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NUTRITIONAL TRENDS AND METHODS OF PRODUCING FRUIT AND VEGETABLE HEALTH-PROMOTING SNACKS[®]

Trendy żywieniowe i metody wytwarzania owocowych i warzywnych przekąsek prozdrowotnych[®]

Key words: fruit and vegetable chips, production methods, drying.

Diet has a large impact on people's health and self-sense, which is why consumers more and more often pay attention to the quality of food and its pro-health benefits. It is especially important in striving to limit the development of many civilization diseases. The use of appropriate manufacturing techniques using pre-treatment and drying results in products of high quality and nutritional value. It also makes it possible to find new directions in food production that may include a „clean label” declaration. Apart from essential nutritional trends, the article presents selected treatments used in the technology of producing healthy snacks from dried fruit and vegetables.

Słowa kluczowe: chipsy owocowe i warzywno, metody wytwarzania, suszenie.

Dieta ma duży wpływ na zdrowie i samopoczucie ludzi, dlatego konsumenci coraz częściej zwracają uwagę na jakość spożywanej żywności i jej walory prozdrowotne. Szczególnie ważne jest to w dążeniu do ograniczenia rozwoju wielu chorób cywilizacyjnych. Zastosowanie odpowiednich technik wytwarzania z zastosowaniem zabiegów wstępnych i suszenia pozwala uzyskać produkty wysokiej jakości i wartości odżywczej. Stwarza to również możliwość znajdowania nowych kierunków w produkcji żywności. W artykule obok istotnych trendów żywieniowych przedstawiono wybrane zabiegi stosowane w technologii wytwarzania prozdrowotnych przekąsek z suszy owoców i warzyw.

INTRODUCTION

Fruits and vegetables and their products are a source of bio-components necessary for the proper functioning of the human body, and their increased consumption helps to prevent many civilization diseases [2, 16, 39, 55, 56, 66]. However various types of snacks, generally divided into salty and sweet, have become common and often eaten between meals. They are widely available, especially for busy consumers [25]. They allow you to temporarily satisfy the feeling of hunger or are the result of the need to snack between meals or even to replace them [5, 25, 36]. Dried snacks made from them constitute a concentrated content of many ingredients, especially dietary fiber, easily digestible sugars and bioelements, as well as compounds with antioxidant properties. Another important aspect is that they can be produced without the so-called „Artificial additives” which are considered undesirable.

Currently, consumers are more and more aware of the impact of consumed food on the functioning of the human body. Noteworthy is the growing demand for high-quality nutritional and [32, 36]. Such products largely retain the

properties of the raw materials and do not contain additional substances such as artificial colors, preservatives or flavors. Offering products with „clean label”, with functional bio-ingredients, as well as the use of sustainable production methods fueled sales in the snack market in 2021 [24]. The consumption of health-promoting snacks in Poland is much lower than in other European countries. However, forecasts indicate its rapid growth [7, 30]. In 2016, the value of the global market of the so-called „healthy” snacks stood at \$ 21.1 billion. Euromonitor reported that the market for this type of products will grow in the years 2020-2025, successively by approx. 5.8% annually, and in 2025 it will reach a value of USD 98 billion [8, 24].

For many years, there have been low-calorie products on the market, with a reduced salt, fat and simple carbohydrate content, as well as enriched with functional ingredients of a pro-health character [46]. Dried snacks (chips) from fruit and vegetables and their use, e.g. in properly composed multi-grain bars, perfectly match the current nutritional trends and the possibility of declaring a „clean label”.

The aim of the article is to review the available literature on current market trends and the technology of producing fruit and vegetable chips as health-promoting snacks.

CONSUMER BEHAVIOR AND NUTRITION RECOMMENDATIONS

Nowadays, consumers more and more often pay attention to the health quality and nutritional value of food, because improperly composed diet is the main cause of cancer, cardiovascular and digestive system diseases, including obesity and type 2 diabetes [21, 44]. In order to counteract this type of health problems, the National Health Program covering the years 2016–2020 was launched in Poland. The basic concept of this program focused on strategic goals, which included factors influencing health improvement, extension and quality of life [63].

