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SUBSTANTIATING THE FEASIBILITY OF PROCESSING THE SECONDARY PRODUCT OBTAINED AFTER OSMOTIC DEHYDRATION OF DRIED APRICOTS

The object of research is the production technology of dried apricots by the method of osmotic dehydration and the derived products that are formed in the process. An improved technology for processing the secondary product of apricot production has been proposed, which is based on increasing the osmotic pressure in the cells of plant raw materials by increasing the concentration of dry substances. The improved technology involves the use of the process of osmotic dehydration in a 70 % sugar solution with a temperature of up to 55±5 °C as an alternative to the blanching process. This provides a reduction in drying time to 1 hour due to the partial transition of water from the fruit cells into the sugar solution. The spent osmotic solution contains biologically valuable substances. The mass fraction of dry substances in the spent solution decreased by 17.4 %. It was found that spent osmotic solutions contain 15.87±0.05 mg/100 carotenoids, which cause their orange color. Color stability is likely caused by the acidity of the osmotic solution (pH=3.7±0.05). As a result of hydrolysis, sucrose, which was the main component of the osmotic solution before dehydration of apricot fruits, is partially inverted into glucose (21.41±0.05) and fructose (19.99±0.05 g/100 g). Fortified sugar had a light beige color, pure without stains and impurities, sweet taste, and aroma of apricot. The jelly-like soft drink, made on the basis of a derivative product formed during the production of dried apricots, had a sweet taste, a slight aroma of apricot. The color of the meal is cream. Light straw-colored jelly, sweet in taste, with a faint aftertaste and aroma of apricot, had a jelly-like uniform consistency that can be cut. The study showed the possibility of practical application of derived products, which are usually disposed of, for production

Keywords: derivative product, apricot, fortified sugar, food concentrates, osmotic dehydration, carotenoids

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1. Introduction

Recently, there has been an increase in research into food production based on secondary raw materials and production by-products, which were previously ignored or underutilized [1]. The replacement of some traditional raw materials in the production processes of some basic food products is an actual area of research since the reduction of food waste remains a global problem in the world [2]. An important source of non-traditional raw materials, which can be successfully used for the production of food products, are secondary products obtained as a result of various technological processes in the food industry.

During fruit processing, a large number of by-products containing bioactive compounds are formed [3]. Owing to their reprocessing, it is possible to recover valuable components and minimize the amount of waste at the same time. A popular way to extend the shelf life of fruits is to preserve them with sugar.

One of these methods is combined drying, which involves preliminary dehydration by osmotic dehydration in a sugar solution and subsequent convective drying. This method was proposed for obtaining dried apricots and candied fruits in order to preserve their natural color without the use of sulfur dioxide [4].

Osmotic dehydration is one of the best and most suitable methods for increasing the shelf life of fruits and vegetables [5]. This process is preferred over others because of its ability to preserve vitamins and minerals, color, aroma, and taste. In addition, when using osmotic dehydration, there is no need to use preservatives. The economic interest is the reduced energy consumption compared to conventional drying.

One of the limitations of the osmotic dehydration process is control over the osmotic solution. Usually, this is the most important technological problem in the process of osmotic dehydration on an industrial scale [6].

Finding ways to repeatedly reuse the osmotic solution is one of the most important issues that needs to be solved. The urgent task is to devise a rational technique for processing fruits with the comprehensive use of all derived products.

2. Literature review and problem statement

Osmotic syrup can be concentrated and reused at least 5 times without adversely affecting fruit concentration [7].

In grapefruit dehydration, osmotic solutions were reused for five cycles of osmotic dehydration with or without pasteurization. The cited study showed that the osmotic solution could be used up to five times without any re-concentration. It is recommended to pasteurize the solution each time to obtain a product with a shelf life of 7 to 12 days when stored in a refrigerator [8]. The advantages of reusing the osmotic solution in successive cycles can be derived not only from an economic point of view but also due to a better preservation of citric acid in the samples and an extended shelf life of the product. However, repeated pasteurization significantly increases the cost of products as energy costs increase.

