PROCESSING OF AGRICULTURAL PRODUCTS BY LYOPHILIZATION

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Abstract

Lyophilization is the process of removing water from a frozen product by drying, where the water from the frozen phase passes directly into the gaseous state, without turning into a liquid. In this way, easily perishable products are preserved, since the removal of water prevents the growth and reproduction of bacteria that would lead to their spoilage. Lyophilization as a way of food processing increases the shelf life of products, without the need to add artificial preservatives, while preserving their nutritional value. The lyophilization technology can be used in the processing of fruits, vegetables, bee products and other primary agricultural products, in order to obtain innovative, healthy and safe agro-food products of high nutritional value. The aim of this review paper is to present methods of preserving fruits and vegetables by drying, with an emphasis on the process of lyophilization, as an innovative modern method of drying and processing of primary agricultural products.

Key words: *lyophilization, processing of fruits and vegetables, innovative food products, market*

Instroduction

Contemporary consumers are looking for high-quality, healthy and safe food. Namely, in the production of agro-food products, in adition to quality, special attention should be directed to safety and shelf life of such products at the market. Processing of primary raw materials, as well as storage or distribution of final products, more or less affects physico-chemical and/or biological characteristics of agro-food products (Ciurzynska & Lenart, 2011). In order to produce helathy and safe food products, atractive to the consumer, which also has a longer shelf-life, it is necessary to apply appropriate methods of processing the raw material. This issue is especially important in the case of foods such as fruits and vegetables, since they have a lot of water in their composition, and therefore spoil quickly. In order to prevent growth of microorganisms, it is nec-

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essary to remove water from the raw food, which can bee done in many ways: drying outdoors, microwave drying, vacuum drying, spray drying, lyophilisation, combination of several drying methods etc. Each method of dehidratation has its advantages and disadvantages, which are related to the qualitative characteristic of the final product, cost price of the procedure and thus the price of the final product. This paper will present an overview of methods of drying fruits and vegetables, with focus on lyophilisation, and also the current state in Serbia regarding processing of fruits and vegetables.

Methods of drying fruits and vegetables

There are several methods for dehidrating fruits and vegetables and each method affects to some extent basic characteristics of the raw material. For example, all drying methods increase the scent of plants such as mint, which can be positive in the case of tea production (Abascal et al., 2005). The oldest way of drying raw food is drying outdoores, by air flow. However, in this way, the quality of the final product is lower in compare to the raw material, since there are signifinact changes in size, porosity, ability to bind water, content of important compounds, etc. (Ciurzynska & Lenart, 2011). Also, there is the question of safety of final dried products, considering that the drying takes place in an open space, where the raw material comes into contact with microorganisms from the air.

A more modern way of drying raw materials is drying in ovens, microwaves etc. The success of this method, i.e. the quality of the final dried product, depends largely on the temperature at which the drying is performed, as well as the properties of the primary raw material. For example, in the case of strawberries, dehydration in the oven leads to complete destruction of shape and texture, so only this method can not be applied in drying this fruit species, but must be used in combination with lyophilization or osmotic dehydration (Prosapio & Norton, 2017). Namely, the combination of several drying methods significantly reduces the drying time, which affects the better preservation of the mechanical and structural characteristics of the strawberry, which is important regarding acceptance of the final product by consumers. The next modern way of drying food is the spray drying, which is a method of rapid evaporation of water in a stream of warm air inside the drying chambers. With this method there can be a significant loss of volatile substances and degradation of thermolabile substances in the raw material due to high input temperatures (Ishwarya et al., 2015). Osmotic dehydration is a drying meth-

od, which involves immersing the product in a hypertonic solution (fructose, sucrose, maltose or some other sugar) which reduces the water content in the raw material by 50%. In this way, a semi-product is obtained, which must be additionally dried using some other method (Prosapio & Norton, 2017). Blanching can have a similar effect as osmotic dehydration, but in the case of soft fruit it cannot be applied. The most modern way of drying the raw material is lyophilization. This is an innovative way of dehydrating the raw material, while maintaining the high quality and safety of the final product, however, it is an expensive method of dehydration, which costs can be reduced by reducing the time required to dry the product (Yeu-Pyng Lin et al., 2005). Also, in addition to lyophilization, new drying methods of fruits and vegetables, may include a combination of several different drying methods, which may be the best option for certain raw materials. For example, the combination of several methods for drying onions significantly reduces production costs and does not affect the deterioration of the quality of the final product (Abbasi, S., & Azari, S., 2009).

