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DETERMINATION OF THE FEATURES OF THE USE OF THREE-COMPONENT VEGETABLE AND FRUIT PASTE IN MARMALADE TECHNOLOGY

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The object of the study is the technology of marmalade based on pumpkin, apple and dogwood paste.

The development of a vegetable and fruit paste allows to solve the issue of marmalade structure formation, provide high organoleptic quality indicators, without the use of dyes and essences, enrich the chemical composition of products and give functional properties.

Due to the use of short-term low-temperature concentration and a well-founded recipe (pumpkin 50 %, apple 35 %, dogwood 15 %). The paste contains a significant amount of functional ingredients, which is confirmed by the study of its chemical composition. The paste has a dynamic viscosity of 280 Pa·s, a high content of non-starch polysaccharides of 3.89±0.11 g, vitamin C of 1.89±0.05 mg, β-carotene 21.13±0.60. For optimal management of the concentration process (55...65 °C), an effective viscosity is set in the range of 5...35 Pa·s.

The improved method of producing marmalade based on pumpkin, apple and dogwood paste is characterized by increased quality. The marmalade mass at a temperature of 80...82 °C before gelatinization has a viscosity 24 % higher than the control. The developed marmalade has a pleasant ruby color and a lingering consistency. The content of non-starch polysaccharides, mainly pectin substances and vitamin C increases almost twice. The new marmalade is characterized by the presence of vitamins A, C, E and β-carotene. The number of macro- and microelements increases significantly compared to the control sample. According to the content of non-starch polysaccharides, vitamin A, β-carotene and potassium, marmalade based on vegetable and fruit paste can be classified as functional, since the percentage of provision of these substances per day exceeds 10 %. The method of marmalade production can be implemented at confectionery enterprises.

Keywords: fruit marmalade, vegetable and fruit paste, viscosity, strength, functional ingredients, quality improvement

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1. Introduction

It is well known that functional nutrition is one of the most promising areas of the modern food industry. A number of studies have found that functional food products have potential health benefits, in addition to other nutritional benefits, namely reducing the risk of chronic diseases [1]. Marmalade, jams, juices, smoothies, fruit drinks, are made from fruits and berries, which are an excellent source of nutrients and are consumed by all segments of the population due to their sweet taste, attractive appearance. These products are a good source of a number of functional and biologically active substances, namely dietary fiber, polysaccharides, minerals, vitamins, phenols and other antioxidants. These substances can protect from chronic diseases such as diabetes, cardiovascular and many other diseases, as well as suppress oxidative stress and a key factor of aging [2]. Polysaccharides are among the most important active components in fruits and vegetables due to their non-toxic side effects and strong biological activity. Polyphenols, in particular, are widely known for their antioxidant activity, which helps in the absorption of free radicals and reduces the risk of various chronic diseases. They also contribute to the stability and shelf life of food products by preventing oxidation.

Modern industrial technologies for the production of confectionery products based on plant raw materials have been characterized by low quality in recent years. This is due to the replacement of the traditional fruit base with additives that form the structure, the use of dyes, flavor enhancers and flavors. Along with this, an increasing number of people, in parallel with changing lifestyles and increasing environmental sensitivity, are paying attention and, as a result, forming a demand for healthy food with functional benefits.

One way to solve this issue is to search for plant raw materials to create "healthy confectionery products" with functional properties and high-quality indicators.

The combination of various plant raw materials for optimization and prediction of complex quality indicators of confectionery products is promising. The multicomponent nature of vegetable and fruit paste will allow to ensure a high content of a number of functional and biologically active substances, to create original sensory indicators of the quality of the finished product. Therefore, studies devoted to the features of using vegetable and fruit paste for the production of fruit marmalade are relevant.

2. Literature review and problem statement

Over the past few decades, "superfoods", i.e. products with high nutritional value, namely with a significant content of one or more nutrients or bioactive compounds, have been of interest to people, the food industry and research groups. Therefore, having analyzed the existing range of marmalade products, it is possible to distinguish a trend towards the introduction of natural products in the form of vegetable or fruit purees into the recipe composition [3–9]. This is due to the growing demand for confectionery products with therapeutic, prophylactic and functional purposes.

