

Досліджено технологічні властивості насіння чіа. Встановлено, що ступінь його набухання залежить від виду середовища (вода, розчин альбуміну, жир) та стану насіння (ціле або подрібнене). Відмічено, що у цілого насіння чіа здатність до утримування води вище, ніж здатність до утримування розчину альбуміну або жиру в 1,87 та 17,28 рази, а у подрібненого – в 1,75 та 17,49 рази відповідно. У разі подрібнення насіння його здатність до набухання покращується незалежно від виду середовища. Також подрібненому насінню притаманна краща жироемульгувальна спроможність, але піноутворювальними властивостями воно не володіє. Хороші піноутворювальні властивості характерні для цілого насіння чіа. Отримати збиту білкову масу, яка за стабільністю та піноутворювальною здатністю не поступається контрольному зразку, можна у разі заміни 40 % сухого альбуміну на ціле насіння чіа.

Рекомендовано під час виготовлення кремovo-збивних цукеркових мас ціле насіння чіа вносити на стадії збивання білкової маси, а подрібнене – на стадії отримання жирового емульсійного напівфабрикату. Відповідно знижується рецептурна кількість сухого альбуміну та жиру. Внесення 30 % цілого та 30 % подрібненого насіння сприяє зменшенню щільності структурованої кремovo-збивної цукеркової маси на 6,7 %. За подальшого збільшення дозування добавки значення показнику щільності децю зростає. Також підвищення вмісту насіння чіа зумовлює зростання показнику міцності зразків. Органолептичний аналіз показав, що структуровані кремovo-збивні цукеркові маси з максимально досліджуваним дозуванням насіння чіа мають ущільнену структуру, нерівномірну пористість та міцну тягучу консистенцію. Встановлено, що для забезпечення високої якості кремovo-збивних цукеркових мас дозування цілого насіння має становити 40 % від маси яєчного альбуміну, а подрібненого – 40 % від маси жиру.

Отримані результати мають практичне значення для удосконалення технології кремovo-збивних цукеркових мас в напрямку зменшення рецептурної кількості альбуміну та маргарину. Також внесення насіння чіа дозволить покращити харчову та біологічну цінність кремovo-збивних цукерок

Ключові слова: насіння чіа, функціонально-технологічні властивості, кремovo-збивні цукеркові маси, показники якості, кондитерські вироби

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HARNESSING THE TECHNOLOGICAL POTENTIAL OF CHIA SEEDS IN THE TECHNOLOGY OF CREAM-WHIPPED CANDY MASSES

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1. Introduction

The peculiarity of the European confectionery market is the highest level of consumption of chocolate products in

the world comparing to other types of confectionery products [1]. Chocolate candies, including cream-whipped candies, make up about 25 % of this segment according to market research [2]. The current trends in the improvement of

the technology of cream-whipped candies are either oriented towards solving technological problems or aimed at improving the physiological value of products. The technological tasks relate to ensuring the proper structural-and-mechanical, physical-and-chemical, and organoleptic characteristics of products throughout their shelf life. The producers use non-traditional raw materials with a high content of nutrients useful for a human body to improve the physiological value of chocolates [3].

The structural-mechanical and organoleptic characteristics of cream-whipped candy masses and finished candies depend largely on the quality of a foaming agent [4]. Producers use a white of a chicken egg in the dry form, that is, egg albumin, mostly. However, dry egg products may differ in functional and technological properties depending on production technology. Therefore, one of the technical tasks in the production of candies is a search for alternative raw materials with high foaming properties.

One needs to improve the physiological value of chocolates, because of the low content or absence of physiologically valuable substances, such as polyunsaturated fats, vitamins, minerals, dietary fibers, etc. The reasons are the peculiarities of the formulation compositions of products. The raw materials and semi-finished products, which contain almost no nutrients (margarine, sugar, water, and confectionery glaze), make up larger than 75 % of candies formulations.

Thus, the studies aimed at the creation of technologies of cream-whipped candies with the addition of non-traditional raw materials are expedient. The use of the non-traditional raw materials would not only improve the physiological value of products but could have a positive effect on the structural-and-mechanical, physical-and-chemical, and organoleptic characteristics of finished products.

