

A method for manufacturing multi-component fruit and berry paste based on apples, cranberries, hawthorn with a high content of pectin substances has been improved. A special feature of the technique is the concentration in a rotary film apparatus until a dry matter content of 28... 30 % under a mild mode during 25...50 s provided that the puree is preheated to 50 °C. The limiting shear stress for each type of raw material and the effective viscosity index for the samples of the formulations of the studied pastes have been established. It was found that the best properties are demonstrated by composition with the following formulation ratio of components: apple – 50 %; cranberries – 40 %; hawthorn – 10 %. That makes it possible to obtain pastes with the best chemical composition (the higher content of pectin substances, organic acids, ascorbic acid, etc.).

The rational amount of adding 75 % of fruit and berry paste to replace apple puree has been determined and substantiated. That makes it possible to manufacture pastille with a high degree of structure formation, which is confirmed by the viscosity index of 616 Pa·s, compared with control – 354 Pa·s. A decrease in the mass fraction of dry substances by 5.0 %, an increase in acidity and reducing substances are ensured, which meets the requirements set by regulatory documents. This amount of paste provides for excellent organoleptic properties, i.e. it gives the products an even red color, pleasant taste, and smell. The developed technology expands the range of “healthy food” by partially replacing raw materials with a low content of physiologically functional components with a multicomponent composition, as well as provides for an increase in the pastille nutritional value. The use of sparing modes of concentration makes it possible to intensify the process of manufacturing a multicomponent paste, which indicates energy and resource-saving technology

Keywords: pastille, fruit and berry paste, structural-mechanical properties, physiologically functional ingredients, quality indicators

IMPROVING PASTILLE MANUFACTURING TECHNOLOGY USING THE DEVELOPED MULTICOMPONENT FRUIT AND BERRY PASTE

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1. Introduction

Confectionery products have significant advantages, in particular original taste, attractive appearance, aroma,

which, in general, contributes to introducing these products in the daily diet by various consumer groups in many countries. Considering the beneficial effect on the human central nervous system, including the impact on the performance

of the human body, an expedient product for consumption is sugar confectionery [1]. The chemical composition of the proposed products is characterized by the combination of mono- and disaccharides with other components, in particular with an unbalanced content of substances, deficiency of dietary fiber, vitamins, micro- and macronutrients. The pastille group of sugar confectionery is represented by pastille, marshmallow, candies, which include pectin, apple puree, and other fruit and berry raw materials. These raw materials act not only as technologically necessary components but also as useful functional ingredients [2]. However, the specified group of products manufactured by high-capacity enterprises currently almost lacks or includes small amounts of physiologically functional ingredients. This is due to the desire of manufacturers to reduce the cost of production by using improvers and structuring agents instead of traditional raw materials [3, 4]. The low-temperature treatment of pastille products with the introduction of blended fruit and berry compositions allows obtaining functional confectionery, confirming the expediency to improve techniques for manufacturing them [5, 6].

2. Literature review and problem statement

Pastille products are made by whipping boiled fruit and berry puree with sugar and egg white and then mixed with gelling substances. These products have a foam-like structure that is reinforced with a structuring agent such as agar [7], pectin [8], gelatin [9], and others [10]. Their technological and organoleptic properties differ depending on the used hydrocolloid, the resulting characteristics, and the type of confectionery.

One of the trends in the manufacture of sugar confectionery is an approach to reduce sugar while ensuring high product quality, without compromising sensory properties [11]. Paper [12] notes an increase in the demand for sugar-free confectionery, achieved by adding fruit additives. The study investigated adding dried acai powder (10.4/100 g per dry base) to finished products followed by the analysis of changes in taste, taking into consideration the use of conventional formulation. Sensory tests showed that the addition of dried acai powder to isomalt- and erythritol-based products is acceptable compared to sugar-based products. But issues remain about the content of sugar in the form of powder with which candies are sprinkled, considering further recommendations for consumers with diabetes that stipulate the need for a detailed analysis of the results with further studies into the use of fruit fillings in confectionery.