Thus, in the work [3] the influence of structure-forming recipe ingredients on the quality of pumpkin jelly marmalade was investigated. The authors used pumpkin puree, food agar and natural honey as a sweetener, which allowed to improve the organoleptic quality indicators and increase the nutritional value. The disadvantage of these studies is the use of honey, which is a known allergen. Pumpkin puree was also used during the development of fruit marmalade in combination with clarified whey to expand the range and increase the biological value of the finished product [4]. Fruit and berry purees, namely persimmon [5], hawthorn [6], cherry plum [7], raspberry and blueberry [8], have found their application in marmalade technology. Thus, in work [5] it is proposed to include persimmon in the recipe of functional marmalade, which allows to reduce the sugar content and increase the biological value of the finished product. Persimmon puree forms an orange color in marmalade due to the presence of a large amount of beta-carotene in it. In work [6] the use of natural hawthorn puree for functional nutrition is justified due to the content of activated low-esterified pectin in it, which increases the complexing ability of the product with respect to zinc and lead ions. The use of ripe cherry plum fruits contributes to the formation of good organoleptic quality indicators in jams [7] and can be a source of natural antioxidants and dietary fiber. The use of raspberry and blueberry puree [8] allows to obtain jelly-fruit marmalade with natural ingredients that have a beautiful appearance and excellent taste, and the use of low temperatures during pasteurization of the puree helps to preserve vitamins, macro- and microelements. However, the conducted studies [5–8] are limited to the use of single-component selected raw materials, which, as a rule, cannot comprehensively solve the issue of increasing nutritional value, ensuring high quality indicators and expanding the range. It is known about the use of tomato puree in an amount of 2.5 % and table red beet powder as a replacement for synthetic dye in an amount of 2 % during the production of jelly marmalade [9]. Of course, food dyes have been used since ancient times to increase the aesthetic value of food products and interest from consumers. They are divided into three groups: natural food colors, nature-identical colors (synthesized by imitating natural ones), and artificial/synthetic colors. Currently, natural food colors have begun to attract much more attention in parallel with changing lifestyles and increasing environmental sensitivity [10].

Confectionery and fruit-based products are two main categories of jelly-like structure of food products with low moisture content. They are characterized by high dry matter content and low water activity. Therefore, it is these products that can be colored with natural pigments stable during storage, contained in plant raw materials [11]. The use of cranberries as a natural dye, preservative and source of useful, biologically active and minor food components has been proposed [12]. Cranberries were used in the form of juice concentrate in the amount of 6–15 % by weight of white sugar in the preparation of pectin-based jelly marmalade. Cranberry juice concentrate was added to the marmalade jelly. This made it possible to obtain pectin-based marmalade with biologically active substances, high organoleptic indicators and increase the strength of the marmalade jelly [12].

It is known about the use of berry extracts with a high content of anthocyanins of strawberries, raspberries, black currants for the production of marmalades and jams [13].

The concept of superfruits, which is currently popular and characterizes, on the one hand, fruits with a significant content of phytochemicals, and on the other hand, takes into account the availability and access of the population to these products, encouraging the consumption of local products [14]. Therefore, the use of fruits as raw materials with high nutritional and health-promoting values is positive for organic and sustainable production in many countries. In this regard, the conducted studies are relevant [15–18]. Thus, it is known about the use of quince as a seasonal fruit, which is usually processed in the food industry for the production of marmalade, jelly and wine, and is a source of pectin and lignin [15]. The use of plum puree in the amount of 40...60 % in marmalade technology to increase the content of vitamins, minerals, dietary fiber and phenolic compounds has been studied [16].

Along with the use of fruit base in marmalade technology, an important issue is the formation of a jelly-like structure of products, as one of the important quality indicators. The most common is the use of pectin [19], agar [18], gelatin [17], other gelling agents are used less often, including those obtained by microbial synthesis [20, 21]. In [19] it is shown that pectin is a natural biopolymer that can be extracted from food by-products, which adds value to the raw material, with a structure more complex than that of other polysaccharides. Its ability to create jelly in the presence of sugar and acids is widely used in the manufacture of fruit marmalades. However, a significant drawback is the inability to form the structure of the product when changing the recipe ratio of raw materials, which is especially important when expanding the range of confectionery products. This explains the use of other gelling agents, such as agar. Thus, the influence of various gelling agents and processing technology was assessed during the concentration of pomegranate juice to obtain jelly [18]. In [17], a study was presented to determine the most suitable gelling agent (agar-agar, pectin and gelatin) for marmalade using melon processing products. It was found that the most appropriate is the use of gelatin, since it has good gelling properties and low cost. However, the specificity of the organoleptic quality indicators of gelatin itself can worsen these properties in the finished product, which created the prerequisites for the use of structure-forming agents obtained by microbial synthesis [20, 21]. Thus, the effectiveness of the use of polysaccharides xampan, enposan and polymyxan [20] was shown. However, xampan has the best properties for a number of confectionery products [21], which is explained by its structure and ability to form a strong bond in the system. The use of these gelling agents [17–21] emphasizes their significant range and feasibility of use, but the issues of forming a stable and strong jelly structure remain unresolved. In this regard, it is important to emphasize that the products of fruit and berry processing are not only food ingredients with a high content of functional substances. At the same time, they are also additives that can be used to improve the structure of marmalade products [19]. The largest amount of food waste that can be converted into by-products is formed during the production and preservation of vegetables and fruits (14.8 %), so the effective processing of by-products has enormous potential for obtaining functional ingredients [19]. For example, a product obtained from beet production waste is, on the one hand, a source of dietary fiber, and on the other hand, an additive that has an impact on the formation of the structure of products [22].

