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EFFECT OF STRUCTURE AND TEXTURE FORMING ADDITIVES ON PROPERTIES OF FREEZE-DRIED SNACKS – REVIEW®

Wpływ dodatku substancji kształtujących strukturę i teksturę na właściwości liofilizowanych przekąsek – przegląd®

Key words: freeze-dried snacks, hydrocolloids, fruit pomace, carrier agent, food properties.

The purpose of this paper was to review recent findings focused on the development of freeze-dried snacks with addition of hydrocolloids as carrier agents and evaluate the possibility of replacement of such additives with fruits pomace on the base of reports conducted on their application as additives modifying properties of various food products. The use of hydrocolloids allows to obtain freeze-dried gels characterised by porous and crispy structure that attracts consumers. These carrier agents increase glass transition temperature and reduce water adsorption ability of products, improving their stability and easing storage. On the other hand, fruit pomace managed as new foods ingredients affect functional properties of products too. There are findings proving that dried pomace powders affect quality of bread, confectionaries, yoghurt and meat products, principally enhancing their nutritional value and texture. Moreover, products fortified with fruit pomace are attractive and interesting for consumers, what improve their value even more. Dried fruit pomace powders has great potential for application in food industry, especially considering environmental point of view, therefore replacement of hydrocolloids in freeze-dried products seems to be promising subject for further research.

Słowa kluczowe: liofilizowane przekąski, hydrokoloidy, wytłoki owocowe, nośniki, modyfikacja właściwości żywności.

Celem pracy był przegląd najnowszych doniesień naukowych dotyczących opracowywania liofilizowanych przekąsek z dodatkiem hydrokoloidów jako nośników oraz dokonanie oceny możliwości zastąpienia tych składników wytłokami owocowymi na podstawie wyników otrzymanych w czasie badań prowadzonych na różnych produktach spożywczych wzbogaconych dodatkiem wytłoków. Dzięki zastosowaniu hydrokoloidów możliwe jest otrzymanie liofilizowanych żeli charakteryzujących się porowatą i chrupką strukturą, która jest atrakcyjna dla konsumentów. Te nośniki podwyższają także temperaturę przejścia szklistego produktów oraz obniżają zdolność pochłaniania wody z otoczenia, co poprawia stabilność i ułatwia przechowywanie. Zastosowanie wytłoków owocowych wpływa także na właściwości funkcjonalne żywności. Wykazano, że dodatek proszku z wytłoków kształtuje jakość produktów piekarsko-ciastkarskich, mlecznych oraz mięsnych, ze szczególnym uwzględnieniem wartości odżywczej i tekstury. Ponadto, produkty z dodatkiem wytłoków są atrakcyjne dla konsumentów i wzbudzają ich zainteresowanie. Proszki z suszonych wytłoków owocowych mają duży potencjał aplikacyjny w przemyśle spożywczym, szczególnie uwzględniając aspekt środowiskowy, dlatego też zastosowanie ich jako zamienników nośników hydrokoloidowych w produktach liofilizowanych jest obiecującym kierunkiem do dalszych badań.

INTRODUCTION

Fruits and vegetables are a natural source of nutrients and bioactive compounds a lot of which may be lost during processing. Because of high water content, extension of shelf life of fruits and vegetables is provided e.g. due to drying, which aims to reduce water content and activity, but also causes changes in products quality. Therefore, among many drying methods, freeze-drying was found to be the one ensuring the best quality of obtained products in terms of raw material characteristics preservation [4]. Recent research, focused on the development of healthy and attractive for consumers snacks, shows that producing of fruit and vegetable snacks due to freeze-drying requires the use of carrier agents that support structure, texture and functional properties creation [22]. That

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need results from low glass transition temperature of simple carbohydrates contained in aforementioned plant materials. Therefore, high molecular weight compounds (biopolymers), like hydrocolloids, maltodextrins, proteins and fibres, are applied to increase glass transition temperature that improves processing efficiency and, what is more important, products quality and stability [27,35]. Low glass transition temperature causes unwanted changes, such as stickiness, caking, structure collapse and phase transition, as a consequence of which products lose crispiness and became gummy, occurring even already at the time of freeze-drying or during storage [35]. The addition of carrier agents results in obtaining better quality and stability of products, but particular compounds used in this role affect characteristics of freeze-dried materials in the matter of mechanical, chemical and functional properties in their own way [13].

There were several research on the possibilities of using various biopolymers as additives modifying properties of freeze-dried snacks based on fruits, vegetables, pulps, juices and concentrates [8,9,14,35], but knowing freeze-drying is very time and energy consuming process, those products may not fit in the policy of food and agriculture industry sustainable development [20,39]. It is a fact that manufacturing of hydrocolloids, being compounds typically used as carrier agents, also is energy and resource demanding and such components usually are acquired using by-products as raw materials [17]. Combining that with recent findings about ability of such by-products, e.g. fruits pomace that are used as source for pectin extraction, to have positive influence on properties of food products they are applied in [24], it seems to be promising direction for further research to substitute traditional additives with new, more sustainable ones.

Therefore, the purpose of this review was to summarize recent findings focused on the development of freeze-dried snacks with addition of hydrocolloids as carrier agents. The second part was to evaluate the possibility of replacement of such additives with fruits pomace on the base of reports conducted on juice production by-products used as additives modifying various food products properties.