2. Literature review and problem statement

It is known that it is possible to replace a part of dry egg albumin with milk whey or products of its processing in the formulation of cream-whipped confectionery masses [5]. Work [6] proposes to use milk whey with a solids content of 4.5...5.0 % in the production of foamy protein semi-finished products [6]. Preparation of milk whey involves its mixing with a salt-modifier (lactate, citrate or sodium acetate), boiling and combination of it with a mixture of polysaccharides. The mixture includes sodium alginate, carboxymethylcellulose, and xanthan gum. They act as stabilizers of a structure [7]. Thus, the production of chocolates implies a complete removal of dry albumin from a formulation, but the process becomes more complicated and we have to use additional formulation components, such as salts of modifiers and polysaccharides. Other authors [4] propose to replace up to 50 % of dry egg white with whey protein concentrate with a solids content of 95 %. The disadvantage of the technology is a lack of enrichment of a final product with substances useful for humans. The authors of [8] propose to use vegetable hydrogenated Butao-26 fat as a fat component to extend the shelf life of cream-whipped candies. However, such fat as margarine has a low biological value. The authors of study [9] recommend replacing agar with a mixture of hydrocolloids, which consists of gelatin and κ -carrageenan or gelatin and LM pectin, in a formulation to provide the possibility of formation of cream-whipped chocolates by

a method of co-extrusion. There is an aggregate-resistant structure formed during the implementation of the technology. That makes it possible to obtain candies with combined bodies. The authors of work [10] propose to replace a jelly forming agent with a mixture of xanthan gum and guar gum (25:75 ratio) in whipped masses to improve the structural characteristics of a finished product.

A comprehensive approach to improvement of food technology involves the use of a variety of additives based on vegetable raw materials, which contain not only nutrients useful for humans but also substances with certain functional and technological properties. In particular, study [11] shows that the oilcake of oat and rose hips contribute to the intensification of maturing processes of rye wheat dough for bread. The use of grape seed powder improves the oxidative stability of fats of confectionery glaze [12]. The addition of oilcake of pine nut and walnut provides stable cookie emulsion with the replacement of part of solid fat with liquid oil [13]. The implementation of technologies developed in studies [14, 15] makes it possible to obtain multicomponent fruit and vegetable pastes, which can be useful to regulate the consistency of confectionery products.

One should note that the use of fruit or vegetable purees and powders in production of cream-whipped candies has a positive impact on the stability of whipped masses because of the presence of polysaccharides responsible for the structure, such as pectic substances, cellulose, and cellulose, and hemicelluloses, in them [16, 17]. The authors of paper [18] propose adding the powder of fruits, berries, or vegetables in the amount of 13...17 % of the total amount of whipped mass [18]. The authors of work [19] recommend using artichoke powder in combination with a vitamin premix. Paper [20] recommends adding 20 % of feijoa puree or 15 % of kiwi puree during whipping. The use of these additives can reduce the content of sugar and jelly forming agents in a formulation of cream-whipped candies. In addition, they enrich a finished product with dietary fiber, minerals, vitamins, phenolic compounds, and organic acids.

Chia seeds (*Salvia hispanica L.*) are promising raw material. They draw more attention from researchers as a food ingredient. Chia seeds have a status of a super-product, because of a wide range of their beneficial properties. According to studies [21–23], *Salvia hispanica* promotes lowering of cholesterol in the blood. It also has anti-inflammatory, hepatoprotective and antidiabetic action. It prevents the development of arthritis, autoimmune diseases, and cancer. Chia seeds affect a human body positively due to the uniqueness of their chemical composition. The product contains 16–26 % of proteins, 31–34 % of fats, and 37–45 % of carbohydrates [23, 24]. The peculiarity of chia seeds proteins is their high biological value. Limiting amino acids are lysine and threonine, but the value of their amino acid score is more than 90 % [25]. Thus, chia seeds enrich a diet with protein. Dietary fiber makes up 60 % of chia seed carbohydrates. The mentioned substances provide a number of important functions in processes of digestion and metabolism in the human body. Chia seed fats have a high content of polyunsaturated fatty acids (about 80 % of all fats), which are represented predominantly by ω -3 fat acids [24]. Peculiarities of the fatty acid composition of chia seeds determine its prophylactic effect against cardiovascular diseases. Despite the high content of polyunsaturated fats, *Salvia hispanica* shows high resistance to oxidation due to the presence of a powerful complex of antioxidant substances of phenolic nature,

such as tocopherols, myristin, quercetin, gall, coffee, and chlorogenic acids [26]. Antioxidants have a radioprotective, hepatoprotective, immunomodulatory, and antitumor effect on a human body.

Chia seeds have a high value, also because of the presence of minerals (potassium, calcium, magnesium, copper, zinc, and phosphorus) and vitamins (group B, vitamins C, E, and PP) in significant quantities for a human body in its composition.

