*Dr hab. inż. Monika JANOWICZ, prof. SGGW
*Dr inż. Sabina GALUS
*Dr hab. inż. Agnieszka CIURZYŃSKA
**Dr Mia KUREK
*Mgr inż. Marlena MICHALSKA
*Department of Food Engineering and Process Management, Institute of Food Sciences, Warsaw University of Life science (SGGW-WULS) Warsaw, Poland
*Katedra Inżynierii Żywności i Organizacji Produkcji, Instytut Nauk o Żywności
Szkoła Główna Gospodarstwa Wiejskiego w Warszawie, Polska
**Faculty of Food Technology and Biotechnology, University of Zagreb, Pierottijeva 6, 10000 Zagreb, Croatia

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

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

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

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

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

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

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

INTRODUCTION

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

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

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

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

THE ROLE OF FRUIT IN HUMAN DIET

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

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

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

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

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

FRUIT SNACKS BASED ON PUREE – LEATHER FRUIT

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

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

The aim of the study was to evaluate the properties of leather fruit based on puree from own and industrial production. The scope of work included: developing the composition and method of obtained fruit structures with the use of puree: blackcurrant, plum, apple and apple with skin; developing a method of pouring properly prepared puree so as to obtain structures after drying, the dry substance content will be between 0.04 and 0.05 $g_{d.m.}/cm^2$ of the surface obtained by Fruit leather after the drying process; selected properties of leather fruit with particular emphasis on: dry substance content, solubility, opacity, testing mechanical properties are investigated.

MATERIALS AND METHOD

Technological methods

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

Preparation of apple puree

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

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

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

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

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

Source: Own study

Źródło: Badania własne

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

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

The solubility was calculated from the formula:

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

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

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

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

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

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

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

RESULTS AND DISCUSSION

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

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

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

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

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

Source: Own study

Źródło: Badania własne

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

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

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

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

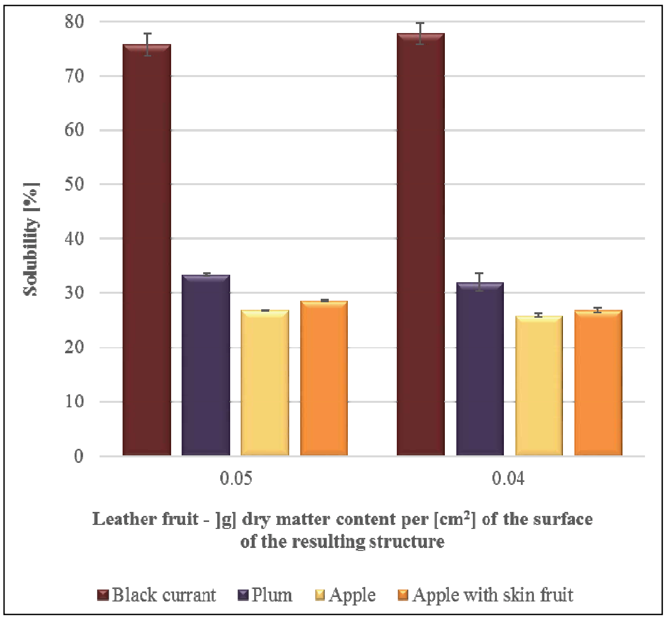

Fig. 2. Effect of the type of fruit puree and the dry substance content on the solubility of leather fruit.

