

*A formulation composition and a low-temperature technique have been devised for concentrating fruit and vegetable puree with the following component content: 20 % apple; 20 % pumpkin; 15 % beets; 15 % cranberries; 15 % hawthorn. The puree is concentrated in a rotary evaporator to a solids content of 50 % at a temperature of 50...56 °C under vacuum. The processing time was reduced to 1...2 min, which is several times less compared to conventional single-case pump vacuum evaporators (60...90 mins). Reducing the temperature influence of concentrating contributes to an increase in the organoleptic and physico-chemical parameters of the resulting paste. To determine the effect of the contribution of each component to the structure of the paste, the structural and mechanical properties of the puree from each raw material and concentrated semi-finished products were investigated. The devised paste has an increased strength of the structure with a dynamic viscosity value of 394 Pa·s, which is 2.5 times more than that in the control sample. The devised blended fruit and vegetable paste has an increased content of physiologically functional ingredients and good organoleptic parameters, unlike control (apple paste).*

*It was established that the partial replacement of apple puree in the formulation composition of marshmallow with 75 % of the devised multicomponent fruit and vegetable paste gives the product original properties. The dynamic viscosity value of the marshmallow in which 75 % of apple puree was replaced with the devised paste has increased, compared to the control sample (marshmallow without additives), from 408 Pa·s to 908 Pa·s. The color of the marshmallow mass where 75 % of apple puree were replaced is bright pink with a wavelength of 596.7 nm and a brightness of 62.3 %. The data reported here make it possible to improve the quality of original marshmallow products when adding fruit and vegetable semi-finished products whereby an increase in functional properties is provided*

**Keywords:** *low-temperature concentrating, multicomponent fruit and vegetable paste, marshmallow mass, structural and mechanical properties, structure formation*

# IMPROVING MARSHMALLOW PRODUCTION TECHNOLOGY BY ADDING THE FRUIT AND VEGETABLE PASTE OBTAINED BY LOW-TEMPERATURE CONCENTRATION

**Mariana Bondar**

*Corresponding author*

Assistant\*

E-mail: bondarmariana34@gmail.com

**Alla Solomon**

PhD, Associate Professor\*

**Natalia Fedak**

PhD, Associate Professor

Department of Food Technology in the Restaurant Industry

State Biotechnological University

Alchevskykh str., 44, Kharkiv, Ukraine, 61002

**Mariia Paska**

Doctor of Veterinary Sciences, Professor, Head of Department

Department of Hotel and Restaurant Business

Lviv State University of Physical Culture

Kostiushka str., 11, Lviv, Ukraine, 79007

**Anna Hotvianska**

PhD

Department of Plant Production

Dnipro State Agrarian and Economic University

Serhiya Yefremova str., 25, Dnipro, Ukraine, 49600

**Lyudmila Polozhshnikova**

PhD, Associate Professor

Department of Food Industry Technologies and Restaurant Industry\*\*\*

**Denys Mironov**

PhD\*\*

**Larisa Kushch**

Senior Lecturer\*\*

\* Department of Food Technologies and Microbiology

Vinnitsia National Agrarian University

Soniachna str., 3, Vinnitsia, Ukraine, 21008

\*\* Department of Hotel, Restaurant and Resort Industry \*\*\*

\*\*\* Poltava University of Economics and Trade

Kovalia str., 3, Poltava, Ukraine, 36000

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## 1. Introduction

One of the priority directions in the development of the food industry today is the creation of functional confectionery products. Namely, due to the enrichment of their chem-

ical composition with plant-based ingredients, it is possible to obtain an original range of structural, mechanical, and organoleptic properties.

Fruit and vegetable raw materials are a natural source of functional physiological ingredients (FPI), which makes

it possible to provide the population with the necessary nutrients as much as possible; however, many countries do not fully use the potential of plant raw materials.

More rational utilization of fruit and vegetable raw materials is possible through the introduction of the latest technological and equipment solutions for the production of high-quality natural semi-finished products for functional purposes, using modern achievements in science and technology.