In a view of the above, the European Parliament approved chia seeds as a new foodstuff in 2009 [27]. Chia seeds are interesting not only due to its physiologically beneficial properties but also to the presence of certain functional and technological abilities. These properties determine the technological potential of using chia seeds in food technology. A unique feature of chia seeds is their high hydrophilicity due to their protein and polysaccharide composition. According to various information, chia seeds are capable of retaining water in multiplicity from 7 to 27 units relative to its mass [28]. This is a prerequisite for using chia seeds not only as a concentrate but also for the regulation of technological characteristics of food. In particular, researchers recommend using chia seeds as a regulator of consistency in the production of smoothies [29], kefir [30], pasta [31], and cookies [32]. Producers use chia seeds as a moisture-retaining agent in the technology of cheese desserts [33], sausage products [34], and chopped meat semi-finished products [35]. The addition of the mentioned additive into a paste-like emulsion base for sauces makes it possible to increase the formulation amount of water and to reduce the content of the fat component, which helps to reduce the energy value of a product [36]. The use of chia seed flour in wheat and rye bread technology [37] contributes to inhibition of staling and prolonging the shelf life of a product.

The weakness of the presented information sources is a lack of studies aimed at the identification of mechanisms of manifestation of functional and technological properties of chia seeds. In particular, authors of papers [29–32] use chia seeds to enrich production with nutrients. Authors take the effectiveness of chia seeds as thickeners [29, 30] and dough consistency regulators [31, 32] as a known fact. The authors of work [33] note that the addition of chia seeds in the production of cheese desserts makes it possible to use cheese with a moisture content of 80 % instead of 65 %. However, they also refer to studies of hydrophilic properties of chia seeds. Authors of works [34, 35, 37] describe the effectiveness of the use of this additive for moisture retention similarly. Paper [36] shows the results of studies of a degree of swelling of whole chia seeds in water depending on the pH value of a medium. But there is no explanation for a mechanism of the process under study. Probably, because the aim of the presented works is the improvement of the nutritional value of target products. The authors do not aim to study the functional and technological properties of chia seeds.

Thus, our analysis of information sources of recent years shows the prospect of research on the use of chia seeds in food production, both as a technological additive and as a concentrator. The addition of chia seeds will regulate the composition, structure, and texture of products; it will increase their yield and reduce their energy value. In addition, their use improves the nutrient composition of products significantly. However, the question of a study of functional and technological properties of chia seeds in specific food systems, in particular in albumin solution or in fat systems,

remains unresolved. There is no systematic understanding of the possibility of using chia seeds to regulate the quality characteristics of cream-whipped candy masses. This is a prerequisite for further studies in these areas.

3. The aim and objectives of the study

The objective of the study is the evaluation of the technological potential of chia seeds and prospects for their use in the technology of cream-whipped candy masses.

We set the following tasks to achieve the objective:

- to study the functional and technological properties of whole and ground chia seeds (ability to retain water, albumin solution or fat; fat-emulsifying and foaming ability, and ability to stabilize foam systems);
- to study the impact of chia seeds on the quality of cream-whipped candy masses (density, strength, and organoleptic characteristics).

4. Materials and methods to study the functional and technological properties of chia seeds and the quality of cream-whipped candy masses

4.1. Characteristics of materials for studying the functional and technological properties of chia seeds and the quality of cream-whipped candy masses

The following materials were used in the study: whole chia seeds and ground chia seeds (country of origin – Bolivia; producer – PE “SPC Sigma” Ukraine) and samples of cream-whipped candy masses with the addition of whole and ground chia seeds. The dosage of whole chia seeds was determined at the stage of obtaining a foamy protein semi-finished product in the amount of 30, 40, and 50 % by weight of dry egg albumin. We added ground chia seeds at the stage of obtaining an emulsion semi-finished product in the amount of 30, 40, 50 % by weight of fat. The formulation amount of albumin and fat was reduced accordingly.

Control samples were the cream-whipped candy masses made by using the technology of “Bird’s milk classic” candies. We used white sugar (DSTU 4623:2006); starch syrup (DSTU 4498:2005); food agar-agar (GOST 16280-88); citric acid (GOST 908-2006); dried egg albumin (DSTU 2212:2003, produced in Holland); aromatic food essences (DSTU 4716:2007); drinking water (GOST 2874-82); whole milk condensed with sugar (DSTU 4274:2003); margarine (DSTU 4498:2005); chia seeds (TU 15.8-31062161-010:2008) as raw materials for cream-whipped candy masses.

4.2. Methods to prepare the samples for studying the functional-and-technological properties of chia seeds

The chia seeds were ground at the Apach ACT6 industrial grinder (Italy). The size of particles of ground chia seeds was 150...180 μm.