The authors [23] proposed a technology for making jelly marmalade from waste from the production of candied vegetables using various gelling agents (of plant (agar) and animal (gelatin) origin). It was determined that the use of candied beet and carrot, provided that agar is used, allows to get marmalade with good organoleptic properties and meets the requirements of the standard for physicochemical indicators. At the same time, the product does not contain synthetic dyes, flavors and other food additives. However, the disadvantage of the research is the complexity of the technological process, which is associated with the processing of vegetables into candied fruits. The technology for making marmalade using products of melon crops processing on various gelling agents (agar-agar, pectin and gelatin) is known. According to the results of the study, it was found that the most appropriate is to use gelatin, since it has good gelling properties and low cost [17]. However, the use of animal-derived gelling agents is always successful due to the specificity of the smell in the finished product. The effect of various gelling agents and their processing methods for the production of pomegranate juice marmalade was evaluated [18], which allows obtaining products with a high content of anthocyanins and a bright natural color.

Therefore, the use of vegetables, fruits and berries and various processed products is promising as sources of nutrients, natural dyes and flavors, and structure-forming agents, but at present the problem is not completely solved. This is due to a number of factors, in particular the lack of a systematic approach to solving this problem.

A method for producing a functional fruit and berry paste with a selection of components (apples; jujube; blueberries) is proposed, which is a source of dietary fiber, vitamin C, low-molecular polyphenolic compounds [24] and can be used as a raw material for the manufacture of confectionery products. This is achieved by concentrating in a rotary film evaporator under gentle operating parameters (60...65 °C) and pasteurizing the concentrated paste in a scraped heat exchanger at a temperature of 95...98 °C with subsequent packaging [25].

The specified technology for obtaining pastes has found its application in the technology of pastilles [26] and jelly-fruit marmalade on agar [27]. Thus, fruit and berry paste based on apples, cranberries, hawthorn is added in an amount of 75 % with the replacement of apple puree [26]. This allows to obtain a pastille with a high degree of structure formation, high organoleptic properties and increase nutritional value. The disadvantage is the partial replacement of raw materials with a low content of physiologically functional components with paste, which causes certain technological difficulties. In the technology of jelly-fruit marmalade on agar, apple, quince, and blackcurrant paste is used in an amount of 30 %, which simultaneously allows reducing the agar content by 30 % [27]. These methods have significant advantages, but they also have disadvantages. Namely, the insufficient content of pectin as the main structure-forming agent, the significant cost of fruit and berry raw materials (cranberries, blackcurrants, etc.) compared to vegetables, as well as a limited assortment.

In this regard, it is promising to create compositions of pastes from vegetables and fruits, which will allow to obtain a high content of pectin in it, high sensory indicators due to not single-component, but combination. Therefore, the following raw material is of scientific interest, which has already found its successful application. Thus, pumpkin is an important source of bioactive substances for the population, and its production in countries around the world is massive. Pumpkin is an excellent source of trace elements, such as potassium, vitamins B, C, E, carotenoids, is characterized by low calorie content and high fiber content. Adding pumpkin pulp when creating a paste composition can be a viable solution to meet the growing consumer demand for healthy food with functional benefits.

It is known that billions of tons of edible products are thrown away annually due to aesthetic imperfections, overproduction and logistical inefficiency [19]. At the same time, unripe apples make up a significant part of this lost bioresource. The use of such apples in the manufacture of paste will solve the problem of reducing waste, which indicates the efficiency of resource use. On the other hand, it is known that it is unripe apples that contain a significant amount of pectin, which is a structural component of the jelly-like structure of confectionery products.

Dogwood is used as a valuable food, medicinal, ornamental, honey plant, the fruits of which have nutritional, dietary, dietetic and other health-improving value for adults and children due to their unique chemical composition. Thus, the fruits are a source of vitamin C, tannins, sugars, pectin, organic acids, minerals, various anthocyanins, phenolic compounds and antioxidants with high bioactive activity. The fruits are very valuable for direct fresh consumption and processing for the production of syrups, juices, jams, marmalade, paste, sorbet, fruit yogurt, compote, jelly, tarkhan, dried fruit roll.

A review of the literature has established that the issues of forming a stable structure of products, ensuring high organoleptic quality indicators, without the use of artificial dyes, enriching the chemical composition of products and providing functional properties remain unresolved. The listed raw materials (pumpkin, unripe apples, dogwood) are promising for creating vegetable and fruit paste and marmalade based on it, which will solve the above problems.

3. The aim and objectives of the study

The aim of the study is to substantiate the introduction of a three-component vegetable and fruit paste from pumpkin, apples and dogwood into marmalade technology. The introduction of the proposed paste will allow expanding the existing range of additives from plant raw materials and functional marmalade made on its basis.

To achieve the aim, the following objectives were set:

– to determine the structural-mechanical and qualitative indicators of the proposed paste from pumpkin, apples and dogwood;

– to establish the structural-mechanical, organoleptic, physico-chemical indicators of the quality and chemical composition of marmalade based on vegetable and fruit paste.

