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SUBSTANTIATING THE TURKISH DELIGHT TECHNOLOGY BASED ON FRUIT AND BERRY PASTE FROM APPLES, APRICOTS, AND HONEYSUCKLE

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This study considers the technological process of Turkish delight production using fruit and berry paste made from apples, apricots, and honeysuckle. The task addressed is to form the structure, preserve traditional organoleptic quality indicators of Turkish delight without the use of various additives, as well as increase the nutritional value, by using natural fruit and berry paste. Exploiting the natural properties of the specified raw material makes it possible to substantiate the production of a plant-based paste and introduce it into the Turkish delight technology.

The study's results established that the introduction of short-term concentration at a temperature of 62…65°C enables the preservation of functional components in the paste, which is characterized by a dynamic viscosity of 320 Pa·s, a content of non-starch polysaccharides of 3.3 g, vitamin C – 19 mg, and vitamin A – 210 mg.

The introduction of fruit and berry paste into the Turkish delight recipe helps improve its quality. A decrease in humidity from 17.2% to 16.8%, an increase in titrated acidity from 1.5° to 1.7°, as well as an increase in the content of reducing substances from 22.1% to 22.6%, were noted. Structural and mechanical studies showed that the strength of the experimental sample on 1, 12, and 24 h was 21; 38; and 42 kPa, respectively, which exceeds control values (14; 32; and 38 kPa), while adhesion decreased from 1.7 to 1.5 kPa. The results confirm the effectiveness of using fruit and berry paste to produce Turkish delight with improved texture and increased nutritional value.

The proposed technology opens up opportunities for making a wide range of natural confectionery products with enhanced functionality. The introduction of this technology could expand the market for environmentally friendly sweets and might contribute to integrating products with high competitiveness into production

Keywords: Turkish delight, fruit and berry paste, structure formation, rheological properties, organoleptic properties, functional ingredients

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1. Introduction

Modern trends in the food industry indicate an increase in demand for health-promoting food products, in particular confectionery. This interest is associated with the growing awareness of consumers about the impact of nutrition on health and the desire to minimize the use of products containing excessive amounts of sugar, artificial additives, and dyes [1].

At the same time, the younger generation, the so-called Z-generation, prefers confectionery products with a jelly-like structure – chewing candies, marmalade, other products with a jelly-like structure, which are characterized by a high content of dyes and synthetic flavors [2]. Therefore, there is a discrepancy between modern requirements for the formation of a healthy diet and actual consumer preferences.

An effective way to address this problem is to replace additives with natural components by including fruits, berries, and fruits in the recipe. This will also make it possible to fortify products with useful functional ingredients, thereby increasing their nutritional value. At the same time, an important task is to preserve the biologically valuable properties of such raw materials during processing. One of the promising areas is the use of low-temperature processing techniques that enable maximum preservation of natural antioxidants, vitamins, and dietary fiber [3].

Fruit and berry pastes obtained under gentle temperature regimes, which are distinguished by a multi-component composition, attract special attention [4]. Such a composition makes it possible to simultaneously form various technological properties and provide functional characteristics of the product. Variations in the composition of raw materials for obtaining fruit and berry pastes determine their effect on foaming, improving structure formation and stabilizing consistency. Multi-component plant-based pastes predetermine a variety of organoleptic quality indicators in color, taste, and aroma, and increase functional value due to the presence of pectin substances, vitamins, minerals, phenolic compounds, and other components [5].

The effectiveness of such solutions has already been confirmed when devising technologies for whipped cream candies [6], marshmallows [7], as well as marmalade [8]. Therefore, it is a relevant task to carry out studies on the scientific substantiation of Turkish delight technology based on fruit and berry paste from apples, apricots, and honeysuckle, aimed at expanding the product range and improving technological features of the product.

2. Literature review and problem statement

Turkish Delight is a specific confectionery product with its unique taste and textural properties, which is currently known and widely consumed all over the world. Moreover, Turkish Delight is one of the oldest desserts in the world. The raw materials for its production are starch (mainly corn), sugar, water, natural fruit flavors, tartar, and natural/artificial colors [9]. A wide range of nuts, fruits, and their processed products are used as additional ones. When making Turkish Delight, starch is used to form the texture, sugar acts as a sweetener, and these two components are the main elements of the recipe [10].

Turkish Delight structure formation is one of the key aspects of the technology since it is on it that the quality of both the Turkish Delight mass and the finished product depends. At the same time, the conventional technology has certain limitations, which led to the search for alternative recipes. The main disadvantage is that the traditional structure-forming system is based on a combination of starch and sugar, which does not always allow for the stability of the texture during storage, as well as complicates the regulation of the physicochemical indicators of the product quality. That is why in scientific and industrial practice it has been proposed to use other structure-forming agents, in particular plant polysaccharides, including microbial [11], which are able to form a more stable gel network.

