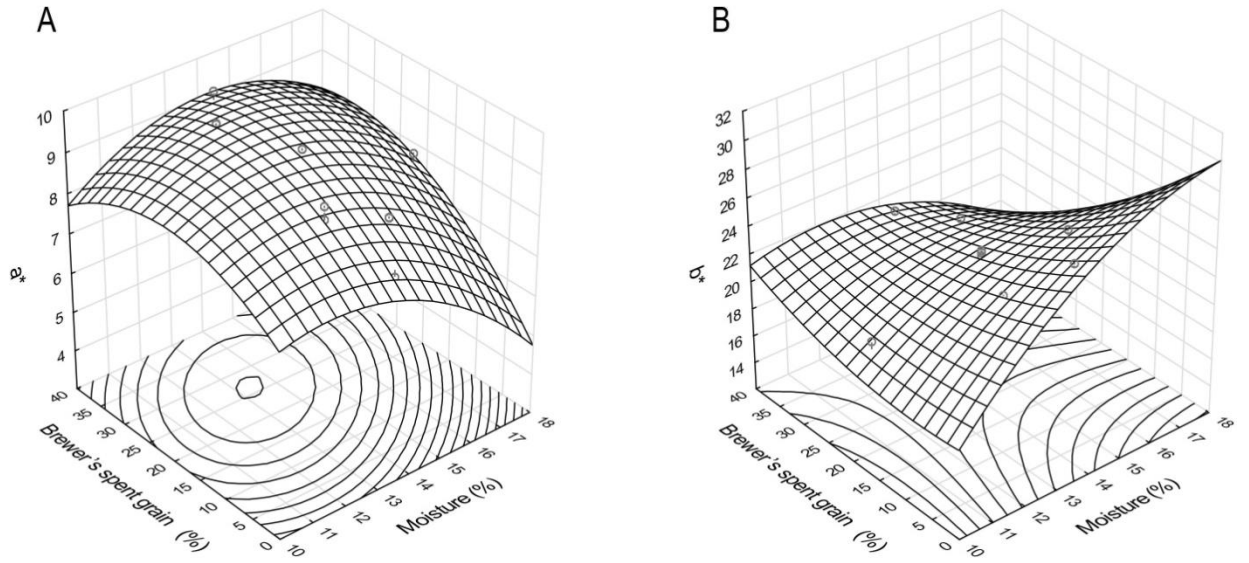

Figure 5. Effect of BSG addition and moisture content of the blend on: A) colour space parameter a *, B) colour space parameter b *.

3.6. Colour

Findings show that all the variables subjected to analysis had a significant effect on changes in the L* brightness index. Analysis of the diagram (Figure 4B) shows that as the share of BSG grows, the colour
gets darker, which is true for the entire moisture range. Additionally, when the share of BSG is low (3.18 and 10%), a growth in the material moisture content causes intense increase in extrudate brightness, while when the participation of brewer's grains is high (20 and 36.82), increase in the moisture content only slightly darkens the product. Changes in the brightness depending on the content of BSG were also observed by Demiranda *et al.*, (1994). In order to precisely verify the remaining constituents of the colour according

to CieLab, the response surface for a* and b* colour space parameters was presented on subsequent diagrams (Figures 5A and 5B). It was found out that the a* colour space parameter grows together with the addition of BSG up to 20%, whereupon a decline is reported. A similar effect is exerted by feed moisture content. The highest a* values (9.35±0.06) were reported for feed moisture content of 14%, 20% of BSG and process temperature of 130°C. The distribution of the b* colour component is similar to the distribution of the L* colour component (Figure 4B), with the highest values of the parameter being noted for the highest moisture content, i.e. 17.61%, and the lowest BSG share used. This can be justified by a high participation of yellow, which is dominant in corn extrudates. Observations of the layout of changes in a* and b* colour components show that extrudates containing brewer's grains have brown shades, which they owe to high participation of shades of yellow and blue/purple. The natural brown colour of extruded products can be beneficial, as it is usually acceptable to consumers (Demiranda *et al.*, 1994). Brown colour is typical of wholemeal bread, which is by many considered healthy (Bangert, 1989). Functional extruded products with brown as the dominant colour can therefore be competitive, for instance, for traditionally baked bread. There was also found a high positive correlation between L* and b* colour components and a negative a* to WSI correlation (Tab. 6). The brown colour of extrudates was thus attributable not only to the BSG addition and feed moisture content, but also to the process temperature, which is the main factor responsible for the Mailard reaction in starch-rich products. Furthermore, brightness of the product was negatively correlated with hardness (Tab. 6). Therefore, observations of variations in brightness of the products analysed make it possible to establish their texture parameters with a high degree of accuracy.

Table 6. Pearson correlation matrix for selected physical and chemical properties of snack extruded

Variable	Correlation							
	VEI	**Force**	**WAI**	**WSI**	**Aw**	**L***	**a***	**b***
VEI	1.00	-0.80[a]	-0.19	0.68[a]	-0.69[a]	0.41[a]	-0.12	0.25
Force (hardness)		1.00	0.20	-0.64[a]	0.79[a]	-0.32[a]	-0.05	-0.17
WAI			1.00	-0.37[a]	0.51[a]	0.32[a]	-0.16	0.35[a]
WSI				1.00	-0.54[a]	0.41[a]	-0.44[a]	0.29[a]
Aw					1.00	0.15	-0.33[a]	0.29[a]
L*						1.00	-0.71[a]	0.94[a]
a*							1.00	-0.64[a]
b*								1.00

[a] - Significant at P≤0.05 correlation

3.7. Statistical verification

To verify the model, some values obtained from statistical regression analysis (predicted values) were compared with the values obtained by way of empirical teststing (Tab. 7). These were mean values obtained in 5 experimental runs with standard deviation. Changeability of the response prediction in the model was verified in a two-tailed test for independent samples. As the test significance (p-value) was higher than 0.05, there were no grounds to reject the zero hypothesis assuming the equality of means between empirical and predicted values. Exactly as in this case, the values were nearly close to 1, it can be assumed that the model relevance for prediction of different kinds of responses is high.

Table. 7. Test results t carried out to compare the actual experimental values and predicted values

Statistical coefficients	Results							
	VAI	**Force**	**WAI**	**WSI**	**A_W**	**L***	**a***	**b***
Expected value	22.19	4.73	4.12	31.65	0.27	47.98	8.82	22.72
Actual value*	22.194 (±0.240)	4.732 (±0.0478)	4.115 (±0.143)	31.647 (±0.761)	0.271 (±0.005)	47.982 (±0.108)	8.818 (±0.0566)	22.720 (±0.0957)
Quotient F Variations	1.079	1.08	1.69	1.13	1.13	1.079	1.23	1.12
p Variations	0.79	0.79	0.075	0.68	0.68	0.79	0.48	0.69
p (two-tailed)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Ho; $\mu_o=\mu_1, t_{cal}<t_{tab.}$ at $p<0.10$,

Ho; was accepted,

* Average of 5 repetitions.

4. Conclusions

According to the proposed plan of the experiment, BSG is suitable for use with corn grits in extruded mixtures, but in order to obtain a high expansion index and low hardness, its share must not exceed 20%. It is possible to produce extrudates with a share of BSG exceeding 30% (the maximum addition used during the tests equalled 36.82%), but products so manufactured will be characterised by lower expansion, bigger hardness and darker colour (L*) when compared to products with smaller content of brewer's spent grains. If a high share of BSG (above 20%) is used in the product with the aim to increase the expansion index and reduce hardness, extrusion performed on feed with low moisture content proves beneficial (the tests produced favourable results for moisture content of 13% and process temperature of c.a. 140°C and 146.8°C. It is possible to produce extrudates with higher brewers' spent grain, expansion, solubility moisture content (max. 17.55% in the tests performed), but the extrudate so produced will be characterised by increased water activity (Aw).

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EVALUATION OF DIETARY PRACTICES OF WOMEN OVER 60

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ABSTRACT

The purpose of the work was an evaluation of dietary practices of the group of women over 60. Participants of the study came from a senior activation program. The research was performed on a group of 72 women over 60 years of age. Participants in the examination filled 7-days long dietary diaries. In the preliminary section, they reported the age, body weight, height, education, and marital status. Energy and nutritious value were calculated using the software Dietetyk Pro and compared to the current norms for the Polish population. Most of the women had a correct body weight (38 people), the obesity was stated only for 8 people. However, there were 19 overweight women (21%), 5 respondents were underweight. The analysis of the macroelements and the supply of the energy showed, that overweight and obese women exceed norms for daily caloric recommendation by overconsuming fat at the cost of the carbohydrate deficiency. Fiber intake was significantly different from the group with correct body weight and didn't fulfill recommendations.

Underweight women had caloric and fiber deficit in their diet but exceeded in protein consumption. The analysis of the supply of selected vitamins showed a significant deficit in vitamin D but excess in vitamin A. Vitamins K, C, and of B group were consumed in accordance with recommendations. Mineral consumption was similar for all body weight groups. Participants consumed a sufficient amount of iron, but an insufficient amount of magnesium and calcium. However, phosphorus content in all analyzed menus significantly exceeded recommendations.

1.Introduction

The aging process of societies is a pressing problem in many developed countries. The course of the aging process of the organism can be modified by many factors, out of which most essential are dietary practices and physical activity.

The demographic situation in Poland has decayed within last 20 years. Main reasons are the drop in the birth rate and simultaneous drop in the death rate, as well as the mass emigration of young people to foreign countries. According to the GUS (Central Statistical Office, Polish: Główny Urząd Statystyczny) data in 2018 of 38.4 million Poles, 8.2 million people constituted as in the so-called retirement age (above 60 years for women and above 65 years for men) and it is over the 21% of the total population. Amongst elderly people the majority are the women, for 100 men at the age of 60 there are 110.3 women, for the age 70 131.3 women and in the group of 80 years old for 100 men, there are 183.7 women. Many factors play the role, including life hygiene, men take much less care of themselves and are more exposed to diseases of affluence. The life expectancy in the course of 20 years grew respectively about 4.1 years for men and is now

79.2 years, and for women, about 4.5 years and they live on an average 84.3 years (stat.gov.pl).

The type of consumed food has an immense impact on the state of the organism, the resistance to illnesses as well as the lifespan. Seniors' dietary choices are influenced not only by their knowledge but also by economic factors. Socio-economic conditions can force incorrect nutrition resulting from the lack of full physical fitness or financial constraints that prevent independent preparation of meals.

Seniors are at higher risk of developing illnesses which can cause a deficiency of micro- and macro of elements. This mostly applies to B-group vitamins (particularly B12), vitamin C and D, folic acid, zinc and calcium. Elderly people can develop eating disorders which are directly associated with weakening of the smell and the taste (Goldfinch, 2011; Menebröcker and Smoliner, 2018; Roszkowski and Gawęcki, 2018).Balancing a meal plan for elderly people is a challenging task. Seniors need the same nutrients as the youth and to some nutrients, the demand grows with age, at the same time caloric requirements are significantly smaller. The two reasons are limited physical activity and the decline of the basal metabolic rate (BMR). The diet should supply suitable for the age amount of calories, high content of nutrients and also be adapted for the physical activity of seniors (Ciborowska and Rudnicka, 2018; Roszkowski and Gawęcki, 2018).Studies show that many seniors do not follow even the basic rules of healthy nutrition. Meals are often eaten irregularly and not often enough, in many cases there was not a single hot meal per day. Prepared dishes are often excessively ground down or overcooked, some seniors avoid eating products that are difficult to bite (lack of teeth or the badly fitted prosthesis). Some elderly people choose meals which are not very rich in nutrients - foods are prepared for a few days and heated up (Błedowsiki et al., 2012; Roszkowski and Gawęcki, 2018). The results show that the elderly have poor knowledge about elementary principles of correct nutrition. Moreover, they are unwilling to seek professional help of dietitians, even in situations, when they fall diet-related illnesses (Augustów and Augustów, 2015). Generalizing, the dietary recommendations for seniors can be summed up in few important principles: eat diverse food products every day, increase the consumption of essential unsaturated fatty acids and dietary fiber, reduce fat, cholesterol, sugar and salt intake.

2. Materials and methods

The purpose of the work was to evaluate the dietary practices of seniors living in Warsaw. For the study, a group of 72 women 60 years old and older was selected. They filled weeklong dietary diaries. The object of the study was 504 twenty-four hour menus. In the preliminary part, participants reported: the age, education, body weight [kg] and height [cm]. For each participant, the basal metabolism with the Harris - Bendict's equation and the BMI body mass index were calculated. Energy and nutrient content of the diets was calculated with the software Dietetyk Pro and related to current standards of nutrition in Poland (Jarosz et al,. 2017). Mean values of macro- and micro-elements were compared with the t-student test at $\alpha = 0.05$.

3.Results and discussions

Over half of women participating in the examination (53% of the group) had a secondary education, only 19% had higher education, quite numerous group had the vocational secondary education (27% of respondents).

Based on the polled data concerning the height and the body weight the BMI was calculated and participants were split into 4 groups: the underweight, correct body weight, excess weight and obesity, following WHO guidelines. Most of the participants had correct body weight (38 women), the obesity was stated for 8 women, many women were overweight -19 persons (21%), 5 respondents were classified as underweight.

Table 1. Daily number and caloric value of consumed meals by the participants

BMI	Obesity	Overweight	Norm	Underweight
Number of meals	4.2b	3.8bc	4.7a	4.3b
Energy [kcal]	2424a	2317a	1922b	1749c

Values make with the same letter in the row have no significant difference at $p < 0.05$

Table 2. The average daily intake of macroelements and fiber in the diet of the subjects

Component	Obesity	Overweight	Norm	Underweight
Protein (g)	92.1	90.6	72.3	89
Fat (g)	89.5	79.1	45.2	36.4
Carbohydrates (g)	286.1	288.2	245.2	211.8
Fiber (g)	19.5	20.1	32.6	19.5
Energy contribution coming from individual groups of macroelements and fibre in total caloric value of diets				
Protein (%kcal)	15.63a	15.98a	16.61a	22.68b
Fat (%kcal)	34.14b	31.39b	23.35a	20.86a
Carbohydrates (%kcal)	48.54a	50.85a	56.30b	53.96a
Fiber (%kcal)	1.65a	1.77a	3.74c	2.48b

Values make with the same letter in the row have no significant difference at $p < 0.05$

Table 3. Consumption of selected vitamins and minerals

	Obesity	Overweight	Norm	Underweight	Recommended RDA
Vitamin A (μg)	1104.3a	989.4bc	1036.2b	1001.2b	700μg
Vitamin C (mg)	68.2a	68.1a	69a	58b	75mg
Vitamin D (μg)	4.3a	4.1a	4.2a	3.8b	15μg
Vitamin E (mg calculated as tocopherol)	7.1b	7.0b	7.9a	6.3c	8mg
Calcium(mg)	934.8c	987.8b	1101.9a	998.1b	1200mg
Phosphorus (mg)	1102.3a	1004.2b	987.3bc	999.8b	700mg
Magnesium (mg)	269.3b	270.2b	299.2a	287.9a	320mg
Iron (mg)	9.2b	10.1a	10.1a	9.13b	10mg

Values make with the same letter in the row have no significant difference at $p < 0.05$

Table 1 presents an average number of meals eaten through a day and an average twenty-four-hour calorific value of the diet. The obese people and the overweight group had a statistically significant higher supply of the energy in the diet than people with the correct body weight, and in addition, they ate the statistically significant smaller number of meals.

The quantity of meals is one among many indicators of the quality assessment of dietary customs. Recommendations are straightforward: favorably is to eat more frequent, smaller meals (5-6 meals). Women with obesity and overweight ate on average 3.8 of meals per day, however, women with the correct body weight ate almost 5 meals. Studies concerning dietary practices of persons above 60 years of age conducted in the south part of Poland (Różańska et al., 2013), demonstrated that only 25.2% of respondents ate 4 or more meals. The majority consumed only 3 meals (65.7% of respondents).

Daily energy recommendation for an elderly person should depend on their physical activity. For a person with a low to a moderate physical activity, their BMR should be multiplied by 1.5. BMR of the still working and physically active people should be multiplied by 1.8. Results show that the calorific value of the one-day diet of obese and overweight people exceeded recommendation. Energy supply by people with BMI above 25 (the excess weight and the obesity) was higher than of the respondents with BMI below 25 (in the norm). The average supply of the energy for underweight persons amounted to 1749 kcal, but it should be emphasized that in none of the analyzed cases it reached below BMR.

Apart from covering the caloric requirement, keeping the right proportions between energy substrates in the diet is very important. Table 2 presents average consumptions of macroelements and dietary fiber.

Data included in table 2 demonstrates, that people with obesity and excess weight ate more fat but fewer carbohydrates and fiber than those with correct and too low body weight. According to recommendations, carbohydrates should constitute 55-60% of total energy consumed, fats should not exceed 25-30%, for elderly people even little reduction of fat supply is recommended, but in favor of complex carbohydrates. Proteins should provide 10-15% of caloric intake.

In the studies by Różańska et al., (2013) concerning dietary practices of elderly people coming from a small towns showed a lower total supply of the energy compared to this study, amounting to 1372.6 kcal. The contribution of proteins, fats, and carbohydrates in the total caloric intake was: 14.9%, 33.5%, 51.3%. respectively. These results confirm excessive consumption of fat and too small of carbohydrates. Other studies concerning the evaluation of dietary practices of women above 60 years old were conducted in Subcarpathia (polish: Podkarpacie) (Malczyki et al., 2014) gave similar results to this work. They stated that the average caloric value of their meals was 2157 kcal, and the contribution from individual groups of macroelements was: 22% of the energy from proteins, 19% of the energy from fats and the 59% of the energy from carbohydrates. In the correctly balanced diet carbohydrates should be the main source of energy. For elderly people demand this nutrient should be satisfied by complex carbohydrates (wholegrain products, vegetables, legumes). These products help to keep the correct glucose and cholesterol level in the blood. Products with complex carbohydrates contain a lot of the dietary fiber which promotes a healthy digestive tract and it prevents absorption of undesirable dietary components (Hirani and Scott, 2015; Ciborowska and Rudnicka, 2018). According to the newest recommendations consumption of the dietary fiber should amount to the at least 20 g per day, in addition, higher consumption of 30 - 40 g is even more advantageous (Jarosz et al., 2017). The analysis of the fiber consumption by the respondents stated deficit

of this element in the diet of obese and overweight people alike as well as in those with too low body weight. The desired amount of fiber was observed only in the group of people with the correct body weight. The shortage of fiber is a universal dietary mistake made by seniors, stated in studies conducted by many authors (Stawarska et al., 2008; Pachocka, 2010; Rózańska et al., 2013; Malczyk et al., 2014).

Wholegrain products apart from delivering the dietary fiber are also a source of phosphorus, zinc, magnesium, iron and vitamins B. Phosphorus is important for the correct formation of teeth and bones, as well as for correct functioning of the metabolism. Iron is necessary for the immune system and magnesium is essential for the right functioning of the muscles and the nervous system (Hiranii and Scott, 2015). In the diet of seniors vegetables and legumes should be another important source of carbohydrates. Apart from the dietary fiber, they contain essential vitamins, unfortunately, on account of digestive discomfort, they are often excluded by seniors from the diet (Barylski et al., 2011; Okrusz and Górksa, 2016).

Elderly people, peculiarly over 65 years old often suffer from protein deficiencies, caused by malabsorption of this compound in the digestive tract and excessive use by the organism on account of certain health conditions (Goldfinch, 2011; Menebröcker and Smoliner, 2018). For healthy persons it's recommended to consume 1g of protein per 1kg of body mass (in some cases more), a complete protein should be consumed in 3 meals per day.

Participants with correct body weight ate sufficient amount of whole protein, however, people with the obesity and the excess weight and the underweight exceeded recommended daily consumption. However, Stawarska et al. (2008) similarly as Ożga and Małgorzewicz (2013) when analyzing menus of seniors from Warsaw stated insufficient consumption of protein. The major source of protein in the diet of seniors should be milk and milk products, 2-3 portions of milk products are recommended per day. Seniors should drink at least two glasses of milk per day because both men and women in the menopause are at risk of osteoporosis. The most beneficial dairy products are ferment drinks with the lowered fat content due to the presence of the lactic bacteria. They reduce blood-cholesterol, eliminate constipation, flatulence, indigestion, have anti-cancer properties. Fermented drinks improve assimilation of calcium and iron, regenerate natural microflora of the digestive tract, especially important after antibiotic treatment (Cieplak and Sienkiewicz, 2008; Brodziak and King, 2016; Lordan et al., 2018; Mędrela-Kuder and Szymura, 2018).

Vegetable oils and fish should be a primary source of fats (seniors should eat 2-3 portions of fish during the week). It is recommended to eat nuts which are abundant in EFA, the fiber, B-group vitamins, vitamin A and E and minerals: potassium, iron, calcium, zinc, and magnesium. Elderly people should eat a handful of nuts, i.e. about 30 g per day (Alska et al., 2014; Ciborowska and Rudnicka, 2014). A detailed analysis of menus showed that consumption of fats qualitatively was far from recommendations. The meals contained a lot of fatty meat, butter and fatty cheeses - products that promote the development of atherosclerosis and cancers. Similar results were obtained by Różańska et al., (2013) and Ożga and Małgorzewicz (2013). Participants ate nuts occasionally, and fish appeared in their menus on average 1 time during the week and often these were smoked fishes. Diets of overweight people and with obesity had an oversupply of fats (tab. 2).

Vitamins are the next group of nutrients, which main task is to regulate metabolic processes. Although metabolic rate drops with age, same happens to vitamins absorption. Elderly people are more susceptible to vitamin deficiencies than young also due to more often appearing illnesses (Ożga and Małgorzewicz, 2013).

Seniors very often lack vitamin D (Terlikowska et al., 2013). The shortage of vitamin D disturbs metabolism of phosphorus and calcium what results in the inappropriate mineralization of bones. Consumption of vitamin D by participants was unsatisfactory and constituted between 23.3 and 28.7% of the RDA, similarly as in other studies (Pachocka, 2010; Terlikowska et al., 2013; Różańska et al., 2013). Seniors could improve their diet by introducing foods fortified with vitamin D or considering supplementation, after prior medical consultation (Małgorzewicz and Ożga, 2013; Mędrela-Kuder and Szymura, 2018).

Oxidative stress can cause toxic effects through the production of peroxides and free radicals that damage all components of the cell, including proteins, lipids and DNA. These reactions contribute not only to the faster aging of tissues but also triggers many diseases: diabetes, cancers, cardiovascular and neurodegenerative diseases. Vitamins A, C, and E are antioxidants and play an important role in the defense of the organism against the free radicals. The sufficient supply of these compounds with the diet is essential to prevent many illnesses (Jarosz, 2017; Roszkowski and Gawęcki, 2018). Participants of this study exceeded the recommended RDA of vitamin A. However, consumption of vitamin C was insufficient, especially in the underweight group (77% of the norm). Consumption of vitamin E didn't diverge much from established norms, the lowest was in the group of people with BMI below 18.5, it amounted to the 78% of the norm. Terlikowska et al. (2013) and Malczyk et al. (2015) received similar results.

Table 3 shows the consumption of selected minerals and vitamins. Participants with correct body weight and overweight provided with their diets a sufficient amount of iron, an insufficient amount of magnesium and calcium, however, phosphorus levels were above the norm. Calcium deficiency in the diet of women in the menopause can induce development of osteoporosis and contribute to changes in the cardiovascular system. A hormone that regulates the calcium-phosphate metabolism also affects the functioning of the heart and the state of blood vessels, regulates the arterial pressure, and as anti-inflammatory properties. Phosphorus is abundant in most of the foods, and its excess can hinder absorption of calcium (Artaza-Artabe et al., 2016; Mędrela-Kuder and Szymura, 2018). In these studies, a very low level of calcium with the simultaneously high level of phosphorus intake was noted. The particularly disadvantageous proportion was stated in the diet of obese women. These people consumed only 77% of the norm for calcium and the phosphorus level in the diet amounted to 157% of the norm. Other researchers also noted too low consumption of the calcium in the group of women in the menopause and postmenopausal period (Pachocka, 2010, Terlikowska et al., 2013; Okrusz and Górska, 2016; Mędrela-Kuder and Szymura, 2018).

Magnesium helps regulate neurotransmitters, which send messages throughout the brain, nervous system and muscles, including cardiac muscle. The magnesium deficiency leads to the hampered synthesis of calcitriol resulting in hypocalcemia. This results in contraction of the smooth muscular coat of blood vessels contributing to the rise of the blood pressure. Hypomagnesemia can cause increased synthesis of cholesterol and increase the aggregational potential of the platelets.

In the examined women an insufficient supply of magnesium was stated in all groups. Insufficient consumption of this element was observed amongst populations coming from various regions Poland by other researchers (Terlikowska et al., 2013; Malczyk et al., 2014).

4. Conclusions

In studied menus, many serious dietary mistakes, which can increase the risk of the development of such diseases like

obesity, osteoporosis, and cardiovascular diseases were observed.

Diet of the obese women and the women with excess weight was characterized by a low number of meals, with the too high total supply of the energy and the too high share of energy coming from fat with a simultaneous too low supply of a dietary fiber, vitamins, and calcium. In the diet of the all examined groups of women, an insufficient supply of vitamin D and of calcium with coexisting excess of phosphorus was stated.

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PREFERENCES OF THE CONSUMERS OF COLD MEAT MARKET IN LIGHTS OF A SURVEY RESEARCH IN THE REGION OF LUBLIN

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ABSTRACT
The main goal of the article was to identify key determinants affecting consumers of meat products, including especially those on the cold meat market. Questionnaire surveys were carried out in the Lublin region; the respondents were diversified due to the grouping variables, which made it possible to identify determinants that would describe the behavior of different groups of consumers. In the opinion of the persons participating in the research, various factors determining the type of product that consumers are willing to buy, were indicated. However, as it seems, the price, but also the quality and certain purchasing habits we purchase over the long term are still of great importance. n addition, it turns out that depending on the age of the respondents, such factors as the place of shopping are also important.

1. Introduction

People in Poland, as a result of enrichment and a systematic increase in the awareness of health, nutrition and lifestyle, began to change their expectations in regard to products offered on the market. This change also applies to the food market, including the meat and meat-based products market (also cold meat). Changes in the diet and consumer preferences need be noticed by producers and sellers who should adapt their offer to the modified requirements (Kossakowska, 2013; Pawlonka 2017).

With the development of nutrition sciences consumer awareness of the principles of rational nutrition has raised, also their preferences have changed diametrically (Xintao, 2016). Food menus started to follow the nutritional pyramid (Orłowska, 2005) and resulted in decreasing pork and increasing poultry consumption (Knecht and Środoń, 2012). According to current WHO recommendations a new Pyramid Healthy Diet and Physical Activity formula, developed by the Institute of Food and Nutrition in 2016 recommend limiting meat consumption (especially red and processed meat products up to 0.5 kg/week.) (https://ncez.pl). Other kinds of food are also very important in human life, as so as physical activity, too.

In Poland consumption of meat and its products is still quite popular. Among various types of meat seven basic types can be distinguished: pork - meat of pigs, beef - meat of adult domestic cattle, poultry meat - coming from farmed birds, mutton - adult sheep meat, goat meat, horseflesh and venison – meat of hunted game animals (Litwińczuk, 2012).

Apart from raw meat, meat products (mainly smoked meat and canned meat) obtained as results of meat processing have also a significant share in the human diet. There are many kinds of cold meat including: smoked meat and cured products obtained from one or more kind of

meat, subjected to smoke; sausages - meat products made of shredded meat of different types with spices, fat and additives, in natural or artificial casings; offal sausages - meat, fat and offal preparations with or without blood additive, in natural or artificial casings or in molds; block products - of partially or completely preserved tissue structure with spices, fat and offal additives, in artificial casings or in molds (Moskal and Michalska, 2017).

The consumption of meat and meat products in Poland seems to be at a stable level. In 2013, the report on the healthy lifestyle "USP Health - Styles of Health of Polish Women and Men" was presented. Except for various issues concerning the lifestyle, raised from the research, it resulted, among others, that 59% of Poles eat meat every day.

According to various studies, the annual meat consumption in Poland is around 72.5 kg/person (Pawlonka, 2017) which is not significantly different from the analyzes made by the Institute of Agricultural Economics and Food Economy (Kwasek, 2010; 2013). However, in the highly developed countries, the opposite trend is noticeable, i.e. a society with higher pro-health awareness, preferring a healthy lifestyle, is increasingly inclined to limit the amount of consumed meat and its products. Importantly, despite the increase in wealth, the consumers limit the consumption of meat and, in most cases, this change is not accompanied by economic pressure but it is a conscious consumer choice (Świetlik, 2013).

Scientific research show that consumer behaviour regarding meat and meat products is shaped by multiple factors (Font-i-Furnols and Guerrero, 2014). It was observed that the dietary preferences of Poles are changing, however it is happening quite slowly (information provided, among others, by the latest IERiGŻ – PIB report (October 2017)). The convenience of purchase is also an important factor as well as economic aspects. Consumption trends are reflected in the production volume. In the first half of 2017, the production of three basic types of livestock in Poland (without offal) reached 2337 thousand tons – 1.3% more than in the same period of 2016. The decrease in pork production (2.5%) was accompanied by an increase in the production of poultry (3.1%) and beef (7.7%). The last one has low impact on total meat production due to low popularity of beef despite its highest growth rate. Lately, the highest consumption increase can be observed for poultry products, which are more and more popular in polish households as a result of their comparatively low price and broad availability.

According to data from the Institute of Agricultural Economics and Food Economy (IERiGŻ), consumption of poultry meat in Poland in 2016 brought 29.5 kg per capita (by 9% more than in 2015). However, pork is still the most frequently eaten kind of meat. It is estimated that in 2016 the average Pole consumed over 41 kg of this type of meat. The third choice of the Polish consumer is beef, which consumption in 2016 (similarly to the previous year) amounted to approx. 1.9 kg per person (Milan, 2017).

Also worth noting is the process of reducing food prices on global markets that began in 2012. According to FAO data for 2015, compared to 2011, global food prices decreased by 28.2% on average, after an prior increase by 42.4% in 2008-2011 (FAO, 2017). This phenomenon has also affected the Polish food market. According to GUS data, the growth in food prices in Poland in 2013 clearly slowed down, and in 2014 was negative at the stabilization of the average level of consumer prices (Table 1).

Table 1. Price rates for meat and meat products in Poland in 2013-2015

Specification	2013		2014	2015	
	2008=100	previous year =100			2013=100
Meat and meat products	124.1	101.8	98.9	97.0	95.9
Pork meat	119.9	100.8	97.0	94.0	91.2

Source: GUS (2009-2016b).

As noted by some researchers, for the purchase of meat and meat products nearly 60% of domestic consumers is guided by the subjective criterion of quality, which is the taste value (Cyrek *et al.*, 2017). However, in the research carried out by Pawlonek, the significance of the place of origin and the place of production of the product are indicated as the second important factor (Pawlonka, 2017).

Analysing the hierarchy of households expenditure for food, it can be noticed that meat products are the most preferred, and in 2015 consumed as much as 28.9% of all food expenses. However, comparing the expenditure structure within the years 2008 and 2013, the substitution effect consisting in replacing meat with fish and other products can be observed (Świetlik, 2017). Therefore, if the expenses for such products are so large, it is important to indicate the factors that determine what kind of meat products are bought, how often and where the consumers make these purchases.

2. Materials and methods

It should be remembered that consumer behaviour on the market is a changing category and depends on many factors affecting the decisions of selecting products and purchasing them.

One of the most reliable methods of obtaining information on the behaviour of consumers on the market are questionnaire surveys.

The research for the needs of the work was carried out in 2017 within a group of 230 respondents. Original questionnaire was used, using a deliberate attempt because the study involved only the respondents who declared that they eat meat and processed meat products. The results were developed taking into account the division of respondents into four age groups: up to 18 years, 19-30 years, 31-50 and over 50 years. They came from villages and cities with a diverse population: up to 100,000, and above 100,000. The questionnaire contained 17 questions, of a closed nature. The results of the surveys were developed statistically.