4. Materials and methods

The object of the study is the technology of marmalade based on pumpkin, apple and dogwood paste.

The hypothesis of the study is the use of all the natural properties of various vegetable and fruit raw materials for the justified creation of a three-component paste and marmalade based on them. The introduction of the developed vegetable and fruit paste will allow to solve the issue of forming the structure of products, ensuring high organoleptic quality indicators, without the use of dyes and essences, enrich the chemical composition of products and give functional properties. The selected pumpkin is one of the most common vegetables and a source of low functional ingredients, unripe apples – pectin substances, dogwood – phenolic compounds. The combination of these raw materials into a three-component paste will allow to form original sensory properties. In addition, the specified raw materials will allow to reduce the costs of paste production, which as a result will be reflected in the cost of marmalade. This will also allow to solve the issue of reducing waste, which indicates the efficiency of resource use.

Abbreviation: DM – dry matter.

Raw materials for creating a recipe for vegetable and fruit paste: pumpkin (Novinka variety), apples (Antonivka variety), dogwood (Lukyanovskyi variety). The structural and mechanical characteristics of puree and paste from pumpkin, apples, dogwood and marmalade obtained by the developed method were established. The structure formation indicators were determined by a rotational viscometer "Rheotest-2" (Germany).

The content of pectic substances was determined by the calcium-pectate method, carotenoids - by the colorimetric method, the mass fraction of vitamin C – by the titrimetric method. The study of the composition of fat-soluble vitamins in the paste was carried out by the method of thin-layer chromatography.

The control sample was the "Apple Molded" marmalade, for the manufacture of which (g) were used: white sugar (68.96), molasses (3.1), apple puree (8.6), lactic acid (0.21), sodium lactate (0.9), fruit and berry essence (0.023), dyes (0.04). To prepare the experimental sample, the apple puree was completely replaced with vegetable and fruit paste and essence and dyes were excluded from the composition of the recipe. The control and experimental samples of fruit marmalade were prepared using traditional technology, which involves the preparation of raw materials, boiling sugar with plant raw materials, sodium lactate and molasses, processing the marmalade mass, adding lactic acid. After that, molding, gelatinization, drying and cooling, packaging of finished products take place.

The determination of the organoleptic quality indicators of the control and experimental samples was carried out by an expert commission consisting of 8 tasters (teaching and pedagogical workers and postgraduate students of the State Biotechnological University (Kharkiv, Ukraine) on a 12-point scale, where 1...3 is a poor-quality sample, 4...6 is a satisfactory sample with shortcomings, 7...9 is good with the possibility of improvement, 10...12 is excellent.

The mass fraction of moisture in the marmalade was determined by the refractometric method, acidity by the titrimetric method, the content of reducing substances by the ferricyanide method, the strength by the ultimate shear stress on the "Labor" penetrometer. The calculation of the chemical composition of the marmalade was carried out using data from reference literature.

The error for all studies was 3...5 %, the number of repeatability of experiments – n=5, probability – $p \geq 0.95$. The package was used for data processing MS Office programs, including MS Excel, as well as the standard MathCad software package.

5. Improvement of the marmalade production method based on three-component vegetable and fruit paste

5. 1. Structural-mechanical and qualitative properties of the proposed vegetable and fruit paste

During the creation of the recipe of the three-component vegetable and fruit paste, different percentages of pumpkin, apples and dogwood were used. The raw materials were selected for their high content of pectin substances, which will contribute to the structure formation of the paste itself and products based on it. The influence of the color of the initial raw materials on the final color of the resulting vegetable and fruit paste and the total content of important physiologically functional ingredients was also taken into account.

The percentage content of the experimental samples of puree from vegetable and fruit raw materials is given in Table 1.

Table 1

Recipes of three-component puree

Raw materials	Percentage of composition		
	1	2	3
Apple	30	35	50
Pumpkin	50	50	40
Dogwood	20	15	10

To substantiate the recipe composition and ratio of raw materials, a paste was prepared. For this, apples, pumpkin and dogwood were washed, inspected, pre-heated, crushed, blended, concentrated, pasteurized, packaged.

The primary mechanical processing of raw materials for the production of apple, pumpkin and dogwood puree was carried out in a unified multifunctional machine. Dogwood was loaded into the machine and blanched in hot water at a temperature of 90 °C for 3 minutes. The apple was crushed using a crusher and blanched for three minutes with steam at a temperature of 103…105 °C. The pumpkin was blanched for 5 minutes at a temperature of 103…105 °C, previously crushing into pieces of 6…10 mm in size. Then the resulting masses of vegetables and fruits were separately wiped through a sieve with a hole diameter of 0.4–0.5 mm. The purees produced in this way were mixed according to the recipes given in Table 1. The puree compositions were briefly (30…60 s) concentrated to a concentration (paste 28…30 % dry matter) in a rotary evaporator using a low-temperature method (50…65 °C). Before being submitted for concentration, the puree compositions were heated to a temperature of 45…50 °C. Heating allows to reduce the viscosity of the puree, predicting its increased fluidity, which necessitates the study of changes in the structural and mechanical characteristics of purees and pastes.