Thus, in [12], the ability of a model protein-free system based on corn starch to form dough under the conditions of adding xanthan, enposan, and gellan in an amount of 0.1…0.5% to its mass was investigated. It was established that with an amount of 0.3…0.5% of all the studied microbial polysaccharides, dough is formed with indicators that enable the formation of the required dough structure in the absence of gluten. However, the studies are aimed at the formation of the structure of gluten-free protein-free bread and gluten-free muffins and are limited by the lack of data on sugar confectionery.

The author of [13] considered the issue of partial replacement of starch with pullulan and found that replacing up to 20% of starch with pullulan makes it possible to change the characteristics of the gel and maintain an acceptable structure for Turkish delight. It is possible to reduce the starch content in the Turkish delight recipe by 20% by adding fruit and plant-based paste with a high content of pectin substances (4.31%) to the recipe [14]. In addition, there are craft recipes where agar, gelatin, or other similar ingredients are used as alternative gelling agents. However, their use leads to the formation of a marmalade-like structure, as a result of which the product loses the unique structural characteristics inherent in Turkish delight. Therefore, the formation of a stable Turkish delight structure is one of the tasks.

However, it should be noted that the issue of Turkish delight structure formation is not the only problem of its current formulation. Along with technological aspects, the depleted chemical composition of the product, which is traditionally limited to sugar, starch, and water, remains important. Such a formulation causes a low biological value of the product and the absence of physiologically functional ingredients. Another relevant area of improvement is the replacement of synthetic dyes and flavors with natural ones, which would not only increase the food safety of the product but also improve its organoleptic indicators.

The use of quince (*Cydonia oblonga mill.*) to replace artificial dyes and flavors in the production of functional soft candies (Turkish delight) in an amount of 10% and 15% [15] has been proposed. An increase in antioxidant activity in Turkish delight samples, an improvement in color to a natural reddish-amber color, and structural and mechanical properties have been established. Although the use of quince in Turkish delight technology is indeed a promising area as it makes it possible to simultaneously exclude artificial dyes from the recipe, improve structural and mechanical characteristics, and increase nutritional value, this approach has certain limitations. The use of quince alone actually provides only a single-component enrichment and forms a stable color in a narrow range of shades, which does not make it possible to comprehensively solve the problem of increasing the biological value and variability of the organoleptic characteristics of the product.

For the same purpose, work [10] established the feasibility of adding 2.5% black grape concentrate for the production of Turkish delight; however, the indicators of strength, adhesion, elasticity decrease, which could cause difficulties during transportation and sale of products.

The use of barberry extract as a natural dye in a number of confectionery products is widespread [16]. At the same time, the effectiveness of this approach is limited. The addition of extracts, as a rule, occurs in small quantities, which does not provide a significant increase in nutritional value. It is known about the use of black carrot juice concentrate [17] and plum juice [18] as a natural dye. The use of juices also has drawbacks: they contain a high percentage of moisture with a relatively low content of dry matter, so their inclusion in the recipe leads to minimal fortification of products with biologically active components. In addition, such raw materials complicate the processes of structure formation, requiring additional control during technological operations. As a result, these solutions do not make it possible to comprehensively solve the problem of increasing the nutritional value and quality of Turkish delight.

In work [19], the use of dogwood pulp in an amount of 4.4 and 12.2% in Turkish delight technology was proposed. It has been determined that the use of dogwood pulp contributes to the microbiological stability and strength of Turkish delight, the acquisition of intense color and pleasant taste. We know about the use of pomegranate and its juice, which has high bioactive properties, in the production of Turkish delight [20]. It has been determined that pomegranate juice is unsuitable for the production of Turkish delight, and the use of seeds is limited due to the difficulties associated with the formation of products. Along with this, in soft candies and marmalades, which are similar to the structure of Turkish delight, the effectiveness of using puree from fruit and berry raw materials rich in functional ingredients has been proposed and proven. These are plum puree [21] and hawthorn [22], which make it possible to increase the nutritional value of products, provide pleasant sensory properties and contribute to the formation of proper structural and mechanical characteristics. In marmalade technologies, persimmon puree [23], blueberries and raspberries [24] are used to form the structure and give products functional properties. However, the studies reported in [21–24] are limited to soft candy and marmalade technologies, and their use in Turkish delight technology requires additional research.