An important aspect of the use of fruit ingredients is their organic and environmental nature, which makes it possible to abandon synthetic dyes and flavors [13]. Work [14] addresses the production of confectionery with the aroma of *Bacillus coagulans* GBI-30 6086 with the subsequent assessment of their suitability during certain shelf life. The authors determined that the resulting candies made from fruit are an excellent carrier of *B. coagulans* (a substitute for artificial colors), including their role as a source of bioactive compounds necessary for a healthy diet. The effect of the content of fruit filler on the resulting structural-mechanical properties, quality, and consumer properties remain debatable, thereby necessitating research into this area.

The use of barberry fruit extracts as a natural red dye in the samples of pastille-marmalade products with different

content (1 %, 5 %, and 10 %) was proposed in [15]. Products with barberry extract demonstrated higher colorfastness, improved antioxidant properties; the strength values of marshmallows decreased with its addition. However, the use of natural dyes and flavors in confectionery is limited due to their instability and changes during storage, primarily the aroma released during consumption. It is proposed to use microencapsulation [16], which creates a physical barrier between color or aroma and the environment. Colored and aromatic compounds are protected by a coating film from damage, which increases stability. However, the application of this method is limited due to the complexity and high cost.

In recent years, there has been a significant demand in the confectionery market for “healthy”, functional products with improved formulation and chemical composition [17]. The search for new sources and physiological effects of various functional ingredients such as probiotics, sources of dietary fiber, pectin, polyphenols, vitamins, etc. defines the relevance of research. At the same time, there are issues related to industrial implementation and the form of products offered to the consumer.

Work [18] investigated the effect of adding grape skins on gel-like fruit candies. During the research, three types of fruit candies with grape skin fractions and reference candies were manufactured and analyzed. It was found that the addition of grape skins helped reduce the duration of processing in terms of adding a certain amount of fruit puree, including useful compounds, for further use in the confectionery industry, thereby emphasizing the feasibility of further application of fruit and berry fillers in sugar products to be followed by a detailed study into the effect of additives on the resulting product.

In [9], the physical-chemical and sensory properties of honey jelly candies made by two different mixing methods (cold and hot) were studied. They were subsequently added with certain doses of gelatin (15, 20, and 25 % by weight of honey) and fruit juices (orange, strawberry, and black mulberry). The addition of fruit juices increased the value of acidity and sugar content in the tested samples. The evaluation of the organoleptic characteristics of the obtained candies with honey confirms the expediency of further studies of various plant additives in confectionery in order to increase the resulting biological and functional value.

The use of plant-based by-products as nutritious and cheap natural supplements is increasingly important. In [19], the effect of grape pomace and seed powders of various fractions (100, 200, 288, and 415 μm) on the structural-mechanical, organoleptic, physical-chemical properties of soft candies was studied. The reported results confirm the feasibility of introducing grape pomace in the technology of soft candies with the need to take into consideration the used fraction of the introduced components.

Worth noting is the increased interest that currently exists in the introduction of fruit and vegetable raw materials as fillings in the *formulation* of sugar confectionery in the form of physiologically functional ingredients [20]. The authors emphasize the expediency of further research into determining the proportion of plant-based supplements required for the resulting rheological, organoleptic, and physical-chemical properties of confectionery. At the same time, the cited work does not fully reflect the impact of the share of pre-substantiated addition of fruit raw materials on the shelf life of products.

Paper [21] investigated the potential use of dates and their seeds as functional food ingredients for confectionery. The information acquired from determining the biological compounds and nutritional properties of the proposed fruits confirms the feasibility of their use in confectionery while leaving unresolved issues related to the possibility of using other plant raw materials as formulation additives to provide improved physiologically functional ingredients for the diet of consumers.

Despite WHO guidelines for daily consumption of fruits and vegetables, it is low among adolescents. In paper [22], the role and expediency of healthy food were investigated in comparison with harmful, at educational institutions. That substantiates the need for further research into the area of forming a healthy diet for young people [23] while leaving the issue of the rational menu for children, aimed at forming high immunity, unaddressed.