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

Source: Own study

Źródło: Badania własne

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

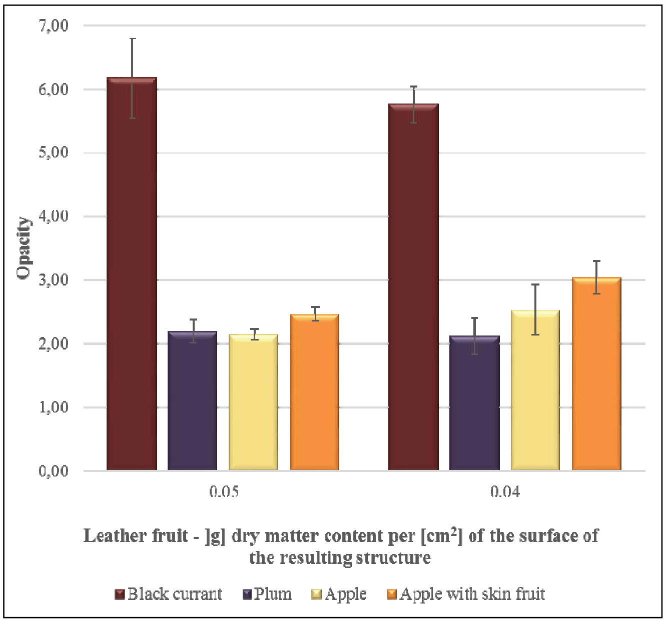

Fig. 3. Effect of the type of fruit puree and the dry substance content on the opacity of leather fruit.
Rys. 3. Wpływ rodzaju przecieru owocowego i zawartości suchej masy na nieprzeźroczystość leather fruit.
Source: Own study
Źródło: Badania własne

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

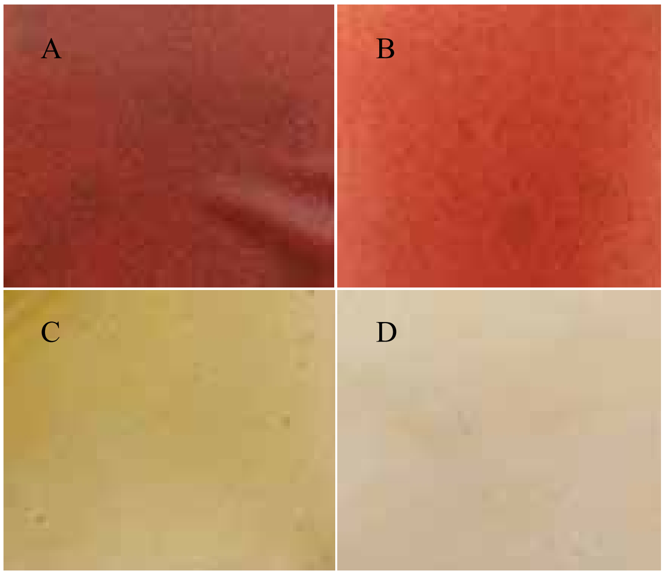

Fig. 4. Leather fruit with different dry matter content per cm² of the resulting structure area: A - plum 0.05 $g_{d.m.}/cm^2$; B - plum - 0.04 $g_{d.m.}/cm^2$; C – apple - 0.05 $g_{d.m.}/cm^2$; D - apple -0.04 $g_{d.m.}/cm^2$.
Rys. 4. Leather fruit o różnej zawartości suchej masy na cm² powstałej powierzchni struktury: A - śliwka 0.05 $g_{s.s.}/cm^2$; B - śliwka - 0.04 $g_{s.s.}/cm^2$; C – jabłko- 0.05 $g_{s.s.}/cm^2$; D - jabłko -0.04 $g_{s.s.}/cm^2$.
Source: Own study
Źródło: Badania własne

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

Statistical analysis showed a significant difference between leather fruit obtained from blackcurrant puree and apple puree due to the variable dry matter content per cm^2 of the resulting structure surface. On the other hand, no statistically significant differences were found in plum and apple skins with skin. The analysis of the effect of the type of fruit puree used to produce leather fruit showed a significant statistical relationship between the types of fruit on the strength of the tested structures with different dry matter content in the materials. Analysis of mechanical properties is a fundamental pre-market research in food technology due to the wide variety of food products. Research into mechanical properties allows us to better understand the structure changes occurring during the drying process. Texture is a very good indicator of food quality and sometimes even decisive in consuming food choices. Mechanical properties make it possible to determine, inter alia, the strength and durability of fruit skins when used as coatings for edible films [14]. Leather fruit are products with low humidity and low durability. The composition of Leather fruit depends on the type of puree and the additives used. A common feature of all Leather fruits are large amounts of carbohydrates, which largely affect the texture properties [28]. The analysis of mechanical properties consists mainly of testing the tensile strength, sample elongation and the Young's Model.