The most important characteristics of the final product to be observed after drying, by any method are: the degree of water removal from the raw material (because it directly affects the perishability of the final products, since organisms multiply in humid environment), nutritional value of the final product, odor, color and taste of final product, as well as quanitites of final product after drying.

Lyophilisation as a method of drying fruits and vegetables

The lyophilization process is used today for many purposes, mainly by pharmaceutical and biotechnology companies, but also by the food industry (Bondoc & Bratucu, 2017; Tsinontides et al., 2004). There is a developed industry of lyophilized food in the world, which includes vegetables, fruits, meat, seafood, beverages, dairy products, ready-made meals, and even pet food. Such products are placed on the market through large markets, retail stores, online sales, etc. Due to the possibility of long-term preservation of lyophilized agro-food products, there is an increase in demand for lyophilized products by consumers in the international market. The fast way of life has caused the increased demand for quality and safe food, which is prepared quickly. Numerous scientific and professional papers deal with the topic of lyophilization of fruits and vegetables, and include experiments done on e.g. sweet potatoes, strawberries, cherries, lettuce, corn, berries, carrots, tomatoes, pumpkins, peas, apples, eggplant, etc. Also, research in this sense has

been done on spices such as garlic, coffee, tea, ginger, etc. The stages in the lyophilization process to the final product are successive and include the following stages: preliminary treatment of the raw material, freezing, primary drying, secondary drying, packaging, storage and rehydration during use (Bondoc & Bratucu, 2017).

Preliminary treatments of the raw material can be mechanical (e.g. grinding, chopping), physical (e.g. cooking, blanching), chemical (addition of some substances), followed by drying in a device specially designed for lyophilization. The final product is a dehydrated substance in the form of powder or larger particles (whole fruit, or pieces of different sizes). The final product is porous and hygroscopic, so the packaging must be in a vacuum or in a protected atmosphere, and the material must not be permeable to water vapor, gases and grease, that is it must be metal, glass or multilayer foil. Properly processed products can be stored for several years at temperatures up to 30°C (Bondoc & Bratucu, 2017). In addition to the dehydration of the raw product, the possibility of its rehydration after the addition of water is very important, as well as the content of vitamin C in the dried product (Luanda G. Marques et al., 2007).

Lyophilized products can be used as snacks, additives to muesli, porridge, honey, chocolate, fruit bars, in the tea industry, as natural food colors, etc. (Różyło, 2020). If organic fruits and vegetables are dehydrated, value-added products are created. Lyophilized products can be used during winter months, as the best substitute for fresh fruits and vegetables, which may not be available in the cold season. According to some authors, lyophilized fruits are of better quality than candied, otherwise dried, or frozen fruits, because they do not contain additional sugar, nutrients are not significantly changed, do not contain additives and colors, do not contain added water and do not have to be stored in the freezer (Bondoc & Bratucu, 2017).

The positive aspects of lyophilization are: easy transport, increase in products' shelf-life, high quality of the final product, i.e. preservation of morphological, biochemical and immunological properties in relation to other drying methods (Ciurzynska & Lenart, 2011). The negative aspects of lyophilization are: high investment costs (machines, packaging, etc.), relatively complicated and long lyophilization process (the whole process can take about 24 hours) and high energy consumption (Bondoc & Bratucu, 2017).