It has been observed that consumers very frequently consume „snacks” between meals. They reach for it, not only when they feel hungry, but when they just want to „bite” something. Unfortunately, among the many on the market, there are high-calorie snacks with low nutritional value. Some consumers are willing to try to compensate for the „unhealthy” snack with physical activity, but often these are just unfulfilled ideas [3, 5], and the lack of physical activity exacerbates health problems. The World Health Organization [74] emphasized that excessive consumption of foods rich in saturated fatty acids, salt and simple carbohydrates, as well as low consumption of fruit and vegetables and whole grains are the main risk factors for the development of diet-related diseases. Fruits and vegetables and whole-grain products are two important food groups at the base of the Nutrition Pyramid, which clearly emphasizes their role in proper human nutrition. They are a valuable source of complex carbohydrates, dietary fiber and health-promoting ingredients, such as vitamins, antioxidants, as well as macro- and microelements [69]. Due to the fact that the formation of proper eating habits takes place even before adolescence, it is important to introduce proper nutritional practices from childhood [72].

The trend of being „fit” among consumers calls for a change in diet, which is one of the key factors responsible for human health, well-being and physical condition [72]. Therefore, apart from the sensory quality (taste, appearance, texture) and safety (microbiological quality, chemical composition), it is very important to produce products with high nutritional value and at the same time containing only natural ingredients. There are products that offer the consumer something „extra” compared to traditional products such as functional ingredients with higher levels of proven positive effects on the human body. Such products include protein bars for athletes or bars containing chia seeds (source unsaturated omega-3 fatty acids, dietary fiber, protein, minerals, antioxidants and polyphenols) or spirulina, which is a rich source of protein and B vitamins [28, 80]. In the case of fruit and vegetable chips, it is possible to enrich the plant raw material with a nutrient desirable component that is not present in the raw material, e.g. fructooligosaccharides or inulin, which, thanks to their functional properties, have a beneficial effect on the body, stimulating the proliferation of beneficial intestinal microflora [11, 45, 57].

The leading aspect in the development of nutritional science in the 21st century is the improvement of the quality of life, and thus the development of the science of functional food, which has a scientifically proven beneficial effect on the human body. This type of food, performing one or more functions in the human body, improves the health condition or reduces the risk of diseases [38, 47].

ADVANTAGES AND AVAILABILITY OF FRUIT AND VEGETABLE SNACKS

There is a wide variety of dried fruits and vegetables on the market today. However, only some of them are used to make fruit and vegetable chips. These include apples, pears, peaches, bananas, mangoes, kiwi, pineapples, strawberries, beetroots, broccoli, onions, potatoes, tomatoes, carrots, pumpkin and Jerusalem artichoke. Often, in order to improve the sensory characteristics of a product, producers add numerous natural spices and herbs, such as pepper, paprika, chili, cinnamon, and ginger [13, 20, 22]. Dried fruit and vegetables are used as a valuable addition to many products, e.g. food concentrates, soups, cereals, yoghurts and desserts. They can also be considered a valuable snack as they are increasingly appreciated by many consumers [51]. Forecasts indicate that the production of dried fruit and vegetables of different taste, shape and texture using different drying methods will expand the market of „healthy” snacks [8, 24]. The fruits and vegetables preserved through the drying process, obtained in the form of crunchy chips, are a healthy and fat-free snack. In addition, dried fruit and vegetable based crisps do not contain chemical preservatives or flavor enhancers. They are an high-fiber, gluten-free and often low-calorie snacks [33, 37].

PROPERTIES OF FRUIT AND VEGETABLE SNACKS

Fruits and vegetables are a source of ingredients important for the proper functioning of the human body. According to experts from the World Health Organization [75], the consumption of fruit and vegetables should be at least 400 g per day, excluding starchy tuberous vegetables. Fresh fruit and vegetables are a rich source of micro- and macronutrients (including phosphorus, calcium, iron), carbohydrates, vitamins, dietary fiber, flavonoid compounds and organic acids, and they are also characterized by a low concentration of lipids [21, 52, 71]. Many research studies show that increased consumption of fresh and processed fruit and vegetables has a prophylactic effect in the prevention of many diseases [2, 16, 55, 56, 66], including reducing the long-term risk of obesity [39].