The effective viscosity of vegetable and fruit purees from changes in shear deformation was determined on a rotational viscometer "Rheotest-2". The temperature of the test samples and control (apple puree) was 20…22 °C. The dependence of viscosity on the shear rate is shown in Fig. 1.

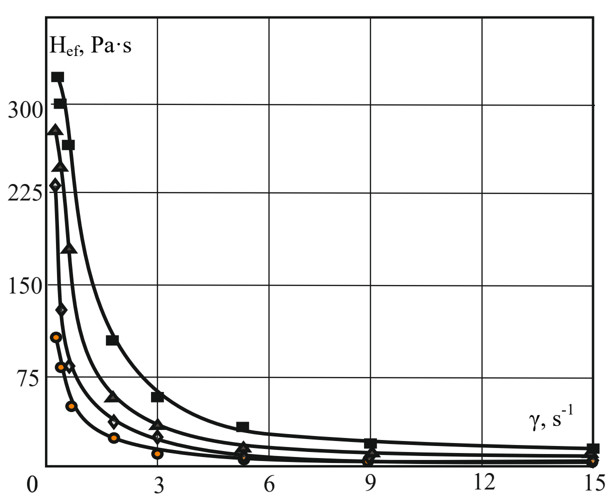

Fig. 1. Dependence of the compositions of vegetable and fruit purees on the change in shear rate 20 °C: ● – apple puree; ■ –1; ▲ –2; ◊ –3

The analysis of the obtained curves shows that when applying a moment of shear force, the effective viscosity has a maximum value and with increasing speed of rotation begins to gradually decrease. That is, the structure gradually collapses and at values at the level of 8…15 s^{-1} begins to flow almost at the same level as a Newtonian fluid. Comparing the initial viscosity of the experimental samples with the control (109 Pa·s) there is an increase in the first approximately 2…3 times. The unbroken structure of the three experimental samples of the compositions has a dynamic viscosity of 328; 280; 230 Pa·s, respectively. Thus, there is a strengthening of the structure of the obtained vegetable and fruit purees with a difference of 230…328 Pa·s depending on the percentage content of individual raw materials. To establish the optimal sample of puree, it is possible to conduct their organoleptic evaluation.

The first experimental sample obtained has a pronounced smell and taste of dogwood and a pleasant pumpkin orange color with a purple tint (Table 2). The second sample has a harmonious taste of dogwood and pumpkin with apple and an orange-ruby color. Unlike the two samples listed, the third has a barely noticeable smell and taste of dogwood, a pleasant apple with pumpkin. Taking into account the organoleptic assessment and indicators of structure formation, it is possible to select sample 2 for further research.

Table 2

Properties of organoleptic assessment of experimental samples

Indicator	Properties		
	1	2	3
Appearance	Homogeneous, puree-like mixture		
Color	Orange with a purple hue	Orange-ruby	Orange
Taste and smell	Pronounced smell and taste of dogwood, pleasant pumpkin, apple almost not noticeable	Pleasant harmonious taste of dogwood and pumpkin with apple	Faint smell and taste of dogwood, a pleasant apple and pumpkin
Consistency	Puree-like, easy to shape		

The behavior of a vegetable and fruit sample (apple – 35 %; pumpkin – 50 %; dogwood – 15 %) was studied under operating modes of concentration in a rotary evaporator. The change in the viscosity of puree (14…15 % DM) and paste (29…30 % DM) was established in the temperature range from 20 to 70 °C. The speed of rotation of the evaporator rotor shaft was equal to the speed of rotation of the cylinder of the rotational viscometer at the level of 2.7 s^{-1}.

A tendency to decrease in viscosity with increasing temperature of the experimental samples was established (Fig. 2). The dynamic viscosity index of the selected sample 2 when boiled to 30 % DM (170 Pa·s) increases by 3.5 times at a temperature of 20 °C. The main mode of stationary operation of the rotary apparatus has the following parameters: processing temperature 55…65 °C; shaft speed 2.7 s^{-1}, while the effective viscosity is in the range of 5…35 Pa·s. With such a low-temperature short-term concentration mode, the manufactured paste will be distinguished by increased quality indicators. To confirm this statement, an analysis of the chemical composition of the vegetable and fruit paste was carried out (Table 3).