The use of dried date powder in combination with starch allows for partial replacement of gelatin in Turkish delight [25], but the texture of the products is difficult to categorize as traditional. Study [26] considers determining the effect of using carob, carrot, and orange pulp powders, which are food industry wastes rich in dietary fiber and other functional components, on the textural, rheological, and sensory properties of Turkish delight. According to the results from determining the organoleptic and structural-mechanical quality indicators, it is recommended to use all three types of pulp powders in an amount of 9%. Undoubtedly, processing by-products require rational utilization since they retain a number of biologically valuable components. For example, pomace is often used in confectionery production technologies as a source of dietary fiber and other substances [27]. At the same time, it is worth emphasizing that regardless of their nutritional value, these materials are still processing waste, while the most valuable biologically active substances and functional ingredients are concentrated directly in fresh fruits, berries, and vegetables [28]. They are of primary importance for the formation of qualitatively new products with increased nutritional value.

An effective way to increase the nutritional value of confectionery is to use fruits and berries as sources of natural biologically active substances. At the same time, an important task for scientists is to devise effective techniques of their processing that enable preservation of the content of vitamins, phenolic compounds, pectin substances, and other functional components inherent in the source raw materials [29]. In this context, a method for obtaining multicomponent plant-based pastes using low-temperature technology deserves special attention [4]. The use of this approach makes it possible not only to preserve valuable substances but also to expand the range of confectionery products through the targeted selection of pastes with certain technological properties.

Thus, in marshmallow technology, the use of plant-based paste contributes to improving the structure formation [7], in the production of whipped cream candies [6] – to intensify foam formation, in marmalade technology – to enhance gelation processes and contribute to the formation of a stable consistency [8]. However, issues related to the multicomponent composition of fruit and berry pastes remain unresolved. This is due to the variety of raw materials used to obtain them, and therefore differences in chemical composition. In particular, it is known that the pectin-cellulose complex has a different effect on structure formation compared to the cellulose-hemicellulose complex [30].

Therefore, unresolved issues are related to the formation of the necessary structure, improvement of organoleptic quality indicators and sensory characteristics in the technology of Turkish delight. It is also important to emphasize that when using plant-based pastes in the recipe, it is necessary to enable preservation of the specific consistency of this product, which is traditionally formed on the basis of gelatinized starch.

3. The aim and objectives of the study

The purpose of our study is to substantiate the Turkish delight technology based on fruit and berry paste made from apples, apricots, and honeysuckle. The use of the substantiated recipe for the paste could contribute to expanding the range of plant-based supplements and Turkish delight made on its basis.

To implement the goal, the following tasks were set:

– to analyze the structural and mechanical properties and quality indicators of fruit and berry paste made from apples, apricots, and honeysuckle;

– to investigate the organoleptic characteristics, physicochemical quality indicators, as well as texture of Turkish delight, prepared by using the devised paste.

4. The study materials and methods

The object of our study is the technology of Turkish delight based on apple, apricot, and honeysuckle paste.

The hypothesis of the research assumes the possibility of using the natural properties of fruit and berry raw materials (apples, apricots, and honeysuckle) for scientifically substantiated production of plant-based paste based on it and its introduction into Turkish delight technology. It is assumed that the use of the specified paste in Turkish delight technology could make it possible to preserve the traditional level of starch, to form a characteristic structure and organoleptic quality indicators without the use of dyes and flavorings. Due to the content of biologically active substances and natural pigments, the paste would provide distinct organoleptic properties, fortified chemical composition, and could provide additional functional characteristics to the product. It is expected that its use would contribute to the intensification of the processes of structure formation, which could positively affect the quality and stability of the finished product.

Our study assumes that optimizing the composition of fruit and berry paste from apples, honeysuckle, and apricots could enable formation of the traditional structure of Turkish delight. Varying the ratio of plant components would change the consistency of the product towards a more marmalade-like one. At the same time, the introduction of such a paste would contribute to increasing the organoleptic quality indicators and nutritional value without the use of artificial dyes and flavors.

To produce fruit and berry paste, apples of the Antonivka variety, apricots of the Melitopolsky early variety, as well as honeysuckle of the Spokusa variety, were used. Apples were chosen as a source of high pectin content to stably ensure the gelling ability corresponding to the Turkish delight technology. At the same time, the apple fills the product with a natural sweet taste and improves the texture of the pasty semi-finished product. Apricots have a high content of dietary fiber, carotene (vitamin A) and combine well with other components in terms of taste properties and create conditions for obtaining a rich color. Honeysuckle has a pronounced sweet and sour taste, a high content of vitamin C, anthocyanins, and other antioxidants, which add functional properties to the finished product. Honeysuckle also has high acidity, which contributes to a high degree of gelling in the production of Turkish delight.