Resistance to microbiological spoilage remains an important aspect of the use of various plant raw materials. It is known that the high sugar content in confectionery makes confectionery less prone to microbiological spoilage [24]. Consequently, new technologies to increase the sustainable production of confectionery are relevant. Among the recently established alternatives, gelation technology deserves attention, based on cold curing, and used for the production of jelly candies [25].

Given the growing and steady interest in “healthy products”, pastille products with a foam structure, based on natural fruit raw materials, are increasingly in demand by consumers. It is known that the mass fraction of fruit (vegetable) raw materials in marshmallows is not less than 11 %, in pastilles – not less than 20 % [26]. This makes it possible to better reveal the properties that could enrich pastille with physiologically functional ingredients.

Papers [27, 28] determined the structural-mechanical properties of baby puree at different temperature values; its influence on the resulting rheological properties was established. In addition, the effect of pH and temperature with the addition of glucose syrup was established, which confirms the expediency of pre-determining the structural-mechanical properties when manufacturing products.

Thus, the main areas of quality improvement and expansion of the range of pastille products include the expansion of types of natural additives and fillings; diversification of organoleptic parameters; increasing the nutritional value; production of functional products. The specified trends in updating the range of pastille products show wide prospects for creating the new kinds of them. However, the main direction is still the development of products of high nutritional value, with dietary and health properties while maintaining their traditional appearance and organic nature.

3. The aim and objectives of the study

The study aims to improve the technology of manufacturing functional pastille with the introduction of the developed multicomponent fruit and berry paste. This could make it possible to expand the range of plant-based semi-finished products with a high content of functionally physiological ingredients and pastilles of high nutritional value.

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

- to form formulation compositions for multicomponent fruit and berry pastes and to determine their structural-mechanical properties, as well as their quality indicators;

- to determine the rational percentage of a multicomponent fruit and berry paste in the formulation of pastille, to establish its structural-mechanical, organoleptic, and physical-chemical properties.

4. The study materials and methods

Our experimental study according to the specified tasks was conducted at the Research Center “Latest biotechnologies and equipment for food products of high health properties”, Kharkiv State University of Food and Trade (Ukraine).

Apples (Antonivka variety), cranberries (Pilgrim variety), hawthorn (Arnold variety) with a high content of pectin were used as the basic raw materials for the multicomponent fruit and berry paste. The structural-mechanical properties of the puree made from apples, cranberries, and hawthorn, the blends of their pastes with different percentages of raw materials, as well as the manufactured pastille with the addition of blends of fruit and berry pastes, were determined. The structural-mechanical properties of the experimental samples were determined at the rotary viscometer “Reotest-2” (Germany).

Investigating the resulting organoleptic properties of the experimental samples, based on a 5-point scale, involved an expert board consisting of 5 representatives of the Kharkiv State University of Food and Trade (Kharkiv, Ukraine).

The mass fraction of reducing substances in pastille was determined by the ferricyanide method, the acidity of the products – by the titrimetric method, the mass fraction of dry substances – by the refractometric method, and density – by the weight method.

The magnitude of error for all studies was $s=3...5\%$; the number of repeated experiments was $n=5$; at probability $P\geq 0.95$. Statistical analysis was performed using Microsoft Excel 2007.

5. Improving the technology of pastille manufacturing by the introduction of the devised multicomponent fruit and berry paste in the formulation

5.1. Devising the composition of multicomponent fruit and berry pastes, determining their structural-mechanical properties, and quality indicators

Compositions of apples, cranberries, and hawthorn were selected to form the formulation of a multicomponent fruit and berry paste. The choice of the selected raw material is justified by its pectin content, to obtain a structure-forming effect and good therapeutic and prophylactic properties; the influence of each component in the raw materials on the structural-mechanical properties of the obtained paste and pastille was considered.

The devised multicomponent fruit and berry paste is produced according to the *formulation* given in Table 1. Initially, puree from apples, hawthorn, and cranberries is made. The selected hawthorn fruits are kept in 9...10 % NaCl solution at a temperature of 22...25 °C for 35...40 minutes. Such technological treatment of hawthorn is necessary to remove mechanical contaminants, to stabilize polyphenols, namely anthocyanins and leucoanthocyanidins. In addition, the NaCl solution is added 1 % citric acid to inactivate enzymes for the treatment of hawthorn fruit. Apples are crushed on a crusher before rubbing. The shredded apple and haw-

thorn are gradually blanched with steam at a temperature of 105...110 °C. Apples are blanched over 3 minutes, hawthorn – during 5 minutes. Blanching of cranberries involves water at a temperature of 88...90 °C for 3 minutes.