The main objective of the study was to identify the basic factors affecting consumers' choices regarding cold meats purchasing. Three auxiliary goals were set to achieve the main goal:

1. Identification of the meat kind from which the cold meat is made;

2. Identification of the place where meat products are purchased by respondents,

3. Identification of factors determining the customer's product choice for a given shopping place.

In addition, the following research questions were formulated to conduct the study:

1. Do the consumers, due to gender as a grouping variable (women and men), have the same preferences regarding the purchase of cold meats?

2. Do the consumers, due to age as a grouping variable, have the same preferences regarding the purchase of cold meats?

3. Are price and quality the main criterions for the choice of cold meats in the consumers opinion?

This paper presents the results of surveys upon the impact of selected factors on consumers preferences in the Lublin region in terms of consumption structure, type of products and shopping places.

3. Results and discussions

The authors' research showed different people tendencies in consuming meat and its products dependently on the age and gender. Most of

the respondents were men (66%). The respondents aged 19-30 were the most representative age group - they constituted 19% of all respondents. 53% of the respondents declared that they come from the city up to 100,000 inhabitants.

The study showed that pork is most often consumed - 67% of the total number of respondents, followed by poultry - 14%, mixed meat - 11% and beef - 8.5% (Figure 1).

Similarly to studies conducted by Biegański (2015), among the respondents in the group up to the age of 30, pork and poultry gained the most interest, while those over 50 were rather interested in mixed meat and pork (Figure 2). Augustyńska-Prejsner *et al.* (2014) report that the increasing consumption of poultry meat may result from an affordable price, rich assortment offer, nutritional value and favourable sensory properties. Therefore, some authors state that the poultry market is one of the most developing meat markets in the world, including Poland (Konarska, 2015). As it was mentioned, according to the respondents of the study, the most frequently eaten meat is pork, both by women and men. The fact is that women consume it much less. 36% of women declare consumption of this type of meat every day, while men nearly twice as much (62%) (Figure 3). In the case of women, the most frequently chosen meat (after pork meat) is poultry (21%) and mixed (12%). Men as the second type of meat indicate mixed meat (11%) as well as poultry and beef meat (8% each). Women more often than men declared they choose cold-roasting and baked sausages, whereas men preferred traditional and smoked (Figure 4). The relationship between the type of chosen meat and gender of the respondents is shown in Figure 5.

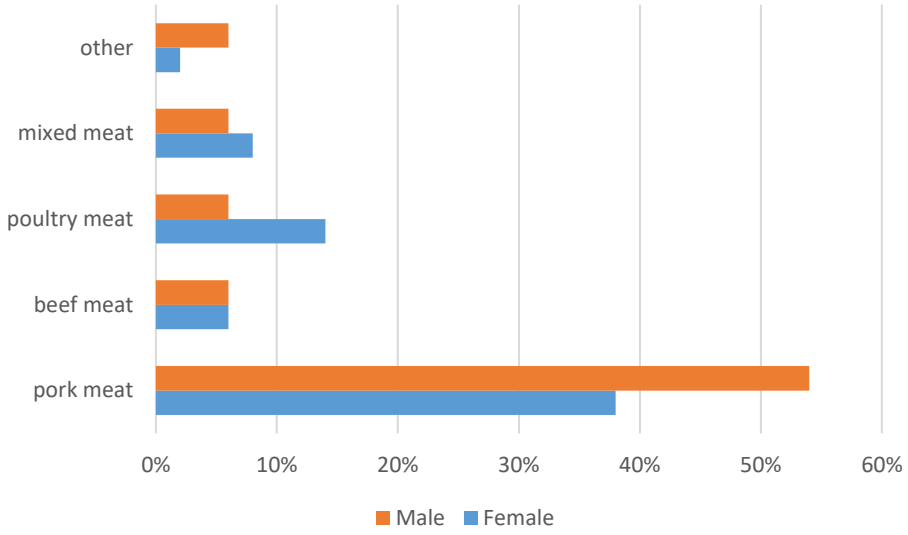

Figure 1. The kind of meat preferred by respondents respectively to their gender

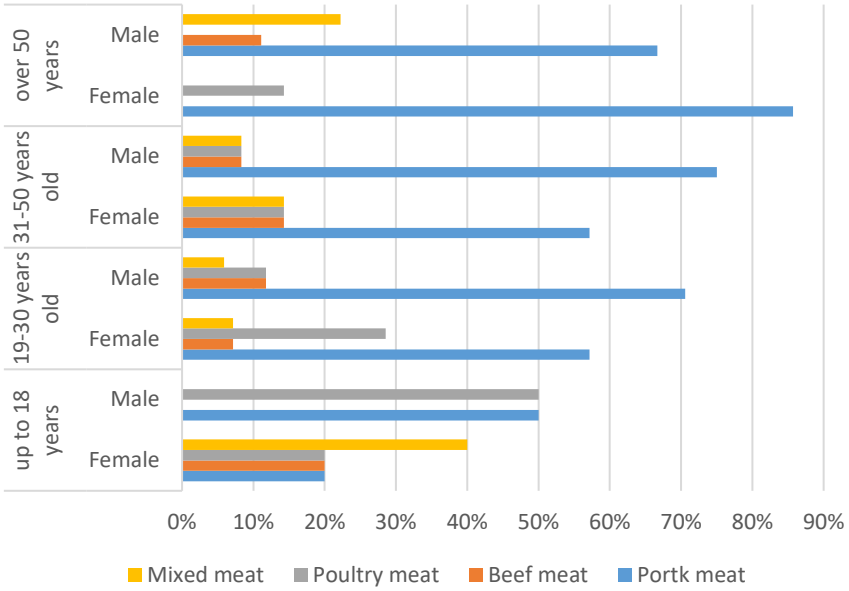

Figure 2. The type of cold meat preferred by respondents respectively to their age and gender

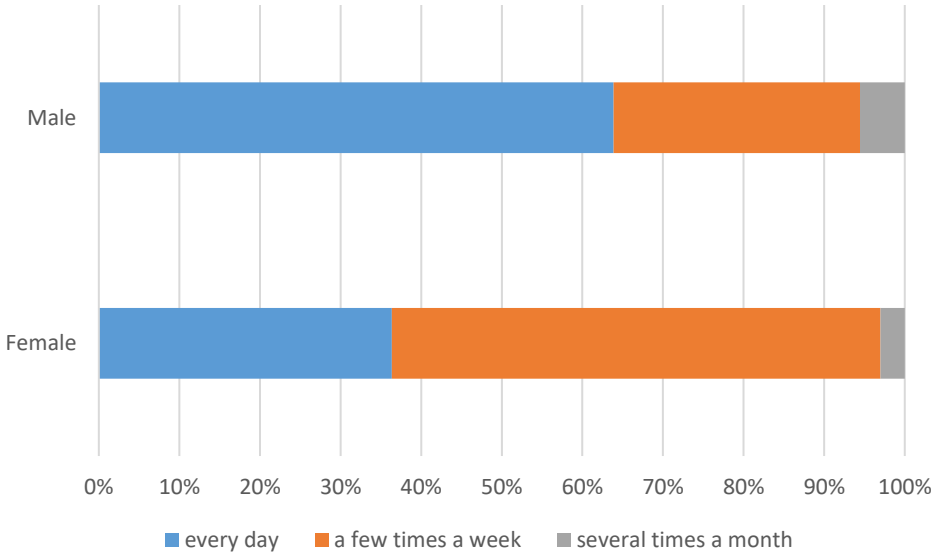

Figure 3. The frequency of meat products consumption on the basis of respondents' gender

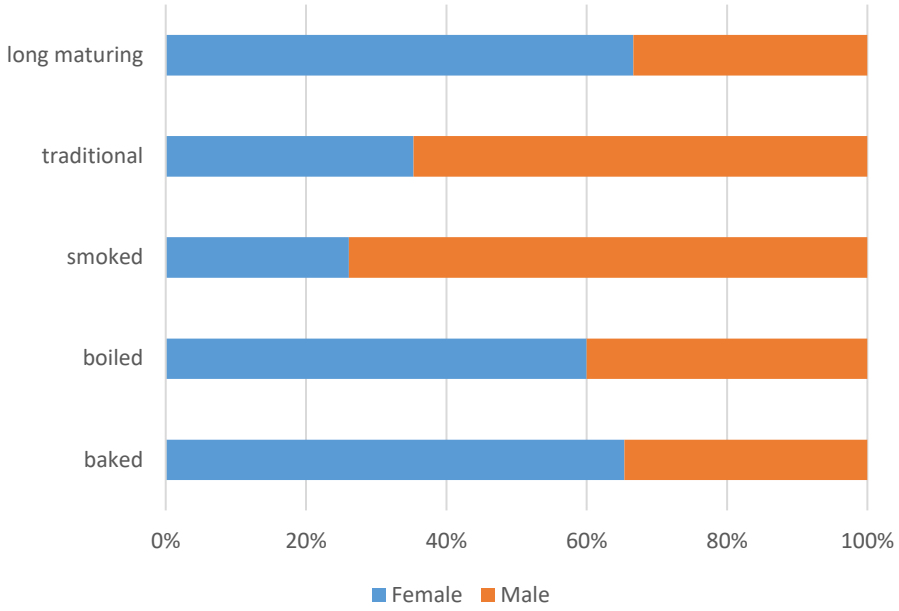

Figure 4. Preferred kinds of cold meat in the opinion of respondents

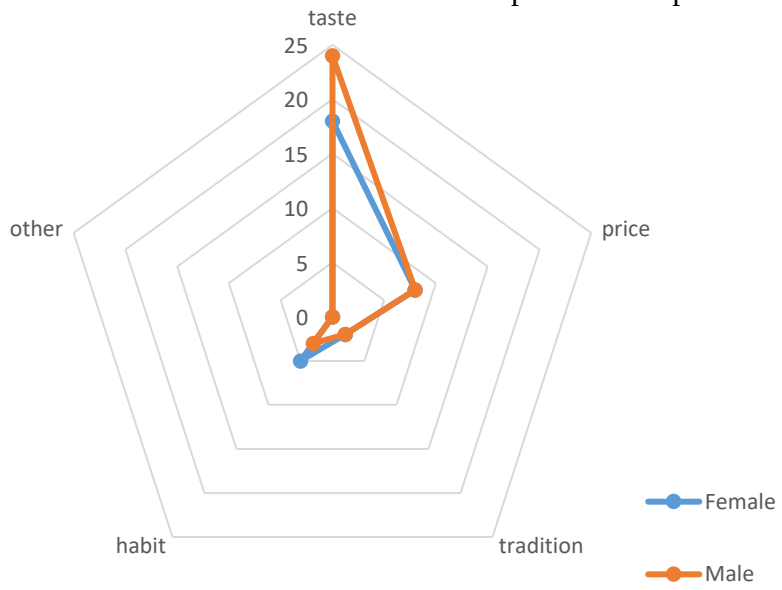

Figure 5. Decisive factors for the selected cold meat type

In reference to the variable "age of the respondent" (Figure 2) it can be observed that women aged up to 18 chose mixed meat (40%), aged 19-30 pork (57%) and poultry (29%). Both groups women aged 31-50 (57%) and over 50 (as much as 86%) also chose pork. Young men up to 18 years of age chose alike pork and poultry meat (50% respectively). In reference to the other remaining age groups, pork was very often chosen by men aged 19-30, 31-50 and over 50 (71%, 75% and 67% respectively). The obtained results can lead to a clear conclusion that the selection of pork meat among respondents is still the most frequent situation.

Figure 6 shows the most popular places visited by women in order to buy cured meats. The

research shows that women in the age up to 18 mainly buy in hypermarkets (as much as 99%), women aged 19-30 also choose hypermarkets (43%) but also company stores (36%). Women who are in the age group of 31-50 buy in company stores mostly (34%) but also do such shopping in big stores (22%) or in local corner shops (22%) or market places (22%). People over 50 more often choose company stores (67%). It can be drawn from Figure 7 that men aged up to 18 similarly like women buy meat products only in hypermarkets (100%), at the age of 19-30 they do cold meat shopping in big stores and company stores. Whereas, men aged 31-50, their purchases carry out mainly in hypermarkets (42%) and company stores (33%). And men over 50 supply themselves both in local corner shops (40%) and company stores (40%).

It can be noticed that there are quite large discrepancies between purchases made by women and men. It seems also very important who in a given household is the person responsible for everyday shopping.

Women aged up to 18, as the main reason for choosing a specific place of purchase (Figure 8) indicate the price and the trust in a brand, in the range of age 19-30 the price is the reason, while for the age of 31-50 it is the trust in a brand. On the other hand, men aged up to 18 indicate the price, at the age of 19-30 they appreciate the availability of a product, and in the age range of 31-50 they choose the price and the trust in a brand. Gentlemen over 50 stand for quality.

The meat product composition (e.g. meat content) turned out to be the most important criterion for choosing a type of meat to buy, the next one was accustomed to a given brand (Figure 9). Males mainly paid more attention to the composition and price of the goods (Figure 10).

Figure 6. "Place of purchase" of cold meats according to women's preferences

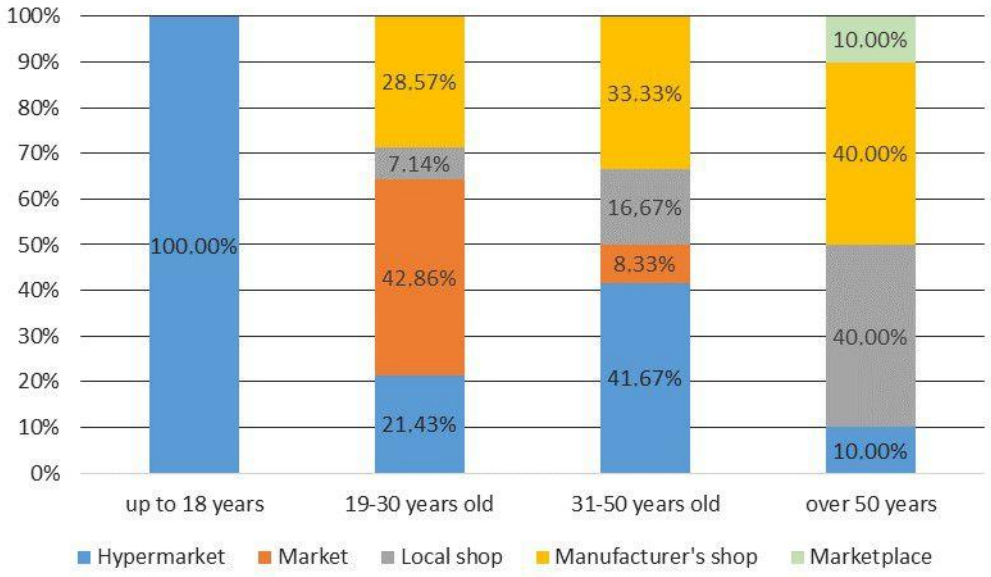

Figure 7. "Place of purchase" of cold meats according to men's preferences

a) Female b) Male

Figure 8. Reason for choosing the "place of purchase" in the opinion of respondents

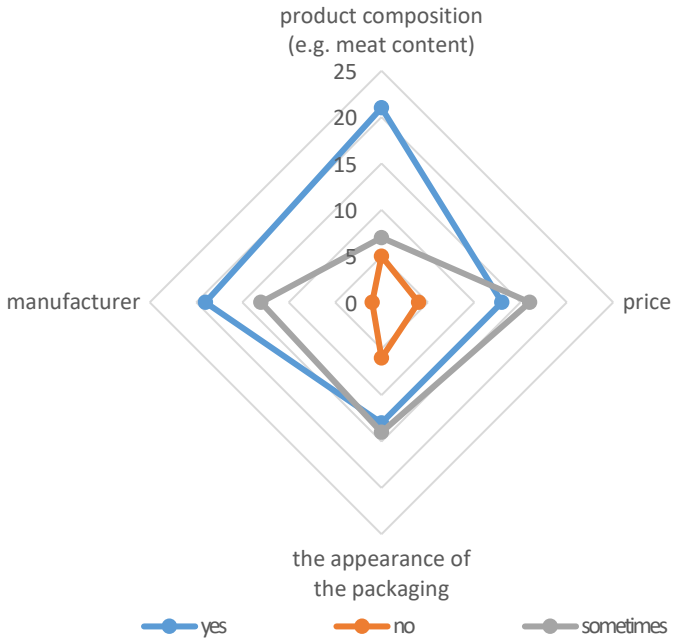

Figure 9. The most important determinants of the selection of cold meats in the opinion of women

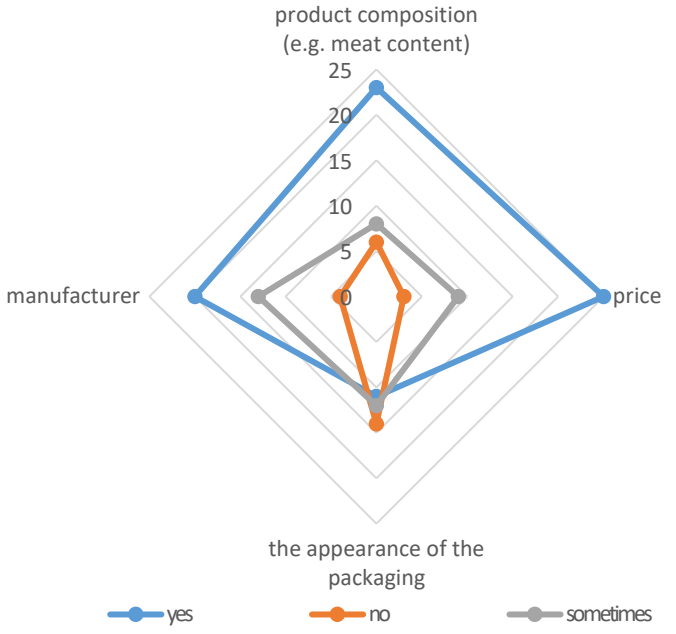

Figure 10. The most important determinants of the selection of cold meats in the opinion of men

4. Conclusions

The conducted research allowed to identify key factors affecting consumer decisions in the domain of cold meats purchasing. It enabled to identify the most frequently chosen shopping places for the products, especially due to the age diversity of the respondents. In some cases, obtained results may indicate the need of change the existing distribution strategy. The information can be valuable for producers and cold meats sellers, especially for the local ones who operate in the region of Lublin. This is an important issue in the area of shaping further development directions of the company's products with a particular emphasis on consumer preferences, expectations and customs related to the purchase and consumption of cold meats.

The main conclusions drawn from the study can be as follows:

- despite recent scientific recommendations on nutrition, meat products are still very often consumed products (34% of women and 66% of men consume them every day),
- there is a clear differentiation of preferences regarding the types of meat products consumed and the place of purchasing them due to sex, age and place of residence of the respondents,
- among the key factors affecting the respondents' decisions of purchasing cold meats can be listed the product composition, its price and customers' habituations to given products,
- the vast majority of buyers declared their meat choice in the presented order: pork, poultry, mixed and beef,
- younger respondents (up to 18 years old) make their purchases mainly in hypermarkets, while mature and older people buy more at local stores or at marketplaces or company stores.

Due to the selection of the target group the research cannot be generalized to the entire population. Conclusions stretched beyond the study group can be representative only for people who declare consumption of cold meat, however, they do not constitute a representative sample for the whole population.

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EVALUATION OF THE KNOWLEDGE OF MOTHERS ABOUT THE PRINCIPLES OF CHILDREN NUTRITION AT AN EARLY SCHOOL AGE

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ABSTRACT

The subject of the work was to evaluate mothers' knowledge about the principles of feeding children of early school age mainly to prevent the obesity. The study involved 98 women who were mothers of children attending classes of 1-3 primary schools in Warsaw. The evaluation was performed with anonymous questionnaire consisting of 30 questions to verify the state of the knowledge about balanced nutrition (the amount and quality of meals and volume of liquids) and physical activity. The knowledge of the majority of respondents about the fundamentals of children nourishing was assessed as considerably good. Mothers knew, how many meals and at what frequency should the child eat through the day (on average 61% of correct answers). Mothers' knowledge of more detailed matters was a bit worse, issues regarded fiber and vegetable consumption, as well as recognizing good sources of calcium and iron in the diet of the child. Unfortunately, the dietary customs of the children were far from the recommended. Too low consumption of fish and vegetables was found, but Mothers participating in the examination had a great awareness of the need for the physical activity of their children. Young and better-educated women had the best knowledge about nutrition. In the conclusion, it's stated that in spite of numerous educational programmes there is still a need to conduct parents' education about healthy eating habits for all family members.

1.Introduction

Child obesity is one of the fundamental problems of public health in the 21st century. This problem has a global reach and appears in both developed and developing countries. In the new report, provided by the WHO and Imperial London College cooperation, published data concerns the phenomenon of obesity and excess weight amongst children and teenagers at the age of 5-19. It turns out, that the number of obese kids at the age of 5-19, grew 10 folds over the four decades. The percentage of obese children and teenagers in 1975 was under 1% (11 million), while in 2016 reached 6% and 8% (124 million), respectively for girls and boys. Moreover, at present also about 213 million children are overweight. It's estimated, that in the modern world the excess weight and the obesity cause more deaths than the undernourishment (Grosso et al., 2013).

As the most frequent causes of the excess weight and obesities genetic factors and environmental are named. Unlike the majority of adults, children are unable to choose the food they eat or the environment in which they live. They are also unable to predict the long-

term effects of their behavior, therefore there is a need for support from the family.

The obesity during childhood has an adverse effect on the joints and the bone structure, leading to distortions of the spine, the aseptic necrosis of the hip joint or the flat foot. It also causes an inflammatory condition and fatty liver what often leads to permanent damage to this organ. Pulmonological diseases are also a consequence of obesity, as it can lead to bronchial asthma with a very heavy course. This lowers physical strength and can cause sleep apnea. Studies also showed that obesity in childhood was positively correlated with the occurrence of many illnesses, including cancer, in adult life (Marcysiak et al., 2010).

Obesity prevention strategies take two directions: an introduction of balanced, rich in nutrients diet adapted for the caloric requirement of the organism and increasing the physical activity of children (Binkiewicz-Glińska et al. 2012; Szanecka and Małecka-Tandera 2014; Kupczak-Wiśniowska et al., 2017).

An important principle of rational nutrition is to consume small assorted meals at even intervals throughout the day (Sadowska and Zakrzewska, 2010; Ciborowska and Rudnicka, 2018). Children should eat 5 meals per day. Recommended energy allocation among the meals should provide 20-25% at breakfast, 15-20 % at the II breakfasts, 35-40 % at dinner, 5-10 % at the afternoon snack and 10-15 % at the supper of the total calories (Blask-Osipa et al., 2015). The easiest and most useful as the educational material is The Nutrition Pyramid, that includes physical activity for children and teenagers prepared in 2017 by Polish Institute of the Food and Nutrition (Instytut Żywności i Żywienia, IŻŻ). Vegetables and fruits should be the foundation of the diet. Products of the cereal origin constitute a second important group of food, and children should reach for products made with whole grains. The source of proteins in the diet of children should be lean fish, eggs, legumes and, particularly as a source of calcium, milk and milk products. Sugar, salt, and saturated fats should be limited to a minimum. Very important is an everyday physical activity, which authors of the pyramid put at its base, and an adapted to the needs of the organism hydration (Jarosz et al., 2017; Riordan et al., 2017).

Many factors affect the eating habits of children like e.g. cultural, social or individual determinants. However, according to studies, correct nutrition of children, in particular, is influenced by the eating habits of their parents or caretakers and the level of their dietary education (Zarnowiecki et al., 2012; Kirpsza-Roszko et al., 2011). Eating habits of children begin to develop at a young age, and mistakes established in childhood affect the development of many diet-related conditions in adulthood (Oellingrath et al., 2013; Rangelov et al., 2016; Sawicka et al., 2017). Studies explicitly confirm that families consuming meals together eat more foods universally recognize as healthy (Sahoo et al., 2015).

Children acquire the knowledge about nutrition in their most immediate environment through observation of parents, but also peers, whom they will imitate, what can strengthen bad habits (Szczepańska et al., 2015). According to psychologists children in the early-school age are mature enough to learn and understand principles of healthy nutrition, so that they are able to make correct dietary choices themselves (Cribb et al., Albrecht et al., 2017). Researchers analyzing diets of Polish children in elementary school often signal low consumption of the milk and milk products, (danger of deficit of calcium, B-group vitamins, vitamin D), monotonous and badly composed meals and the small number of vegetables and fruits. Snacking between meals at unhealthy snacks in the form of chips, chocolate bars and drinking sweet drinks is another problem, as these products are easily accessible for youngest (Blask-Osipa et al., 2015; Bekker et al., 2017).

2. Materials and methods

The subject of this work was an evaluation of the knowledge amongst mothers of early-school children about principles of nutrition to prevent obesity. Surveys were conducted in the period from January to April in 2018. 98 women took part in the questionnaire survey, mothers of children attending classes of 1-3 in primary schools in Warsaw. Authors prepared an anonymous questionnaire consisting 30 questions that verified the state of the knowledge of mothers about balanced nutrition and evaluated dietary customs (quality and quantity of meals and amount of consumed liquids) and physical activity of children. The questionnaire also provided necessary information about the participants in the examination (the age of mother, education, marital status, occupational status and the number of children).

The most numerous group of respondents (47.9%) were women aged 31-40, women aged 26-30 constituted to 36.7%. Less numerous group were women at the age of 41 and more (13.2%), only two mothers in the examined group were less than 25 years old. 67.3% of respondents had a higher education, 28.57% had secondary education. None of the respondents had more than three children. The most numerous group (over the 37.4%) were married women, professionally active and had one child. Most of the women were working, over 77.5% of the participants.

3.Results and discussions

Women were asked to assess their knowledge about the principles of childhood nutrition. Most of the respondents (64.3%) evaluated their knowledge as good, 23.5% of mothers replied as "my knowledge is sufficient". Five mothers judged their knowledge as very good and six respondents marked an answer “it's difficult to tell", none of the mothers rated their knowledge as insufficient. Participants in the survey conducted by Wyka et al. (2012) assessed their nutrition awareness similarly high. However detailed verification of dietary practices of their children shows a sequence of mistakes. Additionally, medical examination revealed, that 22% of children had excess weight and 5% were obese. Mothers were asked where do they draw the knowledge about nutrition. Plenty of mothers search for advice on the internet (38.7% of respondents) and 22.4% reach for specialist literature (books), the majority (68.3%) selected food labels as sours of their knowledge, 11.2% of participants answered that they do not seek such knowledge. Harton et al. (2018) when conducting similar research also noted the high percentage of parents, who look for specialist knowledge on the Internet, at the simultaneous low percentage of parents seeking advice from professionals, dietitian, and doctors. In our own examinations, we noted that young women with one child have most often sought information on childhood nutrition. Only a 13.2% declared, that they always read from information on the label, whereas 53.1% does it often. These were mainly women 31-40 years old and with higher education. A considerable number of children (71.4%) used school canteens, mainly from professionally active mothers. A survey from 2016 showed that only 46.6% of children in southern Poland living in small towns ate meals at school (Jończyk et al., 2016).

Most of the mothers correctly identified the number of meals and the duration of intervals between meals in a child's diet, only 6% of the examined mother thought that three meals would be enough. In many studies from other authors, the most common mistake is too few meals per day (Roszko-Kirpsza et al. 2011; Pitucha and Mitera, 2012; Kotyrba and Wróblewska 2014; Jończyk et al., 2015).

Almost 80% of participants marked breakfast, as the most important meal in a day, 11% pointed at dinner. None of the participants in the examination regarded supper as the most important meal. Meanwhile, studies from 2016 demonstrated, that children at the age of 6-13 had most often eaten the supper (93.9%), and then dinner (80.5%) (Jończyk et al., 2016).

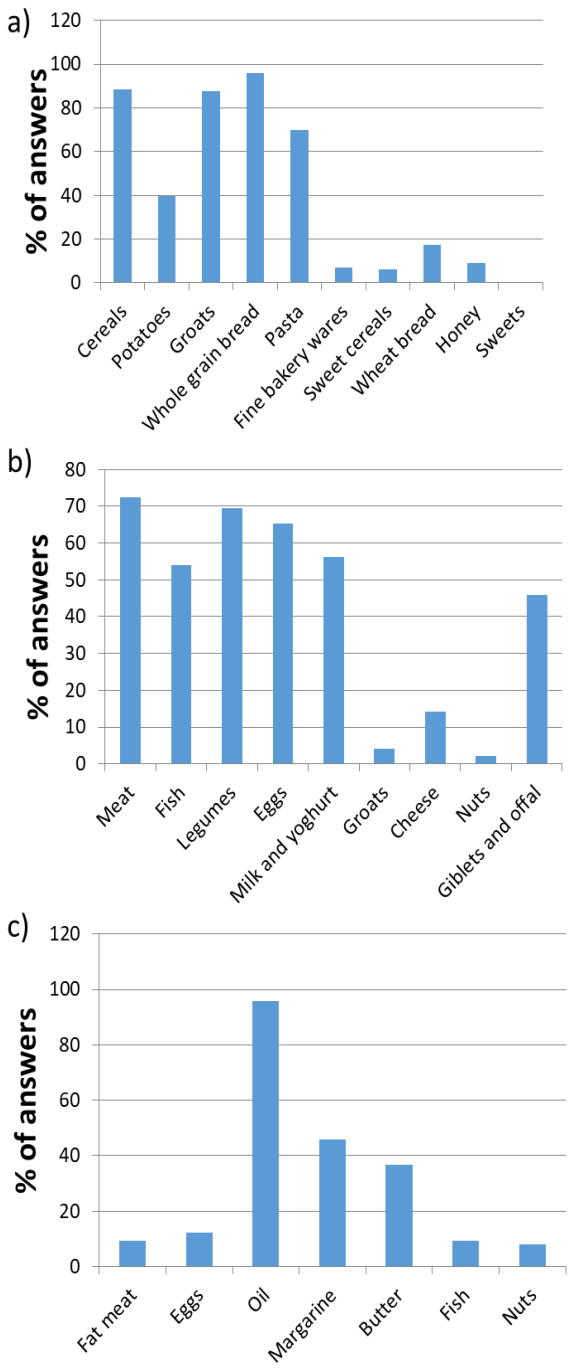

Figure 1. Sources of macro elements in the diet of child in early school age named by surveyed mothers, a) carbohydrates; b) proteins, c) fats

Most of the respondents knew that the last meal should be eaten 2 hours before sleep, though some mothers thought that the child should not eat after 6 pm. When asked what products should be served for breakfast, mothers checked mostly whole grain bread, hams, and eggs. Only over half of the participants in the examination (52%) indicated the milk, and some cream (4.1%).

The problem of low milk consumption was also noticed by other researchers. Jończyk et al. (2016) researched the eating habits of children in the age of 6-13. They stated that only 64.39% of examined children ate breakfast before going to the school and only 61.7% drinks the milk every day, 34.88% declared, that the milk is present in their menus several times during the week. Whereas recommendations for this age group suggest 3 to 4 glasses of the milk (or equivalents) every day.

Surveyed mothers manifested a high level of knowledge about macro elements in the diet, over 80% indicated correct sources of carbohydrates, fats and the protein for a balanced diet. Although, there were few mothers, who named wheat bread, and even fine bakery wares. As the desired source of carbohydrates mothers named mostly whole grain bread, groats and cereals (Fig. 1). They knew that a desirable source of whole proteins can be lean meat - 72.4% (legumes were named second). Whereas, fat in the diet should come from oils (butter was mentioned by 16.3%, fish only by 9.2%). Knowledge concerning calcium and its sources was not satisfying.