The introduction of plant raw materials into the formulation of food products increases the functionality of the product, for example, by increasing the content of pectin substances, which could contribute to the release of heavy metals from the human body [1]. The need for a healthy diet predetermines the need to create functional food products through the introduction of modern technologies and the equipment component for their implementation, in particular due to low-temperature processing of plant raw materials.

Ensuring the expansion of the range of wellness products, in particular confectionery products, is possible by minimizing in the formulation composition of components with low FPI content and replacing them with fruit and vegetable pastes with increased nutritional value [2].

Therefore, it is a relevant task to direct scientific and practical work to improve the techniques of production of fruit and vegetable semi-finished products of high degree of readiness with the possibility of their further introduction to the formulation composition of food products (confectionery, bakery, etc.).

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## 2. Literature review and problem statement

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Paper [3] presents data confirming the positive effect of the use of plant raw materials by humans to increase the functionality of the diet with a variety of phenolic compounds, acids, etc., thereby forming strong immunity. However, in the production of functional products of natural origin, considerable attention is paid to the formation of a rational daily rate of their use, depending on the needs of the person and the implementation of appropriate structural and technological solutions.

Study [4] compares the conventional techniques of processing various raw materials used in the food industry to determine possible ways of resource efficiency but does not determine the effectiveness of the processed and production technologies used. That is why work [5] focuses on human nutrition throughout life; however, an overview of the generalized factors of the effectiveness of the introduction of healthy eating does not take into consideration the effectiveness and feasibility of using natural organic resources. This is due to the growing needs of consumers, the deterioration of the environmental situation, and a decrease in immunity, hence the need to compile generalized recommendations, as well as to use modern equipment and technological lines for the processing of raw materials into functional products. This approach confirms the feasibility of studies aimed at increasing the resource efficiency of processes of processing plant raw materials in semi-finished products of a high degree of readiness and other various foods with an elevated FPI content.

Work [6] defines the demand for consumer cooperation to a balanced diet based on plant raw materials to ensure a healthy functional diet. However, a generalized review of the impact of fruit consumption as biologically active substances is given

without determining the effectiveness of combining plant raw materials in the composition to increase the effectiveness of use. One of the ways to solve these shortcomings is the rational blending of plant raw materials, taking into consideration the FPI received, consistency, possible range of use in the formulation of various products and organoleptic properties [7]. Semi-finished products of natural origin with a high degree of readiness and a wide range of use in many processing and production areas include dried and concentrated products [8, 9]. However, one of the main equipment and technological complications of processing plant raw materials into functional products is low resource efficiency, and, therefore, there is a need to implement innovative design and technological solutions aimed at effective low-temperature processing. Work [10] determines the effectiveness of the introduction of honey into marshmallow in terms of vitamins and minerals but these components do not make it possible to partially replace certain components of the product, such as apple puree. Thus, study [11] reports the technology of production of marshmallow products with the introduction of blends of plant paste into the formulation without specifying data on the impact and efficiency of heat and mass transfer processing of the puree on the resulting quality of the product. In addition, there are unresolved issues related to the impact of changes in the composition of the blend, taking into consideration the natural raw materials used, on the FPI received and the structure of the products obtained. This may be due to a small number of studies aimed at determining the possibility of blending various fruit and vegetable raw materials, the structural, mechanical, and organoleptic properties received. In [12], researchers investigated the effects of the microbial polysaccharides xanthan, enposan, and gelatin on the formation of gluten-free muffins structure. This ensured the forecast of the existing structure of the finished product by replacing the formulation components of the cupcake, which ensured the formation of the necessary structure of the dough without gluten. However, only the issues of quality behavior of products without the influence of regime parameters and equipment solutions during research were considered.

That confirms the relevance of research on expanding the scientific and practical base for finding ways to intensify equipment and technological lines for the resource-efficient production of functional food products, which should ensure the expansion of the range and strengthen the immunity of consumers.

