UDC 664.858
DOI: 10.15587/1729-4061.2024.301651

IMPROVING THE PRODUCTION TECHNIQUE OF PAT BASED ON MULTICOMPONENT FRUIT AND BERRY PASTE

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The object of this study is the technology of making fruit pat based on apple, apricot, and rosehip paste.

To increase the organoleptic and physical-chemical quality indicators, the technology of functional fruit pat for functional purposes has been improved by using fruit and berry paste as a fruit base. Accordingly, a technique for the production of fruit and berry paste (apple 50 %, apricot 35 %, rosehip 15 %) was devised. The peculiarity of the technique is a short-term, 30–40 s, concentration at 52–54 °C in a rotary evaporator, which will positively contribute to the preservation of the functional ingredients of raw materials, unlike conventional batch vaporizers. The paste has an improved viscous structure and organoleptic properties compared to the control, which makes it possible to recommend it as a fruit base for pat.

The viscosity of the pat mass based on the paste at 50 °C is 225 Pa·s, which is 20 % higher than the control ("Fruit" pat), which will contribute to better structure formation. At the same time, the sample with the paste has better indicators of taste and smell, which can be characterized as natural and harmonious. The new pat has a natural orange saturated color and is characterized by a long-lasting consistency, and the content of functional ingredients significantly exceeds the control sample. The quantitative content of dietary fiber, vitamin A, C, β-carotene is important, according to which the devised pat based on the paste can be classified as a functional product. The new products are characterized by an organic composition of raw materials, do not contain artificial dyes and flavors, and the proposed technological solutions simplify the process of their production, which makes it possible to recommend the technology for implementation at craft enterprises

Keywords: fruit pat, fruit and berry raw materials, viscosity, functional ingredients, quality indicators

Received date 26.01.2024
Accepted date 04.04.2024
Published date 30.04.2024

How to Cite: *Zagorulko, A., Kasabova, K., Zahorulko, A., Shydakova-Kameniuka, O., Ponomarenko, N., Bereza, O., Gromov, A., Kholobtseva, I. (2024) Improving the production technique of pat based on multicomponent fruit and berry paste. Eastern-European Journal of Enterprise Technologies, 2 (11 (128)), 46–55. https://doi.org/10.15587/1729-4061.2024.301651*

1. Introduction

The demand for healthy food products is growing every year, among which confectionery products are a special group that is very popular. Sweets are characterized by unsurpassed taste qualities, attractive appearance, and also give the body a good mood and contribute to a surge of energy due to carbohydrates and extremely high energy value. Given the increasing popularity of a healthy lifestyle and, as a result, "healthy and natural food products", a number of doctors, dieticians, and nutritionists advise to pay attention to such products as marmalade, pastilles, and marshmallows. Usually, the term "healthy and natural food products" is perceived by consumers to mean products of organic origin that do not contain harmful additives [1].

These sweets are low in calories compared to baked goods, cakes, pastries, and cookies, and also have a number of beneficial properties. Therefore, it is a good alternative for those consumers who follow a healthy diet, as well as children and athletes. The main advantage of pastille-marmalade products among other sweets is the absence of fats in their composition. For their production, fruit purees, egg white, sugar, and natural thickeners (for example, pectin, agar-agar, or gelatin) are used, which determine the benefits of these products [2, 3]. For example, pectins bind and remove heavy metals, radionuclides, and pesticides from the body. They contribute to the reduction of cholesterol in the body and are used in diseases associated with metabolic disorders, diseases of the gastrointestinal tract, liver, and pancreas [4].

Along with this, marshmallows, marmalade, and pastilles, which are represented in trade networks and manufactured by large-scale enterprises, currently have an impoverished chemical composition, taste, and aroma due to the use of low-quality raw materials. This prompts manufacturers to use a number of artificial dyes and flavors in their products; as a result, such products could be harmful to the human body [5]. At the same time, products made by confectioners using manual labor gained popularity, which contributed to the growth of a number of craft enterprises. The sweets that are produced are positioned as natural, of organic origin, without the use of artificial dyes and flavors, with functional properties.

The production of such healthy sweets is based on the use of fruits, berries, vegetables, which are promising food ingredients for the development of functional food products with high organoleptic indicators of quality and health benefits [5]. However, these raw materials have a short shelf life, and there is an urgent question of processing them into a product for long-term preservation [6]. The purpose of processing plant raw materials is to avoid spoilage of food products during storage, which is caused by the development of bacteria, yeasts, and fungi, which would make seasonal products available for a long time. As well as preserve the organoleptic and nutritional properties of food products, which is also beneficial for human health. Therefore, gentle processing of vegetable raw materials into paste is considered a promising technological food product and raw material for confectionery products.

At the same time, one of the important aspects of launching and maintaining craft enterprises is the improvement and use of compact resource-saving equipment, which will contribute to the production of pastille and marmalade products with a functional purpose and high quality. Therefore, studies aimed at the improvement of the technology of pastille and marmalade products based on fruit and berry paste are relevant.

2. Literature review and problem statement

It is known that locally grown fruit and berry raw materials are an excellent source of biologically active compounds with beneficial properties. Thus, it has numerous health benefits and can be used to prepare functional products [7]. In addition, various components of fruit and berry raw materials can be widely implemented in the food industry as additives in the preparation of, for example, candied fruit for the confectionery industry or as a source of pectin, dye, or flavoring [8].

Thus, modern production cannot be imagined without the use of food additives, that is, substances that give food products aroma, color, taste, and nutritional properties. Along with this, more and more attention is paid to the inclusion of natural supplements obtained from plant raw materials containing bioactive components, which can be a natural substitute for synthetic food additives. Another of their functions is the use of pectin substances as a thickener, stabilizer, emulsifier, gelling agent in the preparation of confectionery products [9].

Therefore, since fruits and vegetables are an important part of a healthy diet, the question arises of their high-quality processing into various food products, such as purees, pastes, jams, jellies, candies, concentrates, etc. [10]. Namely, a technique that would enable preservation of high sensory properties of the raw materials and the content of functional ingredients. Thus, resource-efficient equipment for gentle preliminary heat treatment of plant raw materials before concentration has been proposed [11]. Namely, heating in a tempering device to 50 °C to reduce the dynamic viscosity of raw materials before concentration. Its main disadvantage is the lack of multifunctionality, namely the combination of blending, concentration, and pasteurization operations, which is especially relevant under the conditions of craft enterprises.