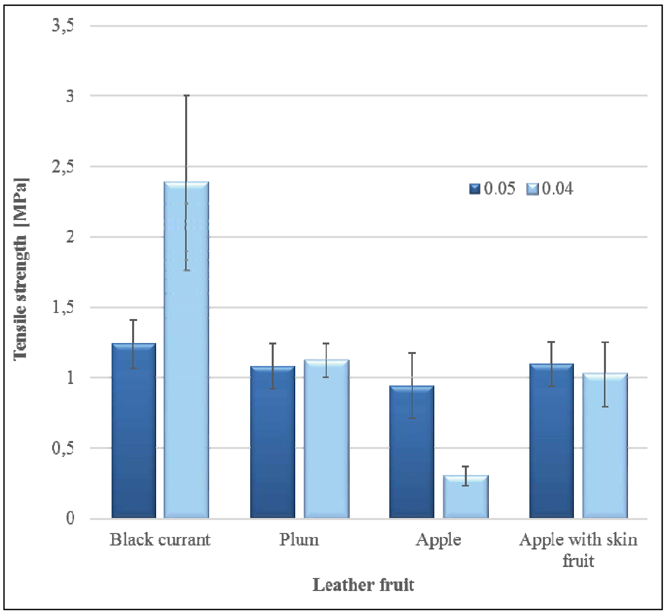

Fig. 5. Effect of the type of fruit puree and the dry substance content on the tensile strength of leather fruit.

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

Source: Own study

Źródło: Badania własne

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

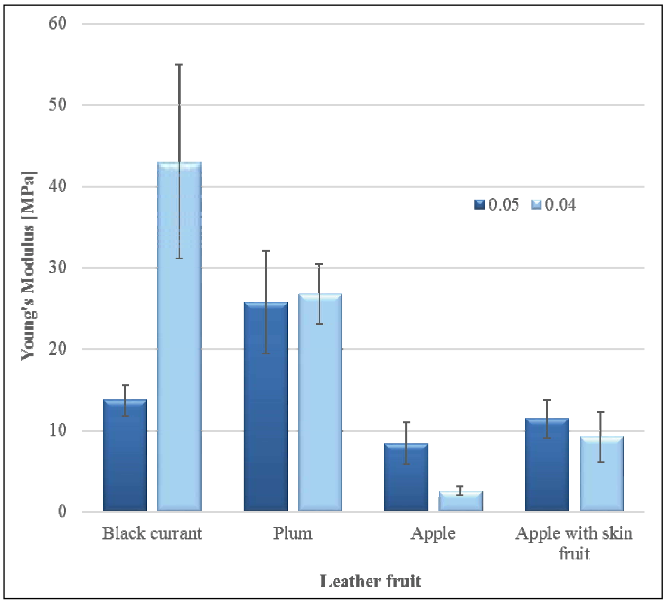

Fig. 6. Effect of the type of fruit puree and the dry substance content on the Young's Model of leather fruit.

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

Source: Own study

Źródło: Badania własne

SUMMARY AND CONCLUSION

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

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

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

PODSUMOWANIE I WNIOSKI

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

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

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

REFERENCES

[1] **ADILAH A., B. JAMILAH, M. NORNIZAN, Z. HANANI. 2018.** "Utilization of mango peel extracts on the biodegradable films for active packaging". Food Packaging and Shelf Life 16: 1–7.

[2] **BASIAK E., A. LENART, F. DEBEAUFORT. 2017.** "Effect of starch type on the physicochemical properties of edible films". International Journal of Biological Macromolecules 98: 348–356.

[3] **CHAN Y., A. MARTYNENKO. 2018.** "Combination of hydrothermodynamic (HTD) processing and different drying methods for natural blueberry leather". LWT - Food Science and Technology 87: 470–477.

[4] **EYIZ V., I. TONTUL, S. TURKER. 2020.** "The effect of edible coatings on physical and chemical characteristics of fruit bars". Journal of Food Measurement and Characterization. https://doi.org/10.1007/s11694-020-00425-0

[5] **FLORES S., L. FAMA, A. ROJAS, S. GOYANES, L. GERSCHENSON. 2007. "**Physical properties of tapioca- starch edible films: Influence of filmmaking and potassium sorbate". Food Research International 40: 257–265.