Work [13] defines the impact of the duration of concentrating baby puree and, as a consequence, the changes in their rheological behavior depending on the temperature component and the range of high-speed shear. However, these data have characteristic properties for baby puree and would differ in low-temperature concentrating of blends of organic origin, having different FPI content, initial and final dry matter content, density, etc. Thus, work [14] investigated the change in the pH of puree when combining mango and peach without determining the rational temperature of concentrating as one of the factors influencing the viscosity and duration of processing. A study reported in [15] is aimed at determining the effect of pressure on changes in temperature characteristics during steam-contact heating of raw materials in working space; however, steam-based technologies are characterized by complexity of operation and a low resource efficiency coefficient. However, most studies consider the technological component of production without taking into consideration the equipment impact, in particular, heat and mass exchange treatment during

the concentrating of the puree, the resource efficiency of heat treatment in general. Work [16] defines the change and the formation of foaming, rheological, and thermal properties of confectionery production using an example of marshmallow without gelatin. However, the effect exerted on the received consistency of marshmallow by the possibility of replacing structure-forming ingredients with blended functional plant-based semi-finished products of high degree of readiness is not taken into consideration.

Paper [17] uses an example of the technique of marshmallow production with the introduction of vegetable puree into the formulation composition when replacing the content of apple puree, followed by determining the functional properties received. Partial or complete replacement in the formulation composition of confectionery products of artificial ingredients (dyes, flavors, etc.) could make it possible to obtain functional products with a high FPI content and original properties. Thus, the need to gradually determine the rheological, organoleptic properties of blended fruit and vegetable semi-finished products and the high content of FPI of the finished confectionery product have been confirmed.

Work [18] describes technologies for the production of confectionery products using food fibers of plant origin, thereby making it possible to minimize the share of foreign ingredients when intensifying own capacities. The use of local plant raw materials and innovative low-temperature processing technologies makes it possible to achieve resource efficiency during production. That could minimize the use of synthetic ingredients in the formulation composition of functional products, replacing them with natural semi-finished products made by the low-temperature processing techniques to ensure maximum preservation of the initial properties of the raw materials [19].

Therefore, it is advisable to conduct research aimed at finding innovative scientific and practical solutions in the technology of marshmallow production with partial or complete replacement of apple puree with functional blended pasty semi-finished products obtained by low-temperature processing. The results of such studies would help meet the demand of consumers for functional products based on a natural raw material base with the minimization of foreign synthetic ingredients.

The introduction of functional blended pasty fruit and vegetable semi-finished products in the confectionery formulation, using the example of marshmallow, would ensure obtaining the original structural, mechanical, and organoleptic indicators.

Thus, it is advisable to direct scientific and practical research to improve the technology of confectionery production using an example of marshmallow when using fruit and vegetable pasty concentrate obtained by low-temperature processing.

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### 3. The aim and objectives of the study

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The purpose of this study is to improve the technology of marshmallow with the addition of a fruit and vegetable paste obtained by a low-temperature concentrating technique. This would make it possible to expand the range of functional competitive products and semi-finished products of high quality.

To accomplish the aim, the following tasks have been set:

- to devise a formulation composition and ways to implement the technique of production of fruit and vegetable paste with the establishment of its structural, mechanical, and qualitative indicators;

- to optimize the amount of application of the devised fruit and vegetable semi-finished product in marshmallow technology while determining the structural, mechanical, color, and organoleptic properties.