The search for new technologies to increase the sustainable production of confectionery products with claims of usefulness, functionality, enriched formulation, and sustainability is desirable. So, jelly candies and marmalades with fruit ingredients, which are positioned as healthy and natural, received a new powerful push. Marmalade candies stand out for their sensory quality, a change in composition with a lower sugar content and without the addition of synthetic dyes and flavors [12]. Thus, the use of the cold gelation technique using alginate and pectin mixtures for the production of jelly candies has been proposed due to lower energy consumption and CO_2 emissions. The authors proved that the content of biologically active substances (ascorbic acid and total phenol content) in the strawberry juice concentrate, which was used as raw material, was better preserved in cold jelly than in pectin jelly. However, the application of this technology requires significant re-equipment of production facilities, and difficulties in the equipment for craft enterprises.

Local raw materials, which contain a number of functional ingredients, became widespread during the creation of functional marmalade all over the world. Thus, the use of jusara and passion fruit pulp in jelly confectionery products as a substitute for artificial dyes and sources of bioactive compounds has been suggested [13]. It is known about the use of plum (prune) in marmalade technology, which showed an improvement in color, consistency, taste, and strength, chemical composition, which received recognition among consumers [14, 15]. Tamarillo is another local raw material that has been used in pectin-based marmalade technology [16]. However, these advancements have significant limitations, which are associated with the cultivation of local raw materials in small volumes. This does not make it possible to globally solve the issue of enrichment of confectionery products due to the use of functional ingredients of plant raw materials without the use of artificial dyes and flavors.

Work [17] suggested the inclusion of persimmons in the recipe of functional marmalade. This makes it possible to reduce sugar content and increase the biological value of finished products. Persimmon puree forms an orange color in marmalade due to the presence of a large amount of beta-carotene in it, which prevents premature aging and also improves eyesight. Paper [18] provides the production technology and recipe of marmalade using processed products of melon crops, in particular watermelon and cantaloupe, on various gelling agents, such as agar-agar, pectin, and gelatin. The possibility of using all gelling agents was determined on the basis of physical-chemical, organoleptic indicators of finished products, but the most appropriate is the use of gelatin, due to its good properties and low cost. Worth noting is the use of a number of polysaccharides of microbial origin in the technology of marmalade products as jelly-forming raw materials [19]. However, it is possible to consider the one-component composition of the purees used as a disadvantage, which does not make it possible to ensure the optimal content of a number of functional ingredients and sensory properties.

In this regard, it is possible to consider multi-component fruit and berry and fruit-vegetable pastes, which are obtained through the use of gentle regimes, as a promising raw material for a number of confectionery products, which allows preserving the full potential of the raw material [20]. Thus, it is proposed to use a multi-component fruit and vegetable paste made of apples, quince, and pumpkin in Turkish delight technology. Its use makes it possible to provide products with good organoleptic indicators, reduce the amount of starch in the recipe by 20 %, and expand the range of "healthy and natural products" with increased nutritional value [21]. The need to optimize the nutritional value of marmalade by using a multi-component fruit and berry paste from apples, quince, and black currant in its composition was substantiated. A rational amount of adding fruit and berry paste has been established – 30 % with a reduction of agar by 30 %, which allows for high quality indicators of products and enriches them with a number of functional ingredients [3]. The use of the same paste in the technology of whipped candies is proposed, which solves the problem of improving structural characteristics and physiological value (enrichment with dietary fibers, vitamin C, polyphenols, organic acids). It is recommended to add paste in the amount of 15 % of the total amount of recipe raw materials and reduce the dosage of agar by 40 % for its introduction [22]. The disadvantage of the cited research is the use of pastes in a small amount from the total content of raw materials, which cannot provide significant enrichment of products with functional ingredients. The development of confectionery technologies based on fruit and berry raw materials is promising.

Along with the use of vegetable purees and pastes, the use of juice concentrates in marmalade technology is proposed. Namely, pectin-based cranberry juice concentrate in jelly marmalade in the amount of 6...15 % to the mass of white sugar. This makes it possible to obtain a product with high organoleptic indicators, to improve the structural and mechanical properties of marmalade products based on pectin, to enrich with biologically active substances and minor cranberry components [23]. It is known about the use of purple grape, watermelon, and beet juice, which allows one to enrich the marmalade with natural substances, in particular a number of micro- and macronutrients, which the authors proposed as a convenient food for athletes before a performance on the go [24]. Pomegranate juice has found its application in the production technology of marmalade (jam) to increase the content of anthocyanins [25]. On the one hand, the use of concentrates has certain advantages in use, however, worth noting are the objective difficulties that arise during the implementation of the technology. Namely, the increase in the duration of boiling the marmalade mass, as a result, significant losses of vitamins.

Together with the creation of products with a functional purpose, it is impossible to bypass such a direction of technology improvement as reducing the sugar content by using sugar substitutes. Thus, changes in the quality of jelly-fruit marmalade with the content of erythritol and xylitol sweeteners with 50 % replacement of white sugar have been established. It was found that the samples have high organoleptic and physicochemical quality indicators [26]. The use of stevia sweetener during the production of chokeberry marmalade is known. The authors established a high content of polyphenols and proved antioxidant activity [27]. They considered the problem of ensuring a long shelf life of jelly marmalade without changing the taste by increasing the mass fraction of glucose syrup from 5 % to 25 %. This leads to an increase in the elastic and plastic properties of jelly marmalade. Adjusting the recipe and reducing the moisture content of the marmalade significantly reduce the risk of undesirable sensory changes on the surface of the marmalade during its storage [28].

In work [29] it is proposed to obtain jelly marmalade using natural buckwheat honey. The authors replaced white sugar and molasses with honey with a conversion to dry matter. It was established that marmalade with Greek honey exceeds the control sample in terms of potassium content by 14 times, calcium by 10, iron by 22, and is rich in vitamins B_1, B_2, C. Marmalade can be classified as a functional product. Along with this, worth noting is the possibility of allergic reactions, which limits the use of the developed products [29].