REFERENCES

[1] **ADILAH A., B. JAMILAH, M. NORNIZAN, Z. HANANI. 2018**. "Utilization of mango peel extracts on the biodegradable films for active packaging". Food Packaging and Shelf Life 16: 1–7.

[2] **BASIAK E., A. LENART, F. DEBEAUFORT. 2017**. "Effect of starch type on the physicochemical properties of edible films". International Journal of Biological Macromolecules 98: 348–356.

[3] **CHAN Y., A. MARTYNENKO. 2018**. "Combination of hydrothermodynamic (HTD) processing and different drying methods for natural blueberry leather". LWT - Food Science and Technology 87: 470–477.

[4] **EYIZ V., I. TONTUL, S. TURKER. 2020**. "The effect of edible coatings on physical and chemical characteristics of fruit bars". Journal of Food Measurement and Characterization. https://doi.org/10.1007/s11694-020-00425-0

[5] **FLORES S., L. FAMA, A. ROJAS, S. GOYANES, L. GERSCHENSON. 2007**. "Physical properties of tapioca- starch edible films: Influence of filmmaking and potassium sorbate". Food Research International 40: 257–265.

[6] **GALUS A., H. MATHIEU, A. LENART, F. DEBEAUFORT. 2012.** “Effect of modified starch or maltodextrin incorporation on the barrier and mechanical properties, moisture sensitivity and appearance of soy protein isolate-based edible films”. Innovative Food Science & Emerging Technologies 16: 148–154.

[7] **HAMUŁKA J., A. GRONOWSKA-SENGER, M. DRYWIEŃ, A. WAWRZYNIAK. 2018.** Oznaczenie zawartości wody i suchej masy w wybranych produktach spożywczych. W: Analiza żywności zbiór ćwiczeń (red. Gronowska-Segner). Warszawa: Wydawnictwo SGGW: 13–15.

[8] **HANANI Z., A. HUSNA, S. SYAHIDA, M. KHAIZURA, B. JAMILAH. 2018.** “Effect of different fruit pesel on the functional properties of gelatin/ polyethylene bilayer films for active packaging”. Food Packaging and Shelf Life 18: 201–211.

[9] **HEDAYATIZADECH M., H. CHAJI. 2016. “**A review on plum drying”. Renewable and Sustainable Energy Reviews 56: 362–367.

[10] **JURGIEL-MAŁECKA G., A. BUCHWAL. 2016.** „Charakterystyka składu chemicznego owoców porzeczki uprawianej w regionie pomorza zachodniego”. Żywność. Nauka. Technologia. Jakość 6 (109): 90–101.

[11] **KAYA S., A. MASKAN. 2003.** “Water vapor permeability of pestil (a fruitl eather) made from boiled grape juice with starch”. Journal of Food Engineering 57 (3): 295–299.

[12] **KHAN A., A. ZEB, M. KHAN, W. SHAH. 2014. “**Preparation and Evaluation of Olive Apple Blended Leather”. International Journal of Food Science 3 (7): 134–137.

[13] **KICZOROWSKA B., P. KICZOROWSKI, A. BOCHNIARZ. 2006. „**Skład chemiczny skórki i miąższu jabłek odmian Jonica i Champion wyprodukowanych w sadach województwa lubelskiego”. Acta Agrophysica 8 (2): 375–382.

[14] **KOKOSZKA S., A. LENART. 2007.** „Charakterystyka wybranych właściwości fizycznych powłok jadalnych.” Postępy Techniki Przetwórstwa Spożywczego 1: 47–51.

[15] **KOWALSKA H., A. MARZEC, J. KOWALSKA, K. SAMBORSKA, M. TYWONEK, A. LENART. 2018**. „Development of Apple chips technology”. Heat and Mass Transfer 54: 3573–3586.