HYDROCOLLOIDS AS CARRIER AGENTS IN FREEZE-DRIED PRODUCTS BRIEF CHARACTERISTIC OF HYDROCOLLOIDS

Hydrocolloids are long chain carbohydrates and proteins the properties of which, including water absorption capability, strongly depend on their molecular structure and configuration [5,10,26] in association with external condition, e.g. pH, sugar content and ionic strength of the solution [8,10,14]. The use of hydrocolloids allows to recreate porous matrixes comparable to cellular tissue, but characterised by a set of designed and controlled properties [8]. Optimisation of gels with specific attributes may also be provided by blending various hydrocolloids, mutually influencing their behaviour. Due to synergism, quality of products obtained with biopolymers mixtures -are improved in comparison to features following the stand-alone application of particular

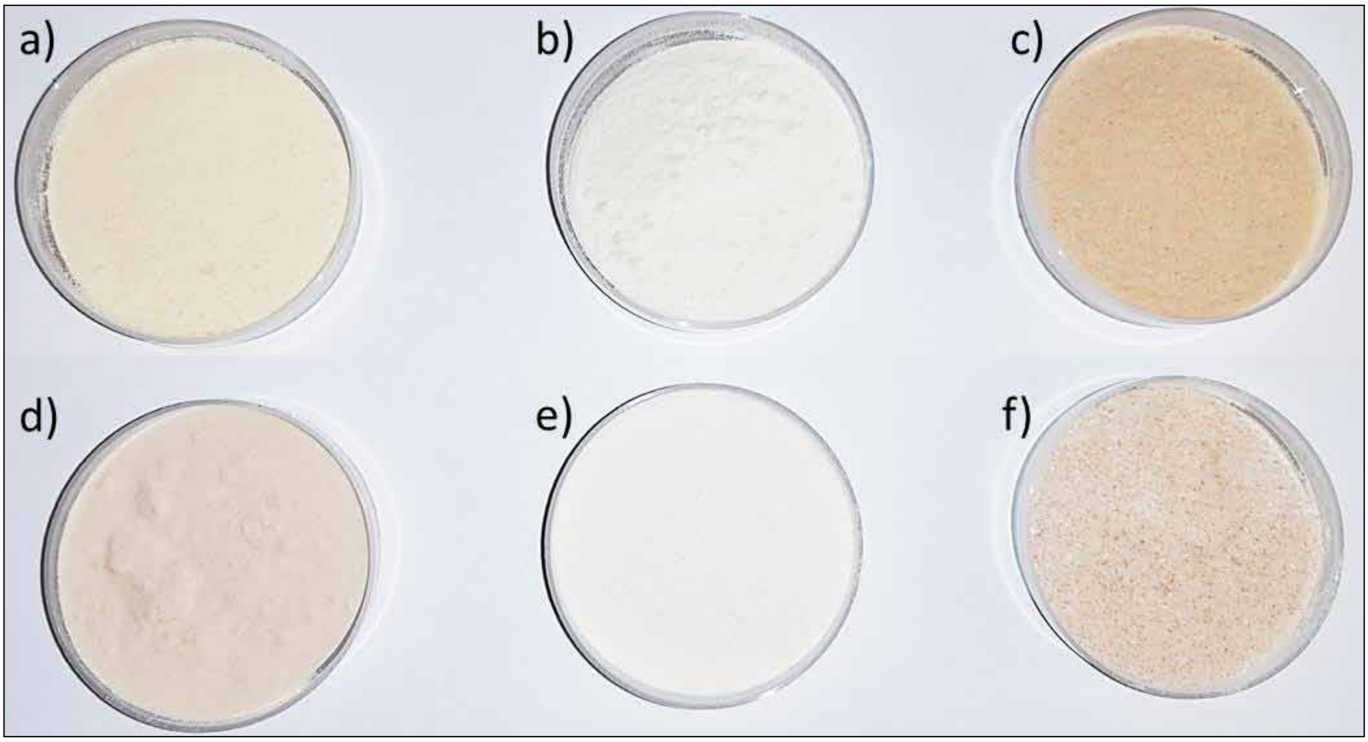

Fig. 1. Exemplary photos of hydrocolloids: guar gum (a), locust bean gum (b), low-methoxyl pectin (c), Arabic gum (d), sodium alginate (e) and high-methoxyl pectin (f).

Rys. 1. Fotografie przykładowych hydrokoloidów: guma guar (a), mączka chleba świętojańskiego (b), pektyna niskometylowana (c), guma arabska (d), alginian sodu (e) oraz pektyna wysokometylowana (f).

Source: Own study

Źródło: Opracowanie własne

compound [10]. Hydrocolloids dissolve or swell, when mixed with water, creating three-dimensional network that can exist at the presence of moisture, causing material to be plastic and viscous, or can be solidified due dehydration at specific conditions [14,18]. The best way to procure solidified gel products, maintaining the internal structure formed by hydrocolloids within processing, is freeze-drying that enables water removal without destroying sensitive bonds [10]. Because of their characteristics, hydrocolloids are used in food industry for various purposes, containing gelling, emulsifying, thickening, coating, structure- and texture-formation [26]. Various hydrocolloids, typically used in scientific research and food technology, are presented in Figure 1.