As a result of drying, depending on the method used and other treatments, the content of ingredients may be reduced, but some ingredients become concentrated. So dried products may have an even better composition than the raw materials, and at the same time are much more convenient to use [79]. According to Morais et al. [47], dried food is a source of easily digestible nutrients (mainly carbohydrates) and bioactive compounds, including fiber, phenolic compounds, carotenoids, minerals and vitamins (E, niacin, folic acid, choline). Drying, especially of fruit, usually increases their calorific value, compared to fresh fruit. In the case of fresh plums, the caloric value was 49

kcal/100 g, and for dried plums 285 kcal/100 g [73]. Moreover, some producers of dried fruit sweeten them and, in order to limit changes related to the surface crystallization of sugar, use vegetable oils, increasing their calorific value to about 530 kcal/100 g [14]. Omolola et al. [53] showed that dried fruit and vegetables have a low (<55) or medium (56-69) glycemic index and are more caloric than raw materials, but emphasized that the benefits of consuming them as a source of bioactive ingredients may be greater than currently recognized, because they influence metabolic pathways and cellular responses associated with the etiology of many chronic diseases. Alasalvar and Shahidi [2] showed that people who regularly consumed large amounts of dried fruit, blueberries, citrus, and more had lower rates of cardiovascular disease, obesity, various types of cancer, type 2 diabetes, and other chronic diseases.

Regarding current trends in consuming the most natural food, some scientists have noticed greater benefits from using natural phytochemicals than from chemically produced ones. Moreover, the interactions of food components and the cell structure of plant materials are important. Nayak et al. [48] showed that mixtures of phytochemicals in foods have increased health benefits as a synergistic effect. Therefore, in the production of dried fruit and vegetables, the use of pre-treatment enrichment in juice concentrates is justified. In addition, it was found that the type of biocomponent and its interactions with the food matrix play an important role in the release of phytochemicals, influencing their bioavailability, thus the possibility of absorption from the intestine and penetration into the blood plasma, as well as other therapeutic and pharmacological activities (cardioprotective, antiviral, anti-inflammatory, anti-cancer) [29, 64, 68]. Synergistic antioxidant effect of dietary fiber in the presence of polyphenolic compounds is also known [68].

APPLICATION OF SELECTED TREATMENTS TO MAKE SNACKS FROM FRUIT AND VEGETABLES

The procedures used in the technology of producing snacks from fruit and vegetables are aimed at obtaining high-quality dried products with the highest possible content of native biocomponents, high sensory quality, as well as long shelf life and safe in terms of nutrition and health. They largely determine the final quality of the obtained product [49]. Depending on the method and process parameters used, dried fruit and vegetables show a reduced content of bioactive compounds, especially thermolabile compounds, such as vitamins and phenolic compounds. Pre-treatment prior to drying such as blanching [60], the application of edible coatings, osmotic dewatering/enrichment in juice concentrates [33, 34, 36].

Application of blanching in the production of healthy fruit and vegetable snacks

Blanching is a type of preliminary thermal treatment of fruit and vegetables in which the raw material is exposed to high temperatures in the range of 70-105°C for a short time (up to several minutes). The main purpose of this process is to inactivate tissue enzymes responsible for faster maturation of the processed raw material. In this way, changes in the

organoleptic characteristics, especially in color and texture, can be significantly limited. Moreover, the blanching process partially inactivates the microflora on the surface of the raw material and may lead to an increase in the nutritional value. The application of blanching to plant raw materials prior to drying allows to obtain dried products with more desirable textural characteristics. It has been shown that some unblanched dried fruit and vegetables are much harder than those after initial blanching [49]. The most common method is hot water blanching, which contributes to the loss of many valuable thermolabile ingredients, e.g. vitamins or flavor compounds, as a result of their washing out of the raw material. Therefore, it is much more advantageous to use steam blanching. Currently, newer technologies, such as microwave blanching or ohmic heating, are used more and more often. These methods allow the preservation of a significant amount of bioactive ingredients and the color of the raw material. They are also an example of technologies generating lower costs related to energy consumption [62, 77]. Very often, the blanching process used as a preliminary treatment before drying is also supported by non-thermal pre-treatment methods, such as ultrasound or pulsed electric field. Nowacka et al. [50] showed in their research that the use of ultra-sounds or a pulsed electric field in combination with blanching had a positive effect on the color and increased antioxidant activity of cranberries dried using the microwave-vacuum method.