The blanched hawthorn and cranberry fruits and the shredded apples are ground at a grinding machine to a particle size of 0.5...0.7 mm. The pomace obtained after rubbing is sent for drying. The mashed apples, cranberries, and hawthorn are blended according to the *formulations* given in Table 1.

Table 1
Formulation ratio of fruit and berry puree raw materials in compositions

Component	Composition		
	1	2	3
Apples	70	60	50
Cranberry	20	30	40
Hawthorn	10	10	10

The blended mass of puree is sent for concentration to a rotary film apparatus (RFA). Boiling is performed until reaching a dry matter content (DM) of 28...30 % over 25...50 s [5, 29], provided that the puree is preheated to 50 °C to reduce its viscosity.

To obtain high-quality competitive confectionery, it is necessary to take into consideration the structural-mechanical properties of the raw materials, semi-finished products, and finished products at all stages of processing. Structural-mechanical characteristics are among the most important physical-chemical parameters, which define the quality of confectionery masses.

The results of studying the dependence of shear rate on the shear stress of the puree of the raw material components are shown in Fig. 1; an apple puree was selected as a control sample. The derived dependences are satisfactorily described by equation (1)

$$\theta - \theta_0 = K_1 \cdot \gamma^n, \tag{1}$$

where θ_0 is the critical shear stress, Pa; K_1 is the coefficient proportional to the viscosity at a velocity gradient equal to unity, Pa·sⁿ; γ is shear rate, s⁻¹; n is the flow index.

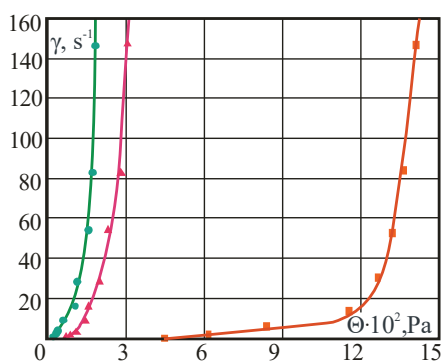


Fig. 1. Shear properties of fruit and berry puree (t=20 °C):
● – apples of Antonivka variety (DM=11 %);
▲ – cranberry of Pilgrim variety (DM=13 %);
■ – hawthorn of Arnold variety (DM=25 %)

The maximum shear stress θ_0 was established: for apples – 29 Pa, cranberry – 73 Pa, hawthorn – 442 Pa (Fig. 1). The resulting data confirm that all components of the raw mate-

rials belong to imperfectly plastic solids. The higher shear stress values for cranberry and hawthorn puree, compared to control, can be explained by the higher content of DM and pectin substances.

The dependence of the viscosity of fruit and berry pastes on the shear rate (Fig. 2) showed that the nature of the curves indicates the pseudo-plasticity of all studied samples, the viscosity of which is a characteristic of the equilibrium state between the process of destruction and recovery. The resulting curves of pseudoplastic fluids are described by equation (2):

$$\eta_{ef} = B \cdot \gamma^{-m}, \tag{2}$$

where B is the effective viscosity at a unity value of the velocity gradient, Pa·s; γ is the shear rate, s⁻¹; m is the rate of the structure destruction

The effective viscosity η_{ef} (Pa·s) of the studied pastes at the time of shear application is, for the samples of compositions, 1 – 484; 2 – 549; 3 – 588; control – 161, respectively. The compositions of pastes made according to the developed technique for the selected raw materials show a significant increase in the effective viscosity indicator compared to control (apple paste), which is a positive phenomenon of strengthening the resulting structure.