To make osmotic dehydration more economically attractive, the osmotic solution should be re-concentrated by evaporation or by adding fresh osmotic reagent. An alternative can be the use of spent osmotic solution for the preparation of other food products such as jam, syrup for fruit preservation, mixing with fruit juices, fruit soft drinks, pharmaceutical and food industries as natural additives and animal feed production [9]. However, the mechanisms of such application have not been identified. Its shelf life and storage conditions are not specified.

Multi-stage osmotic dehydration of pineapple with sugar syrups in gradually increasing concentration was experimentally evaluated and compared with the single-stage dehydration process. In addition, the osmotic solutions were reused for five cycles of osmotic dehydration without treatment. One- and multi-stage osmotic treatment was carried out for 2 hours at 40 °C. It was found that water loss decreased with syrup reuse cycles in single-stage treatments and remained almost constant in multi-stage treatments. The dry matter content of pineapple fruits during the four-stage osmotic dehydration cascade was increased compared to the one-stage dehydration. In addition, it has been shown that multi-stage dehydration achieves better performance compared to single-stage dehydration, and due to the reuse of syrup, it can become a more economical, environmentally friendly process [10]. Despite all the advantages of multiple use of osmotic solutions, they still need to be disposed of after five uses.

Since the osmotic solution is rich in carbohydrates and soluble fibers, one possibility is to use it as a substrate for obtaining fermented beverages. Due to the composition of the solution, the resulting drinks can be prebiotic or symbiotic, depending on the type of fermentation used [11]. A probiotic fermented drink based on beet juice with the addition of residual sugar syrup after three consecutive cycles of osmotic dehydration of blueberries was developed. This is not only an interesting alternative to make the cost of the osmotic dehydration process viable but also a strategy for producing probiotic products for lactose intolerant consumers [12]. Osmotic solutions can also be used as sweeteners [13]. The issue of storing used osmotic solutions and transporting them to the place of further processing remains unresolved.

Osmotic dehydration can be considered an effective method for preserving the quality of apricot pieces as it helps remove water from the tissue without affecting its color and texture, which are the most important quality attributes [14]. Judging by the color of the osmotic solutions formed after the production of dried apricots, significant amounts of carotenoids are added to their composition. At the same time, osmotic solutions are disposed of after five uses.

Data available in the literature demonstrate the potential of osmotic dehydration for fruit processing. Nevertheless, our review of the relevant literature showed that a rational way of processing the secondary product obtained after osmotic dehydration of apricot production has not yet been proposed. No research results were found regarding the possibility of using osmotic solutions for sugar fortification and its subsequent use in the production of food products. This allows us to state that conducting a study on the feasibility of using an osmotic solution for sugar fortification is a relevant task.

3. The aim and objectives of the study

The purpose of our study is to justify the feasibility of processing the secondary product obtained after osmotic dehydration of dried apricot production. The results will become the basis for the commercial production of new food products.

To achieve the goal, the following tasks are set:

– to determine the quality indicators of the osmotic solution formed during the osmotic dehydration of apricot fruits;

– to evaluate the organoleptic indicators of fortified sugar;

– to evaluate the organoleptic indicators of instant jelly-like soft drink;

– to evaluate the organoleptic indicators of jelly.

4. The study materials and methods

4. 1. The object and hypothesis of the study

The object of our research is the production technology of dried apricots by the method of osmotic dehydration and the derived products that are formed in the process.

The research hypothesis is as follows. Usually, the osmotic solution formed during the dehydration of apricot fruits is disposed of after five uses. This is economically and ecologically impractical because before each reuse, temperature treatment of the solution should be carried out to prevent the development of microorganisms. An alternative technique is proposed, which involves using an osmotic solution after the first dehydration of the fruits as a natural food additive for sugar fortification and the production of food concentrates. When fortifying products with a solution, their biological value increases, certain taste-aromatic properties characteristic of raw materials are given. This will allow comprehensive processing of all derived products and minimize the amount of waste. The significance of this study is that the proposed technology is low-waste and will allow expanding the range of sugar and food concentrates.