EFFECT ON WATER-RELATED PROPERTIES

Water acts as plasticiser in freeze-dried products, therefore, apart from microbiological safety, it is the factor determining textural and functional properties. When exposed to water, the freeze-dried material loses its crunchiness and becomes ductile and sticky. Consequently, optimisation of specifically low water content and activity in freeze-dried products is very important in terms of products quality and attractiveness [11,35]. Ciurzyńska et al. [9] investigated the effect of freeze-dried strawberry powder (7, 10%), calcium lactate (0.01, 0.05%), glucose (0, 5.2%) and chokeberry concentrate (0, 5.2%) concentration on the properties of freeze-dried gels obtained with 1.5% sodium alginate addition. Reduced amount of strawberry powder affected water content and activity, causing decrease (from 3.8 to 1.8%) and double increase to 0.39 of such properties, respectively. The investigation of the effect of the contribution of glucose and chokeberry concentrate in the composition of freeze-dried alginate gels revealed that supplementation of sugar source in the form of glucose, concentrate and both reduced water activity (0.39) by more than 50%, but only the addition of simple sugar caused significant increase of water content in the products to 4.9%. It also was found that freeze-dried sodium alginate gels rehydrated better when contained more sugar from fruit concentrates than pure glucose addition. Recently, Jakubczyk et al. [18] found that increasing amount of apple concentrate from 0 to 20% in agar gels had limited water activity reduction due freeze-drying, but maltodextrin used as supportive carrier agent contributed to significant decrease of such property. It was also investigated that freeze-dried gels obtained with strawberry pulp were characterised by lower water activity in comparison to model samples prepared by mixing hydrocolloids, water, sugars and citric acid. However, the use of fruit pulp significantly reduced water absorption capacity of the material, but regardless of composition rehydrated samples contained over 90% of water, which was more than initial water content in fresh mixtures before freeze-drying [12].

Martínez-Navarrete et al. [25] examined the influence of gellan gum and whey protein isolate blends applied in freeze-dried snacks obtained from mandarin juice. It was found that the addition of biopolymers multiplied water content in the products compared to simple freeze-dried juice, what was related to increased amount of non-freezable water that do not sublimate within freeze-drying. However, temperature of processing also affects water removal from the material and, when its increased, dehydration is intensified and final water content lessens, despite shorter drying time. In comparison, Ciurzyńska et al. [14] investigated multilayer freeze-dried snacks based on frozen vegetables, sodium alginate (1.5%) and mixture of locust bean and xantan gum, 1% each, were used to manufacture. Unlike aforementioned products based on fruits or hydrocolloids only, the snacks were characterised by much lower water activity (<0.045) and water content in range of 1.5–3.3%. It was presumed that such results were a consequence of strong water bonding capacity of hydrocolloidal systems used, since preparation of the material for freeze-drying required addition of about 58% of water, but it may be related to lower sugar content in vegetables compared to fruits what indicate more effective water removal as well.

Other research was carried out to examine the effect of hydrocolloid concentration, low-methoxyl pectin at 2, 2.5 and 3.5% specifically, on properties of freeze-dried gels obtained with freeze-dried strawberry powder. It was found that changes in properties are not linear with increasing concentration of hydrocolloid. Material with 2.5% of low-methoxyl pectin featured significantly lower water content and water activity. Even water gain due rehydration did not increase with the rise of carrier agent concentration and samples with 2.5% of pectin absorbed more water than others, but final water content after 30 mint of rehydration at 20°C decreased with the growth of hydrocolloid content [8]. Cassanelli et al. [5] examined impact of amount of hydrocolloid on properties of freeze-dried gels too. They used low and high acyl gellan gums at 1.5, 2, 2.5 and 3% proving that not only concentration but molecular structure of hydrocolloids determine processing and properties of final products. Gels obtained with high acyl gellan gum were characterised by significantly higher water activity and reached its values low enough to ensure microbiological safety after at least 30 h of dehydration, while samples with low acyl gum achieved that level at a time shorter than 24 h, attaining final water activity in range of 0.1–0.2 compared to 0.2–0.4 achieved by material with high acyl gellan gum after 48 h of freeze-drying. That experiment also confirmed that water activity values are not linearly connected with hydrocolloid concentration. A type of gellan gum turned out to be factor settling rehydration properties. Products with high acyl gum gained significantly low water compared to materials structured with low acyl hydrocolloid water content of which were found to depend on gellan gum concentration, thus the addition of 2.5 and 3% notably decreased water absorption capability. Blending of both types of gellan gum (1:1) allowed obtaining of material characterised by water activity reduction and rehydration properties closer to low acyl and high acyl gellan gum, respectively, and not at the halfway.

The use of various biopolymers, such as gums, maltodextrin, starches and fibres, as carrier agents reduces hygroscopicity that is high and crucial for porous freeze-dried materials. An increase of glass transition temperature by 5–15°C resulting from the addition of such compounds blends to orange snacks was estimated too, especially at low water activity [35]. Accordingly, an infusion of carrier agents is followed by an improvement of stability and, as a further consequence, perseverance of products quality during storage.