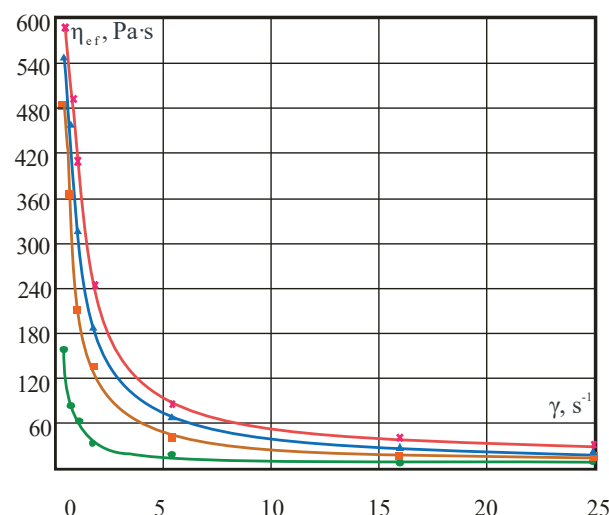


Fig. 2. Dependences of the viscosity of fruit and berry pastes on shear rate at t=20 °C:
● – control (apple paste); ■ – composition 1;
▲ – composition 2; × – composition 3

We determined the rational percentage of the raw materials in the experimental samples of pastes based on an organoleptic evaluation (Table 2).

According to the established organoleptic parameters, composition 1 has a faint smell and taste of cranberries, a pleasant smell of apples and hawthorn; composition 2 has a pleasant harmonious taste of cranberries, hawthorn, and apples, 3 – a more pronounced taste of cranberries and hawthorn. Increasing the content of hawthorn gives an unpleasant specific taste and smell. The color of the first composition is not as bright as that of the second and third. The introduction of cranberries in large quantities gives a specific sweet and sour taste, in small quantities – leads to a deterioration of the color scheme of the paste. Thus, taking into consideration the further use of the paste in the tech-

nology of pastille, the best performance is demonstrated by composition 3 with a *formulation* ratio of the components: apple – 50 %; cranberries – 40 %; hawthorn – 10 %, compared with compositions 2 and 3. The comparison of the content of physiologically functional ingredients of the experimental compositions of pastes to control is given in Table 3.

Composition 3 that was made by the improved method has, in comparison with the control sample, the increased content of pectin substances, by 1.8 times, ascorbic acid – by 3.5 times (Table 3).

Table 2

Organoleptic evaluation of the compositions of multicomponent fruit and berry pastes

Indicator	Parameter		
	Composition 1	Composition 2	Composition 3
Appearance	Homogeneous ground puree without seeds and ground skin particles		
Taste and smell	Barely felt smell and taste of cranberries, pleasant taste of apples and hawthorn	Pleasant harmonious taste of cranberries, hawthorn, and apples	The pronounced taste and smell of cranberries, pleasant taste hawthorn, apple is almost not felt
Color	Light red-violet	Red-violet	Bright red-violet
Consistency	Paste-like, easily spread, and molded		

Table 3

Comparison of the content of physiologically functional ingredients of pastes (per 100 g of product)

Substance	Unit	Control, apple paste	Composition 1	Composition 2	Composition 3
Dry matter content	%	30± ±1.15	30± ±1.15	30± ±1.15	30± ±1.15
Pectin components		1.76± ±0.02	2.98± ±0.03	3.09± ±0.03	3.18± ±0.03
Amount of sugars		8.1± ±0.20	8.9± ±0.20	8.7± ±0.20	8.4± ±0.20
Organic acids recalculated for malic acid		0.52± ±0.01	0.91± ±0.05	0.98± ±0.05	1.11± ±0.05
Ascorbic acid	mg in 100 g	8.03± ±0.11	22.7± ±0.02	24.9± ±0.02	28.7± ±0.02
Polyphenols:		149± ±1.20	519.7± ±2.52	538.7± ±2.52	584.7± ±2.52
Anthocyanins		–	179± ±2.50	185± ±2.50	189± ±2.50
Leucoanthocyanidins		72.1± ±0.85	179± ±3.25	178± ±3.25	178± ±3.25
Catechins		68.9± ±1.55	92.7± ±2.15	94.7± ±2.15	97.5± ±2.15
Flavonols		7± ±0.25	82± ±3.05	83.8± ±3.05	87± ±3.05
Tannins	%	0.05± ±0.01	0.15± ±0.01	0.18± ±0.01	0.23± ±0.01
β-carotene	mg in 100 g	–	0.4± ±0.02	0.4± ±0.02	0.4± ±0.02
Active acidity	–	3.2± ±0.15	3.14± ±0.15	3.11± ±0.15	3.05± ±0.15