We prepared an albumin solution by mixing it with water (1:7) and hydrating it for 10 minutes. The modes for obtaining an albumin solution corresponded to the technology of cream-whipped candy masses.

The fat-emulsifying ability of chia seeds (FEA) was studied on two model systems, which differed in the way of obtaining the emulsion. Model No. 1 provided the pre-blending of whole or ground chia seeds with water, the addition of fat and further emulsifying. The sequence in the addition of

components changed during obtaining model system No. 2. We added water after preliminary mixing the test samples with fat. Refined deodorized sunflower oil was used as fat.

4.3. Methods to prepare the samples for studying the quality of cream-whipped candy masses

We prepared samples for evaluating the impact of chia seeds on the quality of cream-whipped candy masses according to the ratios given in Table 1.

Table 1

The ratio of components in the system for obtaining of whipped protein mass

Dosage of chia seeds, % by weight of dry egg albumin	Ratio of components in the system, parts		
	water	dry egg albumin	chia seeds
0 (control)	7.0	1.0	0.0
10	7.0	0.9	0.1
20	7.0	0.8	0.2
30	7.0	0.7	0.3
40	7.0	0.6	0.4
50	7.0	0.5	0.5

The samples of whipped protein mass were prepared as follows. We mixed dry egg albumin with water, hydrated for 10 min, added chia seeds, and left for 10 min to swell. The resulting mixture was whipped for 20 min.

The samples of the structured cream-whipped candy mass for the study were prepared as follows. We whipped the prepared protein mass for 12 ± 2 min with agar-sugar syrup cooled to a temperature of 65 ± 2 °C. Next, we combined it with pre-whipped milk with condensed milk and ground chia seeds. We poured equal volumes of the finished cream-whipped candy mass in beakers calibrated with distilled water at 20 °C. The structure was formed at a temperature of $19...21$ °C for 60 min.

4.4. Methods for investigating the functional and technological properties of chia seeds and the quality of cream-whipped candy masses

The dynamics of the chia seeds swelling (in water, albumin solution, fat) were estimated at the Bresser Biolux LCD 50x-2000x microscope at magnification $\times 300$.

We determined the ability of chia seeds to retain water (or albumin solution, or fat) by the amount of water (or albumin solution, or fat) retained by a sample after infusion and centrifugation of a corresponding suspension. The ratio of chia seeds:water (or albumin solution, or fat) was 1:5 in the suspension. The value of the indicator was defined as a percentage by the ratio of a difference between the amount of water used (or albumin solution, or fat) and the mass of the obtained fugate to the weight of a sample [16]. Refined deodorized sunflower oil was used as fat. We determined the fat-emulsifying ability (FEA) by the ratio of a volume of the emulsified layer to a total volume of the system after centrifugation of chia seeds with fat and water for 5 min at a speed of 2,000 rpm [37].

The foaming ability of samples (in %) was determined according to the Barilko–Pikielka methodology [38] by the ratio of a foam volume formed during chia seeds whipping with albumin solution to a volume of the solution before whipping. We evaluated the foam stability (in %) by the ratio of a volume of foam stored for 1 hour to a volume of foam formed during whipping.

The density of the structured candy mass was calculated by the ratio of the mass of a sample to its volume.

We determined the strength of structured candy mass at the Valent device under load (in grams) at which the structure of a sample was destroyed.

The organoleptic evaluation of the quality of the structured candy mass was performed according to DSTU 4683:2006 in terms of color, structure, odor, and taste.

The statistical analysis of the experimental results employed the standard Microsoft Office package for a set of parallel measurements ($n=4-5$, $p<0.05$).

5. Results of studying the functional and technological properties of chia seeds and their impact on the quality of cream-whipped candy masses

5.1. Results of studying the functional and technological properties of whole and ground chia seeds

The main functional and technological properties of raw food components, which determine their technological potential, are water-retaining, fat-retaining, fat-emulsifying, and foaming abilities, ability to stabilize foam systems, etc.

The methodology for evaluation of the ability of vegetable raw materials to retain liquid components involves holding a test sample with appropriate liquid for a certain time and its subsequent centrifugation. The degree of chia seeds swelling was studied depending on the duration of contact with water (Fig. 1), albumin solution (Fig. 2) and fat (Fig. 3) using a microscope to substantiate the duration of the hydration of chia seeds.