As an alternative to artificial dyes in marmalade technology, the use of black carrots is proposed, which is a source of anthocyanins, which can also serve as new sources of functional food products [30]. However, the problem of forming the taste of products remains unsolved, which contributes to the need to expand the assortment of raw materials due to the use of fruit.

In conclusion, it should be noted that despite the wide range of proposed solutions, the problem of obtaining healthy and natural confectionery products based on fruit and berry raw materials remains unsolved. The use of fruit and berry raw materials and products of their processing in the production technologies of marmalade products is a promising direction for the correction of nutritional value and consumer properties. Therefore, local raw materials in the form of a multicomponent mixture, which is a source of useful, biologically active food components, as well as a natural dye and flavoring, are of particular interest.

3. The aim and objectives of the study

The aim of our study is to improve the technique to produce fruit pat by introducing the developed fruit and berry paste into its recipe. The use of the new paste will expand the current assortment of herbal supplements with increased content of nutrients and pat with its use.

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

– to establish the functional and technological indicators of the developed apple, apricot, and rosehip paste obtained by short-term concentration at gentle temperatures for its further introduction into pat technology;

– to determine the structural-mechanical, physical-chemical, and organoleptic indicators of "healthy and natural" pat on the basis of apple, apricot, and rosehip paste made by the developed production technique.

4. The study materials and methods

The object of our study is the technique of making fruit pat based on apple, apricot, and rosehip paste.

The hypothesis of the study assumes the possibility of obtaining functional fruit pat with high organoleptic and physicochemical quality indicators. The use of the developed fruit and berry paste will enable formation of high sensory characteristics of the products, which will allow the dye and essence to be excluded from the recipe. The use of multicomponent fruit and berry paste will simplify the technological process under the conditions of craft enterprises.

Pat "Fruit" [31] was chosen as the control sample. This is a special type of marmalade, which is made using apricot puree by molding the marmalade mass into half-sphere molds, the surface of which is decorated with white sugar. The following recipe composition was used to make the pat, g: white sugar for sprinkling 173; gelatinized white sugar 689.7; applesauce 343.7; apricot puree 171.8; citric acid 2; essence 0.9; dye 0.2. Output 1000 g.

The process of making pat consists of preparing the recipe mixture, boiling the marmalade mass in open cooking cauldrons at a temperature of 110...115 °C (dry substances 85±2 %, reducing substances 18±1 %), casting the pat into molds made of granulated sugar, forming the structure of the pat (temperature 10±2 %, 30...40 min.), and packaging.

The quality indicators of the developed pas were evaluated according to DSTU 4333:2018 Marmalade general specifications.

During the creation of the paste, carefully selected raw materials were chosen: apple (Antonivka variety), apricot (Chervonoschoky variety), rosehip (Jubilee variety).

The structural and mechanical indicators of puree, paste, and marmalade mass samples were determined on a rotary viscometer "Reotest-2" (Germany).

The mass fraction of dry substances in the pastes was determined by the refractometric method, and the active acidity was determined by the electrometric method.

Determination of organoleptic parameters of experimental samples of pat was carried out using a point scale.

The mass fraction of pat moisture was determined with the help of a refractometer, acidity – with the titrimetric method, the content of reducing substances – with the ferricyanide method, the ultimate shear stress – with the help of the "Labor" penetrometer.

The margin of error in our studies was σ=3...5 %, the number of repeated experiments was n=5, the probability was $p \geq 0.95$.

5. Results of determining the parameters of the developed fruit and berry paste and pat on its basis

5. 1. Studying the quality indicators of the developed multicomponent paste

The technique for producing blended paste from selected raw materials involved the use of different percentages of apples, apricots, and rose hips. The choice of raw materials for creating a paste-like semi-finished product is due to the high content of pectin substances, which are good structure formers. It is the presence of a large volume of pectin that warrants the further use of the created paste for its use as a component of many confectionery products of increased nutritional value. It is also possible to obtain the color of the future paste and the corresponding food product based on it by selecting plant raw materials.

During the experimental studies, the following pre-grounded recipe mixtures of experimental samples of blended purees were used (Table 1).

Table 1

Variants of prototype samples of puree

Raw material	Variant		
	1	2	3
Apple, %	70	60	50
Apricot, %	25	30	35
Rosehip, %	5	10	15

For the production of puree from apples, apricots, and rose hips, the raw materials were subjected to primary mechanical processing. Rosehip fruits are pre-cured in an 8...10 % NaCl solution with the addition of 1.0 % citric acid at a temperature of 22...24 °C for 32...35 minutes, which helps separate mechanical impurities; stabilization of polyphenols and inactivation of enzymes. The apple passed through the crusher is blanched for 3–4 minutes with steam at a temperature of 100...105 °C. Rose hips and apricots are also subjected to steam blanching for 5 minutes and 3 minutes, respectively. After blanching, step-by-step grinding of raw materials was carried out with a diameter of grinding sieves of 0.3...0.5 mm. After grinding, the pomace was sent for drying. Mashed raw materials were combined in the recipe ratio (Table 1). A mixture of apple, apricot, and rosehip puree was concerted to a paste-like state (30 % dry matter) in a special rotor-type device at a gentle temperature of 52...54 °C. Paste made by this production technique is distinguished by the preservation of the original properties of the raw material.

For quality control of the creation of fruit and berry paste, its structural and mechanical characteristics were determined, which are also an important indicator when creating various confectionery products based on the paste. The dependence of effective viscosity on the change in the applied shear rate at a temperature of 20 °C was established. To compare the rheological parameters of the experimental samples, a control sample of apple puree was chosen. The resulting dependence is shown in Fig. 1.