The content of polyphenolic compounds (anthocyanins, leucoanthocyanidins, catechins, and flavonoids) and tannins

is superior to apple puree. In addition, the resulting new multicomponent pastes contain carotene. This indicates the feasibility of using fruit and berry paste in the technology of pastilles as a raw material that contains a significant amount of physiologically functional ingredients.

5. 2. Determining the rational content of multicomponent fruit and berry paste in the formulation of pastille, as well as its quality indicators

The technology of glue-like pastille has been chosen, whose main production stages include:

- preparation of raw materials;
- production of agar-sugar-molasse syrup and pastille mass, pouring it into trays;
- the structure formation of the pastille mass and drying of the layer;
- pastille drying and cooling;
- sprinkling with powdered sugar, packing.

During the experiments, it was proposed to introduce 25 %, 50 %, 75 %, and 100 % of the devised paste (composition 3) in the technology of pastille when replacing apple puree with a subsequent study of the structural-mechanical properties (Fig. 3). Pastille without additives was selected as a control sample.

The results of studying a change in the dynamic viscosity of pastille depending on shear rate are shown in Fig. 3, at different values of the amount of apple puree replaced with the devised paste. The experimental and control samples of pastille are characterized by a high degree of structuring, and, hence, the highest value of viscosity η_{ef} , Pa·s, in the region of minimum shear rates. For pastille samples, the maximum viscosity was: control – 354; replaced apple puree in the amount of 25 % – 548, 50 % – 590, 75 % – 616, and 100 % – 695, respectively.

The rational percentage of fruit and berry paste in the formulation of pastille was determined based on a study of the organoleptic and physicochemical quality indicators (Table 4).

It is determined that the addition of multicomponent fruit and berry paste changes the organoleptic quality of pastille. At a 25 % replacement of apple puree with the devised paste, the color of pastille turns pink, there is a slight taste and smell of cranberries, the consistency and structure are similar to those in control. Increasing the amount of paste to 50 % and 75 % with the replacement of apple puree gives the products a pleasant taste and smell of cranberries, with a color from light pink to uniform red. The consistency and structure of the products become somewhat viscous, which is allowed by the regulatory documentation for pastille produced on pectin and with various additives. In turn, the complete replacement of apple puree leads to a sample of viscous consistency with a heterogeneous structure and the presence of air bubbles. The color becomes bright red with a violet tinge, there is a sour taste with a pronounced taste of cranberries. That has a negative effect on the consumer properties of pastille. The shape and surface of both control and paste-included products are rectangular and characteristic of this type of product.

It was found that with the addition of paste in the amount of 25 % and 50 % with the replacement of apple puree, the mass fraction of dry matter changes slightly. Increasing the amount of paste to 75 % and 100 % reduces this indicator by 5.0...6.0 %, respectively, compared to the

control sample. There is an increase in the mass fraction of reducing substances when applying the paste in the amount of 25...100 %, by 8.7...31.2 %, respectively, compared with the control sample. The density indicator of pastille with the addition of 25 %, 50 %, 75 % of the paste varies slightly. Complete replacement leads to a decrease in density to 570 kg/m³, which is outside the permissible range set by regulations. The acidity of pastille with the paste in the amount of 25...100 % increases by 11.7...37.2 %, respectively, compared to control, which meets the stated requirements.