Research on the possibility of using a derivative product formed during the production of dried apricots for sugar fortification and the production of food concentrates may be useful for further implementation in production.

For the preparation of jelly-like soft drink, fortified wet sugar was mixed with corn starch in the ratio of components according to the recipe (Table 1) and shaped. After that, it was dried in convective dryers at a temperature of 50±5 °C. Apricot jelly concentrate was formed on the basis of dry fortified sugar and edible gelatin according to the recipe (Table 1).

Table 1

Formulation of food concentrates

Composition	Jelly-like soft drink		Jelly	
	TM "Zolote Zerno", "Abrikosoviy"	Experimental sample	TM "Mriya" "Peach"	Experimental sample
Sugar-sand, g	74	56	85,9	63
Osmotic solution, g	–	24	–	27
Gelatin, g	–	–	10,1	10
Corn starch, g	–	20	–	–
Potato starch, g	20	–	–	–
Concentrated apple juice, g	4	–	–	–
Acidity regulator citric acid, g	1	–	1	–
Flavoring "Peach", g	–	–	1	–
Aromatic composition "Abrikos", g	1	–	–	–
Dyes (carbamic acid, beta-carotene), g	–	–	1	–
Antioxidant ascorbic acid, g	–	–	1	–

4. 2. Materials

Ripe apricot fruits (*Prunus armeniaca*) of the Nadiya variety, gathered in the second half of June in the Sumy oblast, were washed in tap water, and then cut lengthwise into two halves. The prepared fruits were immersed in a 70 % sucrose solution heated to 55±5 °C. Hydromodule is 1. For 1 hour, osmotic dehydration of the solution was carried out in a laboratory setup [15]. After that, the osmotic solution (Fig. 1) was separated and mixed with sugar (with a mass fraction of sucrose of 99.75 %, color – 61 units of ICUMSA) in the amount of 30 % by mass of sugar. This amount of the added derivative product is due to the mass fraction of dry substances in it. With a smaller amount of added solution, sugar is not sufficiently fortified with biologically active components and has less attractive sensory indicators. Increasing the proportion of the solution leads to partial dissolution of sugar crystals. The fortified sugar was dried in a laboratory vacuum dryer. It was established that under the condition of refrigerated storage (t=2–4 °C), osmotic solutions retain their stability for 6 months.

Food concentrates were made on the basis of fortified sugar: an instant jelly-like soft drink, and jelly.

Fig. 1. Osmotic solution after dehydration of apricots

Industrial samples of food concentrates contain much more sugar and various synthetic flavoring additives. Test samples contain only natural raw materials.

4. 3. Determining the quality indicators of solutions obtained after osmotic dehydration of apricot fruits

The active acidity of the osmotic solution was determined by the potentiometric method using a laboratory pH-meter pH-500.

The mass fraction of dry substances in osmotic solutions was determined by the refractometric method. The mass fraction of carbohydrates was determined by liquid chromatography (Shimadzu LC 20A chromatograph, Japan). The column of refractometric detector HP 75 in Ca++ form was used.

The mass fraction of carotenoids was determined by a chemical method (wavelength 452 nm).

4. 4. Evaluating the organoleptic indicators of flavored sugar

Descriptors of organoleptic evaluation were used standard for sugar but taking into account the indicators established for fruit additives for the enrichment of baby food products.

The tasting was conducted by 10 non-professional tasters of different age and gender from the lecturers and graduate students at the Sumy National Agrarian University (Ukraine), who were trained and had previous experience in sensory evaluation. Color, taste, smell, and general appearance were evaluated on a 7-point scale (much dislike: 1 point; neutral dislike: 2 points; slightly dislike: 3 points; neutral like: 4 points; moderately good: 5 points; good: 6 points, very good: 7 points).

4. 5. Evaluating the organoleptic indicators of instant jelly-like soft drink

Descriptors of organoleptic assessment of jelly-like soft drink were devised (Table 2).