Mothers correctly defined the role of calcium, emphasizing it as the building element of the bone and teeth, but they had a problem with correct determining the recommended daily intake. As the source mothers named milk products, eggs, and legumes. However, they did not know calcium content in different milk products. Only 22.4% of respondents indicated cheeses as a rich source, 71.4% chose milk (Fig. 2), but cheeses contain over 10 times more calcium than the milk. Same

unsatisfactory level of the knowledge of parents about the role and sources of calcium observed Harton et al. (2018) and Merkiel and Chalcarz (2016). Insufficient consumption of calcium is a universal problem, not only among children, and consequences for the health can be serious (Kotyrba and Wisniewska, 2014; Pitucha and Mitera, 2012; Harton, 2013).

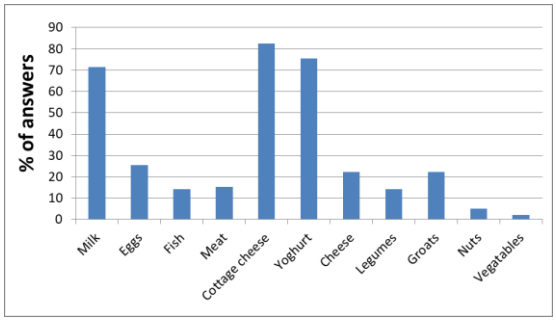

Figure 2. Sources of calcium in the diet of child in early school age named by surveyed mothers

Vegetables and fruits are essential in child nutrition, they are in the base of the Healthy Eating Pyramid and physical activity. It is recommended to consume at least 5 servings of vegetables and fruits, best fresh and unprocessed. In the conducted examination the one in three mothers declared that children should eat 3-4 portions of vegetables, and one in four declared same quantity for fruits. Surveys in the Silesian and Opole province showed that only 22.9% of children ate 3-4 portions of vegetables and fruits per day (Jończyk et al., 2016).

Many researchers of the dietary practices of children emphasize, that in spite of many education campaigns consumption fruits and especially vegetables is alarmingly low (Roszko-Kirpsz et al., 2011; Pitucha and Mitera, 2012; Merkiel and Chalcarz, 2016).

Mothers were also asked about the demand for liquids and desired sources in the diet of children. Recommended supply of liquids is about 2 liters and should be increased if a child has increased physical activity. Over 90% of polled mothers thought that children should drink still water. Many others also thought that fruit juices were a good choice, almost 43% picked juices, mostly blended fruits, just under 10% of mothers selected soft drinks, including sparkly water and even more named flavoured waters (Fig. 3). Only 13.2% of examined mothers correctly determined the necessary amount of liquids, the largest group (67.3%) claimed the child should drink from 1 up to 1.5 l of water per day, remaining weren't able to give the answer to that question.

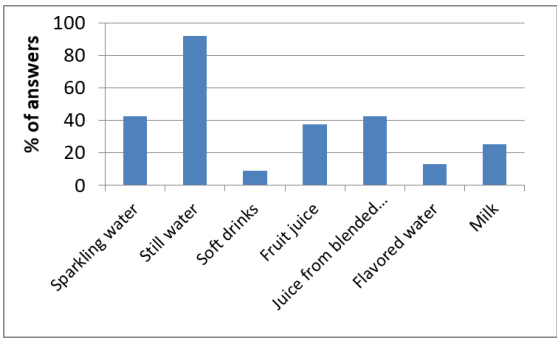

Figure 3. Types of liquids in the diet of child in early school age named by surveyed mothers

The questionnaire included questions concerning the physical activity of the children. Two children in the examined group were not involved in school sports classes, whereas the majority (85.7%) of children practiced various after-school activities. Pitucha and Mitera (2012) studying habits of children in the same age but in small towns stated that only 30% of participants practiced sport in free time, similarly to Ćwirlej et al. (2005). Poor results were achieved in the examination in very small towns where extra activity apart from the physical education at the school practiced only 27.7% of boys and 15.5% of girls (Jończyk et al., 2016). The 83.5% of children practicing extra activity trained1-2 times during the week, while it is recommended to exercise for an hour every day. The most popular activity among children was swimming pool named by 43% of mothers, dance (27%) and football (23%).

4. Conclusions

Parents are responsible for the correct formation of their children's food habits, thus parental education is essential in this respect.

Participants knew enough about the basic principles of meal preparation for children, they also correctly named essential sources of macro elements in the diet. The majority of participants tried to expand their knowledge on this matter, but not always from accurate sources. The results showed insufficient knowledge of mothers about products rich in calcium, what can cause a deficiency in children. Women are also unaware of the importance of vegetables and fruits in the diet of children.

Mothers presented an alarming lack of knowledge about the suitable amount of liquids and quality of drinks, allowing for soft drinks and flavoured waters to be present in the diet f children.

A positive phenomenon is high awareness of the importance of exercises, a considerable majority of children participated in afterschool physical activity.

In order to improve mother's knowledge authors recommend parental meetings with health care workers organized by schools. Health care workers should include dietitians and doctors (cardiologist and orthopedist), but also personal trainers and PE teachers. Exposing mothers to problem of obesity and nutrition from different perspective should be motivating to improve children's health. Aside from educating parents, schools should provide healthy nutrition courses for children. This could be performed in a form of meeting with dietitian or as a event at school in a form of a play day.

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CHEMICAL CONTAMINANTS IN PRODUCTS OBTAINED FROM ATLANTIC COD

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ABSTRACT

Current data on levels of contaminants in cod (*Gadus morhua*) from the Baltic Sea are reported. The aim of the study was to evaluate the consumer exposure to contaminants caused by the fish intake and to examine the compliance of the Baltic fish resources with an EU legislation. Fish were sampled from the five fishing grounds that are most commonly used by Polish fish industry and in the Norwegian Sea for comparison. In addition, products available on the Polish market (frozen fillets of cod and saithe (*Pollachius virens*) and canned cod liver products) were sampled. The scope of the project included a variety of contaminants for which the permissible levels have been established and that are recommended by EFSA to be monitored in food products (mercury, cadmium, lead, dioxins, polychlorinated biphenyls, organochlorine pesticides, brominated flame retardants, nonylphenols, bisphenol A). The differences in contaminant levels between cod from the Baltic Sea and the Norwegian Sea were noted. However, levels of contaminants in the muscles of cod were low in comparison with limits set for food. In contrast, in the cod liver and in the cod liver products that were tested, the permissible limits of dioxins (the Baltic Sea) and cadmium (the Norwegian Sea) were exceeded.

1.Introduction

Due to their nutritional value, fish are high quality food with a beneficial influence on human health. (Usydus *et al,*. 2009; Usydus *et al,*. 2011; Usydus and Szlinder-Richert 2012). However, despite the occurrence of nutrients in fish, undesirable substances that may pose a health risk to consumers can also be found. The level of contamination in fish exhibit temporal and spatial variation and vary significantly depending on species. They are determined by several factors, from which the most important is the quality of ecosystem they inhabit. Aquatic organisms can be indirectly exposed to contaminants through the food chain or directly through abiotic environment compartments such as sediment and water.

Atlantic cod (*Gadus morhua*) is a predatory marine fish which inhabits the northern part of the Atlantic Ocean and the seas of Northern Europe. It is very popular among European consumers. According to EUMOFA report from 2017, the consumption of cod in EU was 2.32 kg per capita in 2015. In terms of the frequency of consumption cod was the second most popular choice among the species available on the EU market. The most common cod products on the market are frozen or fresh fillets, however, also cod liver products are valued by some groups of consumers.

The aims of the study were:

- to examine the levels of chemical contaminants in muscles and livers of cod to determine their compliance with EU legislation

-to examine the spatial distribution of contaminants in cod caught in the Baltic Sea to identify area with the lowest level of contaminants

-to evaluate the consumer exposure to undesirable substances occurring in edible parts of cod.

The Baltic Sea is considered to be a heavily polluted area and in consequence the safety of Baltic fish consumption is a subject of concern. The study was conducted in cooperation with Polish fish processing industry and fish were sampled from the five fishing grounds that are most commonly used by Polish fish industry and in the Norwegian Sea for comparison (FAOII2a). In addition, products from the Polish market (frozen fillets of Atlantic cod and saithe and canned cod liver products) were investigated. The scope of the study included a variety of contaminants for which the permissible levels in food have been established: metals (Cd, Pb, Hg), organochlorine pesticides, polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs). In addition, contaminants which have not yet been widely studied in fish, but which arouse concern in relation to the environment and human health: polybrominated diphenyl ethers (PBDEs), hexabromocyclododecanes (HBCDDs), nonylphenols (NPs), bisphenol A (BPA) were examined.

2.Materials and methods

2.1.Materials

2.1.1.Fish Samples

Cod (*Gadus morhua*) samples were collected during cruises of the r/v BALTICA or fishing boats. Fish were sampled in April 2016 from five sampling areas in the Baltic Sea (Figure 1.): the Gulf of Gdańsk (GG), the Słupsk Furrow (SF), the Polish middle coast (KD), in south coast of Bornholm (BS) and in north coast of Bornholm (BN) and in 2018 from the Norwegian Sea (FAOII2a).

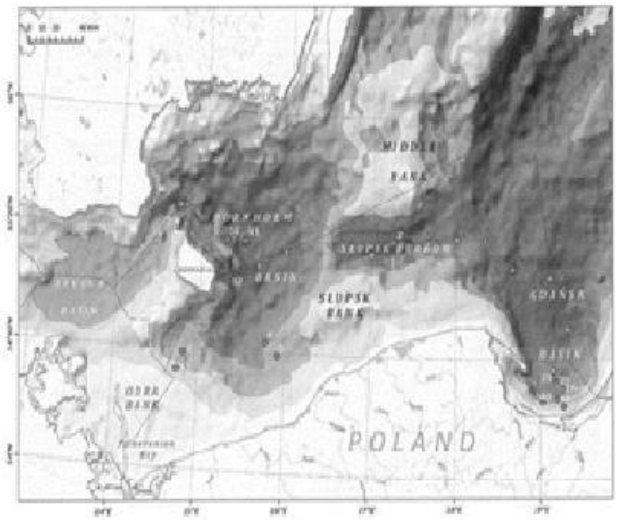

Figure 1. The sampling sites in the Baltic Sea

All the samples were frozen immediately after being caught and stored at -18 ˚C in polyethylene bags until analyzes were conducted. Cod were filleted and skin was removed. Cod fillets and livers were analyzed. Each sample consisted of 1 individual specimen (two fillets) which allows not only to determine the average level of contaminants in cod from the specific fishing ground but also to observe the variability of the results between individuals and the frequency of exceeding the permissible limits of contaminants for which such limits have been established. Metals, PBDEs (nos. 28, 47, 99, 100, 153, 154, 183), HBCDDs (sum of isomers α, β, γ), NPs and BPA were determined in the same specimens and 10 specimens from each location were tested. PCDD/Fs and PCBs were determined in other individuals due to the need to provide the sufficient amount of material for analyzes. Because of high costs of analyzes, tests were carried out in four individuals from each location. The characteristic of individuals sampled from particular fishing ground is given in Table 1.

2.1.2. Samples from the market

Products from the market: canned cod livers, frozen cod fillets from the Baltic Sea (part of a fillet called ”fish loin”) and frozen fillets of saithe (*Pollachius virens*) packed in

polyethylene bags were purchased in 2018 in fish markets in Gdynia. Fillets were analyzed as pooled samples and a sample was comprised of 10 bags.

Table 1. Data of investigated fish

Sampling location	Fish length (cm) Min-Max	Fish weight (g) Min-Max	Liver weight (g) Min-Max
GG	30-60	482.0-1885.2	29.6-104.8
SF	36-46	468.3-1010.2	32.6-77.0
KD	35-45	389.7-838.5	20.8-36.2
BS	39-51	579.4-1298.0	32.6-55.0
BN	30-48	278.3-1117.7	18.6-70.4
FAOII2a	68-89	2376.5-5820.3	69.0-377.5

Four brands of canned products from liver of cod caught in the Baltic Sea were analyzed: the Caucasian liver (liver in an oil), liver in own sauce, the Hungarian liver (liver in vegetable sauce) and liver pate. The sample was the content of one can (150g) and five samples from each assortments were tested. The oil (about 50g) and the liver (about 100g) were analyzed separately. In the case of liver pate, the contents of the whole can was homogenized. Analyzes of PCDD/Fs and PCBs were conducted in pooled samples consisting of five cans and only livers were examined.

2.2.Chemical measurements

All chemical analyzes, except the measurement of polychlorinated dibenzo-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs) were performed in the National Marine Fisheries Research Institute (NMFRI). Organic contaminants in muscle tissue were determined in homogenized, freeze-dried samples. In case of livers organic contaminants were measured in fat obtained by centrifugation of liver tissue. Previously it was confirmed that the result of organic contaminant measurement in fat obtained by the mean of liver centrifugation and in fat obtained by the mean of extraction with solvents on chromatographic column were comparable. All results of contaminant levels in muscle tissue and in livers were converted into wet tissue mass. Metals were measured directly in homogenized muscle or liver tissue.

The detailed description of chemical analysis, standards and reference materials used as well as the description of quality assurance/control procedures and validation parameters were previously published (Szlinder-Richert *et al*., 2008; Szlinder-Richert *et al.*, 2009a; Szlinder-Richert *et al.*, 2011; Szlinder-Richert *et al*., 2014; Ruczyńska *et al.*, 2016; Usydus *et al.*, 2009). The measurement of PCDDs –the sum of seven most toxic congeners, PCDFs – the sum of the ten most toxic congeners, dioxin-like PCBs (dl-PCBs – the sum of four non-ortho PCB nos. 77, 81, 126, 169 and the sum of eight mono-ortho PCB nos. 105, 114, 118, 123, 156, 157, 167, 189) and ndl-PCBs (nos. 28, 52, 101, 153, 138, 180) was subcontracted to accredited laboratory of Wessling (Germany). Tests were conducted, with the isotope dilution method, according to the EPA 1613 method (USEPA Method 1613, 1994). Freeze-dried samples were extracted with n-hexane and clean up was performed using adsorption chromatography. Prior to extraction, the samples were spiked with mixtures of isotope-labeled standards (Wellington Laboratories, Canada). The final extracts were analyzed with the HRGC/HRMS technique. Quantitation limits varied depending on the congener and the sample size. Concentrations below the limits of quantitation (LOQ) were equated to the LOQ. PCDD/Fs and dl-PCBs content were expressed as TEQ values, which were calculated for each sample by multiplying the individual congener levels measured in each sample with the appropriate toxic equivalency factor (TEF). The TEFs used were set by the World Health Organization (WHO) for human and were calculated relative to 2,3,7,8-TCDD (van den Berg *et al*, 2006). Results for ndl PCBs PCDDs, PCDFs, PBDEs (nos. 28, 47, 99, 100, 153, 154, 183) are given as sums of all studied congeners. For congeners

of PCBs and PBDEs occurring in levels below the detection limit (LOD), the zero value was assumed for the calculation the sum of concentrations. When the concentrations were below the limit of quantification (LOQ), the half of the LOQ was assumed.

2.3.Statistical analysis

Statistical analyses were conducted with the STAT statistical software package (Statistica, Version 8.0). The analysis were performed for samples grouped according to a collection site. The concentrations analyzed were log-transformed and a significance level of $p<0.05$ was used. Since no homogeneity of variance, was noted (Levene's test) the nonparametric analyzes (Kruskal–Wallis) were performed.

3.Results and discussions

The most common toxic substances present in fishes and fish products are toxic metals (Hg, Cd, Pb), and persistent organic pollutants (POPs) like: PCBs, PCDD/Fs and organochlorine pesticides. In the interest of consumers' health, the EU has introduced maximum limits of these contaminants in different food groups, among others in fishes. These limits cannot be exceeded in the products admitted to the European market.

3.1.Toxic metals

Toxic metals are contaminants that are monitored in food for a long time. Permissible limits established in EU Commission Regulation no. 1881/2006 for fish are as follows:

Hg: 0.5 mg/kg
Cd: 0.05 mg/kg
Pb: 0.3 mg/kg

Concentrations of metals in tested samples are shown in Figure 2.

3.1.1.Toxic metals in cod muscle tissue

There were no statistically significant differences between mean concentrations of mercury and cadmium in muscle tissue of cod sampled in five fishing grounds in the Baltic Sea and in the Norwegian Sea (FAOII2a) (Figure 2.). Mean concentration of mercury and cadmium dependently on fishing area varied between 0.05 and 0.09 mg/kg and 0.002 and 0.003 mg/kg, respectively. That means that the concentrations of those metals in muscle tissue of cod examined in the current study were over ten times lower than permissible limits established in Commission Regulation no. 1881/2006. Mean levels of lead in muscle tissue of cod were also over ten times lower than permissible limits, and ranged from 0.006 to 0.016 mg/kg, nonetheless some differences between mean concentrations in fish from different areas have been noted. Muscle tissue of cod sampled in the Norwegian Sea contained statistically significantly higher levels of lead in compare with the cod sampled in the Baltic Sea ($p<0.05$).

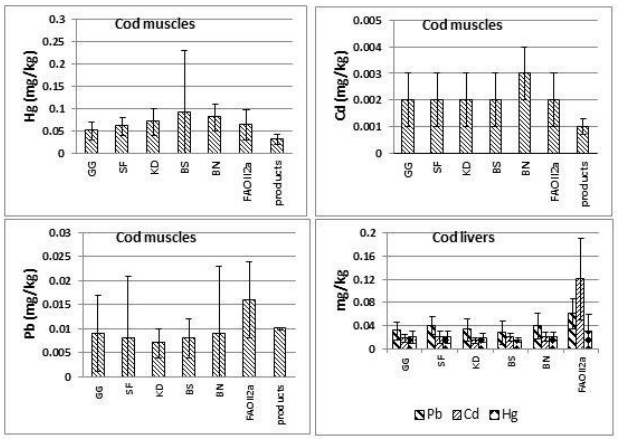

Figure 2. Concentrations of metals in cod samples

3.1.2. Toxic metals in cod livers

Concentrations of toxic metals were several times higher in cod livers than in cod muscle tissue and the highest levels were determined in livers of cod sampled in the Norwegian Sea. However mean concentrations of lead (0.03-0.06 mg/kg) and mercury (0.02-0.03 mg/kg) were still below permissible limits established in Commission Regulation no. 1881/2006 in all cod liver samples studied. In contrast, mean concentrations of cadmium were below permissible limits only in livers of cod caught

in the Baltic Sea, whereas in case of livers of cod sampled in the Norwegian Sea the exceedances of limit were noted in 8 out of 10 tested samples. The differences observed between the average level of cadmium in the cod liver collected in the Baltic Sea and the Norwegian Sea were statistically significant ($p<0.01$). The mean cadmium concentration in livers of cod caught in the Norwegian Sea was more than two times higher than the permissible limit of cadmium in fish.

3.2. PCBs and PCDD/F

PCBs, due to their excellent insulating properties, have been widely used in industry as components of electro-insulating oils. Currently, their use and production are banned in the EU. Unfortunately, due to their high persistence in the environment they will be detected in it for a long time. PCB is a group of 209 compounds (congeners) with a similar chemical structure, but different number and place of substitution of chlorine atoms in the molecule. The limits set for food concern the sum of 6 congeners called indicator or non-dioxin-like (ndl-PCBs) and a total of 12 congeners called dioxin-like (dl-PCBs). In turn, the term dioxins is commonly used for two groups of compounds, i.e. polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) that share a similar chemical structure and a common mechanism of toxic action. These compounds have never been produced intentionally but they are created during combustion processes in the presence of chlorine atoms. Therefore, it is impossible to stop their emissions to the environment completely, although many efforts have been done to reduce it. The limits set for food relate to a total of 17 congeners.

Permissible limits set forth in the EU Commission Regulation 1259/2011/EC for these contaminants are as follows:

PCDD/Fs in fish:3.5 TEQpg/g

sum of PCDD/Fs and dl-PCBs in fish: 6.5 TEQpg/g

ndl-PCBs in fish: 75 ng/g

sum of PCDD/Fs and dl-PCBs in fish liver: 20 TEQpg/g

ndl-PCBs in fish liver: 200 ng/g

3.2.1. PCBs and PCDD/Fs in cod muscle tissue

There were no significant differences between mean PCDD/F, dl-PCB and ndl-PCB concentrations in muscle tissue of cod from different fishery areas (Figure 3) and all samples studied were compliance with Commission Regulation 1259/2011/EC. Total mean TEQ levels were much below permissible limits and varied between 0.25 and 0.33 TEQpg/g. Similarly the mean concentrations of ndl-PCBs were very low in compare with permissible limit and ranged between 0.8 and 1.2 ng/g being the lowest in muscle tissue of cod sampled in the Norwegian Sea. Concentrations of PCDD/Fs and PCBs in the muscle tissue of cod from the Baltic Sea were much lower than in other fish species from that area (Burreau *et al.*, 2006; Pandelova *et al.*, 2008; Parmanne *et al.*, 2006; Struciński *et al.*, 2013; Szlinder-Richert *et al.*, 2009a,b).

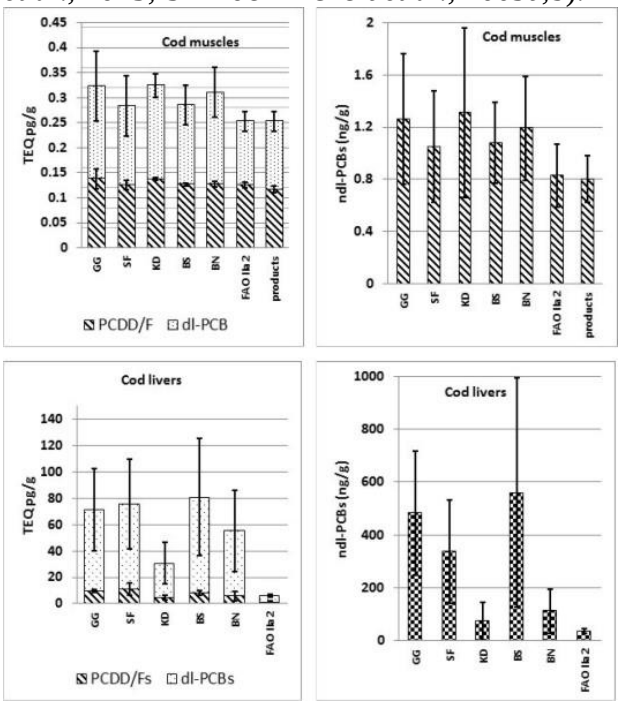

Figure 3. Concentrations of PCDD/Fs and PCBs in cod samples

3.2.2.PCBs and PCDD/Fs in cod livers

In the case of cod livers, apparent differences in PCDDF and PCB levels were found between individuals from different fishing areas. Concentrations of PCDD/Fs and dl-PCBs were much higher in livers of cod sampled in the Baltic Sea than in cod sampled in the Norwegian Sea and the difference was statistically significant ($p< 0.01$). Among livers of cod sampled in the Baltic Sea, the lowest levels of PCDD/Fs and dl-PCBs were observed in livers of fish sampled in the middle part of the Polish coast, however, they still contained higher levels of these pollutants than livers of cod sampled in the Norwegian Sea ($p<0.01$). Levels of ndl-PCBs were comparable in livers of cod sampled in the Norwegian Sea, in the middle part of the Polish coast and in the northern cost of Bornholm and statistically significantly lower than in livers of cod caught in the remaining areas studied. All examined livers of cod caught in the Norwegian Sea were compliance with Commission Regulation 1259/2011/EC. In contrast, total TEQ levels of PCDD/Fs and dl-PCBs exceeded the permissible limit in all examined livers of cod sampled in the Baltic Sea. The mean levels of sum of PCDD/Fs and dl-PCBs in the cod livers caught in the Baltic Sea were several times higher than the permissible limit of these substances (20 TEQpg/g) and ranged from 30 to 80 pgTEQ/g. Mean concentrations of ndl-PCBs, in turn, were higher than the limit permitted by the law in livers of cod sampled in 3 out of 5 examined in the current study fishery areas located in the Baltic Sea.

3.3. Brominated flame retardants

PBDEs and HBCDDs are brominated flame retardants (BFRs) that are added to a wide variety of polymers and resins, and they were the first group of BFRs detected in the environment (Alaee and Wenning, 2002). The production of two commercial PBDE mixtures was banned in Europe, whereas deca-PBDE is still in use. The increasing temporal trends of PBDEs in human or biota observed in the monitoring programs conducted during the past decade (de Wit, 2002; Law *et al.*, 2006) indicate that the environmental levels of this group of contaminants should be monitored.

3.3.1. BFRs in cod muscle tissue

Mean PBDE concentrations, shown in Figure 4 were statistically significantly ($p<0.009$) lower in muscle tissue of cod sampled in the Norwegian Sea (0.007 ng/g) than in muscle tissue of cod caught in the Baltic Sea (0.15-0.30 ng/g) and that levels were much lower than in other fish species from the Baltic Sea that can be found in literature (Burreau *et al.*, 2006; Parmanne *et al*., 2006; Szlinder-Richert *et al.*, 2010). At present, levels of PBDEs in food are not limited by legislation. Nonetheless, the risk stemming from the consumption of contaminated food can be evaluated according to the Provisional Tolerable Weekly Intake (PTWI) established for specific contaminants. The PTWI value recommended by the European Food Safety Authority (EFSA) for PBDEs is 0.7 $\mu g\ kg^{-1}$ body weight (EFSA, 2005; p. 71), which corresponds to a weekly intake of 49 000 ng for an adult weighing 70 kg. However, it should be stressed that this value is derived from a limited set of data, and there is a note in the EFSA Journal (2005; p. 71) that this value is considered as less robust. Taking into account the highest mean value of PBDEs (0.3 ng/g), measured for cod sampled in the northern Bornholm, a meal consisting of 250 g of fish provides about 75 ng of PBDEs and that accounts to 0.2% PTWI for an adult weighing 70 kg. Mean HBCDD concentrations in cod muscles were very similar regardless of the catch region and they were about 0.02 ng/g. Due to the fact that in the case of HBCDDs, the fish muscles are not the tissue that accumulates these contaminants to the greatest extent, the data that can be found in literature often concern whole fish (not just the muscle tissue), so comparison between species is difficult. HBCDD concentrations measured in muscles of cod from the Baltic Sea was ten-fold lower

than those measured in whole fish bodies of Atlantic herring (0.26 ng/g) (Shaw *et al*., 2009) and similar to concentrations measured in muscles of roach (0.03 ng/g) and perch (0.013 ng/g) sampled in 2014 in Polish transitional waters (unpublished data of NMFRI).

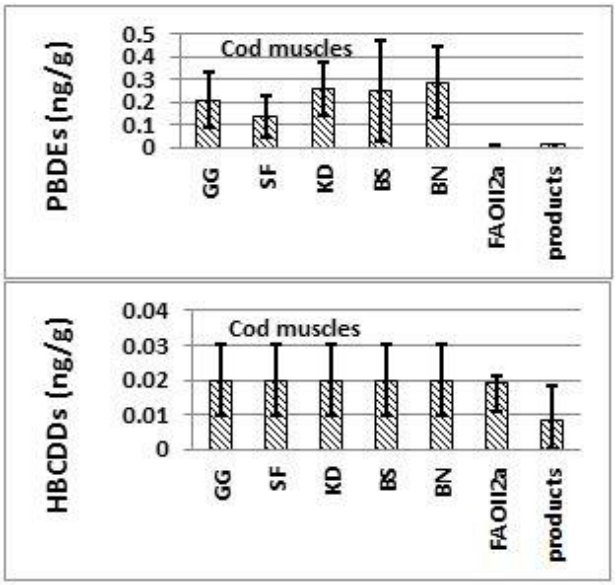

Figure 4. Concentrations of BFRs in cod muscle samples

3.3.2. BFRs in cod livers

Concentrations of both PBDEs and HBCDDs (Figure 5) were many times higher in cod livers than in muscle tissue. However, mean concentrations determined in livers of cod sampled in the Norwegian Sea were ten-fold lower than in livers of cod from the Baltic Sea and the differences observed were statistically significant (PBDEs, $p<0.002$; HBCDDs, $p<0.02$).

Mean PBDE concentrations in livers of cod caught in the Baltic Sea ranged between 5 ng/g (Slupsk Furrow) and 14 ng/g (the middle part of the Polish coast). Taking into account the mean value of PBDEs 14 ng/g, a meal consisting of 250 g of liver of cod from the Baltic Sea provides about 3500 ng of PBDEs and that account to 7% PTWI for an adult weighing 70 kg.

Mean HBCDD concentrations varied between 55 and 25 ng/g in livers of cod sampled in the Baltic Sea and were much higher than in livers of cod caught in the Norwegian Sea (2 ng/g).

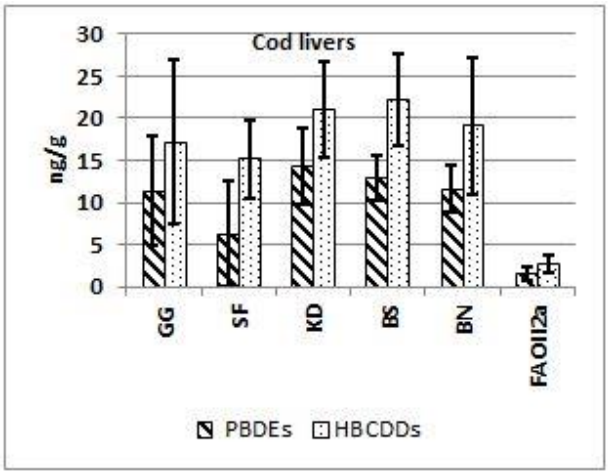

Figure 5. Concentrations of BFRs in livers of cod

3.4. Nonylphenols and bisphenol A

NPs and BPA are toxic xenobiotics classified as an endocrine disrupters (Pojana *et al.*, 2007) affecting the hormonal system of numerous organisms, indicated by HELCOM (Baltic Marine Environment Protection Commission – Helsinki Commission) as hazardous substances of special concern. BPA is an organic chemical compound used in the production of plastics. NP originates principally from the degradation of nonylphenol ethoxylates which are widely used as industrial surfactant.

BPA and NPs were measured only in samples of cod from the Baltic Sea. Concentrations of both contaminants in all examined livers of cod were below LOQ (NPs, 0.02 µg/kg; BPA, 0.46 µg/kg). Concentrations of BPA was also below LOQ in all examined samples of cod muscles tissue (1.7 ng/g). It is easy to calculate that consuming of 250g of cod originated from the Baltic Sea will result in ingestion less than 0.425 µg of BPA. According to EFSA, Tolerably Daily Intake (TDI) for that contaminant is 4 µg kg^{-1} body weight which corresponds to a daily intake of 280 µg for an adult weighing 70 kg. This means that a portion

of 250 g of cod from the Baltic Sea provides less than 0.2% PTWI for an adult weighing 70 kg.

Mean NP concentrations in cod muscle tissue are shown in Figure 6. They varied from 8 to 35 ng/g.

The highest concentration of these contaminants were observed in muscles of cod sampled in the northern coast of Bornholm. Statistically significant differences were observed between concentrations measured in cod sampled in the northern coast of Bornholm and the Slupsk Furrow ($p<0.001$). According to Danish EPA, Tolerably Daily Intake (TDI) for NPs is 5 μg kg^{-1} body weight which corresponds to a daily intake of 350 μg for an adult weighing 70 kg. With the cod for which the highest levels were measured in the current study: a meal consisting of 250 g of fish provides about 8.8 μg of NPs (about 2.5% PTWI).