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### 4. The study materials and methods

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The research was carried out at the Research Center “Newest Biotechnology and Equipment for the Production of Food Products with High Wellness Properties”, the Kharkiv State University of Nutrition and Trade (Ukraine). As the main raw material for the production of fruit and vegetable pasty semi-finished products, we used apples (Antonivka variety), pumpkins (Muskatny Perlina variety), beets (Bona variety), cranberries (Piligrim variety), hawthorn (Arnold variety) with a high FPI content. The structural and mechanical properties of the components puree before blending were determined, blended at different percentages, and boiled pastes with the dry matter content of 50 % (DM), and made with the addition of marshmallow paste. The structural and mechanical properties of the prototypes of puree, pastes, and marshmallow mass were determined at the rotary viscosimeter “Reotest-2” (Germany). We determined the color formation in the prototypes at the spectrophotometer SF-2000 in accordance with the ICO method (International Coordinate System CIE) [20].

The organoleptic properties of the prototypes were estimated by an expert board consisting of 5 members from the State Biotechnological University (Kharkiv, Ukraine) using a 5-point scale.

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### 5. Improving the marshmallow technology by adding a fruit and vegetable paste obtained by low-temperature concentrating

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#### 5.1. Devising the formulation composition, the production technique of a fruit and vegetable paste

When investigating ways to implement the technique of production of a fruit and vegetable paste, we determined the formulation content of the five-component fruit and vegetable blend, taking into consideration the content of FPI, the organoleptic and structural-mechanical properties of each component. The fruit and vegetable raw materials for the formulation of the paste were selected taking into consideration the content of pectin substances and dietary fibers to give the resulting semi-finished product a strong structure; we also took into consideration their therapeutic and prophylactic properties [21].

The proposed formulations for the blended fruit and vegetable paste are given in Table 1.

We prepared the fruit and vegetable paste in the devised way as follows: the puree of apples, pumpkins, and beets was made according to standard technology for the production of fruit and vegetable purees. Hawthorn should be aged in a 8...10 % NaCl solution with the addition of 1 % citric acid at a temperature of 21...26 °C for 36...42 min. This would remove various mechanical contaminants from the fruit and stabilize polyphenols. Hawthorn is steamed at a temperature of 100...110 °C for 5 minutes, cranberries – with water for 3 min. at a temperature of 86...90 °C. Cranberries and hawthorn are ground to a particle size of 0.4...0.5 mm. The received

one-component puree of the selected fruits and vegetables is blended according to Table 1. The low-temperature concentrating (50...56 °C) of the blended multicomponent puree is performed in a rotary evaporator of the improved design [22], within 1...2 mins.

The structural and mechanical indicators of single-component fruit and vegetable puree and blended pastes made of them have been determined. Fig. 1 shows the indicators of shear properties of the samples of puree made from fruit and vegetable raw materials. Apple puree and pasta were chosen as control.

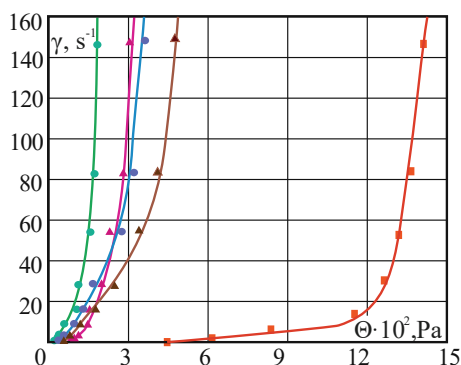


Fig. 1. Shear characteristics of puree from the following raw materials ( $t=20\text{ }^{\circ}\text{C}$ ): ● – apples; ● – pumpkins; ▲ – beets; ▲ – cranberries; ■ – hawthorn

Based on the above dependences, the maximum shear stress ( $\Theta$ , Pa) was determined: for apples – 12, pumpkins – 42, beets – 57, cranberries – 76, hawthorn – 450 (Fig. 1). The resulting nature of the dependences indicates that all puree samples refer to the non-ideal plastic solids. The increase in the shear limit stress of all samples compared to control is caused by the greater source content of DM and the presence of pectin substances.