Table 2

Descriptors of organoleptic assessment of jelly-like soft drink

Indicator ID	Characteristics
Jelly-like soft drink concentrate	
Appearance of the briquette	Whole, regular in shape, uniform in thickness
Ready meal	
Appearance	Transparent viscous liquid, homogeneous without lumps
Color	From cream to light yellow
Taste and smell	Inherent in the recipe composition of jelly, prepared by the culinary method, without extraneous taste and smell

Tasting evaluation was carried out according to the methodology defined in chapter 4. 4.

4. 6. Evaluating the organoleptic parameters of jelly made using osmotic solutions

The organoleptic evaluation of the jelly was carried out according to the indicators given in Table 3.

Table 3

Descriptors of organoleptic evaluation of jelly

Indicator ID	Characteristics
Jelly concentrate	
Appearance	Loose mixture
Ready meal	
Appearance	Inherent in the corresponding dish, prepared by the usual culinary method
Color	Opalescence is allowed; turbidity is not allowed
Taste and smell	From cream to light straw
Consistency	Inherent in the corresponding dish prepared by the culinary method. Extraneous taste and smell are not allowed

In accordance with the proposed descriptors, tasting and sensory evaluation of the samples were carried out according to the methodology defined in chapter 4. 4.

4. 7. Statistical analysis

Statistical analysis was performed by comparing group mean values. The difference between groups was tested by Student's t-test. Results are represented as mean±SD of measurements from three separate extracts. Measurements were performed in three different studies. Statistical significance is expressed at $p \leq 0.05$. The mean value and standard deviation of each group of measurements were calculated using the statistical software SPSS (USA).

5. Results of determining the derivatives and processing products of apricot fruits

5. 1. Results of determining the quality indicators of solutions obtained after osmotic dehydration of apricot fruits

At the first stage of our research, the quality of osmotic solutions formed during the production of dried apricots was analyzed. The results of the study are given in Table 4.

Table 4

Results of quality indicators of the solution obtained after osmotic dehydration of apricot fruits

Indicator ID	Value'	Value''	Value'''
Mass fraction of dry substances, %	52.6±0.05	52.55±0.05	51.65±0.05
pH	3.7±0.05	3.65±0.05	3.75±0.05
Color by ICUMSA	397±0.05	396.95±0.05	397.05±0.05
Mass fraction of sucrose, g/100 g	10.94±0.05	10.83±0.05	11.05±0.05
Mass fraction of glucose, g/100 g	21.41±0.05	21.37±0.05	21.45±0.05
Mass fraction of fructose, g/100 g	19.99±0.05	19.94±0.05	20.04±0.05
Mass concentration of carotenoids, mg/100 ml	15.87±0.05	15.85±0.05	15.89±0.05

The results of our study showed that due to osmotic dehydration, the mass fraction of dry substances in solutions decreases by 17.4 % due to the transition of cell juice. The content of carotenoids, which cause the bright orange color of the osmotic solution, is 15.87±0.05 mg/100.

The stability of the color was determined by the moderate acidity of the solution (pH=3.7±0.05).

Due to osmotic dehydration, the sucrose contained in the initial solution undergoes partial hydrolysis, probably under the catalytic action of acids contained in apricot fruits. Its amount decreases to 10.94±0.05 g/100 g. As a result of acid hydrolysis, glucose (21.41±0.05 g/100 g) and fructose (19.99±0.05 g/100 g) are formed, which significantly increases the biological value of solutions.

5. 2. Results of organoleptic assessment of sugar fortified with apricot processing product

Traditionally, granulated sugar and pressed sugar are white in color, pure without stains or foreign impurities. White sugar has a sweet taste without extraneous smell and taste. Since color, taste, and aroma are among the dominant factors in the formation of consumer interest in any food product, the organoleptic characteristics of fortified sugar were evaluated (Fig. 2).

a *b*

Fig. 2. Fortified sugar: *a* – granulated sugar; *b* – pressed sugar

The sugar fortified with the osmotic solution had a light beige color, clean without stains and foreign impurities, sweet taste, and aroma of apricot. The sugar solution is transparent, without insoluble sediment, mechanical and other impurities.