EFFECT ON COLOUR

Colour of the freeze-dried products is determined by natural colour of compounds used, principally the ones featured the greatest concentration of colourants. The addition of biopolymers induces lightness increase and colour intensity fading, what is related to their natural creamy or close to white colour, which can be observed in Figure 1. On the other hand, freeze-dried materials colour also depends on moisture content and the higher it is, the more intense the colour become, but water could activate biochemical reactions causing colourants degradation and dilution as well [35]. Colour of freeze-dried sodium alginate gels with freeze-dried strawberry powder depended on the addition of the powder and greater quantity intensified colour parameters, such as redness and hue angle, making products more attractive. Glucose and chokeberry concentrate addition to sodium alginate gels with strawberry powder also changed colour of such products in comparison to material without any of those, causing lightness and hue angle decrease and redness growth [9].

Concentration of low-methoxyl pectin in freeze-dried gels with strawberry powder also affected colour parameters, causing lightness and redness of them vary. But among other samples (2 and 3.5%), colour of the material with 2.5% of hydrocolloid was found closer to strawberry powder that was used as reference material, however, the differences of L^* and a^* were still about 10 and 7 units, respectively [8]. Carrier agents affect colour parameters of the material they are in, but they also act like protectors saving colourants from degradation caused by oxidation or thermal treatment [25].

EFFECT ON STRUCTURE AND TEXTURE PROPERTIES

Carrier agents support strengthening of the internal structure of freeze-dried products tending to collapse and lose crispiness to gumminess. Materials featuring high sugar content, such as fruit juices, are difficult to freeze-dry because of its low phase transition temperature that makes them less stable during storage. However, despite the addition of carrier agents, freeze-dried snacks exposed to relatively humid environment lose crunchiness and their mechanical properties change within time [25]. According to Silva-Espinoza et al. [35], biopolymers infusion into the formulation of freeze-dried fruit snacks extends the range of water activity in which the samples retain their properties, making them easier to store.

Structure and texture of the freeze-dried products may be modified not only by containing of certain additives, but also by using specific processes and parameters supporting formation of desired features. Both temperature and pressure, the freeze-drying is conducted at, are parameters influencing specific texture and sensory perception of freeze-dried snacks obtained with biopolymers as carrier agents [32, 33]. Optimisation of freeze-drying conditions also determines energy consumption of the processing, which is high for this dehydration method, so selection of processing parameters that work best lead to improvement of both quality and environmental impact of products [34]. Ciurzyńska and Lenart [7] analysed the effect of a type of hydrocolloid and aeration time, used as a process supporting porous structure formation, on the selected properties of freeze-dried gels. Examination of low-methoxyl pectin (3%) and mixtures of xantan gum with locust bean (1:0.5%) or guar (0.5:1.5%) gums aerated for 3 or 7 minutes implicated that both, type of carrier and time of aeration, determined properties of materials prepared under the same conditions. It was estimated that porosity of every sample was over 98%. Moreover, mean pores size was specific for each structure-forming additive used and increased with the prolongation of aerating. Structure of the freeze-dried gels obtained with low-methoxyl pectin was more organised and characterised by significantly greater pores, that grew with aeration, what induced higher water gain during rehydration. Combination of hydrocolloids may have an synergistic effect on the gelling properties, but considering presented findings, structure of materials obtained using mixes was more delicate and fragile comparing to samples with low-methoxyl pectin only. However, the authors observed that products structure softness after freeze-drying may be a consequence of gels stability before freezing and dehydration that indicates differences in gelling strength of particular hydrocolloids. The freeze-dried gels obtained with low-methoxyl pectin and the mixtures of gums performing aeration at various time showed that a type of hydrocolloid has strong impact on mechanical and acoustic properties. Samples with pectin were even double harder than gels with xantan and locust bean gums and more cracking of the internal structure were observed within compression of such sample, while curves determined for material formed with other carriers were smoother. Harder texture indicated also stronger acoustic emission that also can attract consumers [11]. In other work, significant impact of a type of hydrocolloid and aeration time on structure and texture of the freeze-dried gels was also proven [10]. The authors found that such factors affect porosity and pores size, internal structure and hardness of products, but it may be modified by addition of sugars, citric acid and calcium lactate mixture that interacts with hydrocolloids and works as strengthening factor, causing material to be compact and less porous at the same time. A comparison of low-methoxyl pectin and various hydrocolloids (xantan, locust bean and guar gums) working in synergistic mixtures structuring model system of strawberry containing 6.8% glucose, 1% sucrose and 0.64% citric acid and gel obtained with strawberry pulp induced that freeze-dried products obtained with pectin featured better and more regular structure, whether it was model or regular sample. It was assumed that using pectin is more beneficial for systems characterised by increased sugar content, therefore that is an additive recommended for optimisation freeze-dried products based on fruits and fruits derivatives [12]. Porosity and pore size distribution can be determined by molecular structure of hydrocolloids. In case of gellan gum at 2%, application of low acyl gellan gum leads structure of the freeze-dried gel to be designated by more numerous smaller pores that are evenly distributed in all volume of the material, while samples with high acyl gum were characterised by disarranged structure with smaller number of large pores in irregular shape. Moreover, combination of both types of gellan gum effected creation of structure with bigger pores in comparison to the material with low acyl gum, but not as large and definitely more organised as those observed in samples with high acyl gellan gum [5]. Carrier agent concentration in freeze-dried products has the greatest impact on structure and texture. An increase of low-methoxyl pectin amount had a great impact on texture of the freeze-dried gels, causing them to become harder and less fragile. In terms of functional properties and similarity to conventional products (freeze-dried strawberries and freeze-dried strawberry powder) the results were compared to, the best quality was identified in freeze-dried gels with low-methoxyl pectin addition at 2.5%. Since all samples (2 and 3.5%) were prepared using the same processing conditions, the authors explained variation of results to be dependent on different water binding and gelation ability of pectin at various concentration. As a consequence of that, highly porous and fragile structure was developed [8]. Compression test performed on freeze-dried sodium alginate gels shows that both amount of strawberry powder and calcium lactate significantly influenced textural properties of the freeze-dried gels strengthening their structure by increasing quantity of the compounds. Increasing sugar content also induced strengthening of the freeze-dried gels texture [9]. But it should be concerned that enhancement of sugar content by addition of fruit concentrate may cause structure collapse followed by crispiness loss. So in order to obtain possibly the best freeze-dried gels quality, optimal level of sugar should not be over heightened [18]. Moreover, hardness of freeze-dried vegetable gels structured with sodium alginate (13.2–13.3 N) was two times higher than products with the mixture of locust bean and xantan gums. Such results were found much lower in comparison to similar products obtained on the base of fruits, but closer to plain vegetable tissue subjected to freeze-drying. Considering, porosity of the examined materials also was lower and that usually indicates harder texture, referred results confirm the importance of sugar content and its strengthening effect on dehydrated structure [14]. And, according to Martínez-Navarrete et al. [25], consumers prefer snacks that are not particularly harder, but crispier, what is portrayed as turbulent compression curve characterised by a great number of force peaks and drops.