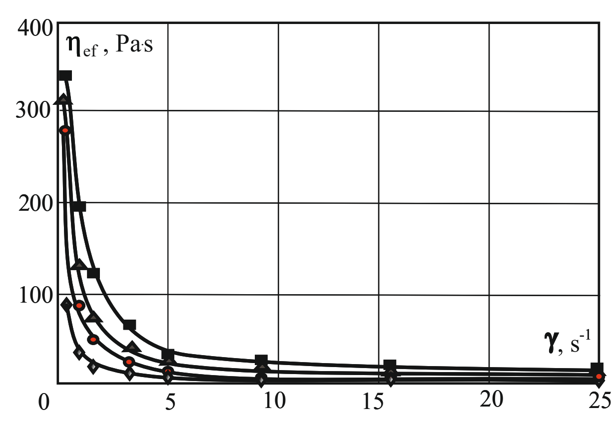

Fig. 1. Structural-mechanical characteristics of puree from experimental samples at a temperature of 20 °C: ◊ – control (apple puree); ● – sample 1; ▲ – sample 2; ■ – sample 3

Data in Fig. 1 indicate a significant increase in the viscous structure of all test samples. The viscosity at the beginning of the displacement of the experimental samples has 3.0...3.2 times higher indicators than the control sample of 92 Pa·s. After applying the shear force, the viscosity gradually decreases, which is explained by the destruction of the puree structure. At the value of the shear rate at the level of 10...15 s^{-1}, the samples begin to behave like the structure of a Newtonian fluid. The viscosity of the samples at the beginning of the shift has the following values: 1 – 278; 2 – 310; 3 – 347 Pa·s, respectively. That is, all test samples have increased rheological indicators, therefore, in order to establish the optimal option, we shall evaluate their organoleptic indicators (Table 2).

Table 2

Organoleptic evaluation of paste samples

Indicator	Characteristics		
	Variant 1	Variant 2	Variant 3
Appearance	Homogenous, uniformly rubbed mass		
Taste and smell	The smell and taste of apricot and rosehip are barely perceptible, the apple is almost not felt	A pleasant harmonious taste of apricot and rosehip, the apple is almost not felt	Expressed smell and taste of apricot, pleasant rose hip, apple almost not felt
Color	Light Orange	Orange	Orange
Consistency	Puree-like, easy to spread and shape		

The resulting organoleptic indicators indicate that variant 1 has a faint smell and taste of apricot, barely felt rose hips, variant 3 of the experimental sample has a more pronounced, and 2 – a harmonious pleasant taste. The color of the first version of the sample is not so bright, unlike the second and third. The introduction of a larger amount of apricot gives a specific pleasant sweet taste, and on the contrary leads to a deterioration of the color range of puree. Our evaluation shows that the best indicators are inherent in the version of sample 3 with the percentage of raw materials: apple – 50 %; apricot – 40 %; rose hip – 10 % compared to the 1st and 2nd option. Taking into account the higher viscosity of this sample, we choose it for further research and recommendations for inclusion in the fruit pat recipe.

An important stage in the production of blended puree of fruit and berry paste based on the developed recipe is its concentration under gentle conditions. To this end, it is recommended to use a rotary evaporator, which is characterized by minimizing the thermal effect on the raw materials. During concentration, the product is processed in 30...40 seconds under the forced influence of the working bodies of the apparatus in a thin layer. Under such conditions, it is necessary to determine the viscosity of the product at temperatures and shear rates close to the real process. Taking into account the actual state of the boiling process, we determine the structural and mechanical parameters of the product when the temperature changes from 20 to 70 °C and the rate of shear deformation at the level of 3 s^1 (Fig. 2).

The viscosity of all test samples of puree and paste decreases at elevated temperature. At a temperature of 20 °C, a paste cooked to a DM content of 30 % has a viscosity of 178 Pa·s, which is 3.2 times more than that of puree with a DM of 17 % (56 Pa·s). For temperature measurement limits of 20...70 °C, the viscosity of the paste decreases by almost 15 times. That is, a change in temperature significantly changes the structural and mechanical parameters of the test samples. The dependences in Fig. 2 demonstrate that under the mode parameters of puree cooking from 17 % DM to 30 % at a temperature of 58...63 °C, the effective viscosity varies within 8...25 Pa·s (shear force 3 s^1).

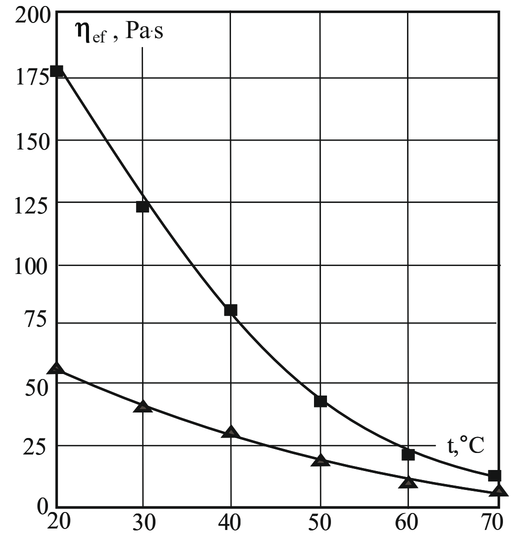

Fig. 2. Dependences of the viscosity of puree and paste on temperature at a rate of shear deformation of 3 s^1: ■ – 17 % dry matter; ▲ – 30 % dry matter

We studied the content of functional ingredients in the developed paste in accordance with the control in Table 3.

Table 3

Chemical composition and quality indicators of pastes (per 100 g of product) σ=3 %, *n*=5

Indicator	Unit of measure	Daily need	Control apple paste	Experimental sample of apple, apricot, rosehip paste
Dry matter	%	–	30.00	30.00
Food fibers	g	20	1.10	6.51
Vitamin A, PE	µg	900	0.00	253.68
β-carotene	mg	5	0.00	1.52
Vitamin B5	mg	5	0.00	0.44
Vitamin C	mg	90	1.60	172.8
Vitamin E	mg	15	0.20	1.77
Vitamin K	µg	120	0.00	8.06
Potassium	mg	2500	124.00	306.40
Calcium	mg	1000	0.00	44.00
Iron	mg	18	1.30	0.72
Manganese	mg	2	0.00	0.46
Copper	mg	1000	0.00	131.92
Active pH acidity	Units of measurement	0.00	3.15	3.20

The resulting data in Table 3 demonstrate that the developed apple, apricot, and rosehip paste has a significantly higher dietary fiber content by 6 times compared to the control. Based on the content of vitamin C, the developed paste makes it possible to fully satisfy the daily need for this substance. In addition, it is characterized by the presence of a significant amount of vitamin A, carotene, and vitamin E. Mineral substances of the developed paste are represented by potassium, calcium, iron, copper, and manganese. The given chemical composition allows us to state that the developed fruit and berry paste made of apples, apricots, and rose hips contains a significant amount of functional ingredients, which allows us to recommend it as a raw material in the technology of "healthy and natural" pat.