Due to its organoleptic properties, fortified sugar can be used as a separate product or raw material for the production of other food products.

Table 5

Sugar sensory evaluation score

Quality indicators	Appearance	Aroma	Taste	Color
Result	6.90±0.83[b]	6.85±0.94[b]	6.95±0.67[a]	6.90±0.89[a(1)(2)]

Note: (1) – each value is expressed as mean±standard deviation (n=20); (2) – different lowercase letters in the same column indicate a significant difference according to Duncan's range test (p<0.05).

It is advisable to fortify sugar within the enterprise, which is engaged in fruit processing, without transporting it. Given that, depending on the apricot variety and its degree of ripeness, the mass fraction of dry substances in the spent osmotic solution can range from 50 to 60 %; the amount of sugar fortification solution can be different.

5. 3. Results of organoleptic assessment of jelly-like soft drink fortified with apricot processing product

Sensory analysis of apricot jelly-like soft drink was carried out (Fig. 3). When preparing the meal, the concentrate was poured with boiling water (100 ml) and slowly stirred until a uniform consistency was obtained.

The results of sensory evaluation of jelly-like soft drink are given in Table 6.

Jelly-like soft drink concentrate had the form of a briquette, uniform in thickness. The finished meal had the appearance of a transparent viscous liquid, homogeneous, without lumps. The color of the concentrate and the meal was cream. The taste was sweet. There was a light aftertaste and aroma of apricot.

a *b*

Fig. 3. Apricot jelly-like soft drink: *a* — concentrate; *b* — ready meal

Table 6

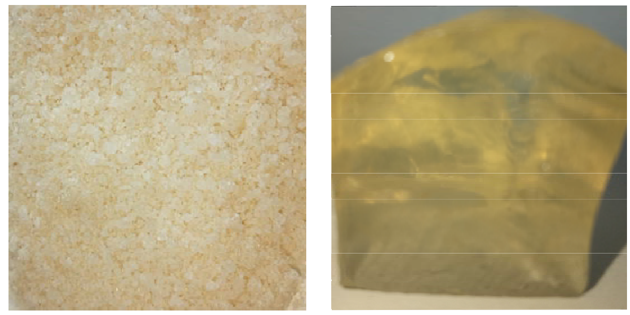
Score of sensory assessment of jelly-like soft drink

Quality indicator	Appearance	Aroma	Taste	Color	Consistency
Result	4.46±0.69[c(1)(2)]	5.40±0.94[a]	5.50±0.69[b]	4.15±0.75[c]	5.20±0.95[b]

Note: (1) – each value is expressed as mean±standard deviation (n=20); (2) – different lowercase letters in the same column indicate a significant difference according to Duncan's range test (p<0.05).

5. 4. Results of organoleptic evaluation of jelly fortified with apricot processing product

The organoleptic properties of jelly were also analyzed (Fig. 4).



a *b*

Fig. 4. Apricot jelly: *a* — concentrate; *b* — ready meal

The results of sensory assessment of jelly are given in Table 7.

Table 7

Jelly sensory evaluation score

Quality indicator	Appearance	Aroma	Taste	Color	Consistency
Result	5.55±0.69[b]	5.40±0.94[a]	6.20±0.83[b(1)(2)]	5.80±0.73[b]	6.65±0.99[c]

Note: (1) – each value is expressed as mean±standard deviation (n=20); (2) – different lowercase letters in the same column indicate a significant difference according to Duncan's range test (p<0.05).

Apricot jelly concentrate had the appearance of a loose mixture. The finished meal had a jelly-like consistency that could be cut. The color was light straw, transparent. The jelly had a sweet taste, with a faint aftertaste and aroma of apricot.

6. Discussion of research results regarding the feasibility of processing osmotic solutions formed during the production of dried apricots

The most important result of our study was the demonstration that the osmotic solution formed during the dehydration of apricot fruits could be used for sugar fortification. Fortified sugar can be used for the production of food concentrates (jelly-like soft drink, jelly).