Table 1

Formulation composition of blended fruit and vegetable compositions

Component composition, %	Composition		
	1	2	3
Apple	20	30	40
Pumpkin	20	20	25
Beet	15	20	20
Cranberry	30	20	10
Hawthorn	15	10	5
Control	100	100	100

The resulting structural and mechanical indicators of the effective viscosity of the concentrated fruit and vegetable pastes based on the formulations of compositions in Table 1 are shown in Fig. 2. The determined indicators of effective viscosity ( $\eta_{ef}$ ) of the resulting paste samples indicate their increase compared to control, 156 Pa·s, and are, respectively, for each composition: 1 – 394; 2 – 360; 3 – 312. The obtained level of effective viscosity indicators indicates an increase in the strength of the structure of all paste compositions, which allows for their recommended use as structure-forming agents in various confectionery products, such as marshmallows, pastila, etc.

The expert board conducted an organoleptic evaluation of the devised compositions to determine the optimal formulation ratio (Table 2).

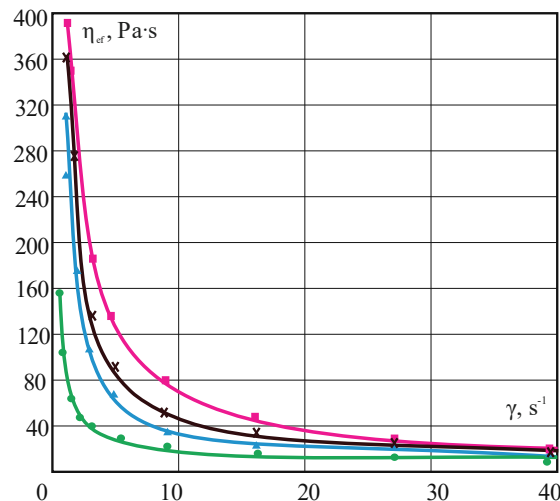


Fig. 2. Rheological curves of fruit and vegetable pastes,  $t=20\text{ }^{\circ}\text{C}$ : ● – control (apple paste); ■ – composition 1; × – composition 2; ▲ – composition 3

It is determined that composition 1 has a pronounced taste and smell of cranberries, pleasant taste of pumpkin, hawthorn, and apples. Composition 2 has a pleasant harmonious taste of hawthorn, cranberries, and apples. Composition 3 has a barely sensible smell and taste of cranberries and hawthorn – pleasant smell of apples and pumpkins.

Table 2

Organoleptic evaluation of blended fruit and vegetable pastes

Indicator	Characteristic		
	Composition 1	Composition 2	Composition 3
Appearance	Homogeneous grated pasty mass		
Taste and aroma	Pronounced taste and smell of cranberries. Pleasant aroma of pumpkin, hawthorn, apples, and beets is hardly felt	Pleasant harmonious taste of cranberries, hawthorn, and apples	Barely sensible smell and taste of cranberries and hawthorn, pleasant – apples and pumpkins
Color	Rich red-burgundy	Red-burgundy	Light red-burgundy
Consistency	Homogeneous viscous sticky mass		

Estimation of the color of composition 3 indicates the non-bright color, unlike compositions 1 and 2. It was found that the presence of pumpkin or beets in a higher percentage gives a sample an unpleasant specific aftertaste. Cranberries have a pleasant taste, smell, and a rich color. According to organoleptic indicators, the best property is demonstrated by composition 1 with a ratio of components as follows: apple – 20 %; pumpkin – 20 %; beets – 15 %; cranberries – 30 %; hawthorn – 15 %, unlike compositions 2 and 3. The evaluation of the chemical composition of the devised compositions of fruit and vegetable pastes in comparison with control (apple paste, the content of DM is 50 %) was performed, Table 3 [21]. The presented samples have an increased FPI content.

The devised paste, made according to composition 1, in comparison with the control sample (apple paste), has a 1.7 times higher content of pectin substances, and ascorbic acid – by 2.6 times (Table 3).