5. 2. Establishing the quality indicators of the improved technology of fruit pat based on the developed fruit and berry paste

The process of making pat according to the improved technique consists of preparing the recipe mixture and concentrating it in a vacuum-evaporating apparatus at a temperature of 65...70 °C (dry substances 85±2 %, reducing substances 18±1 %), casting the pat into molds made of granulated sugar, structure formation of the pat (temperature 10±2 %, 30...40 min.), and packing. In the experimental sample, we replace the puree content with the developed paste, which will reduce heat consumption for cooking the pat and simplify technological operations during storage and preparation of raw materials for production. Also, the use of dye and essence is excluded from the recipe. The use of a gentle mode of boiling the pat in a vacuum-evaporating apparatus of an improved design [32] (65...70 °C) allows obtaining a product of increased quality.

The structural and mechanical parameters of the proposed experimental sample were determined in comparison with the control of the "Fruit" pat (Fig. 3). Taking into account the fact that temperature significantly affects the fluidity of thermolabile jelly masses, for the study of viscous properties, temperature regimes in relation to the technological parameters of pat above its gelation at the level of 50...52 °C were chosen. The intact structure of the test sample has a viscosity value of 225 Pa·s, which is 20 % higher compared to the control of 189 Pa·s. This is explained by the higher content of pectin substances in the experimental sample of the pat due to the use of the developed apple, apricot, and rosehip paste. The nature of the obtained flow curves indicates the pseudo-plasticity of the studied samples, their effective viscosity is a property of the equilibrium state between the process of destruction and recovery. Viscosity indicators of both samples have a high level of structuring within low shear stresses of 0.3...5 s^{-1}. When the shear rate increases, the structure of the samples is destroyed, their particles begin to orient in the direction of the applied shear rate, and a transition from the flow stage to destruction is observed at 5...27 s^{-1}. Subsequently, increasing the shear rate does not significantly change the minimum value of viscosity, which is characteristic of the destroyed structure.

Taking into account the original taste and color characteristics of the fruit and berry paste and considering trial laboratory preparations of the pat, it is proposed to exclude the dye and essence from the recipe under the conditions of the introduction of new raw materials.

The organoleptic and physical-chemical parameters of the pat based on the paste and the control sample were determined (Table 4).

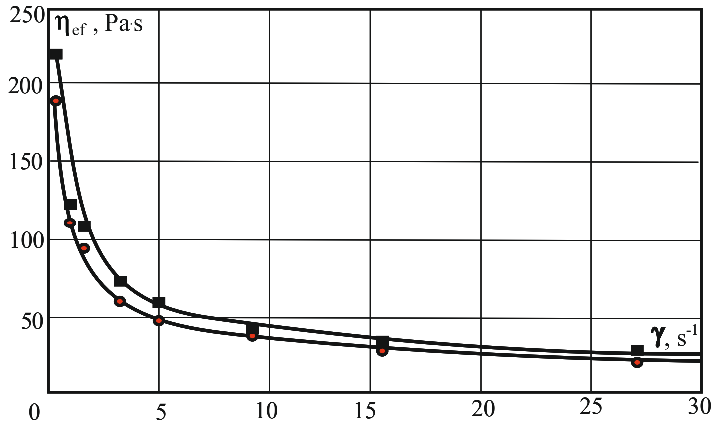

Fig. 3. Structural-mechanical characteristics of fruit pat at a temperature of 50 °C: ● —"Fruit" pat; ■ — experimental pat

Table 4

Organoleptic, physicochemical indicators of the quality of fruit pat and based on fruit and berry paste σ=3 %, *n*=5

Indicator	Characteristics of indicators	
	Pat "Fruit" (control sample)	Pat based on fruit and berry paste
Taste and smell	This product is characterized by a lemon-scented essence	Pleasant harmonious taste and smell of apricot and rosehip
Color	Yellow	Orange
Consistency	Dense, not lingering	Dense, lingering
Form	Proper, hemispherical, without deformation	
Surface	Clear, sprinkled with white sugar	
Mass fraction of moisture, %	13.0	13.0
Titrated acidity, degrees	10.5	10.8
Mass fraction of reducing substances, %	18.0	18.5
Strength at ultimate shear stress, kPa	21.0	26.1

The control sample of "Fruit" pat, as well as the one obtained by improved technology, meets the requirements of the regulatory document in terms of organoleptic quality indicators. At the same time, it is worth noting that the experimental sample with paste has better indicators of taste and smell, which can be characterized as natural and harmonious. The new pat has a natural orange saturated color and is characterized by a long consistency due to an increase in the content of pectin substances in the fruit and berry paste, which will contribute to a better structure of the products.

This was confirmed by the obtained results regarding the determination of the strength index, which is 24.2 % greater than that of the control sample of pat. Physical-chemical indicators of the quality of pat based on fruit and berry paste do not significantly differ from the control sample and meet all the requirements of the DSTU for this product.

An important indicator of the quality of the developed pat is the characteristic of its chemical composition. Therefore, we calculated the content of the main functional ingredients in the fruit pat and based on the fruit and berry paste. The results are given in Table 5.

Table 5

The content of functional ingredients in test samples of pat (per 100 g of product) σ=3 %, *n*=5

Indicator	Unit of measurement	"Fruit" pat (control sample)	Pat based on the fruit and berry paste
Food fibers	g	0.48	3.39
Vitamin A, PE	μg	85.90	131.92
β-carotene	mg	0.52	0.79
Vitamin B5	mg	–	0.23
Vitamin C	mg	1.41	155.52
Vitamin E	mg	0.07	0.92
Potassium	mg	91.24	159.33
Iron	mg	0.69	0.38
Copper	mg	22.33	68.60

As can be seen from Table 5, fruit and berry paste-based pat significantly exceeds the control sample in terms of the content of functional ingredients. Namely, by the content of dietary fibers, vitamins A, B5, C, E, and β-carotene, as well as minerals. It is known that in order for the product to have the status of functional, its content in the product should be from 10 to 50 % of the daily need for the corresponding substance. Therefore, we calculated the provision of the daily need for functional ingredients under the conditions of consumption of 100 g of pat based on paste (Table 6).