EFFECT ON NUTRITIONAL VALUE AND SENSORY PROPERTIES

Freeze-drying is the process carried out at low temperature and with very oxygen-reduced atmosphere, so bioactive compounds contained in materials processed with this method are safe from degradation in general. There were some mentions that an increase of shelf temperature during freeze-drying may even improve vitamin C extraction from the products, but the addition of high molecular weight biopolymers, like hydrocolloids, as carrier agents may limit accessibility of bioactive compounds as well [25]. On the other hand, Silva-Espinoza et al. [33] found that bioaccessibility of vitamin C and phenolic compounds had grown after freeze-drying of orange snacks, what lead to conclusion on protective effect of infusing biopolymers into the formulation on bioactive compounds retention due dehydration.

A huge part of hydrocolloids is accounted to dietary fibre, which improves natural functioning of human body and shows preventive effect on some of serious diseases, e.g. cardiovascular disease or diabetes [26]. According to Ciurzyńska et al. [8], highly porous structure of freeze-dried products obtained by addition of hydrocolloids seems promising as factor influencing satiety and energy intake through slowing down digestion. Therefore, consumption of such products seems promising in terms of body weight control. However, consumers should be cautious, because hydrocolloids decrease sensory perception, therefore to improve attractiveness of freeze-dried gels by intensifying their flavour compounds such as sugar and citric acid may be applied [11]. Those enhance textural properties, but increase sugar content and energy intake of products, causing them to be inappropriate for specific groups of consumers, such as diabetics and people working on weight loss. Freeze-dried gels obtained with hydrocolloids, flavour and aroma shaping additives and water only do not represent high nutritional value, but using fruit pulp instead allows to create similar characteristics and obtaining products of quality improved [12].

FRUIT POMACE AS ADDITIVES IN FOOD PRODUCTS BRIEF CHARACTERISTIC OF FRUIT POMACE

Pomace is a by-product, containing solid matter, peels and seeds, remained after fruits processing, e.g. juice or wine production [1]. Due to its relatively high moisture content, one of the most common method of pomace preservation is drying that eases storing and allow to obtain high quality product for further processing [15]. Figure 2 shows powders obtained by grinding dried fruits pomace. As reported by Diez-Sánchez et al. [15], dried pomace obtained from various berry fruits usually contain over 90% of dry matter that consists compounds as protein (2–17%), fat (0.6–22%), carbohydrates (up to 90%), ash (0.7–7%) and total dietary fiber in the range of 16 to even 96%. Berry pomace also contains great amounts of polyphenols that are responsible for high antioxidant capacity. In comparison, approximate composition of dried apple pomace includes protein (1.2–6.9%), fat (0.3–8.5%), simple sugars (14–72.5%), ash (0.5–4.3%) and total dietary fiber up to 82%. Additionally, it supplies polyphenols and micro- and macro- nutrients as well [3]. Pomace usually is disposed for animal feed, but because of low economical value and high bioactive compounds content, pomace infusion into a formulation of new food products became a significant subject of scientific research [1]. It was often exposed that addition of fruit pomace affects stability, nutritional and functional values of food products, including increase of antioxidant capacity and fiber content and prevention of microbiological spoilage and lipid oxidation, but it induces significant sensory and texture changes, which are not always recognise as attractive or even positive [3,15]. Fruit pomace is a rich source of pectin, therefore after subjection to hydrothermal treatment at certain conditions [16], it has a huge potential to create texture and structure of food products.