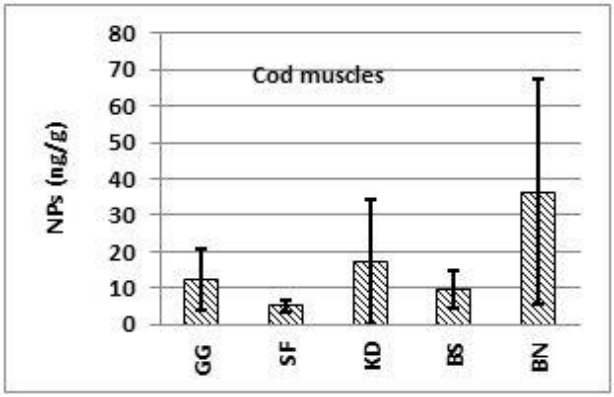

Figure 6. Concentrations of nonylphenols in muscle tissue of cod

3.5. Contaminants in products sampled from the market

Since it was previously proved that technological processing of the raw material might contribute to the reduction of the level of contaminants in the final product (Usydus and Szlinder-Richert, 2016), the tests were also conducted on frozen Baltic cod fillets and on canned products made of liver of cod caught in the Baltic Sea. In addition, saithe fillets were included into the study, as from the consumer's point of view, both species have comparable features. As it is shown in Figures 2-5 concentrations of contaminants tested in frozen fillets of cod sampled in the market were even lower than in muscles from the wild caught cod. The difference can be explained by the fact that the distribution of contaminants in fish is not homogenous (Boalt *et al*., 2014; Usydus and Szlinder-Richert, 2016). Products obtained from the market were only the middle part of a fillet called "sirloin", while in the case of muscle tissue samples obtained in the laboratory, the sample was the entire fillet. Abdominal part discarded during industrial filleting contains higher levels of contaminant that the dorsal and central ones (Usydus and Szlinder-Richert, 2012).

That is probably the reason for lower levels of contaminants in samples taken from the market. The concentration of contaminants in saithe fillets, shown in Table 2 were lower or comparable to those measured in cod fillets obtained from the market. The study conducted revealed the high levels of contaminants in liver of cod sampled in the Baltic Sea and indicated that measured concentrations of PCDD/Fs and PCBs exceeded the permissible limits established in Commission Regulation 1259/2011/EC.

Therefore, the levels of contaminants were also examined in products made of liver of cod from the Baltic Sea to test whether the treatment applied during industrial processing contributes to reducing levels of contaminants in final products. In case of canned cod livers products the scope of study was extended to organochlorine pesticides for which limits in food were set in the EU Council Directive 86/363/EEC:

HCB: 100 ng/g

γ-HCH: 200 ng/g

∑DDTs: 1000 ng/g.

Table 2. Contaminant levels in frozen fillets of *Pollachius virens*

Cd (mg/kg)	Pb (mg/kg)	Hg (mg/kg)	PCDD/Fs/dl-PCBs (TEQpg/g)	ndl-PCBs (ng/g)	PBDEs (ng/g)	HBCDDs (ng/g)
0.001±0.000	0.011±0.002	0.051±0.009	0.125±0.025	0.70±0.07	0.020±0.006	0.004±0.0008

Data are shown in Table 3. Due to the significant amount of oil in the canned liver an oil was tested separately, because it can be assumed that the consumer eats the liver and the oil is discarded. Obtained results clearly indicated that a significant part of contaminants passes from the liver to the oil. The levels of contaminants in the oil were several times higher than in the liver. The highest concentration of contaminants were determined in liver pate samples. With this product, the oil leaking from the liver remains in final product. Concentrations of organochlorine pesticides and ndl-PCBs in canned liver products were below permissible limits. Mean concentrations of PBDEs and HBCDDs in livers ranged dependently on the assortments between 2.26 ng/g and 4.59 ng/g and 1.54 ng/g and 3.2 ng/g, respectively. These levels are much lower than those measured in the raw material.

Measured mean PCDD/ F and dl-PCB levels exceeded acceptable levels in 3 out of 4 tested assortments. The lowest level was measured in Hungarian livers, while the highest in liver pâté. It should also be emphasized that the levels of PCDD/Fs and dl-PCBs in the entire content of cans (liver plus oil) would be even higher.

Table 3. Concentrations of contaminants in canned cod livers sampled in the Polish market

		∑DDT (ng/g)	HCB (ng/g)	γ-HCH (ng/g)	ndl-PCBs (ng/g)	PCDD/F/dl-PCBs (TEQpg/g)	PBDEs (ng/g)	HBCDDs (ng/g)
Caucasian liver	liver	138.5±5	7.97±0.59	0.61±0.59	108.9±10.1	20.83+4.2	2.26±1.36	1.67±0.35
	oil	686±150	41.6±1.7	2.66±0.83	not tested	not tested	11.98±4.52	12.24±2.10
Liver in own sauce	liver	158±88	4.55 ±5	0.66 ±0.40	156.8+15.2	28.97+8.7	4.11±0.93	3.12±0.60
	oil	724+308	22.3±16.3	3.25±0.50	not tested	not tested	14.49±2.39	14.65±1.63
Hungarian liver	liver	116±50.88	1.46±0.5	0.47±0.04	48.48±5.3	15.45+4.5	3.44± 1.62	1.54±0.45
	oil	757±308	5.01±0.01	2.75±0.02	not tested	not tested	1.85± 5.31	15.00±5.27
Liver pate	Entire content	259±51.2	10.8±1.9	0.69±0.25	181.4±182	33.12±9.9	4.59 ±2.31	2.44± 0.48

4. Conclusions

The discussion about the risks and benefits of fish consumption has been going on for a long time and can cause confusion in consumers. Frequently contradictory information is transmitted through the media. It is well documented that fish contain both health-beneficial ingredients as well as toxic contaminants such as methylmercury and persistent organic pollutants, of which the most frequently mentioned are dioxins. Nonetheless, the FAO/WHO panel concluded that despite the presence of pollutants in fish, the health benefits associated with fish intake outweigh any potential detrimental effects of pollutants so they should be recommended as a valuable component of the human diet (FAO/WHO, 2011). The results presented in the study indicate that levels of contaminants in the muscles of cod are low in comparison with the current standards and do not pose a threat to consumer's health. In contrast, the levels of undesirable substances in the cod liver and in

the tested liver products were much higher than in cod muscle. and the exceedance of permissible limits for dioxins and Cd were noted. Therefore, cod liver should not be eaten with high frequency.

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IMPACT OF HEAT TREATMENT AND FREEZING ON VITAMIN C CONTENT IN SELECTED VEGETABLES AND FRUITS

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ABSTRACT
The biggest source of vitamin C are fruits and vegetables and their preserves. It is a vitamin that man does not synthesize and does not have the ability to store it, so it should be supplied with food or supplements. However, it should be mentioned that vitamin C is very often used in the agri-food sector as an antioxidant. Therefore, the work indicated the total content of vitamin C and water activity in selected fruits and vegetables, as well as evaluated the impact of technological processing (cooking and freezing) on the distribution of ascorbic acid. The material for testing was lemon, cranberry, apples, red pepper, broccoli and sweet potatoes. The largest concentration of ascorbic acid among the tested fresh fruits was characterized by lemons. Among vegetables, the highest content of vitamin C has been demonstrated in paprika. The freezing process of raw materials for 1 week at -15 °C significantly affected the breakdown of vitamin C in fruits and vegetables.

1.Introduction

Many studies prove that in the world the main cause of diseases is in 50% incorrect nutrition, in 20% negative impact of the environment and in 30% of infections and accidents. The disease is usually caused by an undifferentiated and poor diet. Adequate nutrition ensures proper development and resistance to disease. Unfortunately, in our diet there is too much sugar, carbonated beverages, saturated fats and salt As dietitians appeal, society consumes not enough fruit and vegetables. The recommended daily dose for an adult is 200g of fruit and 500 to 700g of vegetables (Jarosz, 2012). Fruit and vegetables are relatively cheap, easily available, lightly digested and non-fattening. They provide a feeling of satiety and are suitable for consumption directly as well as after processing for example soups, salads, desserts, purees, preserves, fish additives and main dishes. An additional advantage is that the suitability for consumption is extended considerably after freezing. They are a very rich source of many nutritional values, micro and macro elements, minerals, fiber, organic acids, etheric compounds as well as polyphenolic compounds. That is why they should constitute an inseparable component of a varied diet. It is assumed that along with the diet is delivered to the body, as much as 91% of vitamin C, 27% of vitamin B6, 17% of thiamine and 15% of niacin, as well as 48% of vitamin A from fruits and vegetables (Szczypka, 2000).

Vitamins are divided into fat-soluble: A, D, E, K, which are easy to accumulate in tissues, and all the others that are soluble in water and excreted outside with urine. Although they are not the main source of energy and a structural component of tissues, thanks to them, the human body develops properly and all metabolic processes proceed (Albahrani and Greaves,

2016). Vitamins must be supplied with food, because the body itself can not produce them. They can be of natural origin and can be made synthetically. Even small deficiencies, major vitamins can lead to various types of disorders as well as an increase in the occurrence of civilization diseases. However, it should be remembered that excessive consumption may also have side effects on health, in the form of hypervitaminosis (Miktus, 2000).

Many years of research indicate that fruits and vegetables and their preserves are the largest source of vitamin C. Man cannot synthesize vitamin C and is unable to store it. Therefore, it should be supplied with food or supplements. It should be mentioned, however, that vitamin C is also used very often in the agri-food sector. It is worth remembering that its properties can be applied on a wide scale, in many areas. Vitamin C is relatively stable in the dry state, and in aqueous solutions it is degraded under the influence of many different factors: pH, temperature, the presence of oxygen, the content of metal ions (Wechtersbach, 2007; Tavarini, 2008). In addition, water activity is a parameter that makes it possible to link the thermodynamic state of water in food products with their properties, quality and durability. Pure water has an activity equal to 1, whereas water-free product has a water activity equal to 0 (Lewicki, 2003). This is very important because fresh vegetables have a high value of water activity (up to 0.998) and are exposed to mold, yeast and bacteria (Kowczyk-Sadowy *et al.,* 2016).

Fruit and vegetables are quite different from each other in terms of the presence of vitamins and the content and activity of water in them (Seongeung et al. 2018). There is no one specific product on the market that would be the same source of all vitamins. Therefore, it is important to know which ones contain the most vitamins and what external or internal factors related to food processing are the main cause of their losses (Zych, 2012; Burdurlu, 2010; Tosum et. al 2008).

Therefore, the aim of the study was to determine the total vitamin C content and water activity in selected fruits and vegetables. The influence of technological processing (cooking and freezing) on the distribution of ascorbic acid was also assessed. The material for testing was lemons, cranberry, apple, red pepper, broccoli and sweet potatoes.

2. Materials and methods

2.1. Materials

In order to determine the content of vitamin C and water activity, fruit and vegetables (lemon, cranberry, apple, pepper, broccoli, sweet potato) were appropriately prepared and cut into small pieces (removing seeds and woody parts). Selected fruits and vegetables were tested: fresh, boiled for 15 minutes, stored at -16 °C for 1 week (without blanching).

2.2. Methods

2.2.1. Determination of vitamin (C) content

Determination of the total vitamin C content was done by Tillmans method, which consists in proper preparation of samples with oxalic acid. Then the obtained solution was titrated with 2,6-dichlorophenolindophenol. The titration was repeated three times. The content of ascorbic acid in mg·100g-1 of the product was calculated using the formula:

$$X_{vit.C} = \frac{V_{DCIP} \cdot V_{extract} \cdot C_{DCIP} \cdot 100}{m_{product} \cdot V_{sample}} \text{ [mg·100g}^{-1}\text{]} \text{ [1]}$$

where:

V_{DCIP} – volume of the 2,6-dichlorophenolindhenol solution used for the titration [cm^3]

$V_{extract}$ – ectract volume (in the experiment 100 cm^3) [cm^3]

C_{DCIP} – solution concentration 2,6-dichlorophenolindhenol [$mol \cdot dm^{-3}$]

m – weight of the product [g]

$V_{product}$ – volume of extract taken for titration [cm^3].

2.2.2. Determination of water activity

Water activities were determined using the AQUALAB apparatus. The biologically raw

material was transferred to the test chamber and the result was read. The final result was the average of three measurements made.

3.Results and discussions

3.1. The content of vitamin C in raw, cooked and frozen fruits and vegetables

The results of laboratory tests are presented in Table (1) and the content of vitamin C was summarized successively in raw, frozen and cooked fruits and vegetables.

According to the studies carried out, the highest content of vitamin C from fresh fruit is characterized by lemon (58.24 $mg \cdot 100g^{-1}$), while in fresh vegetables it is paprika (168 $mg \cdot 100g^{-1}$).

The raw materials were subjected to technological processes. Fruits and vegetables frozen for 1 week at a temperature of -15 ^{o}C, lost about 30% of the content of vitamin C, while cooked, more than 50% (fig. 1). It should be remembered that the time of cooking spills over the loss of vitamins. In this case it was 5 minutes. It can be concluded that ascorbic acid is a vitamin very sensitive to the influence of technological factors.

The content of vitamin C determined during the tests, using the Tillmans method, was similar to the results presented by other authors.

Table 1. The content of vitamin C in 100 g · mg-1 in the tested fruits and vegetables

Material	**Fresh raw material** [$mg \cdot 100g^{-1}$]	**Frozen raw material** [$mg \cdot 100g^{-1}$]	**Boiled raw material** [$mg \cdot 100g^{-1}$]
Lemon	58.24	38.64	26.04
Cranberry	35.42	23.8	14.48
Apple	16.24	10.64	6.02
Paprika	168	117.04	83.44
Broccoli	59.64	36.4	27.02
Sweet potato	12.04	7.84	3.64

Table 2. Water activity of selected fruits and vegetables

Material	**Fresh raw material**	**Frozen raw material**	**Boiled raw material**
Lemon	0.969	0.963	0.972
Cranberry	0.960	0.955	0.963
Apple	0.975	0.970	0.977
Paprika	0.974	0.963	0.976
Broccoli	0.972	0.966	0.975
Sweet potato	0.978	0.971	0.980

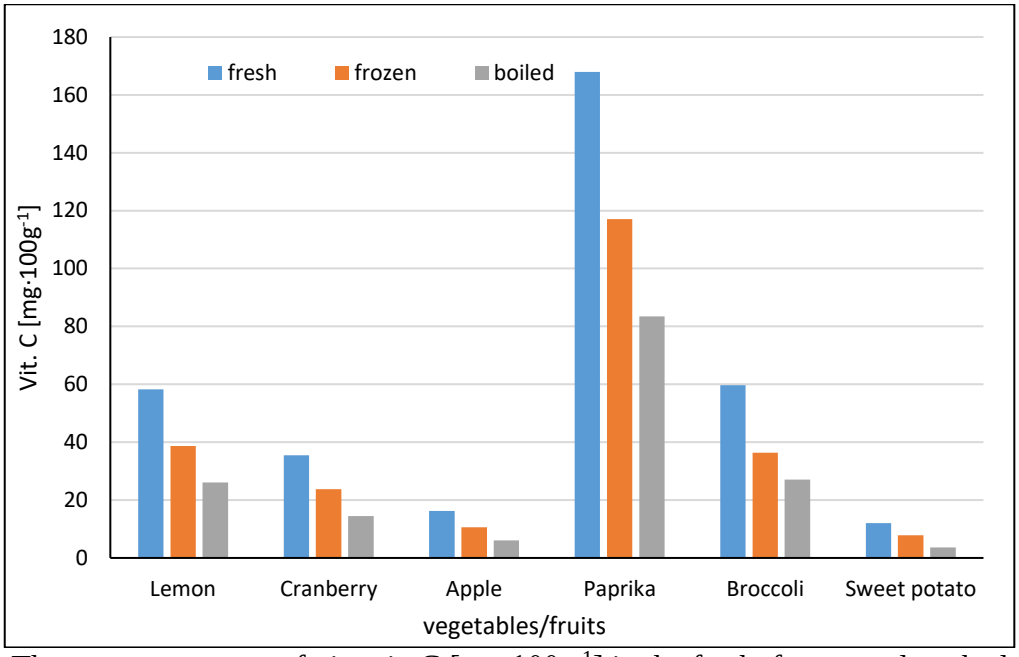

Figure 1. The average content of vitamin C [mg·100g^{-1}] in the fresh, frozen and cooked fruits and vegetables

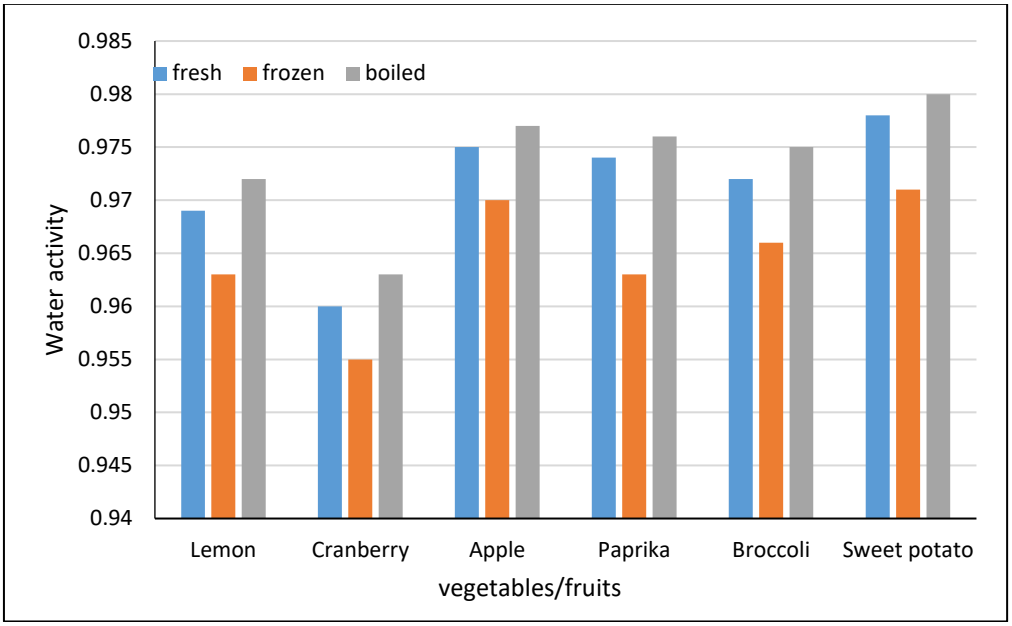

Figure 2. Water activity of fresh, frozen and boiled fruits and vegetables

Research conducted by Gawęcki (2010) indicates that the content of vitamin C in 100g of fresh fruit and vegetables is slightly lower than the results obtained by the authors of the work. Kunachowicz (2005) claims that the content of vitamin C 100g of apple is also much lower (9.2 mg). Gawęcki (2004) believes that through freezing, vitamin C decomposes from 25% to 40%, while cooking over 60%. The main factor determining the differences in the results obtained were the different species of fruit and vegetables tested.

3.2. Water activity in raw, cooked and frozen fruits and vegetables

According to the research carried out, the highest water activity is characteristic for boiled

fruits and vegetables, but comparing them with fresh ones, the difference is minimal (Tab. 2).

Water activity determines the course of chemical processes in food, especially the development of microorganisms. First of all, it influences the development and the ability to divide microorganisms and is one of the factors determining the intensification of chemical, physical and microbiological changes, which affects the storage stability of food (Peng et al 2007, Sinija and Mishra 2008). The higher the water activity, the greater the bacterial growth. The research shows that fresh and boiled raw materials are the most susceptible to the development of microorganisms. However, the most resistant to the influence of bacteria are frozen products.

4. Conclusions

Among vegetables, the highest content of vitamin was found in paprika, and sweet potatoes contained about 14 times less of this compound. The freezing process of raw materials, for one week at -16oC, significantly affected the breakdown of vitamin C in fruits and vegetables. In addition, studies have shown that the content of ascorbic acid decreased by approximately 30%. The process of short-term cooking also negatively affects the content of vitamin C. After examination, the content of ascorbic acid in cooked products has dropped by more than 60% compared to fresh fruit and vegetables. It should be noted that this loss is greater when the time of high temperature operation is longer. The highest activity of water was characterized by boiled fruits and vegetables, while the lowest was frozen. However, differences in fresh and cooked raw materials are insignificant.

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The lowest activity is shown by frozen raw materials (fig. 2).

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EFFECT OF HOUSEHOLD COOKING METHODS ON NUTRITIONAL VALUE OF COD AND SALMON- TWIN FILLET APPROACH

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ABSTRACT
The aim of this study was to determine the effect of fish culinary treatment on the retention of compounds beneficial for consumers' health, such as n-3 fatty acids and fat-soluble vitamins (A, D_3, and E), adopting "twin fillet" approach to avoid the influence of intraspecies variation. Two fish species (cod and salmon) and three types of culinary treatment (frying, baking, and steaming) were examined.
Out of the studied cooking methods, only frying significantly affected the fatty acid profile in the examined fish. In both species, the percentage of monounsaturated fatty acids increased, reducing the share of saturated and polyunsaturated fatty acids. The observed shifts in the fatty acid profile were greater in the case of cod. Varied scale of observed changes suggests that the effect of cooking on fish fatty acid profile depends not only on the type of treatment but is also species-specific. Vitamins A, D_3, and E proved to be stable during baking and steaming. Frying had a greater impact on investigated vitamins, especially for cholecalciferol, the content of which underwent a significant reduction in both fish.

1.Introduction

In light of the increasing number of lifestyle diseases, such as various forms of cancer, cardiovascular diseases, autoimmune diseases, diabetes, or allergies, attempts are being made to find ways to reduce the prevalence of these illnesses. Diet is considered to be one of the solutions. Fish are the food products with unquestionable nutritional values, related primarily to the presence of significant amounts of n-3 polyunsaturated fatty acids (PUFAs) (Marckmann and Grønbæk, 1999; Ruxton *et al.*, 2007) and fat-soluble vitamins A, D_3, and E (Brigelius-Flohé and Traber, 1999; Kim *et al.*, 2001; Cassani *et al.*, 2012; Holick, 2013). All these substances, necessary for the proper functioning of the human organism, are characterized by a high degree of unsaturation. This fact, together with the presence of activators such as heme proteins and trace metals in fish tissue, result in susceptibility to degradation. Such degradation may occur during thermal processing of fish.
Due to their health-promoting impact, fatty acids in fish have been extensively investigated. Regulska-Ilow and Ilow (2002) as well as Larsen *et al.* (2010) and Neff *et al.* (2014) state that the thermal treatment does not cause any significant changes in fatty acid profiles in herring and salmon. Also, Stołyhwo *et al.* (2006) reported no significant effect of heat treatment (smoking) on long-chain PUFAs in mackerel and sprat. In contrast, according to Türkkan *et al.* (2008), the thermal treatment results in significant changes in seabass composition of fatty acids. Therefore, as stated by Hui *et al.* (2012), reports on the effect of

thermal treatment on fatty acids are still ambiguous.

Significantly less attention has been devoted to the effect of thermal treatment on the content of fat-soluble vitamins. Vitamin A is considered to be stable under an inert atmosphere when heated, although oxygen may promote its degradation. According to Ersoy and Özeren (2009), grilling and frying cause an increase in vitamin A, whereas baking and microwave cooking result in a decrease of its content. The data on the stability of vitamin D in fish subjected to heat treatment are also limited, and as stated by Lešková *et al.* (2006), the reported results do not explicitly specify the effect of different cooking methods on the decomposition degree of vitamin D. Presumably, the level of vitamin D loss depends on the type of foodstuff and the heat process used (Jakobsen and Knuthsen, 2014). According to these authors, further studies are required for the optimization of culinary treatment to enhance the retention of vitamin D. In the case of vitamin E, due to its highly unsaturated structure and resulting antioxidant activity, one can expect little stability and thus considerable losses during heat treatment. However, the available research articles are characterized by a significant divergence: Bennink and Ono (1982) reported a 33%–44% loss of vitamin E during thermal processing of beef, whereas according to Piironen *et al.* (1987), this loss was only 5%. Gotoh *et al.* (2011) stated that cooking caused vitamin E losses proportional to the temperature used. Dias *et al.* (2003) reported a significant decrease in the vitamin E content in boiled or grilled gilthead and an increase in hake (cooked or fried), seabass and salmon (cooked and grilled), and bream (cooked, fried, or grilled). Also, Ersoy and Özeren (2009) reported an increase in the vitamin E content in African catfish during frying, baking, grilling, and microwaving.

As demonstrated above, the information on the impact of culinary treatment on fatty acids and, even more, on fat-soluble vitamins present in fish is still neither complete nor comprehensive. Mentioned ambiguity may be caused by strong intraspecies variation in the content of mentioned nutrients and shows the strong need for research planning, which allows to compare the content of nutrients (e.g., vitamins) in the very same fish samples before and after heat treatment (i.e., analyses of left and right fillets). Unfortunately, this approach has been seldom adopted. The aim of the study was to determine the effect of fish culinary treatment on the fatty acid profile and retention of fat-soluble vitamins (A, D_3, and E) adopting the "twin fillet" approach to avoid the influence of intraspecies variation during experiments.

2.Materials and methods

2.1.Sample preparation

The study material consisted of two fish species differing considerably in fat content: Baltic Sea cod (*Gadus morhua*) and farmed salmon (*Salmo salar*), purchased from supermarkets and fish market. All the fish were eviscerated and filleted; salmon samples were also skinned. To reduce the effect of intraspecies variation, the "twin fillet" approach was adopted – one fillet of each fish was randomly assigned as the control or experimental sample. Fish fillets were then homogenized in a mixer (Multi Processor, Zelmer) for approximately 60 s at 1300 rpm. The whole fish samples were freeze-dried in an Alpha 2–4 LSC freeze-drier (Christ). Two lots of the same species were handled separately for duplicate culinary experiments.

2.2.Culinary treatment

The effects of the three types of culinary fish processing, such as frying, baking, and steaming, were investigated. The processing conditions were as follows:

- Frying: Fillets of cod and salmon were pan-fried in deep oil (temp. 180^{o}C) on each side for 4 or 7 min, respectively; rapeseed oil was used as the frying medium.

- Baking: Fillets of cod and salmon wrapped in aluminum foil were baked in a gas oven at 200°C ± 10°C for 20 or 30 min, respectively.
- Steaming: Fillets of cod and salmon were steam cooked for 7 or 15 min, respectively.

Fatty acid profile and the content of fat-soluble vitamins (A, D_3, and E) were determined both in the samples subjected to the culinary treatment and in the control. All experiments were performed in duplicate. The rapeseed oil used during frying was also analyzed for the content of fatty acids and fat-soluble vitamins present.

The weights of raw and processed samples were recorded, and the cook loss was calculated as follows:

cook loss = [(raw sample weight – cooked sample weight) / raw sample weight] x100%

2.3. Chemical measurements

Dry matter and fat content were determined in all the samples studied according to the Polish standards and the methodology outlined in AOAC (1990) – dry matter was determined by drying samples in an oven at 105ºC for 8 h; fat content was determined gravimetrically after Soxhlet extraction with petroleum ether.

Fatty acids were determined in the total lipid fraction. Lipids were extracted with a hexane:acetone mixture (4:1, v/v) in Dionex ASE-350 Accelerated Solvent Extractor. The solvents were removed using a rotary evaporator under reduced pressure. Further analysis was carried out as described by Usydus *et al.* (2011), according to the validated procedure elaborated in the National Marine Fisheries Research Institute (NMFRI). Briefly, fatty acids were converted to the corresponding methyl esters (FAMEs), which were subsequently analyzed using an Agilent 6890N gas chromatograph equipped with a Restek Rt-2560 capillary column (100 m x 0.25 mm), coupled with flame ionization detector (FID). Identification and quantification of individual fatty acid esters were performed based on the retention times and peak areas of the standard mixture (37-Component FAME Mix, C18:4 n-3, and C22:5 n-3; Supelco). The content of the components was expressed as a percentage share of all the fatty acids determined. All assays were performed in duplicate.

Fat-soluble vitamins (A_1 – all-*trans*-retinol, D_3 – cholecalciferol, and E – α-tocopherol) were determined according to the validated procedure elaborated in the NMFRI as described by Usydus *et al.* (2009). Briefly, the freeze-dried samples were saponified with an aqueous KOH solution and neutralized, and vitamins were extracted with hexane. After solvent evaporation, the residue was dissolved in methanol. The final determination was performed by reversed-phase high performance liquid chromatography (Nucleosil 100–5 C18 column, Macherey-Nagel), coupled with UV detection for vitamin D_3 (λ= 265 nm) and fluorescence detection for vitamins A_1 (λex = 325 nm, λem = 480 nm) and E (λex = 295 nm, λem = 330 nm). The peaks were identified by comparing their retention times with those of the standards, and quantification was done using an external standard. All the sample analyses were performed in duplicate. The quality of the determination was assured by parallel analysis of the standard mixture prepared (vitamin A, and vitamin D_3 – Fluka; vitamin E – Sigma-Aldrich). The purity of the standards was verified using a Hach DR/4000 U spectrophotometer, by measuring the absorbance of standard solutions at a wavelength of 325 nm for vitamin A, 265 nm for vitamin D_3, and 292 nm for vitamin E. The concentration of the standard solutions was calculated based on the $E_{1cm}^{1\%}$ factor, which amounts to 1830 for all-*trans*-retinol, 76 for α-tocopherol, and 480 for cholecalciferol.

2.4. Nutrient retention analysis

Two types of retention of vitamins were calculated: apparent retention, ar (ratio of nutrient content in the cooked food to nutrient content in the raw food), and true retention, tr, which considers the weight of the food before and after cooking as well as the contents of the nutrient (Murphy *et al.*, 1975).

The following equations were used:
ar [%] = [nutrient content per gram of cooked fish (dry basis)]/[nutrient content per gram of raw fish (dry basis)] x100%
tr [%] = (nutrient content per gram of cooked fish x gram of fish after cooking)/(nutrient content per gram of raw fish x gram of fish before cooking) x100%

2.5. Statistical analysis

Statistical analysis was performed using Statistica, version 10.0 (StatSoft). As the experiments were carried out in duplicate, statistical dispersion (SD) was estimated based on the range and calculated as follows:
SD = *kr* x *R*
where *R* is the range and *kr* = 0.8862 for experiments carried out in duplicate.
To compare the profiles of fatty acids, hierarchical cluster analysis with agglomeration as a grouping method was used. To assess the significance of changes in the vitamin content during the cooking process, an independent samples *t*-test was performed, and $p < 0.05$ was considered statistically significant.

3.Results and discussions

3.1. Moisture and fat content

The moisture content in raw cod and salmon fillets varied from 80.20% to 82.57% and from 66.88% to 69.79%, respectively. In both the studied fish species, all types of heat treatment resulted in a statistically significant decrease in moisture content, with the largest effect observed in the fried cod. This was caused not only by water loss but also by absorption of the frying medium (rapeseed oil), as both of these effects result in an increase of dry matter and a consequent decrease of moisture percentage in the studied samples. Changes in moisture and fat content, and weight of the samples after cooking processes are presented in Table 1.

Table 1. Moisture and fat content of raw and cooked fillets together with cook loss observed during culinary treatment.

sample	moisture content (%)	average cook loss (%)	fat content (%)
C1 (raw cod)	82.58 [a]	37.74 ± 2.35	0.37
C1F (fried cod)	61.95 [b]		9.36
C4 (raw cod)	80.34 [a]		0.36
C4F (fried cod)	58.45 [b]		10.85
C2 (raw cod)	82.24 [a]	28.82 ± 1.77	0.38
C2B (baked cod)	77.13 [b]		0.33
C5 (raw cod)	80.20 [a]		0.34
C5B (baked cod)	73.93 [b]		0.27
C3 (raw cod)	81.38 [a]	20.86 ± 5.27	0.39
C3S (steamed cod)	78.06 [b]		0.36
C6 (raw cod)	80.62 [a]		0.35
C6S (steamed cod)	75.87 [b]		0.30
S1 (raw salmon)	66.88 [a]	32.44 ± 3.71	13.29
S1F (fried salmon)	49.63 [b]		20.83
S4 (raw salmon)	67.41 [a]		11.00
S4F (fried salmon)	55.73 [b]		15.76
S2 (raw salmon)	68.75 [a]	37.45 ± 1.87	11.05
S2B (baked salmon)	53.81 [b]		14.95
S5 (raw salmon)	69.79 [a]		13.10
S5B (baked salmon)	52.77 [b]		15.75
S3 (raw salmon)	69.30 [a]	16.51	10.34
S3S (steamed salmon)	65.50 [b]		8.50

S6 (raw salmon)	67.58 [a]	± 0.95	10.09
S6S (steamed salmon)	61.93 [b]		8.74

a,b - indexes represent statistically significant differences between the sample pairs before and after heat treatment ($p < 0.05$)

The fat content of the raw cod samples ranged from 0.34% to 0.39%, with the average value of 0.37% ± 0.02%. Due to the drip loss, both baking and steaming resulted in a decrease of fat content in the studied cod fillets. The reduction amounted to 16.87% ± 5.25% in case of baking and 10.99% ± 4.66% in case of steaming. As cook loss, related with moisture evaporation and water/oil drip, grows significantly with increasing temperature and treatment time (Kong *et al.*, 2007), greater decrease in fat content and greater loss of fillet weight were recorded during baking rather than steaming of cod. In case of pan-frying, lean cod fillets absorbed significant amounts of the frying medium, and fat content in the resulting product was on average nearly 28-fold higher than in the raw sample, and reached the value of 10.11% ± 1.32%.