Quality of lyiophilised fruits and vegetables

Today, there are numerous studies on the impact of lyophilization on the quality of fruits and vegetables, whose conclusions are diverse. According to some authors, lyophilized fruits, compared to fresh fruits, have higher energy value, and in most fruit species also higher sugar content (Bondoc & Bratucu, 2017). When drying raspberries, drying methods strongly influence the physical properties, the composition of bioactive substances and the antioxidant activity of the final product. Dehydration by lyophilization to powder causes significantly higher powder hygroscopicity, water solubility, color preservation and anthocyanin content, compared to other drying methods or a combination of methods, which create a product with higher total content of polyphenols, flavonoids, and higher antioxidant activity (Si, X. et al. 2016). When it comes to grapes, a grape juice can be lyophilized, while preserving sensory characteristics such as taste, smell and texture (Codoi et al., 2012). For plums, which are traditionally dried worldwide, convective drying is most often used. However, convective drying greatly reduces the anthocyanin content and the total polyphenol content, compared to lyophilization which has been shown to be better in this regard (Gościnna, K., et al. 2021). In the case of berry fruits, due to their perishability, they are mostly frozen and placed as frozen fruits, or processed into jams, marmalades, etc. (Casati et al., 2019). Sun drying is the most common way of drying blueberries, but there is a high possibility of product contamination (Eminoğlu, M. B., et al. 2019). In the case of lyophilization of blueberry, comparing to other drying methods that are performed at higher temperatures, the contents of total polyphenols and flavonoids, anthocyanins, vitamin C and antioxidant activity are higher (Choi, S. R., et al. 2017). Lyophilized berries, such as blueberry, which contains large amounts of anthocyanin pigments, can be used as a dye in the food industry (Casati et al., 2019). Lyophilization can also be used for forest fruits, whereby the process of lyophilization changes the color of the primary raw material to something darker, which does not affect the quality of the final product (Bondoc & Bratucu, 2017). Lyophilization can also be used for drying tropical fruits: papaya, mango, lemon, grapefruit, etc. In the case of vegetables, such as tomatoes, it should be noted that tomato powder is a product that is often used in industry. Tomato is the main source of lycopene pigment for humans. Some studies show that lyophilization does not lead to a significant loss of vitamin C and the content of polyphenols, but the content of lycopene and carotenoids decreases (Georgé, S. et al., 2011). Some researches show that dehydration of vegetables leads to a reduction of

carotene content in vegetables regardless of the applied method of drying, so in the case of broccoli and carrots there is a reduction of carotene content by over 50% after dehydration (Guiné, R.P.F., 2018).

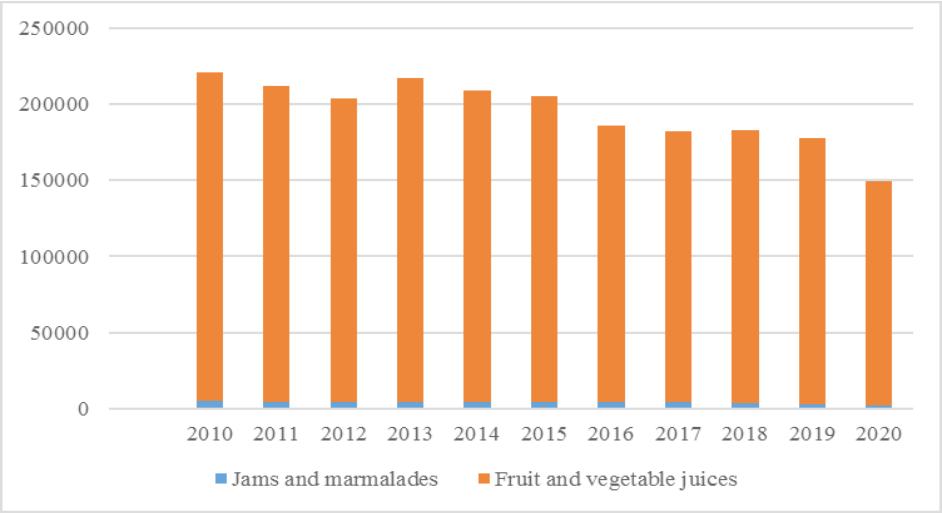
The advantages of lyophilization compared to other methods of drying fruit and vegetables include the formation of a stable product for a longer period of time due to the removal of most water from it, chemical decomposition of the primary raw material is minimized, the chances of oxidation of the product are minimal and since drying is performed in controlled conditions, there is less chance of contamination with microorganisms (Deepak & Iqbal, 2015). However, it should be emphasized that the lyophilization process can have an impact on the content of volatile substances, carotenoids and polyphenols in the final product, in terms of changing their composition and concentration (Abascal et al., 2005) and also some other important compounds, as previously stated.