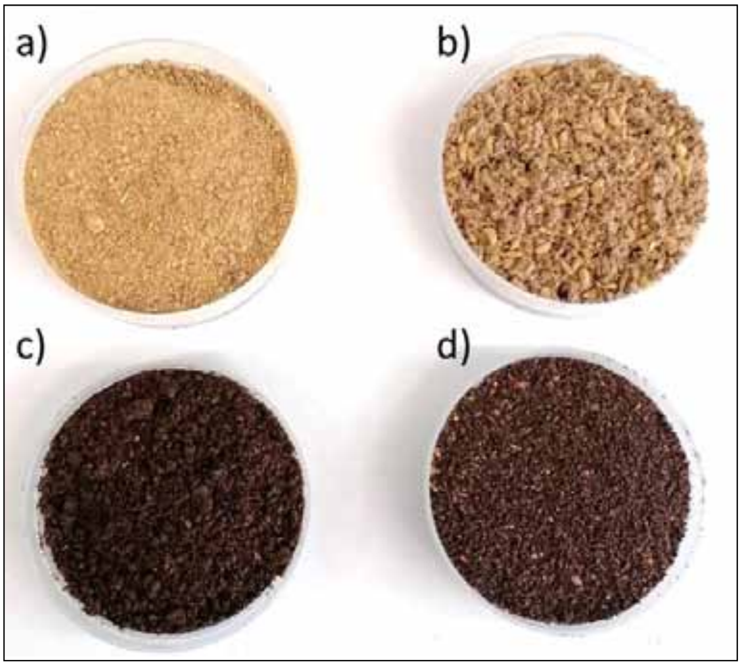

Fig. 2. Exemplary photos of dried apple (a), raspberry (b), blackcurrant (c) and chokeberry (d) pomace powders.
Rys. 2. Fotografie proszków z suszonych wytłoków jabłkowych (a), malinowych (b), z czarnej porzeczki (c) oraz aronii (d).
Source: Own study
Źródło: Opracowanie własne

FRUITS POMACE AS ADDITIVES CREATING FOOD PRODUCTS PROPERTIES

The effect of the addition of strawberry, raspberry, chokeberry, apple and blackcurrant pomace at 10, 20 and 30% on the characteristics of shortcrust pastries was studied in the bakery and pastry industry. Sensory analysis showed that the addition of fruit pomace increased the attractiveness of the products, improving their taste and aroma. Fruit pomace also significantly enriched the composition of the biscuits, so that they were defined as pro-health products [29]. Similar studies conducted by Siemianowska et al. [31] have also shown that fruit pomace increases the antioxidant activity of shortcakes, and its addition does not negatively affect mechanical, storage and sensory properties. Tańska et al. [37] showed that shortbread cookies with the addition of 20% berry fruit pomace (elderberry, rosehip, rowan, blackcurrant) had similar size and shape compared to the control sample, but had higher hardness, fibre content and antioxidant activity. The additives used also caused a significant change in the colour of the products. During the sensory evaluation, all cookies were evaluated by the panellists to be acceptable in terms of taste, sweetness, aroma, hardness, crispness, shape and colour. Due to their high fibre content, fruit pomace significantly lowers the glycaemic index of biscuit products, making this type of product, in which part of the wheat flour is replaced by pomace, suitable for consumption by diabetics [2].

In the case of bread, the addition of grape pomace also affected the product properties, but in contrast to the previously discussed cakes, Šporin et al. [36] described the observed changes as unfavourable. Changes in physical properties, such as colour, volume after baking, firmness and elasticity, as well as the sour aftertaste remaining after consumption of bread with added pomace were the reason for the lower product quality assessment. However, the addition of grape pomace significantly increased the polyphenol content and antioxidant activity of the baked goods, thus having a positive effect on their nutritional value and health-promoting properties. The results of studies in which apple pomace [38] and citrus pomace [6,28] were added to bread dough also indicate that the products obtained in this way are characterised by a higher content of fibre, polyphenols and antioxidants, as well as a higher hardness and a markedly different sensory profile compared to baked goods without the addition of pomace.

Jannati et al. [19] tested the influence of apple pomace infusion to traditional Iranian bread at the level of 1, 3, 5, 7%. There was found that extensibility of the dough was significantly reduced regardless the amount of pomace, but adhesive force was increasing with an increase of pomace addition. After baking, the breads with apple pomace were less hard comparing to control sample, which was bread without any addition of pomace, and hardness was growing slower due storage for 72 hours. The amount of pomace decreased also bread cohesiveness factor measured 24 h after baking, but within elongation of the storage time cohesiveness lowered, but the contribution of pomace was no longer significant. The changes in the texture of dough and bread was explained by interaction between gluten and fiber from apple pomace, what led to weakening the gluten network. Apple juice production waste also caused reduction of lightness (L^*) and an increase of a^* (redness) and b^* (yellowness) colour parameters. Moreover, the results of sensory analysis indicate that the addition of apple pomace to the level not higher than 3% improves bread quality and attracts consumers. In this research, the addition of apple pomace was not to extended, but other researchers investigated 25, 50 and 75% replacement of wheat flour to apple pomace flour in cookies in order to obtain reduced gluten confectionery [45]. They reported dietary fiber content enhanced to over 10, 20 and 30 g/100 g while control sample contained only 1.7 g/100 g. Apple pomace addition significantly multiplied total polyphenols and flavonoid contents, what was followed by boost in antioxidant activity. Sensory analysis showed the use of apple pomace flour may enhance structure, chewiness, odour, taste and overall perception, but only if it is coarse, not fine, ground and the amount do not exceed 50%. However, the best notes were received by attributes of cookies with 25% flour substitution, yet considering nutritional value and the lowest changes in bioactive compound content and sensory properties observed after 12 months storage, it was concluded that replacement of wheat flour with coarse apple pomace powder up to 50% may be successfully apply in pastry products. On the other hand, basing on their own research, Liang et al. [23] stated that dough properties and the quality of biscuits were acceptable only with addition of apple pomace powder at the level of 10%, and exceeding such amount, dough and product value dropped rapidly.