The use of osmotic dehydration in the production of health-promoting fruit and vegetable snacks

Osmotic dehydration is a process very often used in food engineering, which allows modification of the chemical composition and sensory properties of food, depending on the desired characteristics of the product. During this process, a two-way mass exchange takes place. After the material is placed in the hypertonic osmotic solution, the water is removed from the interior of the material to be dewatered. On the other hand, in the opposite direction, an osmoactive substance can penetrate into the place of removed water [57, 66]. Osmotic dehydration is usually used to partially lower the water content in plant raw materials. This does not fully protect the product against unfavorable microbiological and biochemical changes, which in effect affect the short shelf life [10].

Osmotic dehydration in combination with drying is used to obtain food with medium water content (20-50%) and water activity (0.70-0.85), or low, where the humidity does not exceed 20%, and the water activity is below 0.70 [18, 58]. From the point of view of the final quality of the product, its sensory properties and calorific value, the selection of an osmotic solution becomes important. Various sugar solutions are used, eg sucrose, fructose, glucose, fruit and vegetable juice concentrates, natural and artificial honey and the possible addition of other substances, such as calcium or sodium chloride [31, 26]. It is recommended to use fruit and vegetable juice concentrates which contain only natural ingredients. Many fruits and vegetables are underrated or unpalatable when raw. Osmotic enrichment of raw materials with juices can increase the pro-health value of products, but also shape new sensory features. In this way, many different juices can

be used [33, 34, 35, 43], eg from aronia fruit, cranberry, elderberry, red beet. Another proposed solution limiting the unfavorable increase in the content of simple carbohydrates in the product is the initial protection of plant materials against the osmotic dehydration process, e.g. by using edible coatings or convective drying.

Osmotic dehydration prevents changes in color, smell and taste, which often take place during further technological processes, e.g. drying. By limiting the contact of the feed with air, osmotic dehydration also prevents enzymatic and non-enzymatic oxidation. Partial removal of water shortens the drying time and also the time of contact of the raw material with hot air. Therefore, many of the thermolabile components contained in the raw material can be preserved [78]. Despite its many advantages, osmotic dehydration also has disadvantages. This is a time consuming process and, in combination with blanching or vacuum drying, also expensive. The sugar layer covering the dewatered raw material, which occurs as a result of mass exchange, becomes troublesome and it is necessary to rinse it with water [78].

The topic of the possibility of using osmotic dehydration in the production of fruit and vegetable chips is widely discussed in the literature, because the universality of this process makes it subject to continuous improvement. Currently, promising solutions in the osmotic dehydration process, incl. fruit and vegetable chips are mainly juice concentrates or fruit and vegetable extracts, which, being a carrier of natural bioactive ingredients, enrich the product. Thanks to the use of these solutions, it is possible to obtain dried fruit with a high nutritional value, with a new, attractive taste and color [33]. The use of apple and beet juice concentrate, as well as their mixture for osmotic dehydration of apples, made it possible to obtain the same or even greater fruit dehydration effect as in the case of the commonly used sucrose solution. Apples pre-dehydrated in a mixture of apple and beet juice concentrates and then freeze-dried were characterized by an attractive color, regular shape and a homogeneous surface [34]. The research carried out by Czajkowska et al. [12] proved that the use of chokeberry juice concentrate for preliminary apple dehydration resulted in an almost 2.5-fold increase in the polyphenol content in the material to be drained, as well as obtaining an attractive color. An attempt was also made to use ethanol fruit extracts for initial osmotic dehydration of apple slices in the technology of producing dried chips using the osmotic-convection method. The research of Tarko et al. [70] showed that in the production of such chips, a 5-minute soaking in extracts of chokeberry fruit, Japanese quince, dogwood, small cranberry, hawthorn, Chinese schisandra and wolfberry increased the content of polyphenols and antioxidant activity obtained in this way. way it dries. The most useful extracts for enriching the apple chips were those of quince fruit, hea and hawthorn. However, despite the high antioxidant activity, the chips enriched with Chinese schisandra extract obtained a low sensory rating.