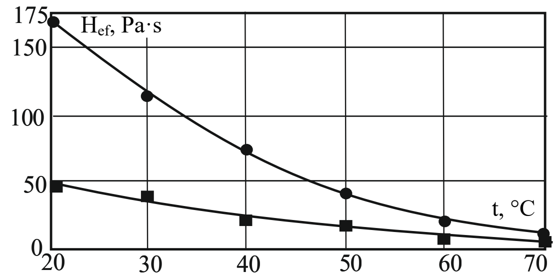

Fig. 2. Dynamic viscosity from temperature change (shear rate 2.7 s^{-1}: ■ — puree (11 % DM); ● — paste (30 % DM)

Table 3

Chemical composition of vegetable and fruit paste (pumpkin 50 %, apples 35 %, dogwood 15 %)

Indicator	Unit of measurement	Daily requirement	Vegetable and fruit paste
Dry matter	%	–	30.00±0.9
Non-starch polysaccharides	g	20	3.89±0.11
Vitamin A, PE	μg	900	316.88±9.3
β-carotene	mg	5	1.89±0.05
Vitamin C	mg	90	21.13±0.60
Vitamin E	mg	15	0.75±0.02
Potassium, K	mg	2,500	1405.75±42.15
Calcium, Ca	mg	1,000	67.00±2.01
Magnesium, Mg	mg	400	35.15±1.05
Sodium, Na	mg	1,300	39.75±1.20
Phosphorus, P	mg	800	53.63±1.59
Ferrum, Fe	mg	18	0.40±0.01

The data obtained in Table 3 show a significant content of physiologically functional ingredients in the paste based on pumpkin, apples and dogwood. The paste contains a large amount of non-starch polysaccharides, mainly pectin substances, which significantly contributes to the formation of structure. The paste also has a high content of vitamin C, is characterized by the presence of vitamins A, E and β-carotene. The obtained vegetable and fruit paste according to the given content (Table 3) is a functional semi-finished product and can be used as an enrichment base for the production of various food products, for example, marmalade.

5. 2. Determination of quality indicators and chemical composition of marmalade based on vegetable and fruit paste

The control sample was the marmalade "Apple molded". Based on the trial preparations and assumptions made, control and experimental (with complete replacement of apple puree with vegetable and fruit paste without dyes and essence) marmalade samples were prepared. Vegetable and fruit paste was boiled with sugar, sodium lactate and molasses.

The structural and mechanical characteristics of the marmalade mass were determined at a temperature exceeding its gelatinization of 80…82 °C. The viscosity of the experimental sample at the beginning of the applied shear force was 164 Pa·s, the control was 132 Pa·s (Fig. 3). The obtained data indicate a strengthening of the structure of the developed marmalade by 24 %. The increase in viscosity is explained by the higher content of pectin substances in the vegetable and fruit paste, which is positive for the formation of the structure of the marmalade mass.

Organoleptic quality indicators of marmalade samples were determined (Table 4).

Table 4

Organoleptic quality indicators of fruit marmalade samples

Indicator	Marmalade «Apple Molded» (control sample)	Marmalade based on vegetable and fruit paste (test sample)
Taste and smell	9.3±0.05	10.8±0.05
Color	9.5±0.05	10.2±0.05
Consistency	11.0±0.05	10.8±0.05
Shape	10.4±0.05	10.4±0.05
Surface	10.5±0.05	10.5±0.05

The control and experimental samples were rated as good and excellent. Thus, the control sample was rated as good with the possibility of improvement in terms of taste, smell and color. According to the same indicators, it was found that the experimental sample received a better rating and is characterized by a more attractive color, taste and smell. The use of vegetable and fruit paste allows to give an attractive ruby color due to the coloring substances of dogwood. The consistency of the experimental sample is slightly lower compared to the control, since it was characterized as "somewhat tight". According to the indicators of shape and surface, all samples were rated as excellent, since it was correct, with a clear contour, and the surface was elastic and evenly sprinkled with sugar.

The physicochemical and structural-mechanical quality indicators of fruit marmalade were determined (Table 5).

Table 5

Physicochemical and structural-mechanical quality indicators of fruit marmalade

Indicator	Marmalade «Apple Molded» (control sample)	Marmalade based on vegetable and fruit paste (test sample)
Mass fraction of dry substances, %	79.0±1.5	79.3±1.5
Titrated acidity, deg	11.0±0.3	11.8±0.3
Mass fraction of reducing substances, %	22.0±0.5	22.5±0.5
Strength, kPa	5.5±0.1	6.34±0.1

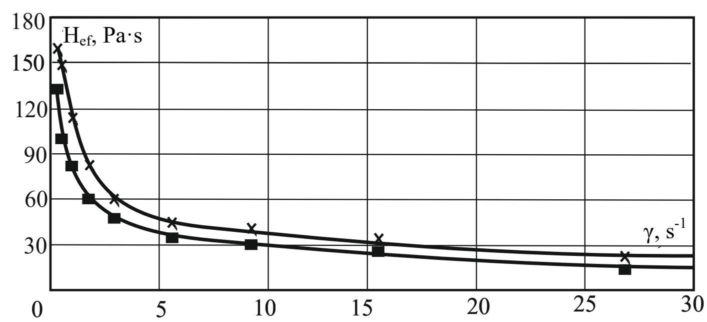

Fig. 3. Dependence of marmalade mass on the change in shear rate (80 °C): ■ — control sample; **x** — experimental marmalade mass

The mass fraction of dry matter of marmalade samples, both control and experimental, is within 79.0...79.3±1.5, and corresponds to the quality indicators for these products according to the requirements of regulatory documentation. Minor changes in values are explained by the error limits. This indicator for marmalade is constantly monitored during boiling and depends on its duration, which is carried out to a certain DM content.

