



UDC 664.643.1

DOI: 10.31548/animal.13(3).2022.43-52

Effect of concentration of coconut oil with demineralised whey powder on the properties of bean pastes

Igor Stadnyk^{1*}, Volodymyr Piddubnuy², Halyna Karpyk¹, Liudmyla Beiko¹,
Khrystyna Kravcheniuk¹

¹Ternopil National Technical University named after I. Puliui
46001, 56 Ruska Str., Ternopil, Ukraine

²Kyiv National University of Trade and Economics
02156, 19 Kioto Str., Kyiv, Ukraine

Abstract. There is a lack of protein products in the human diet, so balancing the nutritional composition of products remains an urgent task. The purpose of the study is to develop and determine the structural and mechanical characteristics of finishing processed products made from bean paste, demineralised whey powder, and coconut oil for confectionery. The main areas of technological use of confectionery pastes are developed: for applying to the surface of products as a layer; for creating flowers and shaped model products, as a decorative element for flour confectionery products. The study used food-grade white beans of the Mavka variety, demineralised whey powder made from whey with a 90% degree of demineralisation in accordance with TS U 15.5-00413890-089:2014. Rheological properties (resilience, elasticity, plasticity) were determined by a plane-parallel elastoplastometer of Tolstoy modification. The surface characteristics of pastes were studied using a dynamometer connected to a MiG-1.3 measuring device. The adhesive strength was determined by separating the steel plate from the bean paste. Empirical regression equations are obtained by correlation and regression analysis using the MATHCAD-14 software suite. The chemical composition of bean pastes with demineralised whey powder, their organoleptic quality indicators and structural and mechanical properties were determined to optimise the recipe composition to improve the functional and technological properties of confectionery pastes. The positive effect of the mutual use of beans and demineralised whey powder on the structural and mechanical properties of new finishing processed products was established. The improvement of the moulding capacity indicators at the concentration of 10-30% demineralised whey powder and 8% coconut oil in the composition has been proven. The reduction of stickiness in the compositions of bean pastes for modelling shaped products, coating confectionery, and making flowers as decorative confectionery products at a concentration of coconut oil up to 10% was established. Accordingly, the total scores of the developed descriptors were: 2.92 for decorative confectionery, 2.98 for coating confectionery, and 2.95 for modelling shaped products. A change in the colour intensity of bean paste compositions in the case of an increase in the concentration of demineralised whey powder is established, which allows expanding the technological methods of manufacturing shaped products. The developed technology and recipe composition allow obtaining high-quality, high-biological value, and low-calorie finishing processed products for confectionery

Keywords: protein, beans, adhesive strength, rheological properties, optimisation, recipe composition, paste composition

Suggested Citation:

Stadnyk, I., Piddubnuy, V., Karpyk, H., Beiko, L., & Kravcheniuk, K. (2022). Effect of concentration of coconut oil with demineralised whey powder on the properties of bean pastes. *Animal Science and Food Technology*, 13(3), 43-52.

*Corresponding author

Introduction

Nowadays, there is a lack of protein products in the human diet. Since protein is a building material for cells, and performs a protective and transport function, supplying oxygen to the tissues of the human body, its lack leads to destructive changes in internal organs, bones, and weakens the immune system. Therefore, an urgent task for researchers and manufacturers is to develop and create products with a balanced nutritional composition. In particular, this applies to confectionery products, because they have a high caloric content and glycaemic index. Especially due to the content of sugar and fat in the recipe, which are of great technological importance in the formation of complex structures. Therefore, measures to develop a rational composition of confectionery products should be aimed at reducing caloric and improving nutritional value [1; 2].

The technological capabilities of the modern confectionery industry allow developing new products with a variety of taste properties, aromas, consistency, and shape. This approach is aimed at attracting the attention of consumers, that is, increasing demand. The creation of bean pastes with a concentration of 12-32% of demineralised whey powder (DWP) and 6% of coconut oil allows expanding the range of their technological properties. Such properties improve the organoleptic parameters of bean pastes and adjust the nutritional value [2]. Promising in this aspect is the influence of bean pastes on the confectionery coating products and modelling of shaped products of the confectionery industry, which were not previously described.