Salmon fillets contained from 10.09% to 13.29% of fat (11.48% ± 1.38% on the average). Similarly as in case of cod, frying caused an increase in the fat content of salmon fillets, but due to the higher initial value, the change was smaller. Fried salmon contained 18.30% ± 4.49% fat, which was 1.5 times the initial value. Steamed salmon contained 8.62% ± 0.21% fat, which accounted for 84% of the raw salmon fat content. Higher (1.28-fold) fat retention was found in case of baked salmon, but most likely increased fat percentage was due to a significant increase in the samples' dry matter content.

During heat treatment of fish fillets, many processes of mass exchange occur, probably the most significant being the moisture loss (evaporation and/or drip loss), solids loss (drip containing lipids, collagen, fragments of muscle tissue, and coagulated sarcoplasmic proteins (Kong *et al.*, 2007)), and sometimes solids gain (e.g., during frying). Although these changes differ in magnitude, as well as direction, depending on the fish species and the cooking method applied, a statistically significant correlation between moisture loss and overall cook loss was observed (Figure 1). The Pearson coefficient of 0.86 indicates that the correlation is high and explains 74% of variation ($r^2 = 0.74$).

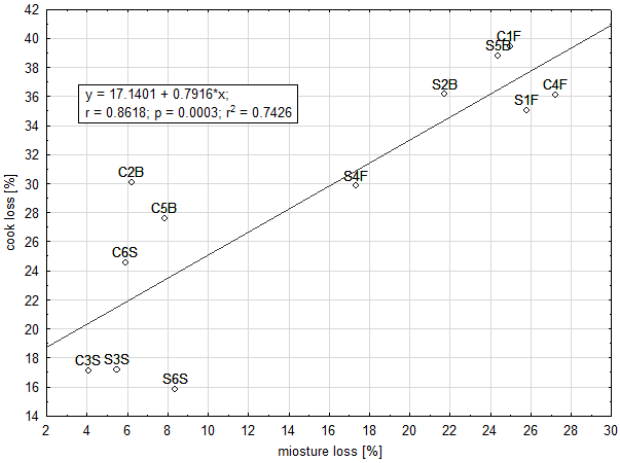

Figure 1. Correlation between cook loss and moisture loss during culinary treatment in cod and salmon fillets; explanation of used symbols in Table 1.

3.2. Fatty acids

In the lipids extracted from raw cod fillets, polyunsaturated fatty acids (PUFAs) were the most abundant (57.4% on average), followed by saturated fatty acids (SFAs) and monounsaturated fatty acids (MUFAs), which accounted for 26.8% and 15.8% of the total fatty acids, respectively. Similar results, especially regarding the percentage of PUFAs, were presented by Gladyshev *et al.* (2007) - the content of SFAs, MUFAs, and PUFAs in cod amounted to 27.9%, 15.0%, and 57.1%, respectively. Among the fatty acids present in the cod fillet lipids, docosahexaenoic acid – C22:6 n-3 was predominant (40.92%), followed by palmitic acid – C16:0 (18.8%), oleic acid – C18:1 n-9c (10.7%), and eicosapentaenoic acid – C20:5 n-3 (5.08%). The available literature

data also point at C22:6 n-3, C16:0, C18:1 n-9c, and C20:5 n-3 acids as dominating in cod lipids. However, the proportions of C20:5 n-3 presented by other authors (Brandsen *et al.*, 2005; Gladyshev *et al.*, 2007; Jensen *et al.*, 2013) are higher (11.9%–16.0%) than those observed in our work.

The proportions of fatty acids present in salmon lipids differed noticeably from those in cod. Salmon lipids consisted mainly of monoene acids (50.2%), whereas the content of SFA and PUFA amounted, respectively, to 15.1% and 34.6% of the total fatty acids. These results differed from those observed for the Baltic salmon (Usydus *et al*., 2011), in which PUFAs were dominant. Among the fatty acids present in salmon fillet lipids, the most abundant was oleic acid (C18:1 n-9c), the percentage share of which was nearly 43% of the total fatty acids and over 85% of MUFAs. The second most abundant was linoleic acid, which constituted nearly 15% of the total fatty acids and 43% of PUFAs. The results of this study are in agreement with a general statement that the n-6/n-3 ratio is lower in the lipids of wild fish than in those of farmed fish (Usydus *et al.*, 2011). It is known that the fish lipid profile reflects the composition of the diet (Bell *et al.*, 2002; Torstensen *et al.*, 2005; Martinez *et al.*, 2009), and according to Martinez *et al.* (2009), the commercial fish feed contains variable, and sometimes high, amounts of vegetable oils that are not present in the diet of wild living fish. Therefore, it can be presumed that the feed supplemented with a vegetable oil is the source of such substantial amounts of oleic and linoleic acids in the tested salmon.

Changes in cod and salmon fillets' fatty acid profiles after three types of heat treatment such as frying, baking, and steaming are presented in Tables 2 and 3. Steaming and baking proved to affect the profile of cod fatty acids insignificantly, only very slightly increasing SFAs and MUFAs, while decreasing the PUFA content. Also in case of salmon fillets, steaming and baking only marginally changed the percentage of fatty acids. Baking slightly increased the content of salmon SFAs, whereas steaming did not cause any change. The percentage of MUFAs decreased a little during both baking and steaming. As a result, the content of PUFAs increased by less than 0.6% during baking and steaming.

Table 2. Fatty acid composition of raw and cooked cod fillets

fatty acids (%)	Frying medium	cod 1 raw	cod 1 fried	cod 4 raw	cod 4 fried	cod 2 raw	cod 2 baked	cod 5 raw	cod 5 baked	cod 3 raw	cod 3 steamed	cod 6 raw	cod 6 steamed
C13:0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
C14:0	nd	0.6±0.0	0.1±0.0	0.7±0.2	0.1±0.0	0.8±0.0	0.8±0.0	0.8±0.0	0.9±0.0	0.8±0.0	0.8±0.0	0.8±0.1	0.8±0.0
C15:0	nd	0.2±0.0	nd	0.4±0.1	nd	0.2±0.0	0.2±0.0	0.3±0.0	0.3±0.0	0.3±0.0	0.3±0.0	0.3±0.0	0.3±0.0
C16:0	4.5±0.0	18.8±0.8	4.9±0.0	17.8±2.0	4.9±0.0	18.5±0.1	18.9±0.1	18.9±0.1	20.7±0.2	19.8±0.1	20.0±0.1	18.8±1.2	20.0±0.2
C17:0	nd	0.4±0.0	nd	0.6±0.4	nd	0.3±0.0	0.3±0.0	0.5±0.0	0.4±0.0	0.3±0.0	0.3±0.0	0.4±0.0	0.4±0.0
C18:0	1.8±0.0	6.4±0.3	1.9±0.0	6.3±0.8	1.9±0.0	6.1±0.2	6.3±0.1	6.3±0.1	6.8±0.1	6.0±0.1	6.1±0.1	6.4±0.3	6.9±0.2
C20:0	0.5±0.0	nd	0.6±0.1	0.1±0.1	0.5±0.0	0.1±0.0	nd	nd	0.1±0.0	nd	nd	nd	0.1±0.0
C21:0	nd	nd	nd	0.2±0.1	nd	nd	nd	0.1±0.0	nd	nd	nd	0.1±0.1	nd
C22:0	0.3±0.0	0.1±0.1	0.3±0.0	0.2±0.1	0.3±0.0	0.1±0.0	0.1±0.0	0.1±0.1	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.1
C23:0	nd	nd	nd	0.2±0.1	nd	nd	nd	0.1±0.0	nd	nd	nd	nd	nd
C24:0	0.4±0.0	0.1±0.3	0.4±0.0	nd	0.3±0.0	nd	nd	nd	0.1±0.0	nd	nd	nd	0.1±0.0
Σ SFA	**7.6±0.0**	**26.6±1.3**	**8.2±0.0**	**26.5±2.1**	**8.0±0.1**	**26.1±0.3**	**26.6±0.2**	**27.1±0.3**	**29.4±0.1**	**27.3±0.2**	**27.6±0.2**	**26.9±1.4**	**28.7±0.4**
C14:1n-5	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
C15:1n-5	nd	0.1±0.1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
C16:1n-7	0.2±0.0	1.4±0.1	0.2±0.0	1.2±0.3	0.2±0.0	1.4±0.1	1.5±0.1	1.2±0.0	1.2±0.1	1.8±0.0	1.9±0.0	1.2±0.2	1.2±0.0
C17:1n-7	nd	5.2±2.4	0.1±0.0	3.8±1.8	0.1±0.0	0.8±0.1	0.8±0.0	1.7±0.4	0.7±0.2	0.7±0.1	0.7±0.0	1.4±0.1	0.8±0.0
C18:1n-9t	nd	0.1±0.1	nd	0.3±0.0	nd	0.1±0.0	nd	nd	nd	0.1±0.0	0.1±0.0	0.1±0.1	nd
C18:1n-9c	60.8±0.1	10.5±0.4	60.0±0.1	10.8±0.4	59.2±0.2	11.9±0.2	12.8±0.1	10.3±0.3	11.3±0.0	10.5±0.1	11.9±0.0	10.0±0.2	10.7±0.1
C20:1n-9	0.9±0.0	0.6±0.1	0.8±0.0	0.7±0.3	0.2±0.0	0.6±0.0	0.7±0.0	0.5±0.1	0.4±0.0	0.6±0.1	0.7±0.1	0.3±0.2	0.4±0.4
C22:1n-9	0.3±0.0	0.2±0.0	0.3±0.0	0.2±0.1	0.3±0.0	0.1±0.0	0.2±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.2±0.0	0.1±0.0
C24:1n-9	0.1±0.0	0.6±0.0	0.2±0.1	0.9±0.1	0.2±0.0	0.5±0.1	0.8±0.0	0.8±0.1	0.8±0.0	0.5±0.0	0.7±0.0	0.8±0.0	0.9±0.0
Σ MUFA	**62.3±0.1**	**18.7±2.0**	**61.6±0.1**	**17.9±1.5**	**60.2±0.2**	**15.4±0.1**	**16.8±0.1**	**14.6±0.4**	**14.5±0.1**	**14.3±0.2**	**16.1±0.1**	**14.0±0.4**	**14.1±0.2**
C18:2n-6t	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
C18:n-6c	19.7±0.0	1.7±0.1	19.0±0.0	2.4±0.1	19.4±0.1	2.2±0.0	2.1±0.0	2.0±0.1	2.0±0.0	1.5±0.0	1.6±0.0	1.8±0.0	2.2±0.1
C18:3n-6	nd	nd	nd	nd	nd	nd	nd	0.1±0.1	nd	nd	nd	0.1±0.0	nd
C18:3n-3	10.3±0.0	0.8±0.1	9.7±0.0	1.7±0.3	11.4±0.0	0.9±0.0	0.9±0.0	1.4±0.1	1.5±0.0	0.7±0.0	0.8±0.0	1.2±0.2	1.6±0.0

C18:4n-3	nd	0.3±0.1	nd	0.6±0.2	nd	0.2±0.0	0.2±0.0	0.4±0.0	0.5±0.0	0.2±0.0	0.3±0.0	0.6±0.1	0.6±0.0
C20:2n-6	0.1±0.0	0.8±0.2	0.1±0.0	1.1±0.3	0.1±0.0	0.7±0.0	0.7±0.0	0.6±0.0	0.8±0.0	0.6±0.0	0.7±0.0	0.9±0.0	0.8±0.0
C20:3n-6	nd	nd	nd	0.2±0.2	nd	nd	nd	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0
C20:3n-3	nd	0.3±0.1	nd	0.4±0.3	nd	0.2±0.0	0.2±0.0	0.3±0.0	0.3±0.0	0.2±0.0	0.2±0.0	0.4±0.2	0.3±0.0
C20:4n-6	nd	3.8±0.1	0.1±0.0	2.5±0.1	nd	3.8±0.0	3.6±0.0	2.7±0.1	2.8±0.0	4.4±0.0	4.2±0.0	2.6±0.3	2.5±0.1
C22:2n-6c	nd	nd	nd	0.2±0.1	nd	nd	nd	0.1±0.0	nd	nd	nd	nd	nd
C20:5n-3	nd	5.0±0.1	0.1±0.0	4.7±0.4	0.1±0.0	4.8±0.1	4.4±0.1	5.4±0.2	5.0±0.0	5.5±0.1	5.1±0.1	5.2±0.1	4.8±0.0
C22:5n-3	nd	3.7±0.0	0.1±0.0	3.0±0.7	nd	3.2±0.0	3.2±0.0	3.2±0.0	2.7±0.0	4.4±0.0	4.2±0.1	3.0±0.1	2.3±0.1
C22:6n-3	nd	38.3±0.5	1.1±0.1	38.8±1.2	0.8±0.0	42.5±0.3	41.3±0.3	42.0±0.5	40.4±0.2	40.8±0.3	39.1±0.1	43.2±0.6	42.0±0.6
Σ PUFA	**30.1±0.0**	**54.7±0.7**	**30.2±0.1**	**55.6±3.5**	**31.8±0.2**	**58.5±0.4**	**56.6±0.4**	**58.3±0.6**	**56.1±0.1**	**58.4±0.4**	**56.3±0.1**	**59.1±1.1**	**57.2±0.5**
n-6	19.8±0.0	6.3±0.0	19.2±0.0	6.4±0.7	19.5±0.1	6.7±0.0	6.4±0.1	5.6±0.2	5.7±0.0	6.6±0.0	6.6±0.0	5.5±0.3	5.6±0.1
n-3	10.3±0.0	48.4±0.7	11.0±0.1	49.2±2.8	12.3±0.2	51.8±0.4	50.2±0.3	52.7±0.8	50.4±0.1	51.8±0.4	49.7±0.2	53.6±0.8	51.6±0.5
n-6/n-3	1.9±0.0	0.13±0.00	1.75±0.02	0.13±0.01	1.59±0.01	0.13±0.00	0.13±0.00	0.11±0.00	0.11±0.00	0.13±0.00	0.13±0.00	0.10±0.00	0.11±0.00

Table 3. Fatty acid composition of raw and cooked salmon fillets

fatty acids (%)	frying medium	salmon 1 raw	salmon 1 fried	salmon 4 raw	salmon 4 fried	salmon 2 raw	salmon 2 baked	salmon 5 raw	salmon 5 baked	salmon 3 raw	salmon 3 steamed	salmon 6 raw	salmon 6 steamed
C13:0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
C14:0	nd	2.8±0.1	1.9±0.0	2.5±0.1	1.9±0.1	2.6±0.1	2.5±0.0	2.5±0.0	2.5±0.1	2.5±0.0	2.5±0.0	2.6±0.0	2.6±0.0
C15:0	nd	0.1±0.0	0.1±0.0	0.1±0.1	0.1±0.0	0.1±0.1	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.1	0.2±0.0	0.2±0.0
C16:0	4.4±0.5	10.1±0.0	8.4±0.1	8.6±0.0	7.5±0.0	9.3±0.1	9.3±0.1	8.9±0.0	9.0±0.1	8.6±0.0	8.6±0.1	9.2±0.0	9.2±0.0
C17:0	nd	0.1±0.1	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0
C18:0	1.7±0.1	2.5±0.0	2.3±0.1	2.5±0.0	2.3±0.0	2.6±0.0	2.6±0.0	2.4±0.0	2.4±0.0	2.4±0.1	2.4±0.0	2.5±0.0	2.5±0.0
C20:0	0.6±0.1	0.3±0.0	0.4±0.0	0.3±0.0	0.4±0.0	0.3±0.0	0.3±0.0	0.3±0.0	0.3±0.0	0.3±0.0	0.3±0.0	0.3±0.0	0.3±0.0
C21:0	nd	nd	nd	nd	nd	nd	0.1±0.0	nd	nd	nd	nd	nd	nd
C22:0	0.4±0.0	0.2±0.0	0.2±0.0	0.1±0.0	0.2±0.0	0.1±0.1	0.2±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.2±0.0	0.2±0.0	0.2±0.0
C23:0	nd	nd	nd	0.1±0.1	nd	nd	nd	nd	nd	nd	nd	nd	nd
C24:0	nd	0.2±0.0	0.3±0.1	0.2±0.1	0.2±0.0	0.2±0.0	0.2±0.0	0.1±0.1	0.1±0.1	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0
Σ SFA	**7.1±0.5**	**16.2±0.1**	**13.7±0.1**	**14.5±0.1**	**12.7±0.2**	**15.3±0.1**	**15.5±0.1**	**14.6±0.0**	**14.7±0.2**	**14.4±0.0**	**14.5±0.0**	**15.3±0.0**	**15.3±0.0**
C14:1n-5	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
C15:1n-5	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
C16:1n-7	nd	3.0±0.1	2.1±0.0	2.7±0.0	2.0±0.0	2.8±0.0	2.7±0.1	2.8±0.1	2.9±0.0	2.8±0.1	2.8±0.1	2.8±0.0	2.8±0.0
C17:1n-7	nd	nd	0.1±0.0	0.1±0.0	0.1±0.0	nd	nd	nd	nd	nd	nd	nd	nd
C18:1n-9t	nd	0.2±0.0	0.2±0.0	0.1±0.1	0.1±0.0	0.1±0.0	0.1±0.0	0.2±0.0	0.2±0.0	0.1±0.0	0.1±0.0	0.1±0.1	0.2±0.0
C18:1n-9c	59.9±0.0	43.0±0.3	48.4±0.3	43.4±0.3	47.9±0.0	42.3±0.0	42.1±0.2	42.6±0.2	42.5±0.1	43.0±0.1	42.7±0.0	42.3±0.2	42.1±0.2
C20:1n-9	0.9±0.0	3.1±0.1	2.2±0.2	3.9±0.1	3.0±0.1	3.7±0.1	3.8±0.2	3.4±0.4	3.1±0.1	3.4±0.1	3.4±0.2	3.5±0.1	3.5±0.0
C22:1n-9	0.3±0.2	0.6±0.0	0.5±0.0	0.6±0.0	0.5±0.0	0.6±0.0	0.6±0.0	0.6±0.0	0.5±0.0	0.6±0.0	0.5±0.1	0.6±0.0	0.6±0.0
C24:1n-9	0.3±0.1	0.4±0.0	0.3±0.0	0.4±0.0	0.3±0.0	0.4±0.0	0.4±0.0	0.4±0.0	0.3±0.0	0.3±0.0	0.3±0.0	0.4±0.1	0.4±0.1
Σ MUFA	**61.4±0.2**	**50.3±0.1**	**53.8±0.1**	**51.2±0.1**	**53.9±0.1**	**49.9±0.1**	**49.7±0.3**	**50.0±0.6**	**49.5±0.1**	**50.2±0.1**	**49.8±0.2**	**49.7±0.1**	**49.6±0.1**
C18:2n-6t	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
C18:2n-6c	19.7±0.4	14.6±0.0	16.1±0.2	14.8±0.1	16.0±0.1	14.5±0.1	14.4±0.1	14.9±0.1	15.0±0.1	15.2±0.0	15.2±0.0	14.7±0.0	14.6±0.0
C18:3n-6	nd	0.1±0.0	0.1±0.0	0.1±0.1	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0
C18:3n-3	11.4±0.2	6.3±0.1	7.6±0.1	6.0±0.1	7.1±0.1	6.2±0.0	6.2±0.3	6.5±0.7	6.8±0.1	6.3±0.1	6.5±0.2	6.4±0.0	6.4±0.1
C18:4n-3	nd	0.5±0.1	0.3±0.0	0.4±0.0	0.3±0.0	0.5±0.0	0.4±0.0	0.5±0.0	0.5±0.0	0.5±0.0	0.5±0.0	0.5±0.1	0.5±0.0
C20:2n-6	nd	1.9±0.2	1.3±0.0	2.3±0.0	1.7±0.0	2.5±0.0	2.5±0.0	2.1±0.0	2.1±0.0	2.1±0.0	2.1±0.0	2.4±0.1	2.3±0.1
C20:3n-6	nd	0.2±0.0	0.1±0.0	0.2±0.1	0.2±0.0	0.3±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.3±0.0	0.3±0.0	0.2±0.0	0.2±0.0
C20:3n-3	nd	0.7±0.1	0.5±0.0	0.8±0.0	0.5±0.0	0.8±0.0	0.8±0.0	0.7±0.0	0.7±0.0	0.7±0.0	0.7±0.1	0.7±0.0	0.7±0.1
C20:4n-6	nd	0.2±0.1	0.2±0.0	0.3±0.1	0.2±0.0	0.2±0.0	0.2±0.0	0.3±0.0	0.3±0.0	0.2±0.0	0.2±0.0	0.2±0.0	0.2±0.0
C22:2n-6c	nd	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0	0.1±0.0
C20:5n-3	nd	1.3±0.0	0.9±0.0	1.1±0.0	0.8±0.0	1.2±0.0	1.2±0.0	1.3±0.1	1.3±0.0	1.2±0.0	1.2±0.0	1.1±0.0	1.2±0.0
C22:5n-3	nd	3.3±0.0	2.3±0.1	3.8±0.1	2.8±0.0	3.4±0.1	3.5±0.0	3.4±0.0	3.4±0.0	3.8±0.1	3.8±0.0	3.6±0.0	3.6±0.1
C22:6n-3	nd	4.3±0.1	3.0±0.1	4.4±0.1	3.6±0.0	5.0±0.1	5.2±0.1	5.3±0.2	5.3±0.0	4.9±0.0	5.0±0.0	5.0±0.0	5.2±0.0
Σ PUFA	**31.2±0.6**	**33.5±0.3**	**32.5±0.2**	**34.3±0.0**	**33.4±0.0**	**34.8±0.0**	**34.8±0.3**	**35.4 ±0.5**	**35.8±0.1**	**35.4±0.1**	**35.7±0.1**	**35.0±0.0**	**35.1±0.2**
n-6	19.7±0.4	17.1±0.2	17.9±0.2	17.8±0.0	18.3±0.0	17.7±0.1	17.5±0.1	17.7±0.2	17.8±0.1	18.0±0.0	18.0±0.0	17.7±0.1	17.5±0.2
n-3	11.4±0.2	16.4±0.1	14.6±0.3	16.5±0.0	15.1±0.0	17.1±0.1	17.3±0.3	17.7±0.5	18.0±0.0	17.4±0.2	17.7±0.2	17.3±0.0	17.6±0.1
n-6/n-3	1.7±0.0	1.04±0.01	1.22±0.35	1.08±0.00	1.21±0.00	1.04±0.02	1.01±0.01	1.00±0.02	0.99±0.00	1.03±0.02	1.02±0.01	1.02±0.00	0.99±0.02

Larger changes occurred as a result of pan-frying. In case of cod, a significant (more than threefold) increase in the percentage of MUFAs was observed, whereas the proportion of SFAs and PUFAs decreased substantially (from 26.5% to 8.1% and from 55.2% to 31.0%, respectively). The most abundant fatty acids in fried cod were oleic acid (C18:1 n-9c), linoleic

acid (C18:2 n-6), α-linolenic acid (C18:3 n-3), and palmitic acid (C16:0). The percentage of these fatty acids in fried cod fillets reflected almost exactly their content in rapeseed oil (C18:1 n-9c – 60.4%, C18:2 n-6 – 19.7%, C18:3 n-3 – 10.9%, and C16:0 – 4.5%), which was used as the frying medium. Changes observed for salmon were not as prominent as in case of cod. One of the reasons for a more modest effect of salmon frying was smaller absorption of the frying medium, resulting from the fact that salmon is much fatter than cod. Salmon fillets absorbed rapeseed oil in an amount corresponding to 50% of fillets' initial fat content, whereas cod absorbed 27 times more oil than it initially contained. Another reason for less significant changes in salmon fatty acid composition after frying was the initial high content of oleic, linoleic, α-linolenic, and palmitic acids. As a result, the percentage of MUFAs increased only by 3.1 percentage points (from 50.7% to 53.8%) whereas the proportions of SFAs and PUFAs decreased from 15.4% to 13.2%, and from 33.9% to 33.0%, respectively. Obviously, an absorption of the frying medium influenced the n-6/n-3 proportion, which rose from 0.11 to 1.66 and from 1.06 to 1.21 in case of cod and salmon, respectively. The n-6/n-3 ratio in the Western diet is estimated to be 15–17/1, whereas it would be desirable to reduce it to 5–2/1 (Simopoulos, 2008). Although the n-6/n-3 ratio in fried cod is 15 times greater than that in raw fish, it is still quite low and therefore, the consumption of fried fish can still have a beneficial effect on the ratio of n-6/n-3 fatty acids in our diet.

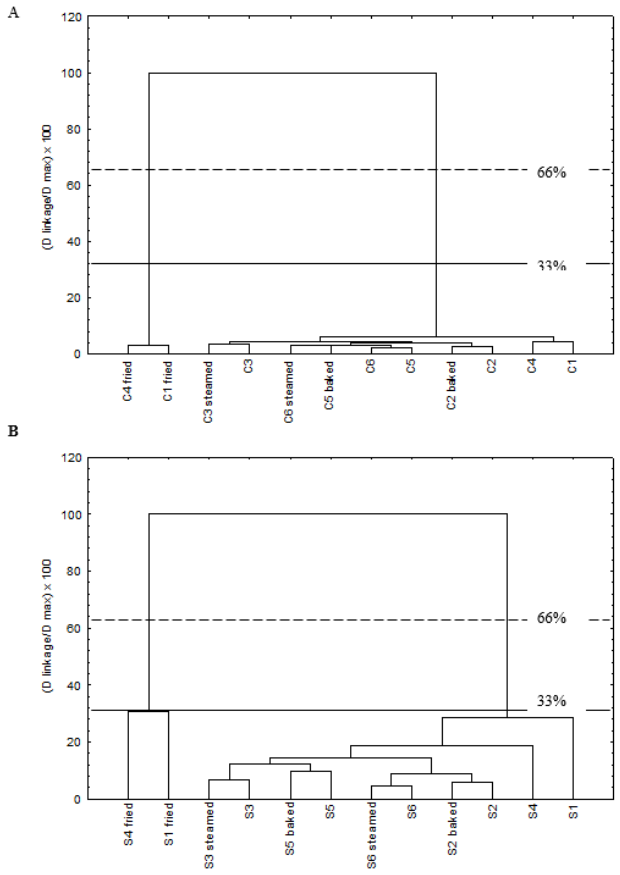

Figure 2. Cluster analysis tree diagram obtained for fatty acids present in the oils from raw and heat-treated cod (A) and salmon (B) fillets.

To determine the significance of changes observed during cod and salmon culinary treatment, cluster analysis with the agglomeration as a method of grouping was used (Figure 2). To assess the number of significant clusters, Sneath criterion was used on two levels – less (66%) and more (33%) restrictive. The use of both options led to the same conclusion, namely, that in the group of tested cod/salmon samples, there are two clearly distinguishable groups of similarity: the first group comprising the raw, steamed, and baked fillets, and the second group comprising the pan-fried ones. This proves that shifts in acid profiles observed in the processes of steaming and baking can be considered negligible. Although Regulska-Ilow and Ilow (2002) as well as Gladyshev *et al.* (2007) and

Neff *et al.* (2014) state that frying does not cause any significant changes in fish fatty acid profile, Türkkan *et al.* (2008) claim the opposite. They suggest that cooking considerably affected the seabass fatty acid composition, and among culinary treatments such as frying, baking, and microwave cooking, frying proved to cause the highest losses of n-3 PUFAs and a significant increase in the n-6/n-3 ratio. In turn, Larsen *et al.* (2010) found that poaching, steaming, baking, microwave cooking, panfrying, and deep oil frying did not cause any significant changes in king salmon fatty acid profiles, although frying in deep oil exerted the greatest influence and unfavorably altered the n-6/n-3 ratio. Our results are consistent with those presented by Weber *et al.* (2008), according to whom boiling and baking only marginally changed the fatty acid profile of the silver catfish, whereas frying exerted a significant influence. Also Garcia-Arias *et al.* (2003) dealing with sardine and Schneedorferová *et al.* (2015) dealing with carp, pike, herring, and cod pointed that oven-baking as heat treatment ensured the preservation of PUFAs, whereas pan-frying seemed to be the most harmful. Ambiguity and inconsistency of these reports, as well as varied scale of changes observed in our work for two studied fish species, support the conclusion drawn by Schneedorferová *et al.* (2015), suggesting that the effect of cooking on fish fatty acid profile depends not only on the type of treatment but is also species-specific. Present study allows to conclude that not only fish species but also fish diet can modify the effect of cooking (especially frying) as it influences initial lipid profile of the fish. Another reason for the above-mentioned variation of results presented by researchers most probably is the intraspecies variation that was not eliminated during sampling procedure. As fatty acid profiles may vary among particular fish due to feeding conditions, it is extremely important to eliminate this factor by adopting "twin fillet" approach.

3.3. Fat-soluble vitamins

Fat-soluble vitamins (A, D_3, and E) were determined in both raw and cooked samples of cod and salmon. The content of all studied vitamins in raw samples varied noticeably. The content of vitamin A (Table 4) in raw samples varied from 29.40 to 61.82 ng/g of cod fillet and from 76.42 to 118.08 ng/g of salmon fillet. Vitamin D_3 in the raw cod samples varied from 14.75 to 18.25 ng cholecalciferol/g of fillet (Table 5). Raw salmon samples demonstrated a significant variability in vitamin D_3 content – it ranged from 18.72 to 73.76 ng/g of fillet. Raw cod and salmon contained 9.68 ± 1.31 and 35.11 ± 4.56 μg of vitamin E/g of fillet, respectively (Table 6).