To optimize the percentage of plant raw materials in the pasty semi-finished product, the following formulations were used in further studies (Table 1).

Table 1

Variants of recipes for prototype blended purees

Sample No.	Apple, %	Apricot, %	Honeysuckle, %
1	50	30	20
2	40	20	40
3	35	50	10

At the first stages of processing, the selected fruit and berry raw materials were washed and inspected, then transferred to preliminary heat treatment. The apple was crushed in a crusher with subsequent steam blanching at a temperature of 103…106°C for 3…4 minutes. Apricot and honeysuckle were blanched in water for 3 minutes. The next stage of rubbing was carried out separately for each type of raw material with a final diameter of the rubbing machine sieves of 0.3…0.5 mm. The resulting single-component purees were blended according to the proposed recipes (Table 1). To bring the recipe mixtures of purees to a pasty state, they were concentrated under vacuum in a special low-temperature film-type apparatus at a temperature of 50…65°C [31]. Apple puree was selected as control.

As a control sample, the classical Turkish delight production technology was used, which involves the use of sugar, starch, fruit puree, as well as the addition of citric acid, dyes, and flavors [32]. The process of preparing Turkish delight involved the gradual introduction of sugar syrup into the starch paste until a homogeneous mass was achieved, and the addition of fruit and berry paste. The mixture was boiled until the mass fraction of dry substances reached 70%, which meets the requirements for Turkish delight.

The structural and mechanical properties of puree, paste, and Turkish delight were determined by "Rheotest-2" (Germany).

The content of pectic substances was determined by the calcium-pectate method, carotenoids – by colorimetry, vitamin C – by titration. The composition of fat-soluble vitamins was analyzed by thin-layer chromatography. The mineral composition was determined by atomic emission spectrography with photographic registration on the DFS-8 device. The mass fraction of moisture was determined by the refractometric method, acidity by titration, the content of reducing sugars by the ferricyanide method. Strength was estimated by the ultimate shear stress on the "Labor" penetrometer. The organoleptic evaluation of the control and experimental samples was carried out by an expert board of 8 tasters at DBTU (Kharkiv, Ukraine) on a 12-point scale: 1…3 – poor quality, 4…6 – satisfactory, 7…9 – good, 10…12 – excellent. The measurement error was 3…5%, the number of repetitions was $n = 5$, the level of confidence was $p \geq 0.95$. The MS Office software package was used for data processing, including MS Excel (USA), as well as the standard Mathcad software package (USA).

5. Improving Turkish Delight production based on fruit and berry paste from apples, apricots, and honeysuckle

5. 1. Analyzing the structural-mechanical properties and quality indicators of fruit and berry paste from apples, apricots, honeysuckle

The condition for devising an improved technique for producing a fruit paste-like semi-finished product is to ensure its previously specified structural and quality characteristics. That is, owing to the combination of several fruits and berries, we prepare a paste-like semi-finished product with high structural and quality characteristics.

To optimize the formulation of compositions made from selected fruit and berry raw materials, the dependence of effective viscosity on the shear rate was determined: Fig. 1.

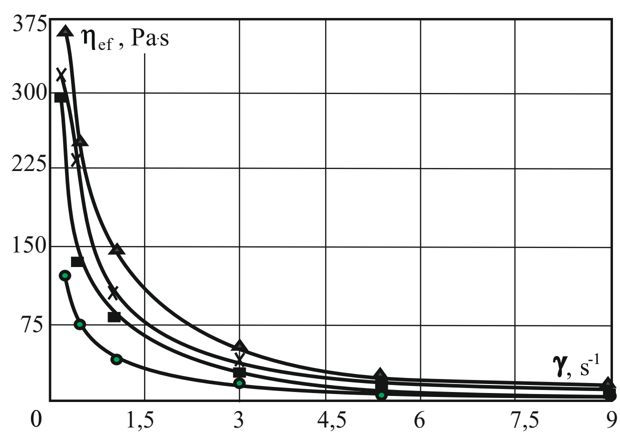

Fig. 1. Complete rheological curve (temperature 20°C): ● — control sample (apple puree); x — blend 1; ■ — blend 2; ▲ — blend 3

Analysis of the obtained rheological curves revealed that when applying a shear moment, the effective viscosity reaches a maximum value, after which it gradually decreases with increasing rotation speed. This behavior indicates a gradual destruction of the internal structure of the samples. Starting from shear rates within 5.4…9 s^{-1}, the rheological behavior of the samples approaches Newtonian, when the viscosity becomes practically constant.