The use of edible coatings in the production of health-promoting fruit and vegetable snacks

Many studies show that an interesting alternative in the production of snacks from fruits and vegetables with increased nutritional value is the use of edible coatings before

the osmotic dehydration process [36]. This technology allows you to obtain the so-called high moisture „soft snacks” or low water „dry snacks” (about 20%). The technology of obtaining „soft snacks” is based on osmotic dehydration and surface drying of the raw material, while „dry snacks” after osmotic dehydration are dried for much longer [36, 40]. Attempts to use edible coatings in conjunction with osmotic dehydration were made in the case of various fruits and vegetables, incl. apples [15, 41], strawberries [17], mango [6], apricots [65], quince [1], pumpkin [61], carrots [42] or potatoes [59]. The use of the edible coating reduces the contact of oxygen with food, and thus the oxidation reactions of food ingredients. The application of an edible coating on the raw material before osmotic dehydration allows to reduce the loss of native components, including those of a health-promoting nature, and to maintain the physicochemical and sensory properties [33, 67]. The use of coatings also reduces the penetration of osmotic substances into the interior of the raw material to be dewatered, thus not limiting the removal of water from the material [41]. Additionally, the coatings increase the integrity of the product, its aesthetics, as well as mechanical strength during the processing, transport and storage process [56].

It is very important to select an appropriate coating and osmotic solution, including the use of fruit and vegetable juices enriching snacks with appropriate bio-components and process conditions that will determine its effectiveness, physical properties of the obtained dried products and their acceptance by consumers [36]. Requirements are made for edible coatings that can be used prior to osmotic dehydration. These are first of all: quick and uncomplicated possibility of applying the coating using simple techniques, adequate adhesion of the coating to the coated material, good water diffusivity, as well as resistance to contact with the aqueous environment during osmotic dehydration [36].

The use of drying in the production of health-promoting fruit and vegetable snacks

Drying fruit and vegetables is one of the oldest methods of food preservation. Lowering the humidity affects the protection of the product against the development of harmful microflora, slowing down the rate of biochemical reactions and physicochemical changes [19]. The quality of the dried product depends on properly selected drying methods and parameters, i.e. time, temperature, drying agent flow rate, raw material properties, e.g. composition, size and degree of fragmentation, structure [19, 76]. Irreversible changes often occur in dried fruits and vegetables, such as shrinkage, change in shape and dimensions, and even surface browning. Therefore, an important factor is the selection of the appropriate technique and drying parameters, depending on the type of raw material. Thanks to this, it is possible to shape the properties of the product to some extent in terms of quality requirements [27]. Due to the content of thermolabile substances, fruits and vegetables are very sensitive to heat treatment. Therefore, drying of these materials takes place at a temperature of 40-70°C from 4 hours (for vegetables, from which the water evaporates faster) to 24 hours for fruit [19].

Dried fruits and vegetables are commonly obtained using simple drying methods, ie drying using solar energy or air. However, these are time-consuming techniques, requiring

a large amount of energy and affecting undesirable changes in quality, e.g. discoloration. Currently, technologies have been developed that allow, first of all, to shorten the drying time, improve energy efficiency and improve the quality characteristics of the obtained dried fruit and vegetables [4].