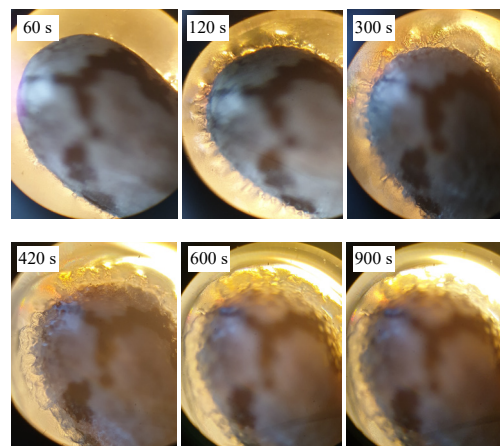


Fig. 1. The degree of swelling of chia seeds depending on the duration of contact with water ($\times 300$)

It was noted that chia seeds began to absorb the water immediately when soaked in water. In this case, a surface became friable, and there was a jelly shell with a pronounced phase boundary formed around seeds. We observed an increase in the thickness of a shell under conditions of prolongation of contact of seeds with water to 600 s. It was established that the size of a shell did not change in case of prolongation of soaking of chia seeds up to 900 s, which indicated the completion of the hydration process.

A similar pattern was observed when soaking the whole chia seeds in a solution of albumin (Fig. 2) and fat (Fig. 3). The degree of swelling was the same at 600 and 900 s.

It was found that there was no clear boundary between a jelly shell and medium in case of chia seeds swelling in

albumin solution. The thickness of a shell was negligible in the case of contact of seeds with fat, and a state of a sample surface remained unchanged.

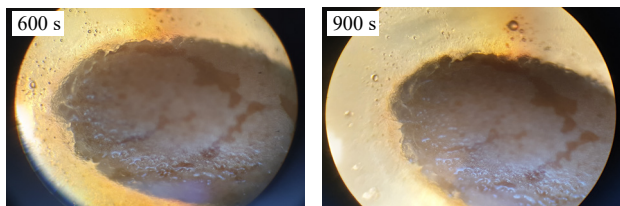


Fig. 2. The degree of swelling of chia seeds depending on the duration of contact with an albumin solution ($\times 300$)

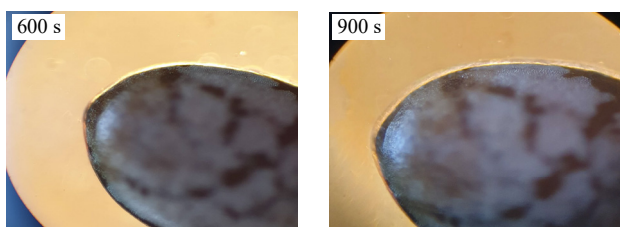


Fig. 3. The degree of swelling of chia seeds depending on the duration of contact with fat ($\times 300$)

Thus, it was substantiated that the duration of soaking of chia seeds for evaluation of their ability to retain water, albumin solution and fat, was 600 s. Fig. 4 shows the average values of the measurement results of these indicators. The relative error did not exceed 4.1 % (for $n=5$).

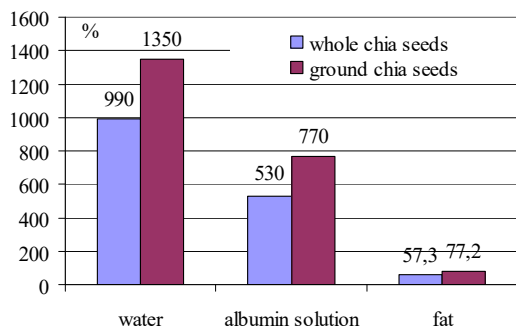


Fig. 4. The ability of whole and ground chia seeds to retain water, and albumin solution, and fat

It was established that chia seeds had the highest water retaining ability in the experimental studies. In particular, the whole chia seeds had a higher ability to retain water than the ability to retain albumin solution or fat by 1.87 and 17.28 times, respectively, and ground chia seeds – by 1.75 and 17.49 times, respectively. It was noted that the grinding improved these properties. The ability to retain water, albumin solution or fat, was higher by 1.36, 1.45 and 1.35 times, respectively, in the ground seeds in comparison with the whole ones.

One of the stages in the technology of cream-whipped candies is to obtain a fat emulsion semi-finished product. Therefore, we considered it expedient to evaluate the fat-emulsifying properties of chia seeds. The studies were performed on two model systems, which differed in the method of emulsion production. Fig. 5 shows the average values of our study results. The relative measurement error did not exceed 3.5 % (for $n=5$).