Comparative analysis revealed that the initial dynamic viscosity of the experimental samples exceeds the indicator of the control sample (124 Pa·s) by 2.3...2.9 times. The dynamic viscosity values for the three experimental compositions were, respectively, for blend 1 – 320; 2 – 295; and 3 – 365 Pa·s.

To further establish the optimal sample, an organoleptic evaluation of the compositions was carried out (Table 2).

Table 2

Organoleptic evaluation of fruit and berry puree samples

Sample No.	General view	Color	Consistency	Taste and aroma
1	Homogeneous mass	Light orange with a purple tint	Medium thick, uniform	Balanced, pleasant fruit and berry aroma
2	Homogeneous mass	Rich dark purple	A little thinner, closer to liquid	Pronounced sour taste, intense honeysuckle aroma
3	Homogeneous mass	Rich yellow	Dense, delicate structure	Soft, sweet taste, weak acidity

The organoleptic evaluation of the samples given in Table 2 allowed us to identify the features of their sensory characteristics.

Sample 1 is characterized by a harmonious combination of components, which contributes to a balanced taste. The resulting puree has a pleasant fruit-berry aroma, has a homogeneous consistency of medium density and a light orange color with a slight purple tint. Due to the well-chosen ratio of raw materials, the sample has a stable structure and pronounced organoleptic properties.

The prepared sample 2 has a rich dark purple color, due to the high content of anthocyanins in honeysuckle. The consistency of sample 2 is somewhat thinner, which can be explained by the lower content of pectin substances. The taste is sour, pronounced with the dominance of the berry component.

Sample 3 is characterized by a thick consistency and a pleasant, sweeter taste with moderate acidity. Due to the high apricot content, the sample has a mild aroma and a rich yellow color.

All the samples have good organoleptic indicators but differ in taste orientation and structural uniformity. The most balanced in terms of the set of characteristics is sample 1 with a predominance of apples and apricots, which provides a harmonious combination of sweetness, acidity and consistency.

Further studies were conducted on the puree recipe of sample 1, which is distinguished by good sensory characteristics and increased indicators of structural and mechanical characteristics.

The structural and mechanical properties of fruit and berry puree at a shear rate of 2.7 s^{-1} are shown in Fig. 2. The curves demonstrate that with increasing temperature, a significant decrease in the ultimate shear stress (τ_0) is observed. Within the studied temperature range, the value of τ_0 decreases approximately five times from 68 Pa at 20°C to 13 Pa at 70°C.

In addition, analysis of our studies makes it possible to determine the effect of temperature on the effective viscosity (η_{ef}) of the puree. Thus, at a temperature of 20°C, η_{ef} is 320 Pa·s, while at 70°C it decreases to 1.5 Pa·s. Such data indicate a significant decrease in the resistance of the puree to deformation with increasing temperature, which is typical for plastic-viscous food systems.

When concentrating fruit and berry puree at a temperature of 62...65°C, when changing the dry matter content from 16% (puree) to 30% (paste), the range of effective viscosity of the processed raw material changes within 1.5...5 Pa·s. Such parameters are important to consider when calculating the technological regime of the processes of heat treatment and transportation of fruit purees.

Provided that the specified technological parameters of low-temperature processing of raw materials are observed, the resulting fruit and berry paste retains a high level of physiologically active components. To confirm this, an analysis of the chemical composition of the paste was carried out (Table 3).

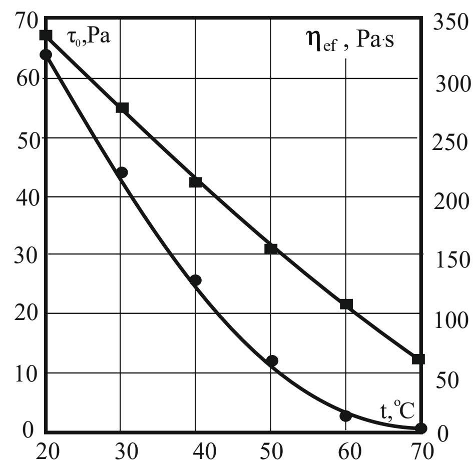

Fig. 2. Structural and mechanical characteristics of fruit and berry puree depending on temperature: ■ – ultimate shear stress τ_0; ● – plastic deformation η_{ef}

Table 3

Chemical composition of fruit and berry paste (50% apple, 30% apricot, 20% honeysuckle) $\sigma = 3\%$, $n = 5$