Table 3

Comparison of the of blended pastes

Chemical composition	Measurement unit	Apple paste (control)	Composition 1	Composition 2	Composition 3	
Dry matter	%	50.0±2.5	50.0±2.5	50.0±2.5	50.0±2.5	
Total sugar		11.2±0.6	11.85±0.6	11.64±0.6	11.53±0.6	
Pectins		3.58±0.2	6.11±0.3	5.93±0.3	5.71±0.3	
Ascorbic acid	mg per 100 g	23.05±1.1	61.35±2.9	59.05±2.8	58.27±2.8	
Carotene		–	1.78±0.01	1.75±0.01	1.82±0.01	
Anthocyanins		107±5.4	199±2.50	187±2.50	179±2.50	
Catechins		104±5.3	63±3.1	62.4±3.1	63.6±3.2	
Betanine		–	40±2.0	38.7±1.9	40.2±2.0	
Active acidity		pH	3.2±0.15	3.24±0.15	3.21±0.15	3.25±0.15

5. 2. Optimizing the amount of the fruit and vegetable paste introduced in the marshmallow mass

Well-known marshmallow manufacturing technology involves the preparation of raw materials, the preparation of agar-sugar syrup, mixing a marshmallow mass, molding with structure formation, drying, and sprinkling with powdered sugar.

By replacing in the marshmallow formulation of apple puree with the devised paste can control, predict the nutritional value to be received, the formed consistency, and reduce the drying time of the product due to the high content of DM in the paste. To determine the optimal amount of the devised blended paste (composition 1), prototypes were offered with 25 %, 50 %, 75 %, and 100 % replacement of apple puree; we determined their structural and mechanical indicators (Fig. 3). Marshmallow without additives was chosen as control.

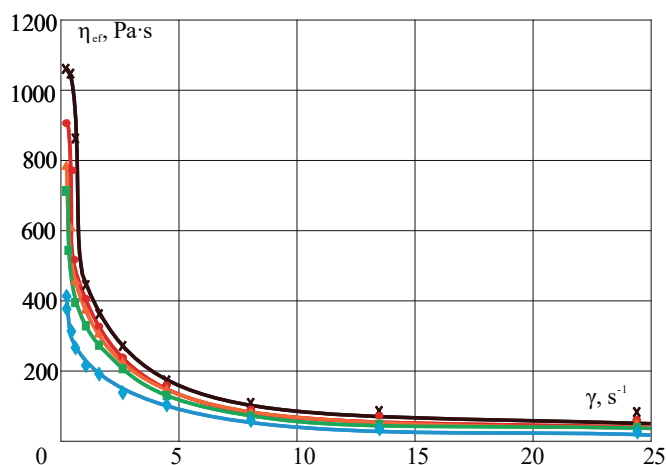


Fig. 3. Rheological curve of marshmallow masses, *t*=20 °C: ◆ – marshmallow additives; replacement of apple puree with a fruit and vegetable paste, %: ■ – 25; ▲ 50; ● – 75; × – 100

We have established dependences (Fig. 3) of the change in viscosity on shear rate at the percentage of

replacement of apple puree with the devised fruit and vegetable paste. Samples of marshmallow mass with the replacement of apple puree with the paste take the following values of dynamic viscosity  $\eta_{ef}$ , Pa·s, replacement: 25 % – 719; 50 % – 774; 75 % – 908; 100 % – 1,079; control – 408.

The color properties of marshmallow masses with the replacement of apple puree with the fruit and vegetable paste compared to control, marshmallow mass without additives, have been established (Table 4).

Table 4

Color characteristics of the examined marshmallow mass prototypes with full or partial (25; 50; 75 %) replacement of apple puree (*S*=0.05, *n*=5, *p*=0.95)

Marshmallow mass prototypes	Dominant wavelength	Brightness	Color purity	Visual assessment of sample color
	$\lambda_{nm}$	<i>T</i> , %	<i>P</i> , %	
control	515.4	42.6	25.3	white
25 %	542.4	49.6	32.3	white with a cream tint
50 %	576.1	54.4	45.1	light yellow-pink
75 %	596.7	62.3	68.3	bright pink
100 %	604.1	66.7	73.1	red