The results of the studies showed (Fig. 5, a) that the whole chia seeds did not exhibit emulsifying properties in

the model system No. 1. An FEA indicator for the whole chia seeds increased almost by 16 %, and for ground ones – by 5.57 times (Fig. 5, b) in case of a change in the order of adding fat and water (model emulsion No. 2). It was noted that the grinding of chia seeds improved their fat-emulsifying properties. FEA for ground chia seeds was almost 1.4 times higher than the value of this indicator for the whole seeds in model emulsion No. 2.

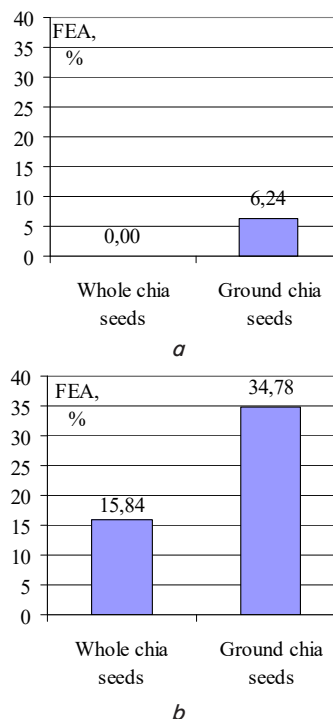


Fig. 5. Fat-emulsifying ability (FEA) of whole and ground chia seeds at different ways of emulsion production: a – model system No. 1; b – model system No. 2

An important stage in the technology of cream-whipped candy masses is to obtain a foamy protein semi-finished product. One step in this stage is to whip up a dry egg albumin solution. It was noted that the whipping of chia seeds hydrated in water did not lead to the formation of a foam system. Therefore, we evaluated the effect of chia seeds on the quality of whipped protein masses based on dry egg albumin solution. We chose the albumin:water system in the ratio of 1:7 as the control one. It was noted that the addition of ground chia seeds to the system did not make it possible to obtain foam mass. Therefore, we studied samples with the addition of whole chia seeds. The dosage of seeds was 10, 20, 30, 40 and 50 % by weight of dry egg albumin (Table 1). Fig. 6 shows the average values of the obtained data regarding the impact of the additive on the foaming ability and stability of whipped protein masses. The relative measurement error did not exceed 3.8 % for $n=4$.

It was noted that the foaming ability of the system acquired its maximum value and exceeded the control value by 1.27 times in case of adding 10 % of whole seeds instead of dry protein. The stability of the whipped protein mass increased by 4.2 % in this case. In case of a further increase in the dosage of the additive, the foaming ability of the system decreased gradually. It was 7.3 % less than the control value when the seed concentration reached 50 %. We observed a similar trend when we evaluated the stability indicator

of the whipped protein mass. According to the presented results, it is possible to obtain whipped protein mass, which is not worse than the control sample in the stability and foaming ability, in case of dosage of chia seeds up to 40 % by weight of dry albumin inclusive.

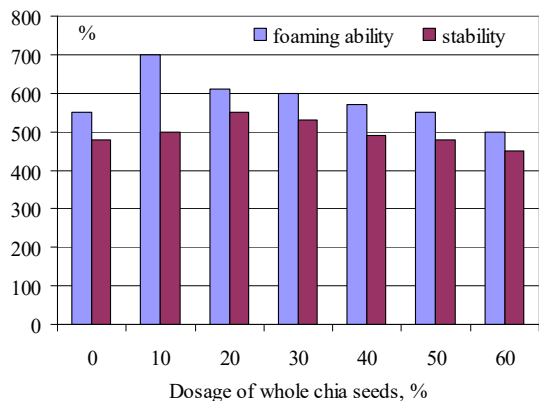


Fig. 6. The impact of whole chia seeds on the properties of whipped protein mass

One can give the following recommendations regarding the use of chia seeds in the technology of cream-whipped candy masses according to the results of the study:

- 1) it is advisable to use ground chia seeds at the stage of obtaining an emulsion semi-finished product. We recommend mixing it first with a fat component and then emulsifying it with moisture-containing raw materials. This method of addition makes it possible to use the maximum of fat-emulsifying and fat-retaining properties of the additive;
- 2) it is advisable to use whole chia seeds at the stage of obtaining whipped protein mass. The recommended dosage of the additive is up to 40 % by weight of dry protein. It will give a possibility to obtain whipped protein mass, which is not worse than the control sample in its stability and foaming ability.