Fruit pomace has also found applications as ingredients infused to meat products. Yadav et al. [42] studied the effect of the addition of dried apple pomace on the quality of poultry sausages. The addition resulted in reduced protein and water content, which was reflected during sensory evaluation as reduced juiciness, and increased fibre content. Changes in colour and textural properties were observed, increasing hardness, gumminess and springiness, but despite this, the pomace-enriched products were also rated very well by the sensory evaluation panellists, although they received lower scores than the control sample. Studies carried out on beef sausages showed that apple pomace performs well as an emulsifying agent, has the ability to retain water and oil, has antimicrobial properties and lowers the glycaemic index of products enriched with it. In the case of beef sausage, it was unequivocally found that the addition of pomace improved both the sensory profile, the physicochemical properties and nutritional value of the products [43]. Younis and Ahmad [44] came to similar conclusions when analysing the properties of beef patties enriched with apple pomace powder, which also shaped both the physicochemical, sensory and structural characteristics of the products. In the meat industry, pomace can be used not only as a source of fibre, but also as a fat substitute in calorie-reduced products [30].

In the dairy sector, the possibility of using fruit pomace was studied on the example of yoghurt. In the case of apple pomace, an increase in the total acidity of yoghurts, changes in the rheological properties, including a particularly significant reduction in the hardness of yoghurts, and a reduction in the process of syneresis were observed. In addition, the products were characterised by a significantly darker colour, but despite this they were very well evaluated in terms of taste, which was dominated by distinct fruit notes [46]. Wang et al. [40] found that the addition of freeze-dried apple pomace powder shortens time of yoghurt fermentation and increases gelation pH. Storage stability of yogurts with pomace powder at the level of 0.5% was improved in comparison to control sample and products with the addition of 0.1 and 1% of dried pomace. When investigating stirred yoghurt fortified with apple pomace, water holding capacity of pomace powder also reduced syneresis, influencing textural properties and storage stability as well. Supplementation was followed by significant increase of polyphenols and dietary fiber in the products, what enhanced their nutritional value [41].

The addition of dried red grape pomace powder as sugar and milk powder substitute in chocolate spreads affected firmness and spreadability, which are crucial parameters for texture of this type of products. It heightened total phenols content, but limited digestibility. Moreover, increasing amount of grape pomace (up to 15%) induced unfavourable changes in sensory perception, so optimal content was recommended to not exceed 10%. It was also emphasized that factors as particle size of pomace powder and processing parameters (conching time, ball-mill rotation) should be modified to adjust product quality [1].

Lately, there were also a few attempts of applying fruit pomace in the form of dried powder as carrier agents in freeze-dried vegetable products [21,22]. The authors pointed out an increasing importance of environmental problems facing food industry and the future of human population in general, which, from food producing point of view, may be reduced by reusing of food waste and by-products as material for new products development. And considering current global changes, such as climate warming and population growth, even the slightest action aimed to sustainability is worth considering. Moreover, a type of carrier agent used in the formulation of freeze-dried snacks determines products appearance and attractiveness for consumers, what is presented in Figure 3. Freeze-dried snacks obtained by Karwacka et al. [21] were characterised by properties similar to aforementioned products obtained with hydrocolloids as carrier agents. Water activity of the products was very low and did not exceed 0.02 and such level was not achieved by any of freeze-dried snacks reported before. Structure of the materials also was highly porous (86-90%), but defined as more fragile and brittle but their hardness was significantly greater than those obtained for other freeze-dried products. Interestingly, such snacks were manufactured only with vegetables (string beans, carrot, potato) and 2% addition