[16] **LOTH K.. A. TATE, A. TROFHOLZ, J. FISHER, D. NEUMARK- SZTAINER, J. BERGE. 2020.** “The Contribution of Snacking to Overall Diet Intake among an Ethnically and Racially Diverse Population of Boys and Girls”. Journal of the Academy of Nutrition and Dietetics 120 (2): 270–279.

[17] **MENZEL J., R. BIEMANN, A. LONGREE, B. ISERMANN, K. MAI, M. SHULZZE, K. ABRAHAM, C. WEIKERT. 2020.** “Associations of a vegan diet with inflammatory biomarkers”. Scientific Reports 10: 1933.

[6] **GALUS A., H. MATHIEU, A. LENART, F. DEBEAUFORT. 2012**. “Effect of modified starch or maltodextrin incorporation on the barrier and mechanical properties, moisture sensitivity and appearance of soy protein isolate-based edible films”. Innovative Food Science & Emerging Technologies 16: 148–154.

[7] **HAMULKA J., A. GRONOWSKA-SENGER, M. DRYWIEN, A. WAWRZYNIAK. 2018**. Oznaczenie zawartosci wody i suchej masy w wybranych produktach spozywczych. W: Analiza zywnosci zbior cwiczen (red. Gronowska-Segner). Warszawa: Wydawnictwo SGGW: 13–15.

[8] **HANANI Z., A. HUSNA, S. SYAHIDA, M. KHAIZURA, B. JAMILAH. 2018**. “Effect of different fruit pesel on the functional properties of gelatin/ polyethylene bilayer films for active packaging”. Food Packaging and Shelf Life 18: 201–211.

[9] **HEDAYATIZADECH M., H. CHAJI. 2016**. “A review on plum drying”. Renewable and Sustainable Energy Reviews 56: 362–367.

[10] **JURGIEL-MALECKA G., A. BUCHWAL. 2016**. „Charakterystyka skladu chemicznego owocow porzeczki uprawianej w regionie pomorza zachodniego”. Zywnosc. Nauka. Technologia. Jakosc 6 (109): 90–101.

[11] **KAYA S., A. MASKAN. 2003**. “Water vapor permeability of pestil (a fruitl eather) made from boiled grape juice with starch”. Journal of Food Engineering 57 (3): 295–299.

[12] **KHAN A., A. ZEB, M. KHAN, W. SHAH. 2014**. “Preparation and Evaluation of Olive Apple Blended Leather”. International Journal of Food Science 3 (7): 134–137.

[13] **KICZOROWSKA B., P. KICZOROWSKI, A. BOCHNIARZ. 2006**. „Sklad chemiczny skorki i miazszu jablek odmian Jonica i Champion wyprodukowanych w sadach wojewodztwa lubelskiego”. Acta Agrophysica 8 (2): 375–382.

[14] **KOKOSZKA S., A. LENART. 2007**. “Charakterystyka wybranych wlasciwosci fizycznych powlok jadalnych.” Postepy Techniki Przetworstwa Spozywczego 1: 47–51.

[15] **KOWALSKA H., A. MARZEC, J. KOWALSKA, K. SAMBORSKA, M. TYWONEK, A. LENART. 2018**. „Development of Apple chips technology”. Heat and Mass Transfer 54: 3573–3586.

[16] **LOTH K.. A. TATE, A. TROFHOLZ, J. FISHER, D. NEUMARK- SZTAINER, J. BERGE. 2020**. “The Contribution of Snacking to Overall Diet Intake among an Ethnically and Racially Diverse Population of Boys and Girls”. Journal of the Academy of Nutrition and Dietetics 120 (2): 270–279.

[17] **MENZEL J., R. BIEMANN, A. LONGREE, B. ISERMANN, K. MAI, M. SHULZZE, K. ABRAHAM, C. WEIKERT. 2020**. “Associations of a vegan diet with inflammatory biomarkers”. Scientific Reports 10: 1933.

[18] **MOZAFFARIAN D. 2020.** "Dietary and policy priorities to reduce the global crises of obsesity and diabetes". Nat Food 1: 38–50.

[19] **OLIVEIRA A., A. AMARO, M. PINTADO. 2018. "**Impact of food matrix components on nutritional and functional properties of fruit based products". Current Opinion in Food Science 22: 153–159.