Fruit and vegetable processing in Serbia

In the processing of agricultural products, cooling, drying and cooking are the most common methods in the processing process (Kovačević, V., 2019). The total number of agricultural holdings engaged in the processing of fruits and vegetables in Serbia is 31.816 (Farm Structure Survey, 2018, Statistical Office of the Republic of Serbia). Fruits are primarily marketed as fresh, although there is a high potential for added value creating through processing into juices, brandies, jams and more (Kovačević, V., 2019). Given that the group of economically weakest agricultural holdings in Serbia includes agricultural holdings focused on fruit growing and viticulture, investments in fruit processing could positively affect the creation of added value, and consequently strengthen the self-sustainability of the agricultural holding (Kovačević, V., 2019). Respectively, a similar conclusion can be made regarding the processing of vegetables on agricultural holdings.

Of the total fruits produced in Serbia, a small amount is processed, only about 10% (Bulatović&Rajić, 2012). According to the available statistical data, the production of fruit and vegetable products in Serbia has a rather declining trend (Graph 1). Fruit and vegetable juices are mostly produced, while significantly less raw materials are processed into jams and marmalades.

Figure 1. Production of fruit and vegetable products in the Republic of Serbia, period 2010-2020



Source: Statistical Yearbook, 2011-2021, Statistical Office of the Republic of Serbia

In Serbia, lyophilization as a way of processing fruits and vegetables by drying, is in its beginings. There are several business entities engaged in the processing of raw materials by lyophilization: Drenovac doo from Arilje, Dibal d.o.o. from Zrenjanin and LYOCAKE from Valjevo. The products created by lyophilization process are diverse, and mostly include lyophilized products of the following fruits: raspberry, strawberry, apricot, apple, cherry, blackberry, blueberry, plum, as well as tropical fruits such as orange, mango, banana and lemon. Lyophilized products are in the form of whole fruit or cut into smaller pieces of different diameters, or in the form of powder. The final products are presented by one fruit or a mixture of different fruits.

In Europe and in the world, this modern technology is already recognized on the market by consumers, so there is a large selection and growing demand for lyophilized products. The largest producer of lyophilized products in Europe is European Frezze Dry, and in the world Asahi Group Holdings Ltd (Japan), Ajinomoto Co.Inc (USA), Harmony House Foods Inc. (USA) and Nestle SA (Canada). Lyophilized products present on the European market are very diverse and include: fruit powders, vegetable powders, produced from organic or convetional raw materials, main dishes (dishes with meat, rice, cheese, etc.) packed for takeaways, vegetable soups, mixtures of fruits and vegetables as breakfast meals, desserts (iccecreams), etc. Sets of meals are made for the entire day or more days/weeks for travel, camping, etc.

Conclusion

Lyophilization of fruits and vegetables is a modern and innovative way of drying fruits, and creating quality and safe final product with a long shelf-life. Also, drying the product in this way can facilitate its transport, handling and storage. However, the effect of lyophilization on the content of certain substances in the final product, comparing to the raw material, may be significantly different. This should be taken into account when choosing lyophilization methods for drying of raw material, so that it does not lose its quality. The quality of the lyophilized products depend on the quality and features of the primary raw material, i.e. with the increase of the quality of the raw material, the probability of obtaining a better final product increases.

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