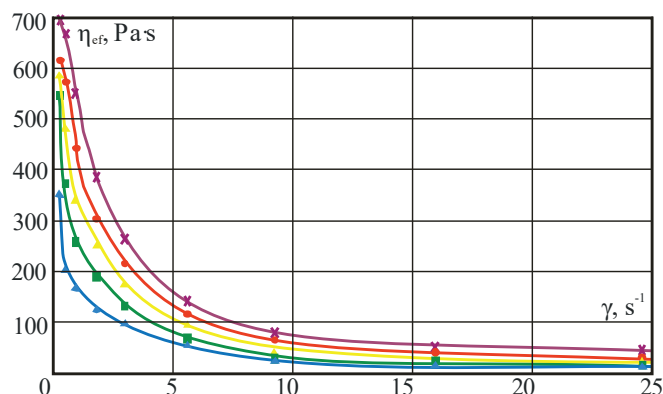


Fig. 3. Dependences of pastille samples' viscosity on shear rate at $t=20\text{ }^{\circ}\text{C}$: \blacktriangle – control (pastille without additives); at replacing apple puree with the devised paste, % of change: \blacksquare – 25; \blacktriangle – 50; \bullet – 75; \times – 100

cranberries (Pilgrim variety), hawthorn (Arnold variety) were chosen as the basic raw materials. The choice of the raw materials is justified primarily by the pectin content. The ratio of the raw materials in blended pastes has an impact not only on the content of physiologically functional ingredients but also on the organoleptic and structural-mechanical properties, which, in turn, would affect the quality of confectionery. That has defined the expediency of research into this area.

The compositions of the pastes (Table 1) were concentrated in a rotary film apparatus by boiling to a dry matter content (DM) of 28...30 % for 25...50 s. These gentle temperatures allow for the maximum preservation of the physiologically functional ingredients contained in the raw materials, as well as their organoleptic properties. The shear stress limit θ_0 has been determined for a puree of apples – 29 Pa, cranberries – 73 Pa, hawthorn – 442 Pa (Fig. 1), as well as the effective viscosity indicator η_{ef} (Pa·s) for the studied pastes, which, at the time of shear application, is: for the samples of the compositions: 1 – 484; 2 – 549; 3 – 588, control – 161, respectively (Fig. 2). According to the defined structural-mechanical and organoleptic quality indicators for all experimental samples, it was found that the best properties are demonstrated by composition 3, with the following formulation ratio of the components: apple – 50 %; cranberries – 40 %; hawthorn – 10 % (Fig. 2, Table 2). It should be noted that this paste has a better chemical composition, namely, a higher content of pectin, organic acids, ascorbic acid, and polyphenols (Table 3).

The organoleptic and physical-chemical quality indicators of pastille samples with a fruit and berry paste

Indicator	Parameter (% of replaced apple puree)				
	Control (pastille without additives)	25 %	50 %	75 %	100 %
Taste and smell	Inherent in this product, without foreign taste and smell	Inherent in this product, with a faint taste and smell of cranberries	Inherent in this product, sweet and sour, with a pleasant taste and smell of cranberries		Sour, with a pronounced taste and smell of cranberries
Color	White, uniform	White with a pink tinge	Light pink, uniform	Red, uniform	Bright red with a violet tinge
Consistency	Soft, easy to break		Soft, slightly viscous		Viscous
Structure	Homogeneous, uniform, fine-porous, pastille is easily cut without sticking to the surface		Homogeneous, slightly viscous, uniform		Heterogeneous, with air bubbles
Surface	Inherent in this product type, without rough curing on side faces				
Shape	Rectangular, inherent in this product type				
Dry matter content, %	85.0±2.0	83.3±2.0	82.4±2.0	81.0±2.0	79.9±2.0
Mass fraction of reducing substances, %	8.0±0.2	8.7±0.2	9.3±0.2	9.9±0.5	10.5±0.2
Density, kg/m ³	605±2	596.0±2	587.0±2	580.0±2	570.0±2
Total acidity, degree	5.10±0.05	5.50±0.05	6.00±0.11	6.40±0.15	7.00±0.20

6. Discussion of results of manufacturing a multicomponent fruit and berry paste, its quality indicators, and pastille with its application

To improve the technique for manufacturing a multicomponent fruit and berry paste, apples (Antonivka variety),

We have established the effect of the fruit and berry paste (composition 3, Table 2) in the amount of 25...100 %, instead of apple puree, in the formulation of glue-like pastille, in order to increase the content of physiologically functional ingredients while ensuring high quality. It was determined that the pastille samples are characterized by a high degree of structuring, and, hence, the highest value of viscosity η_{ef} , Pa·s, in the region of minimum shear rates. For pastille samples, the maximum viscosity was: control – 354; with the replacement of apple puree in the amount of 25 % – 548, 50 % – 590, 75 % – 616, and 100 % – 695, respectively (Fig. 3).