5. 2. Results of studying the impact of chia seeds on the quality of cream-whipped candy masses

We evaluated the impact of chia seeds on the density and strength of structured cream-whipped candy masses to reveal their technological potential. In a view of the above recommendations, the whole seeds were added at the stage of obtaining the whipped protein mass. The dosage of the additive was up to 40 % by weight of dry egg albumin with a corresponding decrease in its formulation amount. We hydrated seeds previously in a solution of albumin for 10 minutes. The ground seeds were added at the stage of obtaining a fat emulsion semi-finished product in the amount of up to 50 % by weight of fat. We reduced the formulation amount of fat accordingly. Table 2 shows the results of the studies.

The data in Table 2 show that the addition of 30 % of the whole and 30 % of ground seeds (sample No. 1) led to a decrease in the density of cream-whipped candy mass by 6.7 %. A further increase in the dosage of the additive (samples No. 2 and No. 3) led to a slight increase in the density, but it remained 5.0 % less compared to the control sample. It was noted that the samples had the same values of this indicator. Sample No. 4 was at the control level by the density indicator. The candy mass with a maximum content of the additive (sample No. 5) had the density higher than the control one, by 6.7 %. The density indicator for the lightweight whipping

masses should not exceed 0.620 g/cm³ according to the technological documentation. Sample No. 6 did not meet these requirements.

Table 2

The impact of chia seeds on density and strength of structured cream-whipped candy masses (n=5, P≥0.95, σ=3...4 %)

Samples of structured cream-whipped candy masses	Quality indicator	
	density, g/cm ³	strength, g
Control without an additive	0.600	580
Dosage of an additive, % by weight of dry protein* (% by weight of fat**)		
Whole* 30 % and ground** 30 %, sample No. 1	0.560	590
Whole* 30 % and ground** 40 %, sample No. 2	0.570	610
Whole* 40 % and ground** 30 %, sample No. 3	0.570	610
Whole * 40 % and ground** 40 %, sample No. 4	0.600	630
Whole * 40 % and ground** 50 %, sample No. 5	0.640	660

The strength of cream-whipped candy masses increased with the addition of chia seeds in comparison with the control sample. The value of this indicator was within the error of the experiment for sample No. 1 (the difference with the control sample was 1.7 %). Samples No. 2 and No. 3 had the same value of strength, which was higher than the control one by 5.2 %. For samples No. 4 and No. 5, the increase in this indicator was 8.6 and 15 %, respectively, compared to the control sample.

The evaluation of organoleptic quality indicators of structured cream-whipped candy masses showed that samples No. 1–4 had a fine-porous fluffy structure. It was noted that the color became darker, the number of seed drops increased, and a nutty taste and odor intensified as the dosage increased. The structure of sample No. 5 was the densest, its porosity became uneven, and consistency was viscous and not usual for whipped light type candies. Therefore, we considered it inappropriate to use such a dosage of additives in further studies.

6. Discussion of results of studying the properties of chia seeds and their impact on the quality of candy masses

The studies on the ability of chia seeds to swell showed that the course of this process depends on a type of medium and a state of seeds (whole or ground) (Fig. 1–4). Chia seeds (whole and ground ones) have a higher capacity for absorption of moisture than for absorption of other test reagents (albumin solution and fat). Water molecules penetrate pores of a shell and are trapped in intercellular and free capillary spaces physically, as well as interact with proteins and non-starch polysaccharides of seeds. The insoluble fraction of non-starch chia seed polysaccharides is 20...22 % of its mass and consists mainly of cellulose, a small amount of lignin, and hemicelluloses [23].

There are a large number of hydroxyl groups and an advanced system of thin submicroscopic capillaries in cellulose. Thus, it has high water retention properties [14].

Soluble non-starch chia seed polysaccharides are predominantly mucous (gums). Their amount is 4...6 % by weight of seeds [39]. Gum is well hydrated in cold water and forms jellies. According to studies [41], formed jellies are placed in cellular structures of the first three layers of a seed shell firstly. After 60 s of hydration (Fig. 1), jellies go beyond seeds through microscopic openings in seed skin and become visible forming a transparent capsule with a sufficiently clear phase distribution boundary around it.

There are several reasons for the lower ability of chia seeds to retain an albumin solution (Fig. 4). Firstly, one can assume that chia seeds are not sufficiently free of water in the test system – it is bound by albumin largely. Secondly, the albumin solution has a higher viscosity, which complicates swelling of insoluble seed polysaccharides. There is no clear boundary of phase distribution in such samples (Fig. 2) because of complex formations of dry egg albumin with mucous substances of seeds. Chia mucous substances consist of xylose, glucose, and galacturonic acid residues (2:1:1) [40]. They are anionic heteropolysaccharides essentially [41]. Interaction of positively charged protein groups with negatively charged polysaccharide groups, as well as hydrophobic interactions and formation of hydrogen bonds lead to the formation of protein complexes with anionic polysaccharides. As a result of this complex formation, the integrity of a seed shell gets broken. It becomes friable and hilly visually (Fig. 2).