Indicator	Measurement unit	Daily need	Per 100 g	% of daily need
Dry matter	%	–	30.0	–
Vitamin C	mg	90	19	21.1
Vitamin A (PE)	μg	800–900	210	23.3
β-carotene	mg	–	1.24	–
Non-starch polysaccharides	g	25–30	3.3	11.0
Anthocyanins	mg	–	38	–
Organic acids	g	–	1.5	–
Total sugars (glucose, fructose)	g	–	14.5	–
Vitamin E	mg	15	0.95	6.3
Potassium (K)	mg	2500	418	16.7
Calcium (Ca)	mg	1000	38	3.8
Magnesium (Mg)	mg	400	26	6.5
Sodium (Na)	mg	1300	56	4.3
Iron (Fe)	mg	18	1.5	8.3
Phosphorus (P)	mg	700	38	5.4

The indicators given in Table 3 illustrate a significant content of physiologically functional ingredients in the experimental fruit and berry paste made on the basis of apples, apricots, and honeysuckle. The paste contains a significant amount of non-starch polysaccharides, primarily pectin substances, which contribute to the formation of the necessary structural and mechanical indicators of the product. 100 g of the product contains about a fifth of the daily requirement for vitamin C and vitamin A, as well as over 16% of potassium, which is important for the functioning of the cardiovascular system. The contribution to providing the body with dietary fiber, iron, magnesium, and phosphorus is noticeable. The content of anthocyanins, which come mainly from honeysuckle, attracts particular attention. Owing to this, the paste can be considered a source of natural antioxidants.

5. 2. Investigating the organoleptic characteristics, physicochemical parameters, as well the texture of Turkish delight, prepared by using the devised paste

The traditional Turkish delight manufacturing technology was used as a control sample, which involves the use of sugar, starch, fruit puree, as well as the addition of citric acid, dyes, and flavorings. In work [14] that considers improvement of Turkish delight technology, the use of fruit and plant-based paste with a simultaneous decrease in the proportion of starch was proposed. However, such a technological modification leads to a change in the structure formation in the direction more characteristic of marmalade products, which distances the resulting product from the traditional Turkish delight consistency.

The basis of our study is the desire to ensure the stability of the texture of the products, intensify the structure formation process, and achieve uniformity of consistency, which can be enabled by using a paste with a different chemical composition and properties. The specified solutions are aimed at obtaining Turkish delight with properties as close as possible to traditional ones, while maintaining the high quality of the finished product.

The value of the effective viscosity of the Turkish delight mass at a temperature of 80±2°C, which exceeds the gelatinization temperature, was established. The nature of the obtained curves has a pseudoplastic behavior (Fig. 3), so the viscosity when applying a shear force takes a value of 210 Pa·s and 178 Pa·s for the experimental sample and control, respectively. The viscosity of the undamaged structure of the Turkish delight mass of the experimental sample is 18% higher compared to the control.

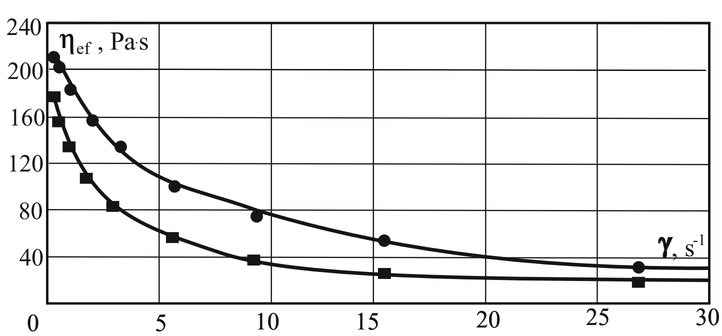

Fig. 3. Viscosity of Turkish delight mass at a temperature of 80±2°C depending on changes in shear rate: ■ – control sample; ● – experimental sample

The characteristics of the organoleptic quality indicators of Turkish delight samples are given in Table 4.

Table 4

Organoleptic assessment of Turkish delight samples quality

Sample	Organoleptic assessment of product quality
Control sample	Products of pink color, sweet taste, without foreign matter, with good structure and appearance
Test sample	Products of delicate yellow-pink color, with a taste of fruit and berry raw materials, with excellent structure and appearance

Differences were established between the control and experimental samples of Turkish delight. Thus, the control was characterized by a pink color, a pronounced sweet taste without foreign flavors, a good structure, and an attractive appearance. In contrast, the experimental one was distinguished by a delicate yellow-pink hue, the presence of a pleasant fruit-berry flavor, as well as an excellent structure and improved appearance.

The physicochemical quality indicators of the Turkish delight samples are given in Table 5, and the structural and mechanical ones are in Table 6.