Table 6

Provision of the daily need for functional ingredients under the condition of consumption of 100 g of pat based on fruit and berry paste σ=3 %, *n*=5

Indicator	Unit of measurement	Daily need	Provision of the daily need, %
Food fibers	g	20	16.95
Vitamin A, RE	μg	900	14.66
β-carotene	mg	5	15.80
Vitamin B5	mg	5	4.50
Vitamin C	mg	90	172.80
Vitamin E	mg	15	6.13
Potassium	mg	2500	6.37
Iron	mg	18	2.11
Copper	mg	1000	6.86

Therefore, according to the content of dietary fibers, vitamins A, C, β-carotene, the developed pat based on the paste can be classified as a functional product. At the same time, worth emphasizing is the number of useful substances (mineral, phenolic), the absence of artificial additives, original sensory properties and high quality indicators. All of the above testifies to the competitiveness of these healthy sweets, as well as the prospect of their introduction at craft enterprises due to the simplification of their production technologies.

6. Discussion of results of the development of multicomponent fruit and berry paste, its quality indicators and marmalade using it

It is known that the production of healthy sweets is based on the use of fruits, berries, vegetables, which are promising food ingredients for the development of functional food products [5, 12]. This is confirmed by the literature [13–15, 17, 18]. In contrast to the proposed solutions, a production technique of fruit and berry paste has been developed, which makes it possible to comprehensively solve the problem of creating useful sweets with a high content of physiologically functional ingredients due to the use of a multi-component composition of the paste. The effectiveness of using pastes during the development of functional confectionery products has been confirmed by a number of studies [2, 3, 21].

Thus, a production technique of fruit and berry paste based on apples, apricot, and rose hips has been developed. This formulation is due to the presence of a significant number of vitamins, minerals, and dietary fibers. The presence of dietary fibers contributes to a better structuring of the marmalade mass. This is confirmed by study [4].

The proposed technique of paste production is characterized by a short duration (30...40 s) of a gentle concentration regime of 52...54 °C in rotary evaporators, which will contribute to the preservation of functionally physiological ingredients, unlike conventional cooking methods. In contrast to [20], in which the temperature regimes are higher and amount to 60...65 °C. This result contributes to greater preservation of the useful substances of the raw materials during the preparation of the paste.

In order to substantiate the optimal percentage ratio of raw materials in the recipe of the paste, the structural and mechanical indicators of various mixes of puree after their mixing were determined. The viscosity at the beginning of the shift of the experimental samples has 3.0...3.2 times higher indicators than the control sample (apple puree) 92 Pa·s (Fig. 1). The sample (apple – 50 %; apricot – 35 %; rosehip – 15 %) with a better structure has a viscosity at the beginning of the application of shear force – 347 Pa·s, and also has more pleasant organoleptic indicators (Table 2).

We investigated rheological behavior of the test sample of puree (DM 17 %) and the manufactured paste (DM 30 %) under regime parameters characteristic of the process of concentration of puree in a rotary evaporator, which is characterized by the minimization of the thermal effect on the raw material. During concentration, the product is processed in 30...40 seconds under the forced influence of the working bodies of the apparatus in a thin layer. Taking into account the actual state of the boiling process, we determine the structural and mechanical parameters of the product when the temperature changes from 20 to 70 °C and the rate of shear deformation at the level of 3 s^1 (Fig. 2). In this way, it was established that under the mode parameters of puree cooking from 17 % DM to 30 % at a temperature of 58...63 °C, the effective viscosity varies within 8...25 Pa·s (shear force 3 s^1). The given chemical composition (Table 3) allows us to state that the developed fruit and berry paste made of apples, apricots, and rose hips contains a significant amount of functional ingredients, which allows us to recommend it as a raw material in the technology of "healthy and natural" pat.

The structural-mechanical, physical-chemical, and organoleptic indicators of the developed pat on the basis of apple, apricot, and rosehip paste compared to the "Fruit" pat (control sample) were determined. As a result, the assumption regarding the expediency of excluding the dye and essence from the recipe of pat at the expense of fruit and berry paste was confirmed. The substances included in its composition make it possible to create an original taste, smell, and color in products. This is a significant advantage because, on the one hand, it makes it possible to reduce the recipe composition, which is especially relevant within the scope of the work of craft enterprises. On the other hand, it makes it possible to get completely natural sweets without the use of artificial additives. In terms of viscosity, the sample of marmalade mass based on apple, apricot, and rosehip paste has an index of 225 Pa·s, which is 20 % more than in the control sample (Fig. 3).

At the same time, the developed pat has better indicators of taste and smell, which can be characterized as natural and harmonious. It has a natural rich orange color and is characterized by a lingering consistency, and the content of functional ingredients significantly exceeds the control sample. Namely, by the content of dietary fibers, vitamins A, B5, C, E, and β-carotene, as well as minerals. Based on the content of dietary fibers, vitamins A, C, β-carotene, the developed pat based on the paste can be classified as a functional product.

Thus, there are reasons to believe that the introduction of improved pat technology based on apple, apricot, and rosehip paste makes it possible to expand the range of "healthy and natural" products and increase competitiveness due to higher quality and nutritional value indicators.

The proposed technological solutions can be implemented taking into account the rational modes of raw material processing substantiated in our work and observing the recipe ratios. In addition, it is important to use modern resource-saving equipment.

The limitations of the current research are the use of plant raw materials of the specified varieties while the use of others requires additional processing. As shortcomings, it is possible to single out non-compliance with the conditions of storage and transportation of raw materials and manufactured pat, the use of low-quality raw materials and semi-finished products.

Further research will be aimed at improving resource-saving equipment for the production of marmalade products at craft enterprises.