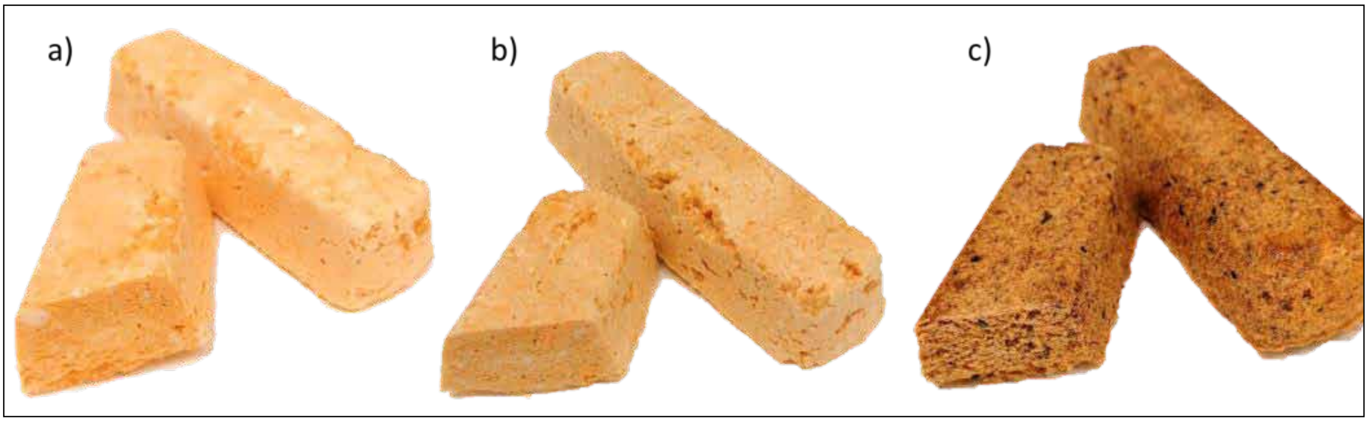

Fig. 3. Freeze-dried carrot snacks obtained with 1.5% of low-methoxyl pectin (a), 2% of dried apple pomace powder (b) and 2% of dried blackcurrant pomace powder (c).

Rys. 3. Liofilizowane przekąski marchewkowe z dodatkiem 1.5% pektyny niskometylowanej (a), 2% proszku z suszonych wytłoków jabłkowych (b) oraz 2% proszku z suszonych wytłoków z czarnej porzeczki (c).

Source: Own study

Źródło: Opracowanie własne

of dried apple pomace powder, without any liquid or additives that could had support formation of proper structure and texture of products. The addition of traditional hydrocolloid carrier, which was sodium alginate at level of 1.5% combined with 0.01% of calcium lactate, required halving the amount of vegetable compound and water substitution [22]. As an effect, despite lower initial water content, freeze-drying process had been lasting as long as it was recorded for samples with sodium alginate, meaning close to 48 h. The use of apple pomace powder as carrier agent resulted in more fragile texture that did not crack under pressure, but slowly compressed, what indicates lower crunchiness and could be related to smaller pores appearance in the structure of the snacks. Regardless weaker structure- and texture-forming ability of apple pomace, attempts to apply them as additives in food products is still promising and worth further research because of health benefits following those compounds. Compared to sodium alginate, dried apple pomace powder multiplied total phenols content and antioxidant capacity of the vegetable snacks, enhancing their pro-health value.

SUMMARY

Recently, development of new freeze-dried products that would do both attract consumers and reduce environmental impact of this type of products is intensively investigated. One of the key role in such process is optimisation of proper formulation that will result in the products characterised by desired quality, which can be modified by infusion of functional additives. A conscious choice of carrier agent applied in the formulation of foods is very important, principally considering its impact on crucial parameters of products, such as physicochemical, textural and structural properties along with sensory perception and nutritional value. Hydrocolloids are typically used as such compounds, however, in the light of recent reports and trends in scientific research motivated by the problem of food waste management, a new branch has emerged regarding the use of fruit pomace as a functional food ingredient. Numerous investigations provided on various food products fortified with fruit pomace show that they significantly affect food properties, especially enhancing nutritional value by increasing dietary fiber and bioactive compounds content that also results in higher antioxidant capacity. On the base of all of the referred findings and discovered properties, fruit pomace has a potential to be apply as substitutes for hydrocolloid carrier agents in freeze-dried snacks.

PODSUMOWANIE

W ostatnim czasie bardzo intensywnie prowadzone są badania nad opracowaniem liofilizowanych produktów, które będą jednocześnie atrakcyjne dla konsumentów i przyjazne dla środowiska. Jednym z kluczowych rozwiązań jest optymalizacja składu w taki sposób, aby otrzymać produkty charakteryzujące się pożądaną jakością, którą można modyfikować poprzez stosowanie dodatków funkcyjnych. Świadomy wybór nośników dodawanych do żywności jest bardzo ważny, szczególnie po uwzględnieniu ich wpływu na fundamentalne cechy produktów, takie jak właściwości fizyko-chemiczne, tekstura i struktura, a także atrybuty sensoryczne i wartość odżywcza. Zwykle w tym celu stosuje się hydrokoloidy, natomiast w świetle najnowszych doniesień i trendów obserwowanych w nauce, napędzanych problemem zagospodarowania odpadów, pojawiła się nowa gałąź, badająca możliwości wykorzystania wytłoków owocowych jako funkcjonalnych składników żywności. Przeprowadzono liczne badania, wzbogacając różnorodne produkty spożywcze dodatkiem wytłoków owocowych, które istotnie wpłynęły na ich właściwości, szczególnie wartość odżywczą i prozdrowotną, co nastąpiło w konsekwencji zwiększenia zawartości błonnika i związków bioaktywnych, a co za tym idzie większej aktywności przeciwutleniającej. Na bazie wszystkich przytoczonych prac oraz wykazanych właściwości wytłoków owocowych, można stwierdzić, że wykazują one duży potencjał jako zamienniki nośników hydrokoloidowych w liofilizowanych przekąskach.

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