The wavelength of 515.4 nm with a color frequency of 25.3 %, which is characteristic of white color, is characteristic of control. For the 25 % replacement of apple puree, the purity of color is 32.3 %, and it corresponds to white-cream color with a wavelength of 542.4 nm. At the 50 % replacement of apple puree, the sample is characterized by light yellow-pink color with a dominant wavelength of 576.1 nm. For the sample with the 75 % replacement of apple puree, the wavelength is 596.7 nm, the brightness is 62.3 %, and it corresponds to a bright pink color. At the 100 % replacement of apple puree with the blended paste, red color is formed with a dominant wavelength of 604.1 nm; brightness, 66.7 %; and color purity, 73.1 %. The resulting color characteristics indicate a change in color scheme from a gently pink cream shade to rich red with an increase in the percentage of the fruit and vegetable paste (composition 1) in marshmallow masses samples. That makes it possible to evaluate and form the color of the marshmallow mass by changing the proportion of the application of the devised paste.

We determined a marshmallow sample with the optimal content of the fruit and vegetable paste by evaluating the organoleptic and physicochemical parameters (Table 5).

As a result of assessing the marshmallow mass with the replacement of apple puree with the devised fruit and vegetable paste, it was established that the content of the paste changes the organoleptic and quality properties of the marshmallow mass obtained. When replacing the puree with a blended paste with a volume of 25 % of the total mass, there is not a significant change, the marshmallow indicators are close to the control sample, which is characterized by white color with a creamy pink tint. Introducing 50 % or 75 % of the paste provides light

yellow-pink and bright pink coloration of prototypes. At 50 % of the content, there is a slight pleasant taste of the paste, and with 75 % of the content, the taste acquires a pronounced character. The prototype with a fruit and vegetable paste content of 100 % has a taste and smell that are not standard for the product, the color of the red hue, which, in general, has a negative impact on the appearance and structure of marshmallow.

100 % increases the nutritional value and strengthens the structure. Strengthening of the structure of marshmallow mass is confirmed by the indicators of dynamic viscosity when replacing apple puree in the following amount: 25 % – 719 Pa·s, 50 % – 774 Pa·s; 75 % – 908 Pa·s; and 100 % – 1079 Pa·s, respectively, compared to apple control paste – 408 Pa·s (Fig. 3).

Table 5

Evaluation of the organoleptic and physicochemical parameters of marshmallow

Indicator	Control	Replacing puree with paste, %			
		25 %	50 %	75 %	100 %
Taste and smell	Inherent in this product	Inherent in this product, the paste is not felt	Light smell and taste of paste	Pro-nounced smell and taste of paste	Excessive taste and pungent smell of paste
Color	white	white with a creamy tint of pink	light yellow-pink	bright pink	red
Consistency	The structure is soft, to be broken				
Structure	Inherent in this product, homogeneous, foamy, uniform				sticky
Surface	Inherent in this product, without coarse curing on the side faces and the release of syrup				
Mass fraction of dry matter, %	80.5	81.7	82.3	83.4	85.3
Mass fraction of reducing substances, %	7.5	8.0	8.3	8.6	8.8
Density, kg/m <sup>3</sup>	495.0	512.0	521.0	527.0	533.0
Total acidity, degree	6.8	7.2	7.6	8.0	9.0

The comparative evaluation of marshmallow samples revealed the optimal content of adding the devised blended paste, which is 75 % replacement of apple puree, yielding a bright pink color with a wavelength of 596.7 nm and a brightness of 62.3 % (Table 4). Adding such a percentage of paste to the marshmallow formulation makes it possible to increase the indicator of effective viscosity and structure formation compared to control and, at the same time, improve the quality indicators of the finished product (Table 5).

A significant body of research is aimed at improving the technology of confectionery products, including marshmallow, by introducing natural fillers into the formulation to ensure an increase in nutritional value and obtain original organoleptic properties [23]. However, the effectiveness of heat and mass exchange processing of blends and the impact of fillers on the properties of finished products have not been fully investigated, predetermining the feasibility of scientific, practical, and technological research in this area.