Changes in the physical-chemical quality indicators of pastille samples with fruit and berry paste were established (Table 4).

Its addition in the amount of 75 % and 100 % reduces this indicator by 5.0...6.0 %, respectively, compared to control. This is probably due to the increase in pectin, which binds and retains moisture, which is consistent with data reported by other researchers [30]. There is an increase in the mass fraction of reducing substances and acidity

when introducing the paste in the amount of 25...100 %, by 8.7...31.2 %, and by 11.7...37.2 %, respectively, compared with control. The values of these indicators do not exceed those regulated by the standard. Complete replacement of apple puree with the paste leads to a decrease in density, which is beyond the permissible range regulated by standards. The consistency of the sample is viscous with an inhomogeneous structure and the available air bubbles, which is consistent with the data obtained earlier on a relatively high degree of structuring (Fig. 3). The rational amount of the addition of a multicomponent fruit and berry paste of 75 % to replace apple puree was determined and substantiated. This amount of paste allows obtaining pastille with high structural values compared to control and provides excellent organoleptic properties (Table 4).

The practical industrial implementation of the proposed improved technology of pastille with a partial introduction in the formulation of the developed multicomponent fruit and berry composition, as evidenced by our research results, confirms the relevance of this study area. That could expand the range of “healthy foods” by partially replacing raw materials with a low content of physiologically functional components with a multicomponent composition, which increases the nutritional value of pastille.

The advantages of the devised technology are the use of mild concentration regimes, which ensures the preservation of the physiologically functional ingredients in rich fruit and berry raw materials. These modes make it possible to intensify the process of manufacturing a multicomponent paste, which indicates the energy and resource efficiency of this technology. Optimizing the composition of the multicomponent paste makes it possible to ensure the technological properties and original color, smell, and taste. The paste could be used as a natural source of anthocyanins, which would contribute to abandoning synthetic dyes and could give new products an attractive pink color.

Many studies are aimed at improving the technology of pastille production as a “healthy product” by adding various fruit and berry blends to the formulation [17]. But the issues regarding the effect of the natural filler on the resulting organoleptic and functional-physiological properties of the finished product remain to be addressed. One of

the limitations during the research may be the verification of the proposed technology involving certain compositions of fruit and berry raw materials, with each change in the components leading to changes in the resulting properties in general. Therefore, the data on the mechanisms of structure formation in the presence of components made from organic raw materials need to be clarified. The above defines the expediency of research into this area in order to expand the range of functional products.

Further research will be aimed at determining the state of water in pastille products with multicomponent pastes, which could provide an opportunity to expand the understanding of structure formation mechanisms. In addition, a study to determine the terms and conditions for storing pastille with paste could prove relevant.

7. Conclusions

1. A composition of a multicomponent fruit and berry paste with a formulation ratio of components (50 % apples; 40 % cranberries; 10 % hawthorn) has been developed. Boiling involves a rotary film apparatus until achieving a dry matter content of 28...30 % over 25...50 s with the puree preheated to 50 °C. The structural-mechanical properties of the raw materials and semi-finished products (paste compositions) have been determined. The compositions of the pastes made from the selected raw materials show a significant increase in the effective viscosity indicator compared to the control with an apple paste, its structure is strengthened. The selected paste formulation demonstrates good organoleptic quality indicators and, by the content of physiologically functional ingredients, it is superior to both control and other compositions.

2. The rational amount of the developed fruit and berry paste has been determined at 75 % with the replaced apple puree. This quantity gives products a pleasant taste and smell, uniform red color, and good physical-chemical quality indicators that meet the requirements set by the regulatory documentation for pastilles. A sample of the new pastille is characterized by a high degree of structuring, with the highest viscosity value η_{ef} of 616 Pa·s.

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