Table 4. Vitamin A in cod and salmon fillets before and after culinary treatment

sample	vitamin A (μg/g dry matter)	SD	vitamin A (ng/g fresh weight)	SD	fillet weight (g)	average ar (%)	average tr (%)
C1 (raw cod)	0.222 [a]	0.011	38.70 [a]	1.85	1152.0	79.03 ± 0.45	105.98 ± 0.76
C1F (fried cod)	0.176 [b]	0.011	66.97 [b]	4.04	701.9		
C4 (raw cod)	0.212 [a]	0.009	41.68 [a]	1.74	821.2		
C4F (fried cod)	0.167 [b]	0.002	69.39 [b]	0.74	525.4		
C2 (raw cod)	0.166	0.019	29.40	3.31	1264.9	84.29 ± 3.12	78.07 ± 5.01
C2B (baked cod)	0.137	0.002	31.33	0.41	884.6		
C5 (raw cod)	0.215	0.055	42.37	10.88	1340.2		
C5B (baked cod)	0.185	0.006	48.12	1.62	963.0		
C3 (raw cod)	0.332	0.007	61.82	1.32	1486.2	94.63 ±	
C3S (steamed cod)	0.307	0.016	67.36	3.50	1231.6		

C6 (raw cod)	0.312	0.003	60.37	0.51	1406.3	3.83	90.69 ± 0.56
C6S (steamed cod)	0.302	0.025	72.87	5.99	1061.2		
S1 (raw salmon)	0.357	0.042	118.08 [a]	13.80	718.4	86.90 ± 2.11	84.29 ± 0.47
S1F (fried salmon)	0.306	0.008	153.88 [b]	4.02	466.5		
S4 (raw salmon)	0.235	0.015	76.42	4.91	724.7		
S4F (fried salmon)	0.207	0.043	91.42	19.22	508.6		
S2 (raw salmon)	0.265	0.022	82.66 [a]	6.92	651.3	100.83 ± 7.50	95.89 ± 6.63
S2B (baked salmon)	0.256	0.022	118.02 [b]	10.24	416.0		
S5 (raw salmon)	0.257	0.008	77.49 [a]	2.41	547.3		
S5B (baked salmon)	0.270	0.017	127.29 [b]	7.95	335.1		
S3 (raw salmon)	0.253 [a]	0.007	77.67 [a]	2.18	674.8	106.54 ± 3.83	102.18 ± 1.41
S3S (steamed salmon)	0.275 [b]	0.004	94.88 [b]	1.22	558.9		
S6 (raw salmon)	0.274	0.029	88.67	9.48	775.1		
S6S (steamed salmon)	0.286	0.033	108.69	12.48	652.4		
oil before frying (µg vit A/g oil)	< 0.02	-			-	-	-
oil after frying (µg vit A/g oil)	< 0.02	-			-		

a,b - indexes represent statistically significant differences between the sample pairs before and after heat treatment ($p < 0.05$)

Table 5. Vitamin D_3 in cod and salmon fillets before and after culinary treatment

sample	vitamin D_3 (µg/g dry matter)	SD	vitamin D_3 (ng/g fresh weight)	SD	fillet weight (g)	average ar (%)	average tr (%)
C1 (raw cod)					1152.0	22.74 ± 9.32	30.56 ± 10.33
C1F (fried cod)	0.018 [b]	0.002	6.85 [b]	0.67	701.9		
C4 (raw cod)	0.075 [a]	0.000	14.75 [a]	0.00	821.2		
C4F (fried cod)	0.021 [b]	0.005	8.73 [b]	0.19	525.4		
C2 (raw cod)	0.087	0.003	15.37	0.47	1264.9	101.07 ± 4.23	93.58 ± 0.62
C2B (baked cod)	0.090	0.010	20.47	2.23	884.6		
C5 (raw cod)	0.076	0.013	14.95	2.63	1340.2		
C5B (baked cod)	0.075	0.007	19.56	1.84	963.0		
C3 (raw cod)	0.098	0.004	18.25 [a]	0.66	1486.2	106.95 ± 3.27	102.44 ± 0.25
C3S (steamed cod)	0.103	0.007	22.60 [b]	1.56	1231.6		
C6 (raw cod)	0.091	0.001	17.54 [a]	0.18	1406.3		
C6S (steamed cod)	0.099	0.008	23.77 [b]	1.92	1061.2		
S1 (raw salmon)	0.057 [a]	0.012	18.72 [a]	3.82	718.4	25.57 ± 4.89	24.43 ± 3.64
S1F (fried salmon)	0.013 [b]	0.003	6.30 [b]	1.34	466.5		
S4 (raw salmon)	0.120 [a]	0.000	39.11 [a]	0.00	724.7		
S4F (fried salmon)	0.034 [b]	0.002	15.05 [b]	0.78	508.6		
S2 (raw salmon)	0.236	0.039	73.76	12.19	651.3	78.46 ± 6.64	74.42 ± 4.22
S2B (baked salmon)	0.194	0.015	89.38	6.96	416.0		
S5 (raw salmon)	0.174	0.012	52.42	3.48	547.3		
S5B (baked salmon)	0.130	0.019	61.16	8.79	335.1		

S3 (raw salmon)	0.196	0.006	60.02	1.91	674.8	100.22 ± 4.91	96.24 ± 7.83
S3S (steamed salmon)	0.191	0.012	65.73	3.98	558.9		
S6 (raw salmon)	0.167	0.032	54.15	10.34	775.1		
S6S (steamed salmon)	0.172	0.028	65.48	10.79	652.4		
oil before frying (µg wit D_3/g oil)	< 0.02	-	-	-	-	-	-
oil after frying (µg wit D_3/g oil)	< 0.02	-	-	-	-		

a,b - indexes represent statistically significant differences between the sample pairs before and after heat treatment ($p < 0.05$)

Table 6. Vitamin E in cod and salmon fillets before and after culinary treatment

sample	vitamin E (µg/g dry matter)	SD	vitamin E (ng/g fresh weight)	SD	fillet weight (g)	average ar (%)	average tr (%)
C1 (raw cod)	61.61 [a]	4.26	10.74 [a]	0.74	1152.0	243.64 ± 64.18	326.18 ± 71.05
C1F (fried cod)	127.80 [b]	0.97	48.64 [b]	0.36	701.9		
C4 (raw cod)	44.96 [a]	0.16	8.84 [a]	0.04	821.2		
C4F (fried cod)	125.82 [b]	21.89	52.01 [b]	9.09	525.4		
C2 (raw cod)	47.20	3.79	8.41 [a]	0.67	1264.9	101.39 ± 16.13	93.28 ± 8.38
C2B (baked cod)	52.15	0.57	11.93 [b]	0.13	884.6		
C5 (raw cod)	43.08	11.66	8.53	1.72	1340.2		
C5B (baked cod)	39.76	8.64	10.37	2.25	963.0		
C3 (raw cod)	62.47 [a]	1.17	11.63 [a]	0.21	1486.2	90.85 ± 1.97	87.02 ± 0.88
C3S (steamed cod)	56.06 [b]	0.46	12.30 [b]	0.11	1231.6		
C6 (raw cod)	51.24	1.91	9.93 [a]	0.37	1406.3		
C6S (steamed cod)	47.12	1.09	11.37 [b]	0.27	1061.2		
S1 (raw salmon)	102.44	13.60	33.93 [a]	4.51	718.4	104.11 ± 16.80	101.18 ± 15.54
S1F (fried salmon)	116.36	6.80	58.61 [b]	3.42	466.5		
S4 (raw salmon)	118.64	12.47	38.67	4.07	724.7		
S4F (fried salmon)	112.27	0.00	49.70	0.00	508.6		
S2 (raw salmon)	110.06	6.90	34.40 [a]	2.15	651.3	94.74 ± 1.37	90.05± 1.93
S2B (baked salmon)	103.41	8.48	47.76 [b]	3.92	416.0		
S5 (raw salmon)	89.56	14.72	27.06	4.44	547.3		
S5B (baked salmon)	85.54	29.38	40.40	8.56	335.1		
S3 (raw salmon)	120.02	3.70	36.84	1.13	674.8	92.11 ± 11.47	88.58 ± 12.53
S3S (steamed salmon)	102.78	28.45	35.46	8.05	558.9		
S6 (raw salmon)	122.65	34.89	39.76	7.76	775.1		
S6S (steamed salmon)	120.91	22.19	46.03	8.45	652.4		
oil before frying (µg vit E/g oil)	231.38*	71.90*			-	95.96	-
oil after frying (µg vit E/g oil)	222.03*	60.60*			-		

a,b - indexes, represent statistically significant differences between the sample pairs before and after heat treatment ($p < 0.05$)

* - mean value and standard deviation for different oil batches

According to a study regarding the methods of calculating the loss of nutrients during cooking (Murphy *et al.*, 1975), the retention estimated only on the basis of the contents of

the tested component in the product before and after treatment (apparent retention, ar) does not reflect the actual changes. Such calculations are based on the assumption that solids are not lost during cooking, which may be true, for example, for steamed vegetables, but it is obviously not valid for any kind of fish treatment. As apparent retention does not take into account the changes in the weight of cooked product and the loss/gain of solids (e.g., fat), it seems reasonable to refer the results to the weight of the product before and after culinary treatment by calculating the true retention (tr).

The apparent retention of vitamin A (retinol) during the heat treatment proved to be high and reached an average of 79.03% for fried cod and 106.54% for steamed salmon. Estimation of true retention also leads to the conclusion that vitamin A is relatively stable during culinary preparation of fish. True retention of vitamin A was the highest (105.98%) in case of fried cod, but it was accompanied by the lowest apparent retention, reaching slightly over 79%. The process of cod frying was the only one for which true retention was significantly higher than apparent retention. This was most likely caused by a significant increase in the dry matter content of the sample, resulting from the simultaneous loss of water and substantial oil absorption.

Analysis of retinol retention leads to the conclusion that among the studied types of thermal treatment, steaming is the most conservative – the apparent retention of vitamin A reaches an average of 106.54% and 94.63% for salmon and cod, respectively. The true retention for the steaming process is also high – higher result was obtained only for fried cod, and as described, it resulted rather from the mass transfer between the fillet and the frying medium than from the exceptional stability of vitamin A in this process.

Ersoy *et al.* (2009) presented the data suggesting that grilling and frying resulted in an increase of vitamin A, whereas baking and microwaving resulted in a reduction of its content. The apparent retention of vitamin A, calculated based on the data presented by these authors, in the process of African catfish baking amounted to 48%. In spite of shorter time of thermal processing adopted (15 min), this retention was significantly lower than that observed in the course of our study for both cod and salmon. However, the same authors reported that the apparent retention of vitamin A in the process of frying reached a value of 133%, which is significantly higher than that observed in our study. These differences in the apparent retention may be due to the different dry matter content in various fish species, as well as due to the intraspecies variation of retinol content. The latter was not eliminated in the work of Ersoy *et al.* (2009), as different fish individuals constituted cooked and uncooked samples.

The effect of cooking on the content of vitamin D_3 is presented in Table 5. Among the cooking methods studied, steaming proved to be the most conservative, in case of both cod and salmon – the average true retention for these fish species was 102.44% and 96.24%, respectively.

Analysis of the results obtained during steaming and baking could suggest high thermal stability of vitamin D_3. This would be consistent with the work of Mattila *et al.* (1999), in which the true retention of vitamin D_3 during baking of vendance, perch, Baltic herring, and trout varied from 78% to 104%. Therefore, the authors concluded that the domestic culinary processing causes only a slight loss of vitamin D. However, the results obtained in our work for the frying process in which the loss of vitamin D_3 reached 69.44% and 75.57% for cod and salmon respectively, show that such a statement is perhaps too general. Also Elmadfa *et al.* (2006) reported that frying substantially reduces the amount of vitamin D_3 in salmon, whereas Dias *et al*, (2003) observed that frying of horse mackerel, hake, and axillary bream resulted in very diversified apparent retentions of vitamin D_3, reaching 11%, 64%, and even 134%,

respectively. However, Dias *et al.* (2003) informed that the results thus presented were often close to or even below the limit of quantification of the method used, and consequently, a very cautious approach to the interpretation of these results should be adopted. Thus, the analysis of literature data as well as of the results obtained in our study leads rather to the conclusion consistent with that published by Jakobsen and Knuthsen (2014), who studied the effect of heat treatment on food products such as eggs, margarine, cakes, wheat bread, and rye bread. These authors found that vitamin D loss during the culinary treatment depends strongly on the type of foodstuff and on the heating process used. Lešková *et al.* (2006), based on the review of the literature on thermal processes to which products such as meat, fish, milk, eggs, or mushrooms were subjected, concluded that fat content could be the main factor affecting vitamin D retention. According to these authors, high fat content results in greater loss of vitamin D due to the substantial drip-off. The results of our study seem to confirm this conclusion, as for all tested types of culinary treatment, true cholecalciferol retention was higher for lean cod, although only in case of baking the difference was statistically significant ($p < 0.05$).

Contrary to the popular opinion on its high lability, vitamin E proved to be stable during the baking and steaming processes to the extent similar to vitamins A and D. Of these two methods, the average true retention of vitamin E (unlike that of retinol and cholecalciferol) was slightly higher in the baking process, and reached 93.28% and 90.05% for cod and salmon, respectively. Frying resulted in an increase of vitamin E content, which was associated with the fact that rapeseed oil used as the frying medium contained 231.38 μg vitamin E/g. This value exceeded by many times the amount of tocopherol present in the raw fish, which was 35.11 and 9.68 μg/g for salmon and cod fillet, respectively. The fact that cod absorbed during frying 27 times more oil than it initially contained is responsible for the pronounced increase in vitamin E content in fried fish. The data presented by Ersoy *et al*. (2009) for African catfish demonstrated that the apparent retention of vitamin E after frying reached 120%. This value is located between the values obtained in our study for fried cod and salmon, for which the apparent retention of vitamin E amounted to 243.64% ± 64.18% and 104.11% ± 16.80%, respectively. Also the fat content reported by Ersoy *et al*. (2009) for African catfish (5.02%) ranged between the fat content of cod and salmon determined during our research. As the fat content in raw fish affects the amount of oil absorbed during frying, it influences the content of vitamin E in the fried product. In turn, Dias *et al*. (2003) reported a diversified result of frying on vitamin E in different fish species, both as to the extent and direction of the effect. They noted that frying resulted in a 1.3-fold increase, an average of 9.2-fold increase, and a 4-fold decrease in vitamin E (based on fresh weight) during frying of axillary bream, hake, and horse mackerel, respectively. According to the same authors, boiling of gilthead, bream, hake, salmon, and seabass resulted, respectively, in a 4-fold decrease and 1.3-fold, 1.5-fold, 1.3-fold, and 2-fold increases in vitamin E (based on fresh weight). However, the research paper mentioned contains no data on proximate composition of studied fish or on the conditions of heat treatment. These data are very important considering that according to Gotoh *et al*. (2011), cooking results in a decrease in vitamin E, which is directly proportional to the temperature used. It is also questionable whether the content of vitamin E in fish before and after heat treatment presented by Dias *et al*. (2003) was measured in the same fish or batch – if not, a strong intraspecies variability makes the interpretation of such results encumbered with a significant uncertainty.

4. Conclusions

Of all the three types of culinary treatment studied (frying, baking, and steaming), only

frying significantly affected the fatty acid profile in both cod and salmon. In both species, an increase in the percentage of MUFAs, coupled with a simultaneous decrease in the percentages of SFAs and PUFAs, was found. The observed changes were greater in case of cod, what is rather due to the larger amount of the frying medium absorbed than to the heat treatment itself. Different scales of observed changes suggest that the effect of cooking on fish fatty acids profile depends not only on the type of treatment but is also species-specific. Fat-soluble vitamins A, D_3, and E were found to be stable during the baking and steaming processes. Frying had a stronger impact on studied vitamins and resulted in an increase in vitamin A in cod and a decrease in salmon. The vitamin E content increased to an extent different for both species studied, and depending on the quantity of rapeseed oil absorbed. The content of vitamin D_3 underwent a statistically significant reduction during frying in case of both, cod, and salmon.

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MATHEMATICAL SIMULATION OF FORCES OF NORMAL CONTACT PRESSURE ON THE EDGES OF DOUBLE-EDGE KNIFE DURING FOOD MATERIALS CUTTING

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ABSTRACT

A mathematical model for determining the normal contact pressure on the back inclined edge of a double-sharp knife has been developed. Mathematical models for calculating the dimensional and dimensionless forces of normal contact pressure have been proposed. The limiting position of the termination contact point with increasing knife speed is determined by the ratio of the sharpening angles tangents. As the dimensionless knife speed increases, the dimensionless force reaches a limit depending on the sharpening angles and the material elasticity. The shortening of the knife side edges affects the position of the termination contact point and the force of normal contact pressures only at small and medium knife speeds. This is explained that at high speeds the process of stress relaxation takes a short time before the material is unstrained.

1. Introduction

Currently, cutting food material with a blade is the main technological process in the primary processing of raw material. Cutting is carried out by various types of knives, which are driven by electric motors. For scientifically substantiated choice of blade geometry, as well as to determine the parameters of the electric drive, it is necessary to know the useful and harmful resistive forces applied to the blade from the processing object side (Pelenko *et al.*, 2008; Ageev and Fatykhov, 2015).

Pagani and Perego (2015) proposed and discussed a computational finite element approach for the simulation of blade cutting of thin shells. Dowgiałło (2005) modeled the relationship between cutting force and cutting speed during cutting operation of fibrous materials. This was based on analysis of their rheological model. In work Schuldt *et al*. (2018) the sharpness of blades for food cutting is analyzed. In a paper by Brown *et al*. (2005) the results of experimental measurements of cutting forces in different foods are presented.

Boisly *et al*. (2016) report the results of both experimental and theoretical investigations that were obtained by using a polymeric food model system. Viscoelasticity was experimentally observed in relaxation experiments at small strains, and tensile tests were performed for large deformations at different tensile speeds. Schuldt *et al*. (2018) used a custom-built high-speed test station for the cutting behavior of representative foods (either based on a protein web, plant tissues or sugar based confectionary) and food models on elastomer basis. Cutting velocity ranged from 0.001 m/s up to 10 m/s. On

the basis of cutting force data and dynamic mechanical analysis performed between 1 to 100 rad/s, the cutting behavior of the systems was investigated.

When cutting a viscoelastic food material with a knife, energy dissipation occurs due to stress relaxation. Therefore, it is necessary to establish, what quantity of energy irrevocably dissipates in the form of heat, and also what quantity of energy is released and can make it work after the material is no more in contact with the knife. For this, it is necessary to investigate the process of straightening the deformation in the material and the attached cavity formation.

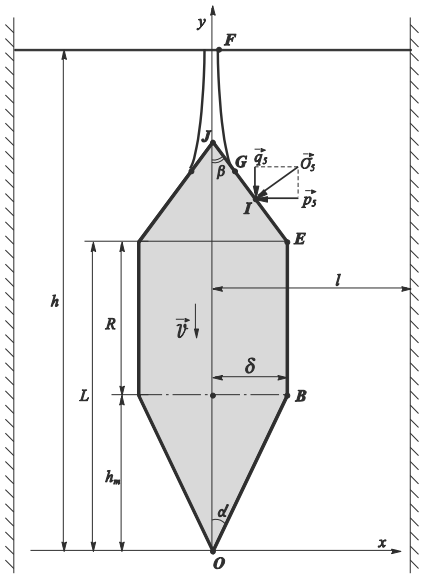


Figure 1. The scheme of double-sharp knife movement in the food material

The geometric shape of a double-sharp knife is shown in fig. 1. This knife has a front edge with a sharpening angle 2α and a back edge with a sharpening angle 2β. The aim of mathematical modeling was to determine the dependences of straightening the deformation and the attached cavity volume on the cutting speed, the rheological properties of the food material, and the knife geometry. Normal contact pressures on the back inclined edge (segment EJ) occur due to stresses in the food material, which had previously been deformed by the front inclined edges and side edges of the knife.

Let us establish the relationship between the stress in the material and the reverse creep, when on the back inclined edge the material is relieving. In this case, the rheological model of Maxwell-Thomson (standard viscoelastic solid) is used.

2. Materials and methods

2.1. Material

For simulation the rheological parameters of food material - fish muscular tissue has been experimentally determined. The results of direct creep, relaxation and reverse creep tests of the muscular tissue for Baltic herring, horse mackerel, mackerel and Atlantic sardinella has been researched. The results of the experimental tests approximately correspond to the three-element rheological Maxwell–Thomson model [5]. Constants of model is instantaneous modulus of material elasticity (Young's modulus) E_0, high-elasticity (delayed) modulus E_1 and coefficient of dynamic viscosity η (Tab. 1).

Table 1. Rheological parameters of fish muscular tissue for simulation

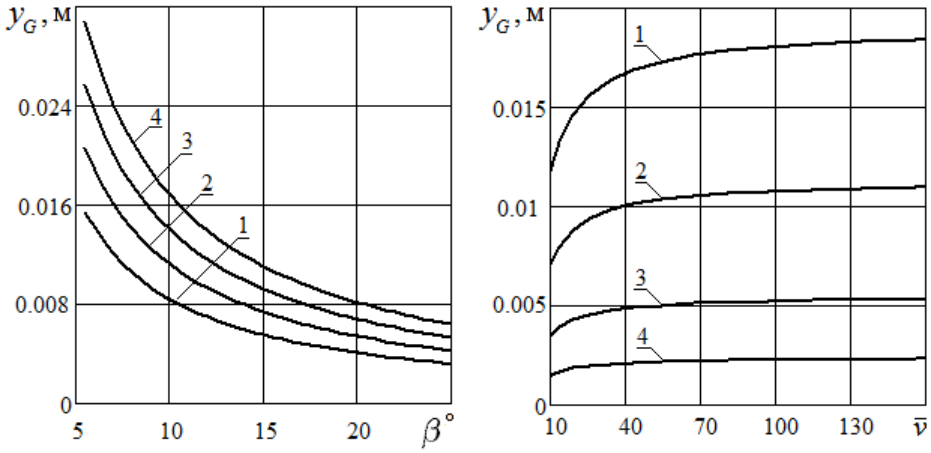
No.	E_0, N/m^2	E_1, N/m^2	η, N·s/m^2
1	$1{,}5\cdot10^5$	$0{,}1\cdot10^5$	$250\cdot10^5$
2	$2\cdot10^5$	$0{,}3\cdot10^5$	$500\cdot10^5$
3	$2{,}5\cdot10^5$	$0{,}6\cdot10^5$	$1000\cdot10^5$
4	$3\cdot10^5$	$0{,}8\cdot10^5$	$1500\cdot10^5$

2.2. Materials and methods

As shown in fig.1, when the back inclined edge is immersed into the material, the relative deformation of the material changes from maximum value δ/l to zero.

However, unlike the process of material splitting by the front inclined edge, there is an termination contact point G. On the segment EG there is a contact of the back inclined edge with the material, and on the segment GJ there is no contact. When the contact is stopped, the material is completely relieved and a straighten deformation of the material occurs with the attached cavity formation. Therefore, the normal contact pressures act on the back inclined edge only in the segment GE, in which the use of viscoelastic energy released during relieving takes place. Generally, the position of the extreme contact point G is unknown.

In the process of immersing the back inclined edge of the knife a decrease in the relative deformation leads to a decrease in the material stresses to value zero at the extreme contact point. Therefore, to determine the force of the normal contact pressures of the material on the back inclined edge, it is necessary to solve the problem of determining the stresses in a viscoelastic material when the relative deformation on the segment EG changes, and also the problem of determining the extreme contact point coordinates. As before, we will assume that stresses in the material occur only in the region of contact of the material with the blade and are normal to the knife surface, and stresses tangent to the edge surface are absent.



a *b*

Figure 2. The coordinate y_G of the termination contact point G on the back inclined edge: *a* – dependence on the sharpening angle β in degrees for different knife thicknesses δ (v = 0,1 m/s; α = 6º): 1 – δ = 0.0015 m; 2 – δ = 0.002 m; 3 – δ = 0.0025 m; 4 – δ = 0.003 m; *b* – dependence on the dimensionless speed $\bar{v}$ for different values of the sharpening angle:1 – β = 6º; 2 – β = 10º; 3 – β = 20º; 4 – β = 40º

Let's go to the moving coordinate system with the center at the point O. Note that at steady motion of the knife the material relieving is at a constant speed $v \cdot tg\beta$ due to the straight shape of the back inclined edge EJ. In this case, the relative deformation ε depends on the time t, on the speed of the knife movement in the material v and on the half the angle of sharpening the back edge of the knife β, as follows.

By analytically solving a differential equation of Maxwell–Thomson rheological

model [Dowgiałło, 2005] with appropriate boundary conditions consequentially in points O, B, E, G as a result, we obtained the following equality:

$$\left\{h_\beta \cdot \chi \cdot \exp(k \cdot R) - \frac{e_{01}}{k} + L\right\} \cdot \exp(k \cdot [y_G - L]) - y_G + h_\beta + \frac{e_{01}}{k} = 0, \quad (1)$$

where y_G – the coordinate of the termination contact point G; v − knife speed; l_k − knife cutting length orthogonal to axes x and y; l – initial thickness of material; $\xi = \frac{E_0 \cdot E_1}{E_0 + E_1}$; $k = -\frac{E_0 + E_1}{\eta \cdot v}$; $\mu = 1 - \exp\left(\frac{k \cdot \delta}{tg\alpha}\right)$; $\chi = \frac{\xi \cdot \eta \cdot v \cdot \mu \cdot tg\alpha}{E_1^2 \cdot \delta}$; $e_{01} = E_0 / E_1$; $h_\beta = \delta / tg\beta$; $\tau = 1 + \chi \cdot \exp\left(k \cdot \left(L - \delta / tg\alpha\right)\right)$.

By solving the equation (1) numerically on a computer, the desired coordinate y_G of the extreme contact point G was determined. In Fig. 2, the dependences of this coordinate y_G on the sharpening angle β of the back inclined edge of the knife and the dimensionless speed $\bar{v} = \frac{v \cdot \eta}{h_m \cdot (E_0 + E_1)}$ of the knife are shown.

Using the expression (1), we obtain the expression for the normal contact pressure p_5 on the back inclined edge with $y \in (L, y_G)$:

$$p_5 = \frac{\xi \cdot tg\beta}{l} \cdot \left(\left\{h_\beta \cdot \chi \cdot \exp(k \cdot R) - \frac{e_{01}}{k} + L\right\} \cdot \exp(k \cdot [y - L]) - y + h_\beta + \frac{e_{01}}{k} \right). \quad (2)$$

The expression (2) has a physical meaning by $y \in (0, y_G)$ in a moving rectangular coordinate system associated with a point O. Let us determine whether the full contact of the food material with the back inclined edge EJ is possible (point G coincident to point J), the conditions of which are presented as follows:

$$\tilde{y}_G = \delta / tg\beta; \quad (3)$$

$$\left\{h_\beta \cdot \frac{\xi \cdot \eta \cdot \tilde{v} \cdot \mu \cdot tg\alpha}{E_1^2 \cdot \delta} \cdot \exp\left(-\frac{E_0 + E_1}{\eta \cdot \tilde{v}} \cdot R\right) + \frac{\eta \cdot \tilde{v}}{E_0 + E_1} \cdot e_{01} + L\right\} \cdot \exp\left(-\frac{E_0 + E_1}{\eta \cdot \tilde{v}} \cdot h_\beta\right) - L - \frac{\eta \cdot \tilde{v}}{E_0 + E_1} \cdot e_{01} = 0. \quad (4)$$

The computational solution of equation (4) relatively $\tilde{v}$ shows that has not positive roots. This means that it is impossible to fully contact the food material with the back inclined edge of the knife when it moves at any speed. Thus, when the knife moves, an attached cavity is always formed, which is expected, since the splitting of the viscoelastic material by the blade is a thermodynamically irreversible process.

By integrating, we obtain an expression for the force P_5 of the normal contact pressure on the inclined edge of the knife:

$$P_5 = \frac{l_k \cdot \xi \cdot tg\beta}{l} \cdot \left(\frac{h_\beta \cdot (\tau - 1) - \frac{e_{01}}{k} + L}{k} \cdot \left(\exp(k \cdot [y_G - L]) - 1\right) + \left(h_\beta + \frac{e_{01}}{k}\right) \cdot (y_G - L) - \frac{y_G^2 - L^2}{2} \right), \quad (5)$$

Let's introduce the dimensionless speed $\bar{v}$ and dimensionless coordinate $\bar{y}_G$ of point G:

$$v = \bar{v} \cdot \frac{h_m \cdot (E_0 + E_1)}{\eta};\ \bar{y}_G = \frac{y_G}{h_m};\ \bar{L} = \frac{L}{h_m};\ k = -\frac{E_0 + E_1}{\eta \cdot v} = -\frac{1}{\bar{v} \cdot h_m};\ t_{\alpha\beta} = \frac{\tan\alpha}{\tan\beta};$$

$$\mu = 1 - \exp\left(\frac{k \cdot \delta}{tg\alpha}\right) = 1 - \exp\left(\frac{-1}{\bar{v}}\right);\ e_{01} = E_0 / E_1 \text{ – dimensionless measure of elasticity.}$$

$$\frac{\xi \cdot \eta \cdot v}{E_1^2} = \bar{v} \cdot h_m \cdot e_{01};\ \chi = \frac{\xi \cdot \eta \cdot v \cdot \mu}{E_1^2 \cdot \delta / tg\alpha} = \bar{v} \cdot e_{01} \cdot \left[1 - \exp\left(\frac{-1}{\bar{v}}\right)\right];$$

$$\tau = 1 + \chi \cdot \exp(k \cdot R) = 1 + \bar{v} \cdot e_{01} \cdot \left[1 - \exp\left(\frac{-1}{\bar{v}}\right)\right] \cdot \exp\left(\frac{-R_0}{\bar{v}}\right);\ R_0 = \frac{R}{h_m};$$

Taking into account the expression for the dimensionless speed $\bar{v}$, we obtain the equation for the dimensionless coordinate $\bar{y}_G$:

$$\left(t_{\alpha\beta} \cdot (\tau - 1) + \bar{v} \cdot e_{01} + \bar{L}\right) \cdot \exp\left(\frac{\bar{L} - \bar{y}_G}{\bar{v}}\right) - \bar{y}_G + t_{\alpha\beta} - \bar{v} \cdot e_{01} = 0, \text{ where } t_{\alpha\beta} = \tan\alpha / \tan\beta.$$

From (5) we obtain an expression for the dimensionless force:

$$\bar{P}_5 = \left(t_{\alpha\beta} \cdot (1 - \tau) - e_{01} \cdot \bar{v} - \bar{L}\right) \cdot \left(\exp\left(\frac{\bar{L} - \bar{y}_G}{\bar{v}}\right) - 1\right) \cdot \bar{v} + \left(t_{\alpha\beta} - e_{01} \cdot \bar{v}\right) \cdot \left(\bar{y}_G - \bar{L}\right) - \frac{\bar{y}_G^2 - \bar{L}^2}{2}; \quad (6)$$

$$P_0 = \frac{l_k \cdot \xi \cdot tg\beta}{l} \cdot h_m^2;\quad P_5 = P_0 \cdot \overline{P_5}.$$

$v = \bar{v} \cdot \frac{h_m \cdot (E_0 + E_1)}{\eta};\quad \bar{y}_G = \frac{y_G}{h_m};\quad \bar{L} = \frac{L}{h_m};$

$k = -\frac{E_0 + E_1}{\eta \cdot v} = -\frac{1}{\bar{v} \cdot h_m};\ t_{\alpha\beta} = \frac{\tan\alpha}{\tan\beta};$

$\mu = 1 - \exp\left(\frac{k \cdot \delta}{tg\alpha}\right) = 1 - \exp\left(\frac{-1}{\bar{v}}\right);\ e_{01} = E_0 / E_1$

– dimensionless measure of elasticity

$\frac{\xi \cdot \eta \cdot v}{E_1^2} = \bar{v} \cdot h_m \cdot e_{01};$

$\chi = \frac{\xi \cdot \eta \cdot v \cdot \mu}{E_1^2 \cdot \delta / tg\alpha} = \bar{v} \cdot e_{01} \cdot \left[1 - \exp\left(\frac{-1}{\bar{v}}\right)\right];$

$\tau = 1 + \chi \cdot \exp(k \cdot R) = 1 + \bar{v} \cdot e_{01} \cdot \left[1 - \exp\left(\frac{-1}{\bar{v}}\right)\right] \cdot \exp\left(\frac{-R_0}{\bar{v}}\right)$

$R_0 = \frac{R}{h_m}.$

To do this, we solved the problem of determining the straightening of the material deformation under restricted compression conditions after instantaneous removal of the external load at the extreme contact point (Fig. 1). It is necessary to know the value of the normal contact pressure on the knife side edge at the specified point.

The mechanical behavior of the food material is described by the Maxwell–Thompson rheological model (Dowgiałło, 2005; Pagani and Perego, 2015). Let us move on to the

moving coordinate system (x, y) associated with the cutting edge of the knife. Let the knife have two-sided sharpened edges and the blade length be $L=(R + \delta/tg\alpha)$, where R – the length of the side edge, δ – half the knife thickness, and α – half the knife sharpening angle. The back edge of the knife is straight. Straightening of the deformation of the material occurs on the site EF.