7. Conclusions

1. A production technique of fruit and berry paste based on apple –50 %; apricot – 35 %; rose hip – 15 % has been developed. The peculiarity of the method is the use of a short-term 30–40 s gentle concentration mode of 52–54 °C in rotary evaporators, which will positively contribute to the preservation of functionally physiological ingredients, unlike conventional batch evaporators. In the developed paste, a 6-fold increase in dietary fiber was established compared to the control. In terms of the content of vitamin C, the developed paste makes it possible to fully satisfy the daily need for this substance, there is a significant amount of vitamin A, carotene, and vitamin E. It was established that under the regime parameters of puree concentration from 17 % DM to 30 % at a temperature of 58...63 °C, its effective viscosity varies within 8...25 Pa·s (shear force 3 s^1). The proposed paste sample has an improved viscous structure compared to apple paste, which makes it possible to recommend it for use in fruit pat technology.

2. The production technique of pat according to the improved technology is characterized by increased quality indicators due to the use of gentle concentration modes in the vacuum evaporation apparatus and the use of the developed paste. The viscosity of the pat based on apple, apricot, and rosehip paste at a temperature of 50 °C is 225 Pa·s, which is 20 % higher than the fruit pat (control sample), which contributes to better structure formation. At the same time, the sample with the paste has better indicators of taste and smell, which can be characterized as natural and harmonious. The new pat has a natural orange saturated color and is characterized by a long-lasting consistency, and the content of functional ingredients significantly exceeds the control sample. These substances are represented in the pat on the basis of fruit and berry paste by dietary fibers, vitamins A, B5, C, E, and β-carotene, as well as minerals. The quantitative content of dietary fiber, vitamin A, C, β-carotene is important, according to which the developed pat based on the paste can be classified as a functional product. The new products are characterized by an organic composition of raw materials, do not contain artificial dyes and flavors, and the proposed technological solutions simplify the process of their production, which makes it possible to recommend the technology for implementation at craft enterprises.

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 and the results reported in this paper.

Funding

The work was carried out under state budget topic No. 3-24-25 BO "Development of hardware and technological solutions for the production of multipurpose functional food products for people under extreme conditions."

Data availability

All data are available 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.

References

1. Gunes, R., Palabiyik, I., Konar, N., Said Toker, O. (2022). Soft confectionery products: Quality parameters, interactions with processing and ingredients. Food Chemistry, 385, 132735. https://doi.org/10.1016/j.foodchem.2022.132735
2. Kasabova, K., Zagorulko, A., Zahorulko, A., Shmatchenko, N., Simakova, O., Goriainova, I. et al. (2021). Improving pastille manufacturing technology using the developed multicomponent fruit and berry paste. Eastern-European Journal of Enterprise Technologies, 3 (11 (111)), 49–56. https://doi.org/10.15587/1729-4061.2021.231730