Table 5

Physical-chemical quality indicators of Turkish delight samples s = 3%, n = 5

Indicator	Control sample (Turkish delight)	Experimental sample (Turkish delight with apple, apricot, honeysuckle paste)
Mass fraction of moisture, %	17.2	16.8
Titrated acidity, deg	1.5	1.7
Mass fraction of reducing substances, %	22.1	22.6

Comparative analysis of the physicochemical parameters of the control and experimental samples of Turkish delight showed insignificant differences. The humidity of the control sample was 17.2%, while in the experimental sample it was 16.8%. The titrated acidity in the experimental sample was higher (1.7 degrees versus 1.5 in the control). The mass fraction of reducing substances in the experimental sample also had a higher level (22.6% versus 22.1%). All parameters meet the requirements of DSTU 4688:2006 for oriental sweets such as soft candies, which confirms the feasibility of using fruit and berry raw materials in the technology of Turkish delight.

Table 6

Structural and mechanical quality indicators of Turkish delight samples s = 3%, n = 5

Indicator	Control sample (Turkish delight)	Experimental sample (Turkish delight with apple, apricot, honeysuckle paste)
Coefficient of ultimate shear stress, kPa	7.3	7.1
Strength, kPa:	14	21
– in 1 hour;	32	38
– in 12 hours;	38	42
– in 24 hours.	1.7	1.5

The ultimate shear stress coefficient of the control sample was 7.3 kPa, while that of the experimental sample was slightly lower at 7.1 kPa. The strength of the samples over 24 hours shows a clear improvement in the experimental sample: 1 hour after preparation it was 21 kPa versus 14 kPa for the control, 12 hours later – 38 kPa versus 32 kPa, and 24 hours later – 42 kPa versus 38 kPa.

The adhesion of the experimental sample was 1.5 kPa versus 1.7 kPa for the control, indicating a decrease in the stickiness of the product.

6. Results of substantiating the Turkish delight technology based on fruit and berry paste: discussion

The growing demand for health-promoting food products, in particular confectionery products [1] with a jelly-like structure, such as marmalade, chewing candies, which often contain synthetic dyes and flavors [2], necessitates the search for new technological solutions. Turkish delight is characterized by a delicate jelly-like structure and a pleasant taste, which has gained popularity all over the world [3]. The formation of its structure is the key technological stage that determines the quality of the finished product. The traditional recipe, which includes only sugar, starch, and water, provides the desired consistency, but has low biological value due to the lack of physiologically functional ingredients. At the same time, a relevant direction for improving technology is the use of natural dyes and flavors, which increases safety and improves organoleptic indicators [4]. This is possible by using new methods of processing plant raw materials. It is proposed to use apples, apricots, honeysuckle to make fruit and berry paste as raw materials for the production of Turkish delight.

By determining the structural and mechanical and qualitative properties of purees and pastes, their optimal content was established: apple – 50%; apricot – 30%; honeysuckle – 20%. Structural and mechanical properties of fruit and berry purees depend on the shear rate and temperature. With increasing speed, the effective viscosity decreases, approaching Newtonian behavior, and an increase in temperature from 20 to 70°C significantly reduces the ultimate shear stress and resistance to deformation. Comparative analysis revealed increased structural strength of the experimental samples, and sample 1 was distinguished by the most balanced organoleptic properties (Table 2), namely, harmonious taste, aroma and stable consistency. The detected increase indicates an increased structural strength of blended fruit and berry purees and varies within 295…365 Pa·s depending on the percentage content of individual raw material components. This is consistent with studies reported by other scientists [5, 7]. The chemical composition of the paste (Table 3) demonstrates a high content of pectin, vitamins, minerals, and anthocyanins, which provides functional value.

The use of fruit and berry paste from apples, apricots, honeysuckle in a reasonable amount (Fig. 1, Table 2) increases the viscosity of the unbroken structure of the Turkish delight mass of the experimental sample by 18% more compared to the control (Fig. 3). The increase in viscosity is due to the higher content of pectin substances in the created paste, which helps strengthen the structure of the Turkish delight mass and is a positive factor for the formation of a stable consistency of the finished product.