[20] **POTTER R., V. STOJCESKA, A. PLUNKETT. 2013.** "The use of fruit powders in extruded snacks suitable for Children's diets". LWT- Food Science and Technology 51 (2): 537–544.

[21] **QUINTERO- RUIZ N., S. DEMARCHI, F. MASSOLO, L. RODONI, S. GINER. 2012.** "Evaluation of quality during storage of apple leather. LWT – Food Science and Technology" 47 (2): 485–492.

[22] **RAABI C., N. OEHLER. 1999.** Making Dried Fruit Leather. Oregon State University Extension Service, Corvallis, USA, 232: 1–4.

[23] **RAVANIC M., V. OBRADOVIC, S. SKRABAL. 2012.** "Change of plum puree rheological parameters during storage in the freezer". In Proceedings. 47th Croatian and 7th International Symposium on Agriculture. Opatija. Croatia (Vol. 839, p. 842).

[24] **SIMÃO R., J. MORAES, B. CARCIOFI, J. LAURINDO. 2019.** "Recent Advances in the Production of Fruit Leathers". Food Engineering Reviews 12: 68–82.

[25] **SUN – WATERHOUSE D. 2011**. "The development of fruit- based functional foods targeting the health and wellness market: a review". International Journal of Food Science & Technology 46 (5): 899–920.

[26] **TAŃSKA M., B. ROSZKOWSKA, S. CZAPLICKI, E. BOROWSKA, J. BOJARSKA, A. DĄBROWSKA. 2016.** „Effect of Fruit Pomace Addition on Shortbread Cookies to Improve Their Physical and Nutritional Values". Plant Foods for Human Nutrition 71: 307–313.

[27] **TONTUL I., A. TOPUZ. 2018.** "Production of pomegranate fruit leather (pestil) using different hydrocolloid mixtures: An optimization study by ixturedesing". Journal of Food Process Engineering 41 (3): 1–12.

[28] **TORLEY P.J., J. BOOER, B.R. BHANDARI, S. KASAPIS, P. SHRINIVAS, B. JIANG. 2018. "**Application of the synthetic polymer approach to the glass transition of fruit leathers". Journal of Food Engineering 86 (2): 243–250.

[29] **TULAMANDI S., V. RANGARAJAN, S. RIZVI, R. SINGHAL, S. CHATTOPADHYAY, N. SAHA. 2016.** "A biodegradable and edible packaging film based on papaya puree, gelatin, and defatted soy protein". Food Packaging and Shelf Life 10: 60–71.

[30] **UTTARWAR V.V., A.T. TAUR, A.R. SAWATE. 2018.** "Development and organoleptic evaluation of mixed fruit leather from bael and Aonla pulp". International Journal of Chemical Studies 6 (2): 2823–2825.

[18] **MOZAFFARIAN D. 2020**. "Dietary and policy priorities to reduce the global crises of obsesity and diabetes". Nat Food 1: 38–50.

[19] **OLIVEIRA A., A. AMARO, M. PINTADO. 2018**. "Impact of food matrix components on nutritional and functional properties of fruit based products". Current Opinion in Food Science 22: 153–159.

[20] **POTTER R., V. STOJCESKA, A. PLUNKETT. 2013**. "The use of fruit powders in extruded snacks suitable for Children's diets". LWT – Food Science and Technology 51 (2): 537–544.

[21] **QUINTERO- RUIZ N., S. DEMARCHI, F. MASSOLO, L. RODONI, S. GINER. 2012**. "Evaluation of quality during storage of apple leather. LWT -Food Science and Technology" 47 (2): 485–492.

[22] **RAABI C., N. OEHLER. 1999**. Making Dried Fruit Leather. Oregon State University Extension Service, Corvallis, USA, 232: 1–4.

[23] **RAVANIC M., V. OBRADOVIC, S. SKRABAL. 2012**. "Change of plum puree rheological parameters during storage in the freezer". In Proceedings. 47th Croatian and 7th International Symposium on Agriculture. Opatija. Croatia (Vol. 839, p. 842).