One of the disadvantages of research that does not give a complete idea of the results is the lack of qualitative parameters of the fruit and vegetable pastes made by the conventional technique of concentrating

**6. Discussion of results of marshmallow production with the introduction of a fruit and vegetable paste**

The maximum shear stress for puree from each component has been established: apple – 12 Pa, pumpkin – 42 Pa, beets – 57 Pa, cranberries – 76 Pa, and hawthorn – 450 Pa (Fig. 1). The blending of fruit and vegetable puree in accordance with the formulation composition (Table 1) was carried out, followed by low-temperature concentrating in a rotary evaporator at a temperature of 50...56 °C for 1...2 min to a DM content of 50 %. It is determined that the effective viscosity (Pa·s) of the pastes takes the maximum value at the time of application of shear force and, for the examined compositions: 1 – 394; 2 – 360; 3 – 312; and for the control sample – 156, respectively (Fig. 2). Comparing the samples of the compositions with control in terms of the structural and mechanical, organoleptic properties, chemical composition, and FPI, has demonstrated a significant advantage of composition 1 of the blended paste (Table 3). Its formulation content is characterized as follows: apple – 20 %; pumpkin – 20 %; beets – 15 %; cranberries – 30 %; hawthorn – 15 % (Table 1).

At the same time, replacing the content of apple puree in the formulation with the fruit and vegetable paste (composition 1, Table 1) within 25 %, 50 %, 75 %, and

in a vacuum evaporator in order to compare them with the devised low-temperature procedure.

A caveat of the study is the significant influence of each component of the blend with its original organoleptic and structural-mechanical properties, which complicates a qualitative approach to blending organic pastes. Non-compliance with the heat and mass exchange parameters of low-temperature concentrating and formulation ratios of components could lead to a change in the initial properties of pastes, which would make it difficult to predict the effect of the blend on the resulting products.

Further research will be aimed at the formation of generalized recommendations for the development of ways of blending plant raw materials in a composition with predictable structural and mechanical properties and FPI under low-temperature concentrating conditions. This would ensure high-quality production of pasty pastes that can be dried to the powdery fraction to expand the range of semi-finished products.

**7. Conclusions**

1. We have devised the formulation composition and the technique of low-temperature concentrating of fruit

and vegetable puree with a component content as follows: 20 % apple; 20 % pumpkin; 15 % beets; cranberries 15 %; hawthorn 15 %. Due to concentrating the puree in a rotary evaporator to the content of DM of 50 % at a temperature of 50...56 °C under vacuum, the processing time is 1...2 min, which is several times less compared to conventional single-case vacuum evaporators. To determine the impact of the contribution of each component, the structural and mechanical properties of the puree of each raw material and concentrated semi-finished products were established. The devised paste has an increased strength of the structure since the derived value of its dynamic viscosity is 394 Pa·s, which is 2.5 times more than the control sample. The devised blended fruit and vegetable paste has an increased FPI content and has good organoleptic parameters, unlike control (apple paste).

2. It was established that when adding to the formulation composition of marshmallow of the devised multi-component fruit and vegetable paste where 75 % of apple puree was replaced, the product acquires original quality properties. The value of dynamic viscosity ( $\eta_{ef}$ , Pa·s) of the marshmallow where 75 % of apple puree were replaced with the devised paste, compared to the control sample (marshmallow without additives), is from 408 to 908. The color of the marshmallow mass where 75 % of apple puree were replaced is bright pink with a wavelength of 596.7 nm and a brightness of 62.3 %. Our data indicate

an improvement in the quality indicators of marshmallow with the added fruit and vegetable semi-finished product, which is a positive phenomenon from a technological point of view. The findings could be implemented in the canning and confectionery industry and would ensure the expansion of the range of products with increased nutritional value.

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