Considering the instantaneous deformation of the Hooke element recovery, the expression for the relative straightening of the deformation ε_x of a viscoelastic food material after the termination of contact has the following form:

$$\varepsilon_x = \frac{\delta}{l}\cdot\left(1-\frac{\xi}{E_0}\cdot\left[1+\chi\cdot\exp(k\cdot R)\right]\right)\cdot\exp\left(-\frac{E_1\cdot(y-L)}{\eta\cdot v}\right), \tag{7}$$

where l – initial thickness of material; E_0 – instantaneous modulus of material elasticity (Young's modulus); E_1 – delayed modulus of material elasticity; η – coefficient of dynamic viscosity of material;

v – knife speed;

$$\xi = \frac{E_0\cdot E_1}{E_0+E_1};\ \chi = \frac{\xi\cdot\eta\cdot v\cdot\mu\cdot tg\alpha}{E_1^2\cdot\delta};\ \mu = 1-\exp\left(\frac{k\cdot\delta}{tg\alpha}\right);\ k = -\frac{E_0+E_1}{\eta\cdot v}.$$

Let us introduce the following dimensionless quantities:

$\bar{v} = \frac{v}{v_n} = \frac{v\cdot\eta}{h_m\cdot(E_0+E_1)}$ – dimensionless knife speed;

$\bar{L} = L/h_m$ – dimensionless length of the side edge

$\bar{y} = y/h_m$ – dimensionless coordinate;

$e_{01} = E_0/E_1$ – ratio of instantaneous and delayed elastic modulus (a measure of the food material elasticity);

$h_m = \delta/tg\alpha$ – length of the front inclined edge of the knife.

From Eq.7:

$$\varepsilon_x = \frac{\delta}{l}\cdot\left(1-\frac{\xi}{E_0}\cdot\left[1+\chi\cdot\exp(k\cdot(L-h_m))\right]\right)\cdot\exp\left(-\frac{E_1\cdot(y-L)}{\eta\cdot v}\right) = \tag{8}$$

$$= \frac{\delta}{l}\cdot\left(1-\frac{1}{1+e_{01}}\cdot\left[1+e_{01}\cdot\bar{v}\cdot\left\{1-\exp\left(-\frac{1}{\bar{v}}\right)\right\}\cdot\exp\left(\frac{1-\bar{L}}{\bar{v}}\right)\right]\right)\cdot\exp\left(\frac{\bar{L}-\bar{y}}{(1+e_{01})\cdot\bar{v}}\right)$$

$$\bar{\varepsilon}_x = \frac{l}{\delta}\cdot\varepsilon_x = \left(1-\frac{1}{1+e_{01}}\cdot\left[1+e_{01}\cdot\bar{v}\cdot\left\{1-\exp\left(-\frac{1}{\bar{v}}\right)\right\}\cdot\exp\left(\frac{1-\bar{L}}{\bar{v}}\right)\right]\right)\times \tag{9}$$

$$\times\exp\left(\frac{\bar{L}-\bar{y}}{(1+e_{01})\cdot\bar{v}}\right).$$

Eq. 8 has a physical meaning when $y \geq L$ and $\varepsilon_x > 0$ if the coordinates of the extreme contact points are (δ, L). At $\bar{\varepsilon}_x = 0$, at the extreme point of recovery, the material expanded by the right edges of the knife touches the material expanded by the left edges, after which the process of straightening the deformation stops. The free surfaces of the material formed during cutting are shifted and touched behind the butt of the knife during the straightening of the deformation. This leads to the fact that when the knife moves, an attached cavity is formed in the material behind the butt.

2.3. Mathematical modeling of the attached cavity formation process

Let us determine the volume of the cavity in the material attached to the knife butt with two-sided sharpened edges when the knife moves in viscoelastic food material (Fig. 1).

$$V_k = 2 \cdot \delta \cdot l_k \cdot \left(1 - \frac{\xi \cdot \tau}{E_0}\right) \cdot \int_L^h \exp\left(-\frac{E_1 \cdot (y - L)}{\eta \cdot v}\right) dy \tag{10}$$

As a result of the transformations, we obtain the following equation for the attached cavity volume:

$$V_k = 2 \cdot \delta \cdot l_k \cdot \frac{\eta \cdot v}{E_1} \cdot \left(1 - \frac{\xi \cdot \tau}{E_0}\right) \cdot \left(1 - \exp\left[\frac{E_1}{\eta \cdot v} \cdot (L - h)\right]\right). \tag{11}$$

Let us express the attached cavity volume (Eq. 11) by means of dimensionless quantities as follows:

$$V_k = 2 \cdot \delta \cdot l_k \cdot h_m \cdot \bar{v} \cdot (1 + e_{01}) \times$$
$$\times \left\{1 - \frac{1}{1 + e_{01}} \cdot \left[1 + e_{01} \cdot \bar{v} \cdot \left(1 - \exp\left(-\frac{1}{\bar{v}}\right)\right) \cdot \exp\left(-\frac{1}{\bar{v}} \cdot (\bar{L} - 1)\right)\right]\right\} \times \tag{12}$$
$$\times \left\{1 - \frac{1}{1 + e_{01}} \cdot \left[1 + e_{01} \cdot \bar{v} \cdot \left(1 - \exp\left(-\frac{1}{\bar{v}}\right)\right) \cdot \exp\left(\frac{1 - \bar{L}}{\bar{v}}\right)\right]\right\} \cdot \left(1 - \exp\left[\frac{(\bar{L} - \bar{h})}{\bar{v} \cdot (1 + e_{01})}\right]\right).$$

Taking into account $\frac{E_0 + E_1}{E_1} = (1 + e_{01})$, we introduce the notation:

$$\varpi = 1 - \frac{\xi \cdot \tau}{E_0} = 1 - \frac{1}{1 + e_{01}} \cdot \left[1 + e_{01} \cdot \bar{v} \cdot \left(1 - \exp\left(-\frac{1}{\bar{v}}\right)\right) \cdot \exp\left(\frac{1 - \bar{L}}{\bar{v}}\right)\right]; \tag{13}$$

$$V_0 = 2 \cdot \delta \cdot l_k \cdot h_m. \tag{14}$$

Finally, we obtain the following Equations 9, 10, and 11 for the dimensionless reduced relative deformation of the material recovery and the dimensionless reduced volume of the attached cavity, respectively:

$$\bar{\varepsilon}_x = \frac{l}{\delta} \cdot \varepsilon_x = \varpi \cdot \exp\left(\frac{\bar{L} - \bar{y}}{(1+e_{01}) \cdot \bar{v}} \right); \quad (14)$$

$$\bar{V}_k = V_к / V_0 = \bar{v} \cdot (1+e_{01}) \cdot \varpi \cdot \left(1 - \exp\left[\frac{(\bar{L} - \bar{h})}{\bar{v} \cdot (1+e_{01})} \right] \right). \quad (15)$$

The developed Equations 14–15 allow to vary the dimensionless knife speed, the dimensionless side edge length, the material elasticity modulus to study the dependences of the dimensionless reduced relative strain, and the dimensionless reduced volume of the attached cavity on these parameters.

Figure 3 shows the dependences of the dimensionless reduced relative deformation $\bar{\varepsilon}_x$ of the material on the dimensionless coordinate $\bar{y}$ at four different values of the ratio of the material elasticity.

In Fig. 4, the dependences of the dimensionless reduced volume $\bar{V}_k$ of the attached cavity on the dimensionless knife speed $\bar{v}$ at four different values of the elasticity measures e_{01} are shown.

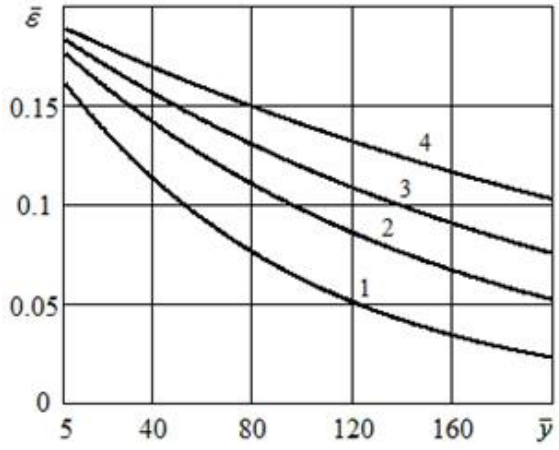


Figure 3. The dimensionless reduced relative deformation of the material recovery at $\bar{v} = 20$; $\bar{L} = 5$ and different values of e_{01}:

1 – $e_{01} = 4$; 2 – $e_{01} = 7$; 3 – $e_{01} = 10$; 4 – $e_{01} = 15$

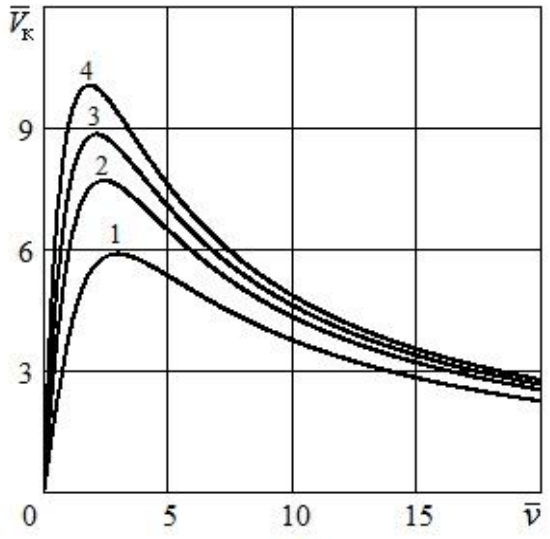


Figure 4. The dimensionless reduced volume of the attached cavity at $\bar{L} = 5$ and different values of e_{01}: 1 – $e_{01} = 4$; 2 – $e_{01} = 7$; 3 – $e_{01} = 10$; 4 – $e_{01} = 15$

3. Results and discussions

The attached cavity is formed due to the instantaneous recovery of the Hooke element, as well as due to the delayed recovery of the Kelvin–Voigt element of the Maxwell–Thompson rheological model. According to Equation 11, the volume of the attached cavity is directly proportional to the knife thickness and

the length of its straight cutting edge. At the same time, the process of straightening the deformation and cavity formation are influenced by the process of material deformation by the front inclined edge, as well as the process of stress relaxation when the material is in contact with the side edge (Brown *et al*., 2005).

Simulation results presented in fig. 2,*a* show that with the increase of the sharpening angle of the back inclined edge, the extreme contact point coordinate nonlinear monotonically decreases. Increase in the sharpening angle at a constant thickness of the knife corresponds to an increase in the material relieving speed.

Accordingly, with an increase in the relieving rate, the lagging of the superelastic straighten deformation from the relieving process increases. In this case, with increasing knife thickness, the coordinate of the extreme contact point is expected to increase, since the viscoelastic energy stored in the food material depends on the deformation magnitude. At the same time, fig. 2,*b* shows that with an increase in the dimensionless speed of a knife, the coordinate of the extreme contact point nonlinearly monotonically increases and reaches the limit. This is due to the relaxation of stresses in the material during its deformation by the side edge. With an increase in the knife speed, the time, during which the stresses relaxation occurs upon contact of the material with the side edge, is reduced. As a consequence, the dissipation of the energy stored in the deformed viscoelastic material is carried out in significantly smaller quantities. At high knife speeds, the relaxation process hardly has time to flow, and the effect of speed on the extreme contact point position is noticeably reduced. Furthermore, as the material relieving speed increases, which is determined by the sharpening angle of the edge, the influence of the stress relaxation process on the position of the extreme contact point decreases.

According Eq. 5 and 6 the dimensional P_5 and dimensionless $\overline{P}_5$ forces of the normal contact pressure on the back inclined edge with increasing dimensionless speed monotonically nonlinearly increase and reach limits. The dimensionless length of the side edge affects the values of these forces only at low knife speeds, and therefore the forces limits practically don't depend on the side edge length. With its increase, the stress relaxation process takes longer, and the forces of normal contact pressure are reduced due to the dissipation of viscoelastic energy in the material. With the reduction of the dimensionless length of the side edge, the dimensional and dimensionless forces increase substantially at low speeds, because the viscoelastic energy dissipation becomes small. The limits of these forces depend on the measure of material elasticity and on the ratio of the sharpening angles tangents.

Also with increasing sharpening angle β of the back inclined edge, the force of the normal contact pressure monotonically nonlinearly decreases. It is due to the reduced contact area of the food material with the inclined edge, since the coordinate of the extreme contact point also decreases. In this case, the increase in thickness leads to an increase in the noted force due to an increase in the material deformation. At the same time, when the measure of the material elasticity increases, the noted force increases, which is explained by the strengthening of the instantaneous elastic properties of the material. When the sharpening angle of the back inclined edge reaches 90º, the force of the normal contact pressure takes a zero value (the knife has a straight butt).

With an increase in the dimensionless height of the knife, the dimensionless force of the normal contact pressure decreases at low and medium speeds, which is explained by the relaxation of stresses in the material. With increasing the ratio of the tangents of the sharpening angles the noted force increases, which is associated with a decrease in the material relieving speed and increasing the contact area of material with an inclined edge.

The force $\overline{P}_5$ limit is practically independent from the dimensionless height of the knife, but depends on the measure of the material elasticity and the ratio of the sharpening angles tangents. When measure of the food material elasticity

e_{01} is equal to 2, the dimensionless height $\bar{L}$ of the knife is equal to 2 and the rations of the sharpening angles tangents $t_{\alpha\beta}$ are 0,7; 0,8; 0,9 and 1.0, the limit of the dimensionless force is 0,735; 0,96; 1,21 and 1,5, respectively. When the dimensionless height of the knife is equal to 2, the ratio of the sharpening angles tangents is equal to 0,7 and the measures of the material elasticity are 2; 3; 4 and 5, then the limit is 0,735; 0,98; 1,225 and 1,47, respectively.

In the Maxwell-Thomson rheological model, viscoelastic energy accumulates in springs, and in the real body the accumulation is associated with the presence of intermolecular attraction and repulsion forces. As shown from the simulation results, the energy conversion during the material splitting by the blade is always accompanied by losses due to the transition of part of the energy into the thermal form. This is due to the irreversible thermodynamically nature of the deformation of the elementary volume of food viscoelastic material. The presence of a cycle of partially reversible transformation of energy from mechanical to viscoelastic form allows us to expect a reduction in energy costs to overcome the resistance force when moving in the material of a two-edged knife compared to a knife having a straight butt. Such an energy gain will significantly depend on the flow of thermodynamically irreversible relaxation process, that is, it is determined by the length of the side edge of the knife, cutting speed and rheological properties of the material. An indicator of entropy production in the food material deformation is the volume of the attached cavity, which decreases with increasing speed of the knife.

Figure 3 shows that with an increase in the elasticity measure, that is, with the decrease in the material rigidity, the instantaneous straightening deformation decreases slightly, and a delayed straightening deformation of the material takes place for a much longer period.

Figure 4 shows that as the dimensionless knife speed increases, the dimensionless reduced volume of the attached cavity increases at low speeds, reaches a maximum, and then decreases asymptotically at high knife speeds. With an increase in the modulus of elasticity ratio, that is, decrease in the material rigidity, the dimensionless reduced volume of the attached cavity increases substantially.

The dependence of the dimensionless reduced cavity volume on the dimensionless knife speed is a nonmonotonic function with an explicit maximum. At the ratio of the material's elastic modulus e_{01} of 4, 7, 10, and 15 the maxima of the dimensionless reduced attached cavity volumes $\bar{V}_k$ of 5,89; 7,70; 8,84 and 10,05 are reached, respectively.

According Eq. 15 with an increase in the dimensionless length of the knife due to an increase in the dissipative losses of viscoelastic energy, the instantaneous volume of the attached cavity increases. With further growth of the dimensionless length, the layer is reduced from the knife to the surface of the material in which the attached cavity is formed, which leads to a reduction of its dimensionless volume until the moment of coincidence of the knife with the surface of the material ($\bar{L} = \bar{h}$).

4. Conclusions

1. When cutting food material with a two-edged knife, viscoelastic energy is accumulated in the material when it is deformed by the front inclined edge and partially released after full immersion of the side edge into the material. At the same time, the forces of normal contact pressure affect on the back inclined edges, and an attached cavity is formed. During the cutting process, the mechanical energy of the knife movement is partially converted into potential viscoelastic and thermal energy, and entropy is produced, the indicator of which is the volume of the attached cavity.

2. The position of the extreme contact point G on the back inclined edge and, accordingly, the attached cavity volume, depend on the sharpening angles of the edges and the cutting speed. The limit position of the noted point is determined by the ratio of the tangents of the noted angles.

3. Mathematical modeling shows that the force of the normal contact pressure depends on the knife thickness, the edge sharpening angle, the measure of the material elasticity and the knife speed. With an increase in the dimensionless speed of the knife dimensionless force reaches a limit value, which depends on the edges sharpening angles and on the measures of food material elasticity. The length of the side edge practically has no affects on the limiting value of the force.

4. The above simulation results allow us to conclude that the attached cavity volume is directly related to the energy losses caused by energy dissipation in viscoelastic food material. The decrease in the attached cavity volume corresponds to the decrease in the amount of viscoelastic energy irretrievably dispersed in the material due to stress relaxation. Thus, the smaller the cavity volume, the more the viscoelastic energy accumulated in the food material, which can be directed to perform useful work.

5. With an increase in the dimensionless knife speed, the instantaneous volume increases at low speeds also due to an increase in the lag of highly-elastic deformation, reaches a maximum, after which at high speeds the knife asymptotically decreases and tends to the limit value due to the dynamic enhancement of the elastic properties of the material. The maximum volume increases with increasing dimensionless knife cutting depth, as well as with an increase in the measure of elasticity.

6. The delay in highly-elastic recovery of the material increases the instantaneous volume of the cavity, and the dynamic enhancement of the elastic properties reduces it. These opposite processes by critical speed of the knife are balanced at the point of maximum volume. This causes the non-monotonic dependence of the instantaneous volume on the velocity - rapid growth, reaching a maximum, and a long-term asymptotic decrease. The reduction of the instantaneous volume also corresponds to a decrease in the amount of viscoelastic energy irretrievably scattered in the material due to stress relaxation in the viscous constituent elements of the material.

7. If the knife has a back inclined edge, an increase in speed leads to a decrease in the attached cavity volume and a simultaneous decrease in the resultant resistance force to movement of the knife in the material.

8. During cutting the material with a blade, it is impossible to completely avoid the dissipation of the viscoelastic energy due to the stress relaxation process. With that condition, complete contact of the material with a stamp, the shape of which corresponds to the considered knife profile, is not possible to use the energy accumulated in the material and reduce the deformation frictional force.

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DIETARY BEHAVIOR AND LIFESTYLE OF WOMEN AT RISK OF OSTEOPOROSIS

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Evaluation of the content of nutrients.

ABSTRACT
The importance of human diet is attributed to the ingredients contained in the diet as calcium, magnesium, vitamins D, K, C, protein and sodium. Nutrition affects the quality of the bone tissue being formed and its strength. The aim of this study was to obtain the data on the way of nutrition (mainly with the foodstuff containing calcium and the vitamin D), and the lifestyle of the women suffering from or threatened by osteoporosis. The investigated group of 50 women aged 45 – 56 was characterized by positive risk factors to get osteoporosis, or they have already clinically confirmed this disease. The characteristics of the way of nutrition of the surveyed group showed that the share of the evaluated nutrients in the realization of the demand differed from the recommended one. Also a low intake of calcium was found with a similarly low intake of magnesium and a high consumption of phosphorus. In the investigated population group suffering of osteoporosis numerous nutrition mistakes were indicated. Most of them affect the worsening of the absorption of calcium. An excessive supply of energetic products, fat, animal proteins, and also phosphorus and sodium was indicated. To low intake of calcium, magnesium and vitamin D in consequence can worsen the disease.

1.Introduction

The skeletal system is one of the systems in the human organism, the development of that depends on both the way nutrition and lifestyle. The importance of diet is attributed to the elements/components contained in diet as calcium, phosphorus, magnesium, vitamins D, K, C, copper, boron, protein and sodium. Nutrition affects the quality of the bone tissue being formed and its strength (Mirosław, 2010).

The WHO defines osteoporosis (OP) as a metabolic disease of the human skeleton characterized by a reduced mass of the skeleton compared with the normal one and its disordered microarchitecture leading to an increased brittleness of bones. It is estimated that over 75 million of people in the USA, Europe and Japan suffer this disease (Johnell, Kanis, 2006). In Poland the epidemical data show that 7% of women aged 45 – 54, 25% aged 65 – 74, and 50% aged 75 - 84 suffer the original OP (Tłustochowicz, Korkosz, 2000).

The original OP is a pathology commonly associated with the population of adults but it should be kept in mind that the quality of the skeleton of the mature people depends to a great extent on the way of nutrition, physical activity, suffered diseases in the past, and medicines taken at the child and juvenile age. The frequency of the occurrence of osteoporosis increases with age. The losses of

the bone mass for women are highest in the early stage after menopause and they reach 3 up to 5% per year. Menopause usually occurs around the age of 50 years. At that time the functioning of ovaries becomes disordered. The number of estrogens decreases and this disturbs the functioning of many organs and causes the formation of the so-called post-menopause osteoporosis. Estrogens affect directly the bone cells, and lack of them causes the atrophy of the bone mass (Czerwiński, Honowski, 2005).

An important factor for the development of osteoporosis is the deficiency of calcium. Its sufficient supply is deemed to be the most important from among nutrition factors that affect the bone mass (Lorenc and Kaczmarkiewicz, 2000). Calcium is intaken with food, mainly milk products. The demand is variable and depends on sex and age. The daily recommendation for adults is 1000 – 1500 mg, for children/juveniles 900 – 1200 mg, and for women in menopause period 1500 g of calcium (Baumgarten, 1996).

A risk factor is also a poor physical activity since movement is that what conditions strong bones that not mechanically loaded lose their density and in consequence osteoporosis develops (Schurman *et al*., 2008).

As other risk factors the abuse of alcohol and smoking tobacco can be mentioned that speed up the development of the disease due to a higher exposure to cadmium. This leads to a demineralisation of bones by the imitation of the synthesis of the vitamin D in kidneys and an increased excretion of calcium in urine and the disorder in building it into bones (Kazantiz, 2004).

The consumption of alcohol affects the bone metabolism by the reduction of the bone cells and decreasing their metabolic activity. Alcohol abuse leads to the lose of the bone mass, and also is the reason for frequent osteoporotic femoral neck and vertebral body fractures (Rapuri *et al*., 2000).

When selecting a treatment method for osteoporosis the pathogenesis of osteoporotic changes should be taken into account. If the losses of the bone tissue occur after menstruation ceases it is the result of the increased skeleton resorption. When it happens in the periods of slow loss of bones in is connected with aging. Fractures are the consequence of a lower activity of osteoblasts (Lorenc, 1995).

The medicines applied for the treatment of osteoporosis can be divided in two groups:

- medicines decreasing bone resorption,
- medicines increasing skeleton formation (Kaplan, 1996).

The effectiveness of the treatment manifests itself in the reduction of the rate of bone tissue loss and the frequency of the occurrence of fractures. The drugs that decrease the bone resorption are: estrogens, calcitonin, active metabolites of the vitamin D. The formation of a new tissue is stimulated by fluorides, small doses of parathormone, anabolic steroids, growth hormone, androgens, silicon, aluminium, growth factors. The essential nutritional factors are calcium, vitamin D, as well as magnesium and fluorine (Lorenc, 1995).

The aim of the study was to obtain the data on the way of nutrition (mainly with the foodstuff containing calcium and vitamin D), and the lifestyle of the women suffering from or threatened by osteoporosis.

2. Materials and methods

The investigations were carried out in December 2017 and they covered 50 women aged 45-56 years, hospitalized in the District Health Centre in Kartuzy, Poland.

The respondents had clinically confirmed osteoporosis or a positive medical history by the abundance of the factors affecting the risk of getting that disease.

The evaluation of the nutrition way and the frequency of eating food products was carried out on the basis of the survey form that included also the questions concerning the lifestyle of the surveyed group, eating habits, the quantity and frequency of drinking alcohol and the usage of stimulants (including caffeine).

The investigation survey included the drawing up a daily diet list and recording the food eaten by the respondents.

Taking into account the daily nutrition survey the mean energy value of the daily food dose, the contents of the basic food components (carbohydrates, fats, protein) and selected mineral ingredients, in particular calcium and vitamin D, was evaluated. Also, other vital elements affecting calcium absorption, as magnesium, phosphorus and sodium, were determined. The important part of the investigation was the identification of the quantity of calcium and vitamin D in the eaten food.

At the analysis of the nutrition survey the album of the photos of the products and dishes as well as the album of the doses of products and dishes (Szponar, 2000; Szczygłowska *et al*.,1999) were used. For the further analysis of the collected data the "Dietetyk" computer software and the Nutrition Standards of the National Food and Nutrition Institute (Jarosz, 2012), and the Human Nutrition Standards (vitamins) (Bułhak-Jachymczyk, 2008) were used.

The obtained survey results were compared with the recommended nutrition standards for the surveyed group of women in the range of age 45 – 56.

3.Results and discussions

The surveyed group of 50 women aged 45 – 56 was characterized by the positive factors of risk of osteoporosis or had this disease already clinically confirmed. The inherent element of the evaluation of the nutrition correctness is the control of the body mass based on the BMI (Body Mass Index). The index was calculated using the Quetelet formula: $BMI = M/H^2$, where M = body mass [kg], H – body height [m].

The analysis of the BMI index value showed that only every second surveyed woman had the index at the correct level. The overweight (BMI = 25 up to 30) was found in 35% of the surveyed persons, whereas they remaining 25% had the 1st degree of obesity.

The data collected from the 24-hour surveys obtained for the investigated group enable to work out the content of diet ingredients. The evaluation of the content of nutritional ingredients was carried out on the basis of the standards presented in Table 1.

Table 1. The overview of the recommended nutrition standards of the determined nutritional ingredients and energetic value (Jarosz, 2012).

nutritional ingredient	recommended daily intake	notes
energetic value	1,900 up to 2,200 kcal	for the women aged up to 50 – at the level of 2,200 kcal, for those aged above 51 – 1,900 kcal.
carbohydrates	300 up to 340 g	for the women in the age range 60 up to 75 at the level of 320 g
fat total	60 up to 90 g	for the women in the age range 60 up to 75 at the level of 70 g
protein	70 up to 78 g	with the diet calorific value at the level 2,000 up to 2,200 kcal

The average calorific value of the meals eaten by the respondents was 2211.5 kcal. In every instance the minimum standard of the supply of energy was met. However, the correct values were supplied in 7 from 22 menus only. In the remaining part the respondents supplied more calories than those recommended. It was noted that it was habitual for the women with overweight (BMI = 25 up to 30) or 1st degree of obesity. In two cases the quantity of the supplied calories was exceeding 3000.

The average value of the carbohydrates in eaten meals was 340 g per day. Not in every instance the recommended supply was met. The correct values (300 up to 340 g) were supplied in 9 of 20 diets. In 9 other menus the indicated supply was exceeding the standard even by 60 up to 90 g per day.

The average content of fat in eaten meals was 94.2 g per day. It means that the

consumption was exceeding the intake standard recommended for the given population. The analysis enables to state that the content of total fats was exceeded in 12 of all menus, assuming the recommended standard at the level of 60 up to 90 g per day. It follows that only 30% of women was eating the amount of fat not exceeding the recommended standard (Jarosz, 2012).

In the diets being analysed the predominance of the consumption of animal proteins over the plant ones existed. The average consumption of total proteins per person per day was 65.5 g. That amount is insufficient according to the nutrition standard established by the National Food and Nutrition Institute (2012). The recommended intake at the level of 70 up to 78 g per day was met only in 8 of 20 menus, and this is 40% of the whole only. 12 menus did not meet the standard, which is as much as 60% of all the diets.

The content of the nutritional ingredients affecting the risk of the development of osteoporosis was determined based on the standards presented in Table 2.

Table 2. Overview of the recommended nutrition standards for the nutritional ingredients being determined (Ziemlański, 2001).

nutritional ingredient	recommended daily intake	notes
Calcium	1,100 up to 1,200 mg	for the women aged 26 up to 60
Magnesium	310 up to 350 mg	for the women aged 26 up to 60
Phosphorus	700 mg	for the women aged 26 up to 60
Sodium	2,000 mg	for the women aged 26 up to 60

In Figure 1 the results of the determined calcium content in menus are presented.

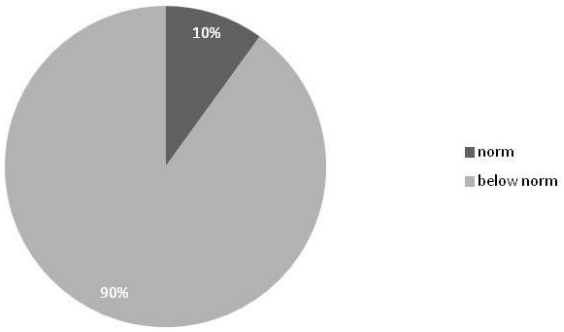

Figure 1. The content of calcium in menus

The women's diets were characterized by an insufficient supply of calcium when compared with the recommended one. The average intake of calcium was low and it was as small as 9555.5 mg per day. Only two menus were meeting the assumptions of the standards. As much as 90% of the diet lists did not cover the recommended consumption.

The analysis of the content of magnesium in menus showed a low intake of this element, at the level between 270 and 290 mg per day. The daily average intake among the surveyed women was 280 mg. The recommended intake was met only in 25% of all diet sets.

The absorption of phosphorus from foodstuff is high and it amounts to 60 up to 70%. Phosphorus commonly occurs in food so the deficiencies of that element happen seldom. The average content of phosphorus in the analysed menus definitely exceeded the Ziemlański's recommended standards (2001) and it was amounted to 1,640 mg per day. The similar values or those not exceeding the standard were found only in 20% of all the examined diet sets (Ziemlański, 2001).

The analysed menus were enabling to state that the basic source of sodium for the surveyed women was meat and meat products. On the average the content of sodium in food doses was 2700 mg per day, and this considerably exceeds the recommended standard.

In Table 3 the recommended daily supply of vitamin D for the women aged 51 up to 56 is presented.

Table 3. The recommended nutritional standard regarding vitamin D (Jarosz, 2012).

vitamin	recommended intake	notes
vitamin D	10 μg	for women aged between 51 and 65, for women below 51 years old it is at the level of 5 μg per day, and for those above 65 - 15 μg per day.

The recommended doses of vitamin D are 5 μg, while for the women above 65 years old its supply is at the level of 15 μg per day.

The results of the determined content of vitamin D in diets are presented in Figure 2.

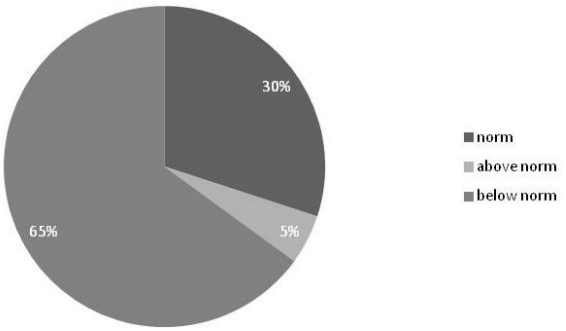

Figure 2. The content of vitamin D in menus

The average content of vitamin D in menus was 6,41 μg per day. Only in two menus the content was in compliance with the standard recommended by Bułhak-Jachymczyk (2008), and two other showed the values close to them. In one instance the intake at the level of 13 μg per day was found (Bułhak-Jachymczyk, 2008).

In the survey investigation the respondents were asked about the preferences of drinking coffee. In the survey investigation the respondents were asked about the preferences of drinking coffee. Only 20% of the surveyed women declared they drink coffee occasionally only, and 15 % do not drink it at all.