The interaction of chia seeds with fat is the least pronounced (Fig. 3, 4), because fat retention occurs only physically in pores of a shell and in intercellular and free capillary spaces inside a seed.

The ability to retain water, albumin solution or fat improves in the case of seed grinding, because of an increase in the active surface of interacting substances and an increase in the availability of functional groups localized within seeds. In addition, there is a release of dietary fiber and protein substances characterized by a capillary-porous structure. They bind and retain the liquid physically.

The release of substances with surface-active properties (proteins, phospholipids) also causes the manifestation of better fat-emulsifying properties by ground seeds (Fig. 5). One can explain the absence of emulsifying properties in whole chia seeds in model emulsion No. 1 (Fig. 5, *a*) by the following. When we add water first and then we add fat, there is fast absorption of moisture by seeds, as a result, the dispersion medium is absent for fat.

It is known that protein-anionic polysaccharide complexes have higher surfactant properties than a single protein. Therefore, the use of whole chia seeds helps to improve the foaming ability and stability of whipped protein masses based on albumin solution (Fig. 6). The best values of these indicators are typical of samples with the replacement of 10 % albumin with chia seeds. One can explain the deterioration of these properties in case of an increase in the dosage of the additive by a decrease in the concentration of protein substances in the system and sedimentation deposition of seeds. One should note that if one replaces 50 % of albumin with chia seeds, the characteristics of whipped protein mass remain at the level of the control sample. The ground seeds do not show the ability to form foams because there is a release of vegetable fat during grinding.

The evaluation of the quality of structured cream-whipped candy masses showed that the addition of up to 30 % of the whole and 30 % of ground chia seeds leads

to a decrease in their density (Table 2). One can explain this fact by high foaming, fat-retaining and fat-emulsifying properties of the additive. There is an increase in the density in case of a further increase in the dosage of seeds due to their higher density compared to candy mass – of 1.069 g/cm³ density [28]. To a certain extent, this leads to an increase in the strength of samples with additives. In addition, mucous substances of chia seeds are able to form jellies. Due to the fact that the formulation amount of agar in the preparation of cream-whipped candy masses did not change, this causes an increase in the total number of jelly forming agents in the system. This helps increase the strength of samples.

The organoleptic analysis showed that structured cream-whipped candy masses with the most investigated dosage of chia seeds have a densified structure, uneven porosity, and strong viscous consistency. Therefore, the recommended dosage of chia seeds in the technology of cream-whipped candy mass is 40 % of whole chia seeds by weight of dry egg albumin and 40 % of ground chia seeds by weight of fat with a decrease in their formulation amount.

The obtained results show that the addition of chia seeds to the technology of cream-whipped candy masses makes it possible to reduce the formulation amount of albumin by 40 % and the formulation amount of fat by 40 %. The obtained products are not worse than the control sample in terms of quality. However, the quality of a product implies its ability to maintain its properties for a regulated period. That is, further studies of changes in quality characteristics of cream-whipped candies with the addition of chia seeds during storage are promising.

7. Conclusions

1. We have determined the dependence of the degree of swelling of chia seeds on the type of a medium (water, albumin solution, fat) and the state of seeds (whole seeds or ground seeds). It was noted that the whole chia seeds have a higher ability to retain water than the ability to retain an albumin solution or fat, by 1.87 and 17.28 times, and ground ones – by 1.75 and 17.49 times, respectively. In the case of seeds grinding, their ability to swell improves regardless of a type of medium. In addition, ground seeds have a better fat-emulsifying ability but they do not have foaming properties. Considering this, we recommend adding the ground seeds to food systems, which contain fat. It was established that the addition of up to 30 % of whole chia seeds improves the foaming ability of albumin solution and increases the stability of whipped protein masses. It is possible to obtain whipped protein mass, which is not worse than the control sample in terms of stability and foaming ability in case of replacing 40 % of albumin with whole chia seeds.

2. It was noted that the structured cream-whipped candy masses with the most investigated dosage of chia seeds have a densified structure, uneven porosity, and strong viscous consistency. We recommend the addition of whole chia seeds at the stage of obtaining the whipped protein mass, and ground seeds – at the stage of obtaining a fat emulsion semi-finished product to ensure the high quality of cream-whipped candy masses. The dosage of whole seeds is 40 % by weight of dry egg albumin, and of ground seeds – 40 % by weight of fat with a corresponding decrease in their formulation amount.

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