According to the requirements of DSTU 4333:2018, the acidity of fruit-shaped marmalade should be 6.0...17.9 degrees. The acidity of the control sample is 11 degrees, and in the experimental one it increases by 7.3 % due to the presence of a slightly larger amount of acids compared to apple paste.

In terms of the content of reducing substances, both the control and experimental marmalade samples meet the requirements of regulatory documentation and are in the range of 22.0...22.5±0.5.

The strength index for marmalade among all structural and mechanical characteristics is one of the most important, as it indicates the process of structure formation. The strength index of the experimental marmalade is 6.34 kPa and is 15.3 % higher than the control sample, which indicates the formation of a stronger product structure.

The vegetable and fruit raw materials selected for the creation of the paste (pumpkin, unripe apples, dogwood) are characterized by a rich chemical composition. Therefore, to determine the functional properties of fruit marmalade, the chemical composition of the control and experimental samples was calculated, as well as the percentage of satisfaction of the daily need for them (Table 6).

Table 6

Chemical composition of the control and experimental samples of marmalade

Indicator	Unit of measurement	Daily requirement	Marmalade (control sample)	Daily requirement coverage, %	Marmalade (control sample)	Daily requirement coverage, %
Non-starch polysaccharides	g	20	1.1±0.03	5.5	2.11±0.06	10.55
Vitamin A, PE	μg	900	–	–	151.81±4.53	16.87
β-carotene	mg	5	–	–	1.0±0.03	20.0
Vitamin C	mg	90	1.57±0.04	1.7	3.81±0.11	4.22
Vitamin E	mg	15	0.197±0.005	1.3	0.406±0.01	2.7
Potassium, K	mg	2,500	122.05±3.66	4.9	762.19±22.80	30.48
Calcium, Ca	mg	1,000	11.83±0.35	1.2	36.33±1.08	3.6
Magnesium, Mg	mg	400	6.89±0.21	1.7	19.05±0.57	4.9
Sodium, Na	mg	1,300	0.98±0.02	0.1	21.55±0.64	1.66
Phosphorus, P	mg	800	16.7±0.50	2.1	29.08±0.87	3.625
Ferrum, Fe	mg	18	1.28±0.03	7.1	0.22±0.006	0.11

The data presented confirm the increase in the content of physiologically functional ingredients in marmalade made on the basis of vegetable and fruit paste. Thus, the content of non-starch polysaccharides, mainly pectin substances and vitamin C increases almost twice. The new marmalade is characterized by the presence of vitamins A, C, E and β-carotene. In addition, the number of macro- and microelements increases significantly compared to the control sample. According to the content of non-starch polysaccharides, vitamin A, β-carotene and potassium, marmalade based on vegetable and fruit paste can be attributed to functional, since the percentage of provision of these substances per day exceeds 10 %.

6. Discussion of the results of improving the method of producing marmalade based on pumpkin, apple and dogwood paste

The low quality and depleted chemical composition of confectionery products in the modern desire of consumers to receive not only pleasure but also benefit from food products, cause a stable and growing demand for "healthy sweets". Marmalade, which is traditionally made on the basis of fruits, berries and berries, is an excellent object for enrichment with nutrients and giving it functional properties. Various single-component purees have become widespread as raw materials in marmalade technology, which is confirmed by studies [3–9]. Along with this, the use of multi-component plant compositions when creating other confectionery products is characterized by a number of advantages [26–29]. It is promising to create compositions of pastes from vegetables and fruits, which will allow to obtain a high content of pectin in it, high sensory indicators due not to single-componentity, but to a combination.

The developed paste is characterized by the selection of raw materials with a high content of functional ingredients and, first of all, pectin. The production of the paste is distinguished by the use of short-term low-temperature (60...65 °C) concentration in a rotary evaporator.

The recipe ratio of raw materials in the composition is justified by the study of the structural-mechanical and qualitative characteristics of purees and pastes. The optimal ratio of raw materials in the paste has been established: apple – 35 %; pumpkin – 50 %; dogwood – 15 %. This proportion provides good organoleptic quality indicators and contributes to the strengthening of the structure, which is consistent with the obtained research results. The chemical composition given in Table 3 indicates the presence of functional ingredients in the developed vegetable and fruit paste, which allows it to be used as the main raw material in marmalade technology.

It was found that the viscosity of the experimental sample of marmalade mass based on pumpkin, apple, and dogwood paste has a value of 164 Pa·s, compared to the control mass of 132 Pa·s, which is 24 % higher (Fig. 3).