Among the respondents as much as 30% declared long lasting smoking tobacco for many years. Almost the same number of women claim they smoke sporadically but permanently.

Among the surveyed women the intake of alcohol 2 – 4 times a week was declared by 10% of them. Occasionally but regularly as much as 80% of the examined women were using alcohol.

The lack of movement is not the determinant of the development of osteoporosis but it speeds up the decay of bones. Altogether 60% of the surveyed women declare a poor movement activity, and 15% of them say they move with difficulty. Only 25% declared a moderate activity which statistically is a insufficient value to ensure proper skeleton states in the surveyed group.

The basis for the functioning of the human organism is the delivery of the proper amount of energy. The daily caloric demand is conditioned by, among other things, lifestyle, physical activity, age and sex. The delivered energy comes mainly from carbohydrates, proteins and fats. Those ingredients serve as energy, building, or regulating material (Czerwińska, 2010).

Almost half of the interviewed women showed the BMI index value considerable exceeded. This is confirmed also by the results of the investigations carried out by Sawicki at al. (1998), as well as Szkop at al. (2003), where they investigated the impact of the nutrition of women on the development of osteoporosis. Those result were indicating an overweight or obesity of the surveyed persons which was a factor of limiting their mobility (Sawicki *et al.*, Szkop *et al*., 2003).

An important nutritional ingredient are carbohydrates (both absorbed and not absorbed). The main source of them are: cereals, bulb and root plants, sugar beets, and the seeds of leguminous plants. Also vegetables, fruits, and milk products (dieta.mp.pl, 2017).

The consumption of carbohydrates in excess leads to the conversion of them into fats. They are accumulated and deposited in the organism as the fat tissue causing overweight (zdrowezywienie.w.interia.pl, 2017).

In the own investigations a higher than that recommended consumption of carbohydrates in the diets of the surveyed women was indicated. Similarly, as found by Ilow at al. (1998) in the investigations of the way of nutrition of the women from the town of Legnica and surroundings (Poland), where a higher than that recommended consumption of carbohydrates was noted. Only two from among all the respondents did not satisfy the recommended standard sufficiently. The correct values to satisfy the standard constituted 45% of the whole (Ilow *et al*., 1998).

The examinated menus were also characterised by a low consumption of carbohydrates consisted of brown bread, groats, rice, or pasta/noodles rich in simple carbohydrates. In the further part of their investigations Ilow R. at al., (1998) found that relation when analysing the investigated nutrition behaviours of women from the point of view of getting osteoporosis (Ilow *et al*., 1998).

The food fats are the source of energy from both saturated and unsaturated fatty acids. This is the source of the essential nutritional ingredients, including the essential unsaturated fatty acids (UFAs) and the vitamins soluble in it (A.D.E.K.). The analysis of menus enables to state that mostly fats of animal origin were consumed that should be limited due to the susceptibility to atherosclerosis (Kunachowicz *et al*., 2009).

The fats of plant origin were only a small part of the total fat eaten. Plant oils are a good nutritional source of UFAs. Unfortunately, their supply in diets was only a sporadic fraction of the total consumed fats. Similar facts were observed by Gacek (2008) when investigating the nutritional behaviours of the group of elderly people living in Poland and Germany. Those investigations indicate the predominance of animal fats (meat, fat sausages) in diets (Gacek, 2008).

In the Sawicki's at al. (1997) and Szkop's at al. (2003) investigations the excessive consumption of fats involves the increased supply of calories which is tantamount to the development of the obesity among the interviewed women in the middle age range (Sawicki *et al.*, 1998; Szkop *et al.*, 2003).

Another essential component affecting the state of the skeletal system is protein. It constitutes the basic functional structure of every live cell in the human organism, and also directly affects the mineralization of bones (Hryniewiecki, Roszkowski, 2010).

The situation similar to the results of the own investigations concerning the low supply of total protein was observed by Pytasz and Lewiński (2004) when investigating the nutritional habits of the women in the period around menopause. However, the investigation results showed that the supply of protein was closer to the limit of the standard though it was insufficient anyway (Jarosz, 2012; Pytasz, Lewiński, 2004).

The filled survey form enabled to indicate the preferences concerning the products containing calcium and protein. The interviewed women declared they eat most readily milk products in the form of hard cheese, processed cheese, yogurt and curd. In the question about the eating of meat products the surveyed wormed were mostly giving positive answers. The most eaten protein food was that containing animal protein. The predominance of animal proteins in the diets of the interviewed women was confirmed by the investigation carried out by Franceschi et al. (1996) showing the relationship between the supply of protein and the bone density (Franceschi *et al*., 1996).

When considering the nutritional ingredients directly affecting the development or prevention of osteoporosis extremely important is a sufficient supply of calcium. Calcium is one of the basic components of the bone tissue. It ensures the correct mineralization of bones and provides their

highest mass. The deficiency of calcium cause brittleness of bones and osteoporosis (Flynn, 2003).

The considerable source of calcium are vegetables: cabbage, curly kale, Brussels sprouts, broccoli, ands also leguminous plants as soy, beans, lentils. The easiest way to satisfy the demand for calcium is to consume milk products. For the person who do not tolerate lactose present in milk fermented milk products are recommended (kephirs, yogurts, rennet cheeses) (Bujko, 2002). The results of the evaluation of the calcium content in the own investigations are confirmed by the Sawicki's investigations (1998). He was indicating the lower than recommended calcium intakes in the meals of the women at risk of osteoporosis (Sawicki *et al*., 1998).

The situation is worsened by the fact that calcium is absorbed from the digestive tract. This makes that ultimately less calcium lands in the organism (25 up to 75%). As Lloyd et al. (1993) indicated the level of the calcium absorption by women decreases along with age (Loyd *et al.,* 1993).

The main calcium sources in the menus being analyzed were milk products, and milk itself. Unlike the Szajkowski's investigations (2001) where the underestimation of milk products as the source of calcium for the people at the retirement age was indicated (Szajkowski, 2001).

Pytasz and Lewiński (2004) claim that the lower consumption of dairy products by women is adverse since the lack of lactose in the diet has an adverse effect reducing the absorption of the intaken calcium even by 50% (Pytasz, Lewiński, 2004).

Magnesium, as an important component of teeth and bones is the essential element of the prevention of osteoporosis. Its role is as vital as that of calcium. Apart from the mineralization it enhances the proper development of bones and speeds up their remodelling. Deficiencies of magnesium trigger strong ageing of bones (Pawlikowski, Niedźwiedzki, 2002).

The absorption of magnesium from a food ration is from 30 up to 40%. Magnesium can be found in the products in relatively small quantities. More magnesium is in brown bread or coarse groats. It is also present in the seeds of leguminous plants, nuts, cacao, chocolate, fish, and rennet cheeses (Kunachowicz *et al*., 2005). Szajkowski's investigations (2001) on the food rations of the people at the retirement age, from the point of view of magnesium content, were also showing an insufficient supply of this element in diets (Szajkowski, 2001). The low content of magnesium in food adversely affects the level of the active metabolite of vitamin D and reduces it. According to Hasik's opinion (1999) this violently reduces the absorption of calcium (Hasik, 1999).

Phosphorus directly affects the maintenance of the proper density of the bone tissue. However, a high intake of it leads to the losses of the bone mass due to the disorder in the calcium metabolism and the synthesis of vitamin D (Gawęcki, Hasik, 2000).

The products rich in phosphorus are mainly offal and fish. poultry, egg yolk, rennet cheeses, nuts, leguminous plant seeds, and also cereals. Phosphorus is added to food in technological processes (powdered soups, meat products, concentrates, frozen dishes, cola-type beverages) (Hodgson, 2007).

Przysławski at al. (2000) indicate the high level of the intake of phosphorus in the daily food rations for women and men in the period of menopause and andropause (Przysławski *et al*., 2000). The high level of phosphorus intake (more than 2 g/day) hinders the phosphorus absorption from the digestive track. According to the Pluskiewicz's opinion (2015) it disorders the utilization of magnesium and iron leading to bone porosity (Pluskiewicz, 2015).

Another essential nutritional ingredient affecting the bone condition is sodium. As indicated by Jensen (2005) the supply of sodium in the diets of Western countries exceeds the recommended standards by 2 up to 5 times. Also, the analysis of the menus shows that the supply of sodium exceeded the standards about twice (Jensen, 2005).

Adverse is a high intake of sodium among the interviewed persons, that is illustrated by the investigations of Przysławski and Nowak (1999) as well Lewandowski at al. (2000), since it causes the conditions favouring osteoporosis. When 1 g of sodium is intaken as much as 26 mg of calcium is excreted in urine. From the quoted literature it also results the similarity of the increased supply of sodium in the group of women in the period of menopause surveyed by Przysławski and Nowak (1999) (Przysławski, Nowak, 1999; Lewandowski *et al*., 2004).

Vitamin D is present in the human organism in 4 forms. The lack of any of them causes some changes in the skeletal system affecting the inability to absorb calcium and phosphorus (Flis, Konarzewska, 1988).

According to Lorenc's opinion (1995) the nutritional sources get the vital importance in winter season when the lack of sun. For elderly people the reserve of vitamin D decreases by 30% when compared with the years of youth (Lorenc, 1995). Vitamin D occurs in food in small quantities. It can be found in the products of animal origin (liver, milk, yolk, salmon, sardines, mackerel, herrings). As noted by Mirosław (2010) the fish fats, (mainly whale oil) oils are the richest in vitamin D. In plant products, as cereals and plant oils, vitamin D occurs in trace amounts (Mirosław, 2010).

The survey of the women in menopause age in point of view of the quantity structure of bones, carried out by Rico at al. (2002), confirm the low intake of vitamin D in their diets. As it results from the investigations, to decrease the risk of fractures at the women in the period of the deficiency of estrogens the supply of vitamin D should be increased (Rico *et al*., 2002).

Caffeine is an alkaloid present in coffee, tea, cacao, chocolate. According to Jarosz (2008) an excessive intake of this drug increases the risk of the development of osteoporosis. The same literature confirms that a cup (180 ml) of strong coffee worsens the balance of calcium by 5 mg per day. Drinking coffee increases the excretion of calcium in urine (Jarosz, 2008).

In the investigations carried out by Cooper (1992) the impact of caffeine on the risk of the development of osteoporosis was determined. It was shown that caffeine hinders the growth of bone cells (Cooper, 1992).

As showed in the survey of the women in post-menopause age carried out by Harris and Dawson-Hughes (1994) a considerable percentage of the interviewed persons drink two or more cups of coffee daily. Also, so high consumption was observed for 5 women what was 25% of all the surveyed persons. The same literature confirms that drinking coffee increases the risk of bone fractures for the women at an advanced age (Harris, Dawson-Hughes, 1994).

Scientific research show that smoking tobacco causes the increase of the frequency of the development of osteoporosis. As it results from the Franceschi's at al. (1996) investigations smoking tobacco and the length of the smoking period increase the risk of fractures twice and enhances the tendency for the development of osteoporosis or intensifies that disease (Franceschi *et al*., 1996). The investigations carried out by Linquist i Bengtsson (1979) indicated a high popularity of tobacco among the women in the middle age range and those in the menopause period. Every form of the use of tobacco by the women at risk of this disease is harmful since smoking tobacco hampers the formation of active vitamin D, decreasing the bone mass (Linquist, Bengtsson, 1979).

According to Jacob's opinion (2007) chronic alcoholic states are connected with the low concentration of calcium and mineral components in the human blood. Ethanol in high quantities affects the bone tissue and hinders its formation (Jacob, 2007). Drinking alcohol causes a reduction of the mineral bone density and the number of bone cells. Drinking alcohol as seldom as once or twice a week impairs the metabolism of vitamin D and reduces the absorption of calcium (Rico *et al*., 2002).

Miazgowski at al. (2000), in their epidemiological investigation of Warsaw and Szczecin (both in Poland) population, in point of view of the factors of the development of osteoporosis found that the persons at risk of the development of this disease do not claim abstinence from alcohol (Miazgowski *et al*., 2000).

An important factor affecting the development of osteoporosis is a poor physical activity. The bone, adapting to mechanical loads, through movement becomes more durable. As noted by Schurman (2008), bones without mechanical load loss their density and as consequence osteoporosis develops (Schurman *et al*., 2008).

The investigations of Anderson at al. (1996) confirm the reluctance to engage in psychical activity by the women at risk of osteoporosis. The authors emphasise also that movement is one of the best factors for the prevention of osteoporosis (Anderson *et al.*, 1996).

4. Conclusions

Abnormalities were found related to the use of stimulants and a poor physical activity. Improper was also the structure of the consumption of products and the resulting low supply of nutritional ingredients protecting the bone tissue. A low intake of calcium, magnesium, vitamin D and plant protein was noted. The food ingredients favouring the development of the disease were eaten in excess (animal protein, sodium and phosphorus). The investigated group was characterised by an improper value of the BMI index, what was caused by the supply of high energetic products (fats, simple carbohydrates).

Nutrition is an essential factor that should be modified affecting by this the maintenance of the bone mass. That is why it is worth to propose to the examined persons a nutrition education. Also the way of the nutrition of the surveyed persons should be adjusted so that to bring about some changes in the diet composition, including a considerable increase of calcium and vitamin D supply.

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RECOVERING NON-DEGRADED MEAT FROM SALMON BACKBONES (OVERVIEW)

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ABSTRACT
The paper presents overview of known and used in fish processing devices for recovery of non-degraded meat from salmon backbones after filleting. On the basis of this review the assumptions of scraping machine were formulated. Analysis of the known solutions of recovering meat equipment from salmon backbones after filleting showed that: mainly they focus on imitating hand processing, before mechanical processing the backbones, loose or hanging fragments resulting from filleting should be removed. This requires additional manual processing or additional functions in the construction, processing of a large mass of available raw material with such devices would force the installation of many additional processing lines in the processing plants only for the needs of waste management. It is economically unjustified.

1. Introduction

As a result of the machine filleting of gutted and deheaded salmon, two fillets with the skin and the backbone with the associated with it meat tissue are obtained. Fillets go to the next stages of the processing process, while the backbones remaining after filleting (Figure 1) are technological wastes.

Figure 1. Backbones after machine filleting of salmon (own study)

Studies have shown (Kołodziej *et al*., 2011) that the average share of meat remaining on the backbone after filleting is about 64.5% of their mass. Because the weight of spine after filleting is 14% of the mass of raw material before filleting (gutted fish with head), it is easy to estimate that the meat that remains after filleting on the backbone constitutes about 9% of the processed raw material. In the case of processed in Poland in 2017, 161.0 thousand tons of salmon, after filleting about 14.5 thousand tons of meat remained on the backbones.

Part of this meat can be recovered by scraping it manually from the backbones (Figure 2). The efficiency of such recovery is about 44%.

Figure 2. Manual recovery of meat from the salmon backbone after filleting (own study)

Meat, recovered by hand from the spine, in terms of sensory characteristics, chemical composition and nutritional value is a first-class food raw material. It is not different from meat in salmon fillets except for fragmentation - it is in the form of meat scraps (Figure 3).

Figure 3. Meat scraps manually recovered from the salmon backbones after filleting (own study)

Despite this, due to the high labor-intensity of manual processing many plants do not use recovery of meat for food purposes, and all the backbones are treated as waste.

Such use of backbones after filleting due to the high content of meat recoverable from them is unreasonable. That is why the National Marine Fisheries Research Institute work has been undertaken to develop a fairly simple and therefore inexpensive device for the mechanical recovery of meat from salmon backbones after filleting.

The conceptual work on such a device is preceded by presented in this article review of known methods of mechanical recovery of meat from salmon backbones and devices used for this purpose.

2. Materials and methods

Mechanical recovery of meat from backbones

In addition to manual recovery, there are three ways to recover meat from the backbone:

- pressure separation,
- thermal-mechanical scraping,
- mechanical scraping.

2.1. Pressure separation

Pressure separation is used in the so-called soft separators, widely used in the meat industry to separate hard and soft parts.

The essence of the pressure separation method is shown in Figure 4.

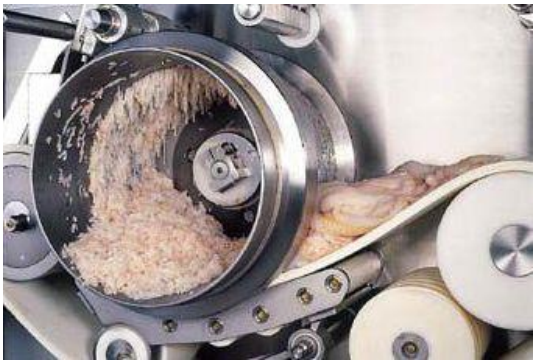

Figure 4. Recovery meat in a soft separator (http://www.bogima.pt/cache/binImagens/XPQL8wwXX1943hFemYbY04KZKU.pdf)

The meat recovered by pressure separation (Figure 5) has the following characteristics:

- it is very fragmented,
- contains more fat than natural meat,
- bone remains may remain in the mass,
- is more susceptible to oxidation.

Figure 5. Meat recovered in pressure separation (own study)

Despite considerable fragmentation, such meat is used to produce:
- frozen molded, breaded and fried products;
- meatballs in a sauce or pate;
- preserves - cold meats (smoked and dried kabanosy) and sausages.

2.2. Thermal-mechanical scraping

The method consists in weakening the bonds of meat with the backbone before the actual process of its recovery. The essence of the example solution is shown in Figure 6 (Fuller, 1980).

The recovery of meat from the bone is carried out by a stream of water or air, while the process of weakening the bonds is ensured by heat treatment and machining.

Three zones were distinguished in the device: I - loading zone with a rinsing section, II - weakening zone and III - meat recoverong zone.

During processing, the backbones lying on the conveyor 1 pass through sections I, II and III. Section II is a chamber with an air heater up to 65°C - 75°C and nozzles atomizing water.

Section III (Figure 7) includes a transverse row of rods, with heads at their lower ends in the form of tapered rubber tips that perform vertical movements due to the eccentric cam. Prepared in section II the raw material gets into section III, in which the efficiency of meat recovery is regulated by the water pressure in two rows of nozzles 5 and 6.

The row of nozzles 5 is a low pressure area, and when the row of nozzles 6 is a high pressure area. Depending on the desired degree of recovering meat, only nozzles 5 or simultaneously 5 and 6 can be used. In another version of the device, jets of water from nozzles 5 and 6 were replaced by an air stream. The advantage of air nozzles is the lack of watering the meat. However, it is more difficult to keep the process hygienic.

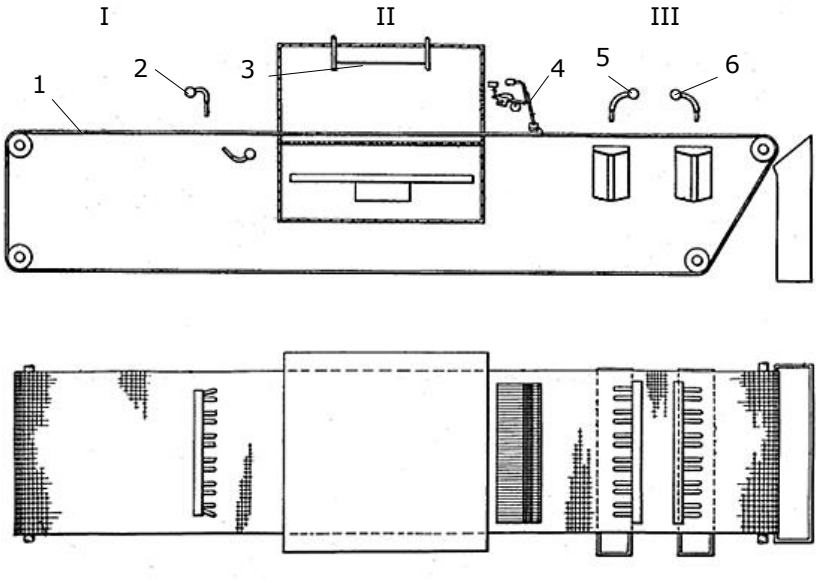

Figure 6. Device for thermal-mechanical salmon backbones scraping (Fuller, 1980)
I - loading and rinsing zone, II - weakening zone, III – meat recoverong zone,
1- conveyor, 2 - washing nozzles, 3 - heating chamber, 4 - mechanicalworking unit, 5 - low pressure nozzles, 6 - high pressure nozzles

2.3. Mechanical scraping

The mechanical method consists in scraping the skeletons in a manner similar to that used in manual processing. The basic difference between the known solutions lies in the method of transporting the raw material in the device.

2.3.1. Scraping machine with roller transport

An example of the solution is shown in Figures 7 and 8 (Francois, 1993). The machine comprises two shafts 1 and 1' which are movable relative to each other and on which there are wheels 2 with knurled surfaces which can draw a fish bone over scrapers 4 and 4' which are provided to scrape meat in the form of strips with the original structure.

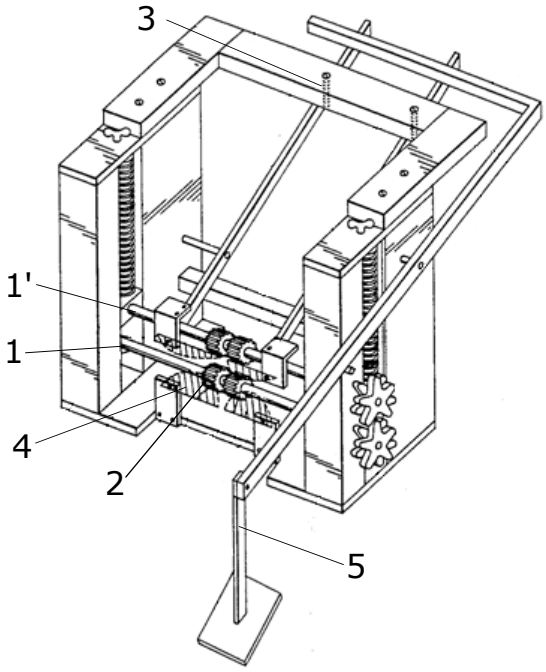

Figure 7. Scraping machine with roller transport (Francois, 1993)
1, 1' - shafts, 2 - wheels, 3 - pressing element, 4, 4' - scrapers, 5 - pressure lever

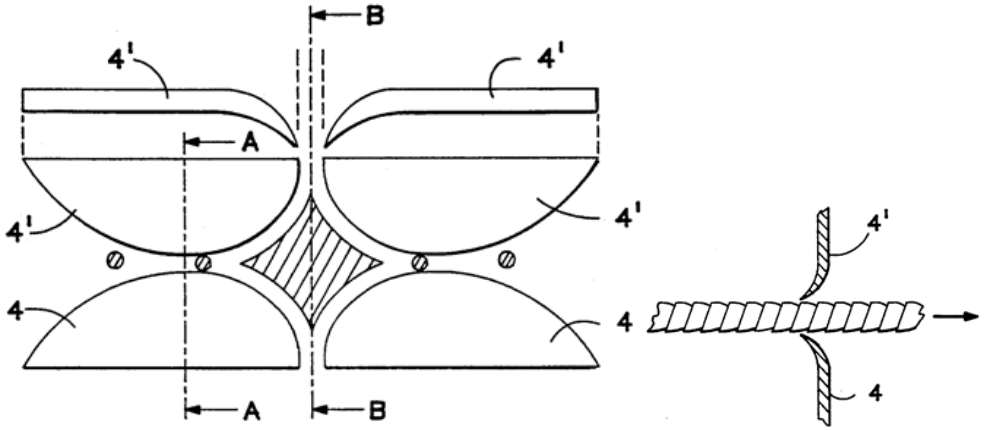

Figure 8. Scrapers (Francois 1993)
4, 4' - scrapers

2.3.2. Scraping machine with transport with spiked drive wheel

Another solution is shown in Figure 9.

The raw material must have ribs removed. The tail part can also be removed (optional). In the machine, backbones are fed between the introducing spiked drive wheel 1 and the pressure roller 2. The wheel 1 moves the backbone between the plates 3 and 4 along the channel 5. Sensor 6 controls scrapers 7. It activates the mechanism of infeed of 8 blades into the frame as soon as the backbone is between the transport wheels with spikes 9. When the backbone moves relative to the scraper blades, the scraped meat, in the form of strips, falls into the container (not shown). During processing, the framework is straightened by the leading plates 11. Behind the plates 10, the spiked wheel 12, removes the cleaned backbone from the device.

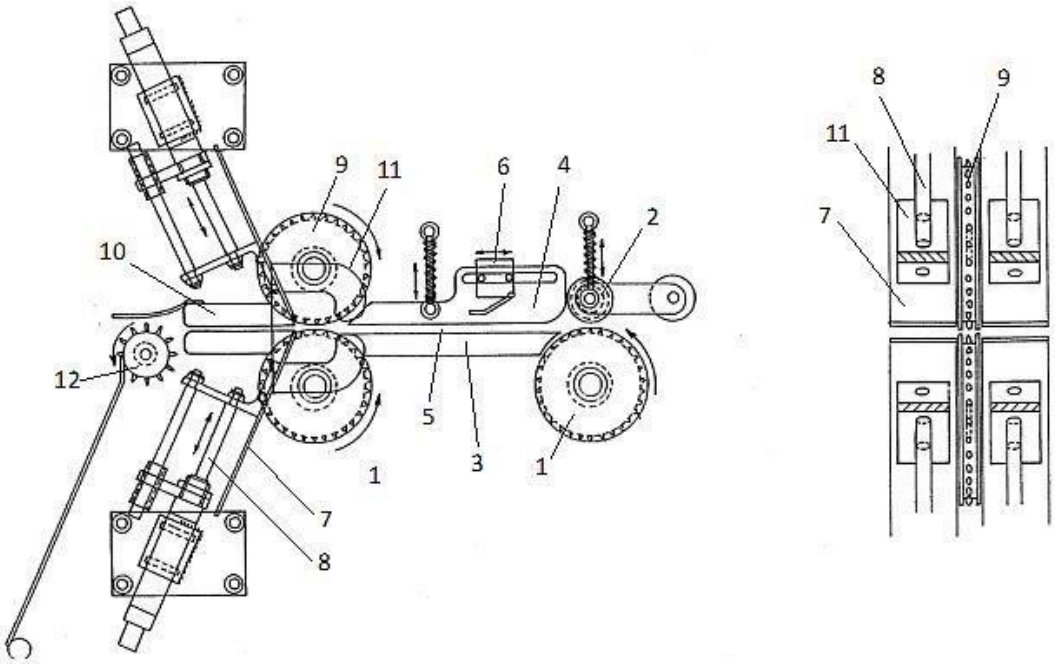

Figure 9. Scraping machine with transport with spiked drive wheel (Hockey and Oates, 2000)
1, 9, 12 - spiked drive wheel, 2 - pressure roller, 3, 4, 10, 11 - leading plates, 5 - leading channel, 6 - control sensor, 7 - scraper, 8 - scraper steering mechanism

2.3.3. Scraping machine with chain transport

A device of this type was proposed by Uni-Food Technic (Scraping machine typ SP 60J). The invention relates to a machine for scraping fish frames in particular salmon backbones, where the head, the tail and the two fillets (side pieces) have been cut off from the fish. The machine (Figure 10) is composed of a plane, oblong base plate 1 with a free deposit zone 4 for the fish frame F at one end, and a drive chain 3 recessed longitudinally in the base plate. Moreover, the machine comprises a hold-down plate 2, which is arranged at an adjustable height above the base plate and is spring-activated in a direction down toward the base plate, as well as four spoon-shaped scraper knives 6a, 6b, 6x, 6y, arranged in an adjustable height and angle position relative to the

base plate and the hold-down plate 2. The scraper knives 7 are disposed in pocket-shaped cutouts,

partly in the base plate, partly in the hold-down plate 2.

The fish backbones F is deposited manually on the deposit zone 4 of the base plate 1 and is moved inwardly below the hold-down plate 5 and 2, where the drive chain grips the fish frame with the toothed carrier links. The fish frame is now pulled longitudinally through the machine, while the scraper knives process their respective sides of the frame. During this procedure, the remaining fish meat is scraped off from the tail bone and the backbone of the fish frame. The fish meat is collected in containers arranged below the machine.

To prevent the relatively loosely attached belly bones of the fish from being scraped free during the scraping process, whereby undesired fish bones are mixed into the meat mass, it is expedient to lift the respective scraper knives 6a and 6x free from the fish frame during the passage of the belly zone. This may take place automatically by equipping the machine with a plurality of photocells and an encoder (not shown in the drawing).

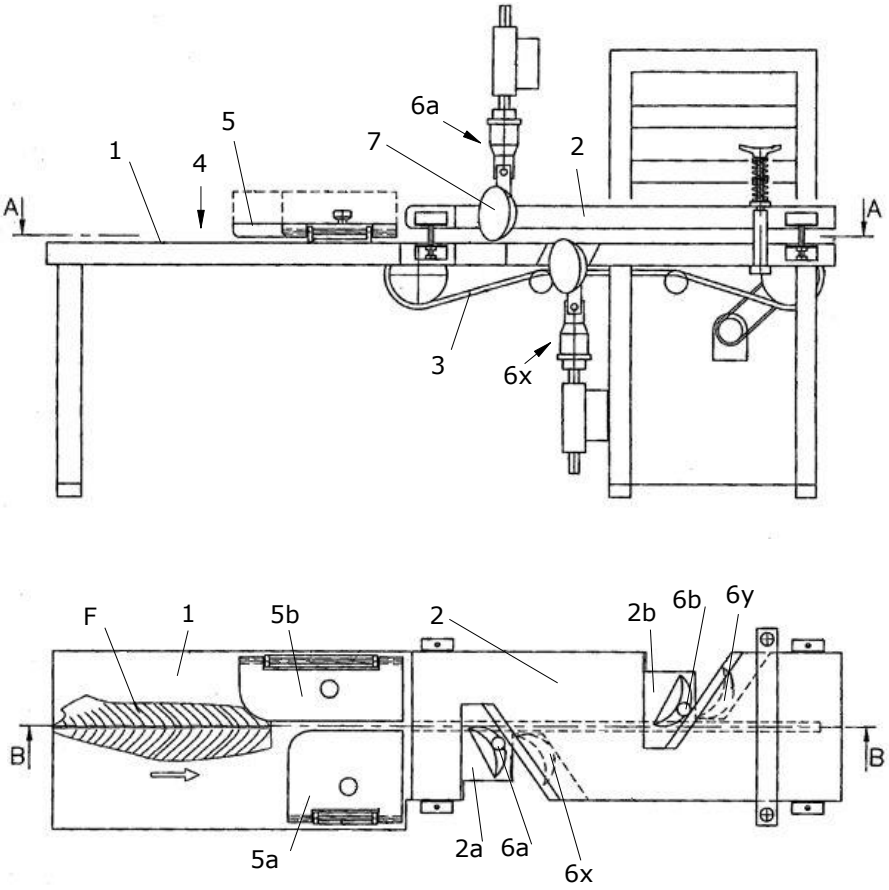

Figure 10. Scraping machine SP 60J (Andreasen, Jensen 2012)
1 - base plate, 2, 5 - hold-down plates, 3 - drive chain, 4 - deposit zone, 6, 7 - scraper knives,

4. Conclusions

Analysis of the known solutions of recovering meat equipment from salmon backbones after filleting showed that:

- mainly they focus on imitating hand processing,
- before mechanical processing the backbones, loose or hanging fragments resulting from filleting should be removed. This requires additional manual processing or additional functions in the construction.
- processing of a large mass of available raw material with such devices would force the installation of many additional processing lines in the processing plants only for the needs of waste management. It is economically unjustified.

There is still no device small enough to allow many such devices to be used in one processing plant and so simple that it is cheap. Therefore, at the National Marine Fisheries Research Institute, work was undertaken to develop such a device assuming the following assumptions:

- simple design requires a departure from the manual processing mapping,
- operation of the device should minimize the pre-treatment of backbones,
- it is advantageous to eliminate from the operation of the device the clockwise movement in favor of continuous motion.

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