The bright orange (Fig. 1) color of osmotic solutions indicates an active transition into their composition of carotenoids, which confirms the results of other researchers [16, 17]. According to previous studies [18], the total content of carotenoids in apricot fruits ranges from 17,353 to 222,098 μg/g. Thus, it can be concluded that the osmotic solution, which contains 15.87±0.05 mg/100 ml of carotenoids, is a valuable source of these pigments. Apricots are a valuable source of vitamin A precursors and provide an important contribution to their antioxidant properties.

According to the results given in Table 3, osmotic solutions contain a high enough amount of glucose and fructose. Sucrose, glucose, and fructose are the most important soluble sugars [19] that are part of apricot fruits. According to some studies [20], the sucrose content in apricot fruits is the highest (57.8 %), the glucose content is 19.4 %, and the fructose content is 14.3 %. According to our studies (Table 3), only 10.94±0.05 g/100 g of sucrose remains in the solution, the rest undergoes partial hydrolysis, and the content of glucose and fructose increases significantly, corresponding to 21.41±0.05 g/100 g and 19.99±0.05 g/100 g. Monosaccharides play an important role in the formation of organoleptic qualities of food products, they soften the taste and give them a sweet taste and fruity aroma. This is confirmed by the results of the organoleptic evaluation of meals prepared using osmotic solutions.

Taking into account the small amount of osmotic solution added to sugar (30 %), in the products of its processing (Fig. 2, 3) almost no color is preserved, however, the smell characteristic of apricot fruits is felt. When increasing the amount of solution added to sugar, its moisture content increases significantly, as a result, energy costs for the drying process increase. In addition, partial dissolution of sucrose crystals is observed.

The practical significance of our research is the possibility of processing derivative products formed during the processing of apricot fruits.

The advantages of this processing technique for spent osmotic solutions are that there is no need for additional processing of solutions before use. And their biological value is also preserved.

The limitations of this study include the lack of normative technological documentation for the production of food concentrates and sugar fortified with a by-product of apricot fruit processing. In addition, it is important to work on the formulation of food concentrates and their production technique, with the aim of increasing the share of the by-product of apricot fruit processing.

The disadvantage of the proposed technique is that when using sugar fortified with an osmotic solution, the taste-aromatic characteristics of fruit raw materials are not fully preserved. This is due to the small amount of added solution.

Further research will be aimed at improving the technology of manufacturing food concentrates and the basis of apricot processing derivatives and researching their physicochemical properties. It is planned to investigate the influence of a single-use osmotic solution with different concentrations of dry substances on the quality of fortified sugar.

7. Conclusions

1. It was established that osmotic solutions formed during osmotic dehydration of apricot fruits contain 15.87±0.05 mg/100 ml of carotenoids, 10.94±0.05 g/100 g of sucrose, 21.41±0.05 g/100 g of glucose, and 19.99±0.05 g/100 g of fructose. This indicates that it is advisable to process this derivative product in order to obtain a variety of food products, in particular sugar and food concentrates.

2. The sugar fortified with the osmotic solution had a light beige color, it was clean without stains and foreign impurities, and it had sweet taste and aroma of apricot. In terms of taste, sugar had the highest preference (6.95), while aroma had the lowest preference (6.85).

3. The jelly-like soft drink, made on the basis of a derivative product formed during the production of dried apricots, had a sweet taste, a slight aroma of apricot. The color of the meal was cream. According to the sensory evaluation, the jelly-like soft drink had the highest advantage in terms of taste (5.5). The lowest – in terms of color (4.15).

4. Light straw-colored jelly, sweet to the taste, with a faint taste and aroma of apricot, had a jelly-like uniform consistency that can be cut. The highest score was given to the jelly consistency (6.65). Tasters liked the aroma of the product the least, it was rated 5.4 points.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

All data are available, either in numerical or graphical form, in the main text of the manuscript.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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