The use of apple, apricot, honeysuckle paste improves organoleptic quality indicators (Table 4). Turkish delight is characterized by a delicate yellow-pink hue, the presence of a pleasant fruit and berry flavor, as well as an excellent structure and improved appearance. The improvement of the structure is also evidenced by the physicochemical quality indicators of Turkish delight samples (Table 5) and structural and mechanical (Table 6). Although the comparative analysis of the physicochemical parameters of the control and experimental samples of Turkish delight showed insignificant differences, it is worth noting certain trends. The humidity of the control sample was 17.2%, while in the experimental sample it was 16.8%, which indicates a slightly better structure-forming ability of the product with fruit and berry paste, which is consistent with data from [30]. The titrated acidity in the experimental sample was higher (1.7 degrees versus 1.5 in the control), which is due to the presence of organic acids in the composition of apples, apricots, and honeysuckle [4]. The mass fraction of reducing substances in the experimental sample also had a higher level, which confirms the fortification of the product with natural sugars of fruit and berry raw materials. All indicators meet the requirements of DSTU 4688:2006 for oriental sweets such as soft candies, which confirms the feasibility of using fruit and berry raw materials in the technology of Turkish delight.

According to our results (Table 6), it was found that the initial structural stability of the Turkish delight sample with fruit and berry paste was better preserved. The strength of the samples for 24 hours demonstrates a clear improvement in the experimental sample, which indicates a more effective formation of the structure and an increase in the elastic-elastic properties of Turkish delight when adding plant-based paste, which is confirmed by data reported by other researchers [26]. The adhesion of the experimental sample showed a decrease in the stickiness of the product. The probable reason for the improvement in the structure formation is the presence of pectin substances in the plant-based paste, which are able to additionally bind water, evenly distributing it in the structure of the product. This provides a more elastic and elastic texture of Turkish delight, while reducing its stickiness and improving organoleptic properties. The data are consistent with studies [22, 26] on the ability of fruit pastes containing pectin substances to change the texture and bind water. Along with this, there is a caveat regarding the effect, which depends on the type of pectin (polysaccharide), the recipe composition and the heat treatment conditions, in contrast to studies [13, 16] in which polysaccharides or the type of syrup modified the texture differently.

Our solutions for the use of apple, apricot, honeysuckle paste ensure the stability of the texture of the products, intensify the process of structure formation, improve the organoleptic quality indicators of Turkish delight and its nutritional value. This makes it possible to obtain Turkish delight with properties that are as close as possible to traditional ones, while maintaining the high quality of the finished product. This is an advantage over study [14], in which due to structural modifications, its change towards marmalade occurs.

The results of our study could be used in the production of oriental sweets: Turkish delight, marmalade, marshmallow to increase their nutritional value and naturalness. The use of fruit and berry pastes as natural structure-forming agents and system stabilizers is appropriate for small and medium-sized businesses. The technology is based on low-temperature concentration and the use of raw materials rich in pectin substances and phenolic compounds, which makes it possible to make functional confectionery products without synthetic additives.

The results have certain limitations due to the specificity of the applied production method and the selected recipe of fruit and berry paste and Turkish delight based on it. Deviation from the recipe or the use of raw materials with a different acid composition could lead to changes in the processes of structure formation and deterioration of the quality of the finished product.

A drawback is the lack of data on the content of phenolic compounds and color characteristics of the paste, as well as the determination of the chemical composition of the finished Turkish delight, which limits their comprehensive assessment. Further work will be aimed at determining the chemical composition of Turkish delight, as well as at systematizing the influence of various types of plant raw materials to predict the quality and expand the functional properties of products.

7. Conclusions

1. The rheological properties of the justified composition of the fruit and berry paste recipe from apple – 50%, apricot – 30%, and honeysuckle – 20% have been determined. It was established that the use of short-term concentration at gentle temperatures makes it possible to preserve a significant proportion of physiologically functional ingredients in the fruit and berry paste. The resulting product is characterized by a dynamic viscosity of 320 Pa·s, an increased content of non-starch polysaccharides 3.3 g, vitamin C 19 mg, and vitamin A 210 mg. To ensure high-quality concentration at temperatures of 62…65°C, the effective viscosity of the paste was determined, which is in the range of 1.5…5 Pa·s.

2. It was determined that the addition of fruit and berry paste from apples, apricots, and honeysuckle improves the quality of Turkish delight, giving it a delicate yellow-pink color, fruit and berry flavor, and improved texture. According to the physicochemical indicators, a decrease in humidity from 17.2% to 16.8%, an increase in titrated acidity from 1.5° to 1.7°, and an increase in the content of reducing substances from 22.1% to 22.6% were noted. Structural and mechanical properties confirm the advantages of the experimental sample, namely the strength after 1, 12, and 24 hours was 21, 38, and 42 kPa, respectively, which exceeds the control values (14, 32, and 38 kPa), while adhesion decreased from 1.7 to 1.5 kPa. Thus, the use of fruit and berry paste contributes to the formation of a more stable structure, reducing stickiness, and fortifying the product with natural components, which increases its nutritional value.

Conflicts of interest

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

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Data availability

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

Use of artificial intelligence

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

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