Expanding the raw material base of confectionery production is becoming a promising area for the development of the latest technologies. The use of raw materials rich in protein substances contributes to the expansion of the range of processed products and products with appropriate organoleptic and physicochemical parameters. The choice of components and their combination with each other should consider compatibility and exclude deterioration of consumer properties of products.

To a large extent, the health of a modern person depends on the nature, level, and structure of nutrition. In Ukraine today, there is an excessive consumption of flour confectionery products with low biological value, containing a large amount of sucrose [1]. The researchers [3] note that the high content of sugars in the daily diet of a person leads to a decrease in the sensitivity of the body's cells to it, the level of glucose in the blood increases, that is, conditions are created for the development of diabetes, metabolic processes are disrupted, and excess weight appears. In addition, high-calorie meals with a significant content of easily digestible sugars and fats can cause high cholesterol and weaken the immune system. Fat saturation also affects the incidence of diabetes and obesity in the population. Recipes of many confectionery products contain animal or trans fats. Saturated fats can cause heart and vascular diseases [1; 3]. Therefore, it is relevant to develop the latest health-improving food products with high quality indicators.

Haricot beans are one of the most common leguminous crops, the use of which is based on the balance of its amino acid composition, good digestibility of proteins by the human body, high taste and nutritional qualities of the crop and products from it, and the effectiveness of

pricing policy. Due to these properties, they are equated with such legumes as chickpeas, soybeans, peas, lentils, and beans [1]. Beans are traditionally grown on the territory of Ukraine. Due to their high biological value, they are widely used in the food industry, medicine, and cosmetics. Food products from this plant meet the human need for vegetable protein. It is consumed to prevent high cholesterol, heart and vascular diseases, and disorders of fat and protein metabolism [2; 3].

Beans have substances that promote the elimination of radionuclides from the human body [1; 2] and contain up to 32% protein. Beans also contain 41.1 to 54.7% carbohydrates, 2.2-6.6% fibre, 0.43-3.75% fat, and vitamins E, B₁, B₂, B₆, C. They contain a number of minerals – calcium, phosphorus, iron (up to 8%), potassium, sodium, iodine, magnesium, citric acid, and dietary fibre. According to the literature data [4-6], beans are a food product that contains almost all the substances for normal human nutrition. The existing toxic substances phenazine and glycoside are destroyed by heat treatment. Therefore, beans are among the dietary products.

Recent studies [7] have proven the possibility of using sweet bean paste made from boiled beans and sugar, for glueing cakes, pastries, and cookies. This paste is used as a layer for desserts, confectionery sticks, flour products, and for the manufacture of plastic mass in the design of confectionery products with curly decor [7; 8]. Such a processed product has a high biological and nutritional value, but has low organoleptic characteristics due to the specific taste and aroma of beans.

In [8-10], researchers suggest using a combination of DWP and beans of the Mavka variety in the recipe of confectionery paste. Due to the high content of biologically active substances, this combination provides a high nutritional value for finishing processed products.

In their papers, A. Dyakonova [11], M. Riabchenko and K. Ulianchenko [12] prove the expediency of studying the quality and safety of legumes, improving their consumer properties with the prospect of further application.

As evidenced by the experience of Ukrainian and foreign researchers, the use of beans in the production of processed confectionery products was insufficiently investigated. This includes an insufficient investigation of the use of the common Mavka variety of beans in the composition of confectionery pastes.

Based on the above, *the purpose of the study* is to develop and determine the structural and chemical characteristics of finishing bean confectionery pastes made from DWP and coconut oil.

To achieve this goal, it is necessary to consider and solve the following scientific and practical tasks:

- improve functional and technological properties of bean pastes in the composition of Mavka beans, DWP, and coconut oil.
- substantiate the prerequisite for the use of bean pastes for confectionery processed products of increased nutritional value and improved consumer properties;
- establish the feasibility of using DWP and coconut oil for the production of bean pastes;
- investigate the chemical composition of confectionery bean pastes with DWP.