[24] **SIMAO R., J. MORAES, B. CARCIOFI, J. LAURINDO. 2019**. "Recent Advances in the Production of Fruit Leathers". Food Engineering Reviews 12: 68–82.

[25] **SUN - WATERHOUSE D. 2011**. "The development of fruit- based functional foods targeting the health and wellness market: a review". International Journal of Food Science & Technology 46 (5): 899–920.

[26] **TANSKA M., B. ROSZKOWSKA, S. CZAPLICKI, E. BOROWSKA, J. BOJARSKA, A. DABROWSKA. 2016**. „Effect of Fruit Pomace Addition on Shortbread Cookies to Improve Their Physical and Nutritional Values". Plant Foods for Human Nutrition 71: 307–313.

[27] **TONTUL I., A. TOPUZ. 2018**. "Production of pomegranate fruit leather (pestil) using different hydrocolloid mixtures: An optimization study by ixturedesing". Journal of Food Process Engineering 41 (3): 1–12.

[28] **TORLEY P.J., J. BOOER, B.R. BHANDARI, S. KASAPIS, P. SHRINIVAS, B. JIANG. 2018**. "Application of the synthetic polymer approach to the glass transition of fruit leathers". Journal of Food Engineering 86 (2): 243–250.

[29] **TULAMANDI S., V. RANGARAJAN, S. RIZVI, R. SINGHAL, S. CHATTOPADHYAY, N. SAHA. 2016**. "A biodegradable and edible packaging film based on papaya puree, gelatin, and defatted soy protein". Food Packaging and Shelf Life 10: 60–71.

[30] **UTTARWAR V.V., A.T. TAUR, A.R. SAWATE. 2018**. "Development and organoleptic evaluation of mixed fruit leather from bael and Aonla pulp". International Journal of Chemical Studies 6 (2): 2823–2825.

[31] **WANG D., L. YANPING, A. AFSHIN, M. SPRINGMANN, D. MOZAFFARIAN, M. STAMPFER, F. HU, CH. MURRAY, W. WILLETT. 2019.** "Global Improvement in dietary quality could lead to substantial reduction in premature death". Journal of Nutrition 149 (6): 1065–1074.

[32] **WOJDYŁO A., J. OSZMIAŃSKI, P. BIELICKI. 2010.** „Zawartość wybranych wyróżników chemicznych w owocach trzech odmian jabłoni z uprawy ekologicznej I konwencjonalnej". Journal of Research and Applications in Agricultural Engineering 55 (4): 173–177.

[33] **WONGPHAN P., N. HARNKARNSUJARIT. 2020.** "Characterization of starch, agar and maltodextrin blends for controlled dissolution of edible films". International Journal of Biological Macromolecules 156: 80–93.

[34] **YOUNIS H., G. ZHAO. 2019.** "Physicochemical properties of the dibble films from the blends of high metoxyl apple pectin and chitosan". International Journal of Biological Macromolecules 131: 1057–1066.

[31] **WANG D., L. YANPING, A. AFSHIN, M. SPRINGMANN, D. MOZAFFARIAN, M. STAMPFER, F. HU, CH. MURRAY, W. WILLETT. 2019**. "Global Improvement in dietary quality could lead to substantial reduction in premature death". Journal of Nutrition 149 (6): 1065–1074.

[32] **WOJDYLO A., J. OSZMIANSKI, P. BIELICKI. 2010**. „Zawartosc wybranych wyroznikow chemicznych w owocach trzech odmian jabloni z uprawy ekologicznej I konwencjonalnej". Journal of Research and Applications in Agricultural Engineering 55 (4): 173–177.

[33] **WONGPHAN P., N. HARNKARNSUJARIT. 2020**. "Characterization of starch, agar and maltodextrin blends for controlled dissolution of edible films". International Journal of Biological Macromolecules 156: 80–93.

[34] **YOUNIS H., G. ZHAO. 2019**. "Physicochemical properties of the dibble films from the blends of high metoxyl apple pectin and chitosan". International Journal of Biological Macromolecules 131: 1057–1066.