3. Samokhvalova, O., Kasabova, K., Shmatchenko, N., Zagorulko, A., Zahorulko, A. (2021). Improving the marmalade technology by adding a multicomponent fruit-and-berry paste. Eastern-European Journal of Enterprise Technologies, 6 (11 (114)), 6–14. https://doi.org/10.15587/1729-4061.2021.245986
4. Pathania, S., Kaur, N. (2022). Utilization of fruits and vegetable by-products for isolation of dietary fibres and its potential application as functional ingredients. Bioactive Carbohydrates and Dietary Fibre, 27, 100295. https://doi.org/10.1016/j.bcdf.2021.100295
5. Richmond, R., Bowyer, M., Vuong, Q. (2019). Australian native fruits: Potential uses as functional food ingredients. Journal of Functional Foods, 62, 103547. https://doi.org/10.1016/j.jff.2019.103547
6. Rashwan, A. K., Karim, N., Shishir, M. R. I., Bao, T., Lu, Y., Chen, W. (2020). Jujube fruit: A potential nutritious fruit for the development of functional food products. Journal of Functional Foods, 75, 104205. https://doi.org/10.1016/j.jff.2020.104205
7. Lim, S. J., Chang, L. S., Fazry, S., Wan Mustapha, W. A., Babji, A. S. (2021). Functional food & ingredients from seaweed, edible bird's nest and tropical fruits: A translational research. LWT, 151, 112164. https://doi.org/10.1016/j.lwt.2021.112164
8. Suri, S., Singh, A., Nema, P. K. (2022). Current applications of citrus fruit processing waste: A scientific outlook. Applied Food Research, 2 (1), 100050. https://doi.org/10.1016/j.afres.2022.100050
9. Samokhvalova, O., Kasabova, K., Oliinyk, S. (2014). The influence of the enriching additives on the dough structure formation and baked muffins. Eastern-European Journal of Enterprise Technologies, 1 (10 (67)), 32–36. https://doi.org/10.15587/1729-4061.2014.20024
10. Sharma, A., Bachheti, A., Sharma, P., Bachheti, R. K., Husen, A. (2020). Phytochemistry, pharmacological activities, nanoparticle fabrication, commercial products and waste utilization of Carica papaya L.: A comprehensive review. Current Research in Biotechnology, 2, 145–160. https://doi.org/10.1016/j.crbiot.2020.11.001
11. Zahorulko, A., Zagorulko, A., Kasabova, K., Liashenko, B., Postadzhiev, A., Sashnova, M. (2022). Improving a tempering machine for confectionery masses. Eastern-European Journal of Enterprise Technologies, 2 (11 (116)), 6–11. https://doi.org/10.15587/1729-4061.2022.254873
12. Mariz de Avelar, M. H., de Castilho Queiroz, G., Efraim, P. (2020). Sustainable performance of cold-set gelation in the confectionery manufacturing and its effects on perception of sensory quality of jelly candies. Cleaner Engineering and Technology, 1, 100005. https://doi.org/10.1016/j.clet.2020.100005
13. Miranda, J. S., Costa, B. V., de Oliveira, I. V., de Lima, D. C. N., Martins, E. M. F., de Castro Leite Júnior, B. R. et al. (2020). Probiotic jelly candies enriched with native Atlantic Forest fruits and Bacillus coagulans GBI-30 6086. LWT, 126, 109275. https://doi.org/10.1016/j.lwt.2020.109275
14. Mohammadi-Moghaddam, T., Firoozzare, A. (2021). Investigating the effect of sensory properties of black plum peel marmalade on consumers acceptance by Discriminant Analysis. Food Chemistry: X, 11, 100126. https://doi.org/10.1016/j.fochx.2021.100126
15. Constantin, O. E., Râpeanu, G., Kukurová, K., Turturică, M., Dubová, Z., Tobolková, B. et al. (2018). Antioxidative Capacity of and Contaminant Concentrations in Processed Plum Products Consumed in Romania. Journal of Food Protection, 81 (8), 1313–1320. https://doi.org/10.4315/0362-028x.jfp-18-066
16. Najmi, A., Holinesti, R., Mustika, S. (2023). The Effect Of Adding Pectin On The Quality Of Tamarillo Marmalade. Jurnal Pendidikan Tata Boga dan Teknologi. 5 (1). https://doi.org/10.24036/jptbt.v5i1.12918
17. Fil, M. I., Mikhailyuk, O. J. (2017). Innovative approach technologies fruit marmalade. Scientific Messenger LNUVMBT named after S.Z. Gzhytskyj, 19 (75), 55–58. https://doi.org/10.15421/nvlvet7511
18. Chomanov, U., Idayatova, M. (2023). Obtaining marmalade using melon crops. The Journal of Almaty Technological University, 2, 140–146. https://doi.org/10.48184/2304-568x-2023-2-140-146
19. Samokhvalova, O., Kucheruk, Z., Kasabova, K., Oliinyk, S., Shmatchenko, N. (2021). Effect of microbial polysaccharides on the quality indicators of protein-free and gluten-free products during storage. Eastern-European Journal of Enterprise Technologies, 1 (11 (109)), 61–68. https://doi.org/10.15587/1729-4061.2021.225003
20. Zagorulko, A., Zahorulko, A., Kasabova, K., Chuiko, L., Yakovets, L., Pugach, A. et al. (2022). Improving the production technology of functional paste-like fruit-and-berry semi-finished products. Eastern-European Journal of Enterprise Technologies, 4 (11 (118)), 43–52. https://doi.org/10.15587/1729-4061.2022.262924
21. Kasabova, K., Samokhvalova, O., Zagorulko, A., Zahorulko, A., Babaiev, S., Bereza, O. et al. (2022). Improvement of Turkish delight production technology using a developed multi-component fruit and vegetable paste. Eastern-European Journal of Enterprise Technologies, 6 (11 (120)), 51–59. https://doi.org/10.15587/1729-4061.2022.269393
22. Zagorulko, A., Shydakova-Kameniuka, O., Kasabova, K., Zahorulko, A., Budnyk, N., Kholobtseva, I. et al. (2023). Substantiating the technology of cream-whipped candy masses with the addition of berry and fruit paste. Eastern-European Journal of Enterprise Technologies, 3 (11 (123)), 50–59. https://doi.org/10.15587/1729-4061.2023.279287
23. Alekseenko, E. V., Chernykh, V. Y., Bakumenko, O. E. (2021). Shaped jelly marmalade with cranberry concentrate. IOP Conference Series: Earth and Environmental Science, 640 (5), 052007. https://doi.org/10.1088/1755-1315/640/5/052007
24. Priya, A., Nikitha, R. (2022). Synergistic marmalade for sports person to improve muscle performance and ergogenic activity. Journal of Advanced Applied Scientific Research, 4 (5). https://doi.org/10.46947/joaasr452022505
25. Velotto, S., Palmeri, R., Alfeo, V., Gugino, I. M., Fallico, B., Spagna, G., Todaro, A. (2023). The effect of different technologies in Pomegranate jam preparation on the phenolic compounds, vitamin C and antioxidant activity. Food Bioscience, 53, 102525. https://doi.org/10.1016/j.fbio.2023.102525

26. Kazantsev, E. V., Kondratie, N. B., Rudenko, O. S. (2024). Improving the safety and quality of jelly-fruit marmalade, recommendations for sweeteners. Agrarian Science, 1, 118–122. https://doi.org/10.32634/0869-8155-2024-378-1-118-122
27. Şengül, M., Karakütük, İ. A., Aksoy, S., Zor, M. (2023). The Effect of Different Cooking Methods and Addition of Different Sweeteners on the Physicochemical and Antioxidant Properties of Aronia Marmalade. Turkish Journal of Agriculture - Food Science and Technology, 11 (10), 1917–1925. https://doi.org/10.24925/turjaf.v11i10.1917-1925.6217
28. Kondratev, N. B., Osipov, M. V., Rudenko, O. S., Kazantsev, E. V., Kalinkina, E. S. (2021). The main factors of marmalade molecular structure formation. Food Systems, 4 (3), 172–179. https://doi.org/10.21323/2618-9771-2021-4-3-172-179
29. Magomedov, G. O., Magomedov, M. G., Lobosova, L. A., Petuhova, E. I. (2019). Development of marmalade recipe using buckwheat honey. Izvestiya Vuzov. Pishchevaya Tehnologiya, 5-6 (371-372). https://doi.org/10.26297/0579-3009.2019.5-6.12
30. Kamiloglu, S., Pasli, A. A., Ozcelik, B., Van Camp, J., Capanoglu, E. (2015). Colour retention, anthocyanin stability and antioxidant capacity in black carrot (Daucus carota) jams and marmalades: Effect of processing, storage conditions and in vitro gastrointestinal digestion. Journal of Functional Foods, 13, 1–10. https://doi.org/10.1016/j.jff.2014.12.021
31. Sbornik osnovnyh retseptur saharistyh konditerskih izdeliy (2000). Sankt-Peterburg: GIORD, 232.
32. Zahorulko, A., Zagorulko, A., Fedak, N., Sabadash, S., Kazakov, D., Kolodnenko, V. (2019). Improving a vacuum-evaporator with enlarged heat exchange surface for making fruit and vegetable semi-finished products. Eastern-European Journal of Enterprise Technologies, 6 (11 (102)), 6–13. https://doi.org/10.15587/1729-4061.2019.178764