The research carried out by Kowalska et al. [32] showed that freeze drying and microwave-vacuum drying combined with previous convection drying allow to obtain high quality of dried fruit and vegetables. Many studies show that freeze-drying is a drying technique that allows to obtain the most satisfactory dry quality. However, it is a long-term process, which is associated with high energy consumption, and thus the cost of production [32]. A more economical solution is to use hybrid drying, i.e. combining different drying techniques. By making several operations, it is possible to obtain dried products with properties similar to the that obtained by freeze-drying. Pre-treatment in osmotic solutions carrying biologically active compounds and innovative methods of drying allow to shorten the drying time, minimize possible disadvantages arising in traditional methods, and also make it possible to create food with the desired properties. The dried Japanese quince snacks obtained in this way received high marks in the opinion of consumers [33]. Nowicka et al. [51] subjected cherries to osmotic treatment with the use of several juice concentrates, incl. from blackcurrant fruit, apples, cherries, chokeberries, raspberries and quinces. The pretreated cherries were dried using a hybrid technique, i.e. a convection-microwave-vacuum technique. The use of „osmotic concentrates” allowed for a significant increase in the polyphenol content in dried cherries, respectively from 6.4% in the case of using cherry juice concentrate to 22.4% in the case of chokeberry juice concentrate. Kowalska et al. [35] attempted to obtain apple snacks with the use of hybrid drying, consisting in preliminary osmotic dehydration in sucrose and sucrose solution with the addition of chokeberry juice concentrate, convection drying, and then microwave-vacuum drying. This drying technique and the use of chokeberry juice concentrate as an addition to the osmoactive solution resulted in a significant increase in the content of such bio-compounds as polyphenols, vitamin C, as well as an increase in the antioxidant activity of the obtained dried products. Horuz et al. [23] showed that hybrid drying, i.e. microwave-convection drying of cherries, not only significantly reduces the drying time compared to convective drying, but also contributes to an increase in the content of bioactive ingredients in dried products, i.e. polyphenols and Vitamin C. Additionally, cherries dried in this way were characterized by greater antioxidant abilities and better reconstitution properties. The positive aspects of another hybrid drying technique, i.e. microwave-vacuum drying, were noticed when comparing this drying method with convection and micro-wave drying of tomatoes. The research showed that the microwave-vacuum drying was characterized by a higher content of lycopene and

antioxidant activity than the dried products obtained with the other two methods. Moreover, in the sensory evaluation, the microwave-vacuum dried tomatoes obtained the highest marks, despite the lighter color. Taking into account all three analyzed methods, the speed of microwave-vacuum drying was the highest, which allowed to reduce the costs of the process related to the amount of energy used [54].

In the drying of fruit and vegetables, research is also carried out on the possibility of using a combination of microwaves, infrared radiation, ultrasounds, radio frequency as drying methods with artificial intelligence techniques, such as: computer vision systems, sensor technology, artificial neural network as an element supporting the control of the drying process in order to obtain a product of the required quality [9].

CONCLUSIONS

New trends in the food market result from the growing awareness of consumers regarding the nutritional and health quality of food, which creates a need for food manufacturers to design a wider range of snack products, especially in the form of dried fruits and vegetables. The health-promoting benefits of such dried snacks encourages consumers to consume them. The challenge for producers of dried fruit and vegetables is to improve and development of new production techniques enabling the preservation of bioactive ingredients. Due to the emerging new manufacturing techniques and variability of raw materials, further research is needed to develop the technology of production of dried fruit and vegetable snacks. Snacks in the form of dried fruits and vegetables are an ideal alternative to snacks that are high in calories and low in nutritional value. Dried fruit and vegetable snacks should dominate both the domestic and global markets.

WNIOSKI

Nowe trendy na rynku żywności wynikają z rosnącej świadomości konsumentów odnośnie jakości żywieniowej i zdrowotnej żywności, co stawia przed jej producentami potrzebę projektowania szerszej gamy produktów przekąskowych, zwłaszcza w postaci suszonych owoców i warzyw. Prozdrowotność przekąsek w formie takich suszy zachęca konsumentów do ich spożywania. Wyzwaniem dla producentów suszonych owoców i warzyw jest doskonalenie i opracowywanie nowych technik ich wytwarzania umożliwiających zachowanie składników bioaktywnych. Ze względu na pojawiające się nowe techniki wytwarzania i zróżnicowanie surowcowe, potrzebne są kolejne badania w zakresie opracowania technologii produkcji suszonych przekąsek z owoców i warzyw. Przekąski w formie suszonych owoców i warzyw stanowią idealną alternatywę dla przekąsek wysokokalorycznych, a zarazem o niskiej wartości odżywczej. Przekąski z suszonych owoców i warzyw powinny dominować zarówno na rynku krajowym jak i światowym.

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