The use of vegetable and fruit paste from pumpkin, apples, dogwood in a reasonable ratio allows to give products high organoleptic quality indicators (Table 4). It is the use of 15 % dogwood that ensures the formation of an attractive ruby color, which is explained by the content of coloring substances in it. The use of vegetable and fruit paste provides excellent taste and smell indicators without the use of essence and dye due to exclusively plant raw materials. It was established that the consistency of the experimental marmalade sample is somewhat stretched, this is due to the increase in the content of pectin substances, which is confirmed by studies (Table 6) and data from other researchers [12]. All product samples had the correct shape, with a clear contour and an elastic surface sprinkled with sugar.

By mass fraction of dry and reducing substances, the samples of the control and experimental marmalade are within the requirements of regulatory documentation (Table 5). Minor changes in values are explained by the margin of error. The increase in acidity of the experimental sample by 7.3 % compared to the control sample is explained by the presence of a slightly larger amount of acid due to the addition of dogwood compared to apple paste. The formation of a stronger structure, established (Fig. 3), is confirmed by the determination of the strength index of the finished marmalade (Table 5). This index is 6.34 kPa and is 15.3 % higher compared to the control sample due to the higher content of pectin substances (Table 6) and is confirmed by other studies [12, 27]. This is positive from the point of view of the formation of a stable and strong structure of marmalade products. The data presented (Table 6) confirm the increase in the content of physiologically functional ingredients in marmalade made on the basis of vegetable and fruit paste. An increase in the content of non-starch polysaccharides and vitamin C by almost two times was established. This is explained, on the one hand, by the content of the listed substances in the starting materials, namely in pumpkin and dogwood. And on the other hand, by the resource-efficient method of obtaining the paste under gentle temperature conditions, which has been confirmed by other studies [24, 25]. Marmalade based on vegetable and fruit paste contains vitamin A in the amount of 151.81 μg and β-carotene – 1.0 mg compared to the absence in the control sample due to the content in pumpkin. The increase in the content of vitamins C, E and macro- and microelements (Table 6) occurs due to the use of dogwood and pumpkin. The use of vegetable and fruit paste allows for the consumption of non-starch polysaccharides, vitamin A, β-carotene and potassium in the amount of 10.55 %, 16.87 %, 20 %, 30.48 % of the daily requirement. This makes it possible to attribute this product to functional foods.

The raw materials used for the paste are pumpkin, unripe apples, and dogwood, which are promising for creating vegetable and fruit paste and marmalade based on it. This allows to solve the issue of forming the structure of products by using raw materials with a higher content of pectin substances. The use of vegetable and fruit paste allows to ensure the formation of high organoleptic quality indicators without the use of artificial dyes, essences, and flavorings. At the same time, the chemical composition of the products is enriched, which gives the marmalade functional properties and allows to characterize them as “natural and healthy.” In addition, the use of pumpkin and unripe apples as the main raw materials for the paste allows to reduce the cost of its paste, which, as a result, will be reflected in the cost of the marmalade. In addition, the developed technology solves the issue of reducing waste, which indicates the efficiency of resource use and is important for the practical significance of the results. However, the limitation of the results obtained is that the experimental studies presented are applied exclusively to the fruit marmalade “Apple Marmalade” with the specified paste in the established proportions. Changing the recipe of fruit marmalade or using other raw materials for paste with a higher acid content can affect the structure formation by changing the sugar-pectin-acid ratio.

As a drawback of the conducted studies, the lack of research on the determination of phenolic compounds and the determination of color characteristics of both the paste and the developed marmalade is noted.

Future studies will be aimed at solving the indicated shortcomings regarding the chemical composition. In addition, it is promising to generalize data on the systematization of the effect of combining various plant raw materials and predicting its quality.

7. Conclusions

1. The determination of structural-mechanical and qualitative indicators substantiated the recipe composition of the developed vegetable and fruit paste from pumpkin – 50 %, apples – 35 % and dogwood – 15 %. Due to the use of short-term low-temperature concentration, the paste contains a significant amount of functional ingredients, which was confirmed by the study of its chemical composition. The paste has a dynamic viscosity of 280 Pa·s, a high content of non-starch polysaccharides – 3.89±0.11 g, vitamin C – 1.89±0.05 mg, β-carotene – 21.13±0.60. For optimal management of the concentration process (55...65 °C), an effective viscosity was established, which is in the range of 5...35 Pa·s.

2. The quality and chemical composition indicators of marmalade based on vegetable and fruit paste were established. Marmalade mass at a temperature of 80...82 °C before gelatinization has a 24 % higher viscosity index compared to the control. The developed marmalade has a pleasant ruby color and a lingering consistency. The content of non-starch polysaccharides and vitamin C increases almost twice. The new marmalade is characterized by the presence of vitamins A, C, E and β-carotene. The number of macro- and microelements increases significantly compared to the control sample. According to the content of non-starch polysaccharides, vitamin A, β-carotene and potassium, marmalade based on vegetable and fruit paste can be attributed to functional, since the percentage of provision of these substances per day exceeds 10 %.

Conflict of interest

The authors declare the absence of a conflict of interest regarding this study, including financial, personal, authorship or other nature that could link the study and its results presented in this article.

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Data availability

The manuscript has no related data.

Use of artificial intelligence

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

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