Materials and Methods

The study began in 2019 at the Kyiv National University of Trade and Economics and continued in 2021 with the participation of the Ternopil Ivan Puluj National Technical University.

Materials under study – demineralised whey powder,

made from subsurface cheese whey with a 90% degree of demineralisation in accordance with TS U 15.5-00413890-089:2014 [13]; model compositions of bean pastes made from white beans of the Mavka variety with a dosage of DWP of 10-30% and coconut oil – 1-12% per 100 g (Table 1).

Table 1. Composition of the recipe for model compositions of bean pastes with DWP, per 100 g

| Raw material name | Control | Sample with coconut oil content, % | | | | |
|---|---------|------------------------------------|------|------|------|------|
| | | 4 | 6 | 8 | 10 | 12 |
| CC (confectionery coating) paste | | | | | | |
| Bean paste processed product | 81.0 | 78.3 | 76.0 | 76.5 | 74.0 | 74.0 |
| DWP | 21.0 | 18.1 | 18.0 | 16.4 | 16.0 | 15.0 |
| H ₂ O (water) | 11.0 | 9.5 | 11.0 | 10.1 | 11.0 | 11.0 |
| Coconut oil | – | 4.2 | 7.0 | 8.11 | 9.0 | 11.0 |
| DC (decorative confectionery) paste | | | | | | |
| Bean paste processed product | 89.0 | 87.6 | 87.0 | 87.0 | 85.0 | 84.0 |
| DWP | 9.0 | 8.1 | 7.0 | 6.0 | 5.0 | 4.0 |
| H ₂ O (water) | 6.0 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 |
| Coconut oil | – | 3.9 | 6.0 | 7.9 | 10.0 | 12.0 |
| MSP (modelling of shaped products) paste | | | | | | |
| Bean paste processed product | 70.0 | 68.0 | 67.0 | 66.0 | 65.0 | 64.0 |
| DWP | 30.0 | 28.0 | 27.0 | 26.0 | 25.0 | 24.0 |
| H ₂ O (water) | 15.0 | 14.9 | 14.9 | 14.9 | 14.9 | 14.9 |
| Coconut oil | – | 4.0 | 6.0 | 8.0 | 10.0 | 12.0 |

Evaluation of the possibility of using paste from white food beans of the Mavka variety with the additives of DWP and coconut oil in the developed recipe formulas is aimed at establishing the rheological, chemical and structural characteristics of their behaviour in a multicomponent system.

The main structural and mechanical properties of pastes with a given range of coconut oil concentrations were determined by the deformation characteristics. The rheological properties of the control and proposed samples were studied on a plane-parallel elastoplastometer of Tolstoy modification [14]. It determines the shear strain related to the thickness of the sample under constant stress. When studying the characteristics of model systems, fixed loads were selected for all variants (65 g), providing a temperature of +6°C and a sample height of 7 mm.

To determine the visco-elastic and visco-plastic properties, the method developed in [14] was used. According to the obtained data, the dependence of the stress action time relative to the strain is graphically displayed. The plastic viscosity of structured systems without destruction, while maintaining constant stresses, was calculated using the equation:

$$\dot{\eta}_0 = \tau / \operatorname{tg} \alpha, \quad (1)$$

where $\dot{\eta}_0$ – plastic viscosity, PA·s; $\operatorname{tg} \alpha$ – the angle of inclination of the linear section of the curve relative to the abscissa axis.

Determination of the aftereffect of elastic viscosity:

$$\dot{\eta}_{el} = \tau / \operatorname{tg} \beta, \quad (2)$$

where $\dot{\eta}_{el}$ – elastic viscosity aftereffect, PA·s; $\operatorname{tg} \beta$ – the angle of inclination of the beginning of the linear section of the curve relative to the abscissa axis.

The surface characteristics of the control and prototype samples were studied with a dynamometer, which was connected to a MiG-1.3 measuring device. It allowed characterising the level of adhesion of the samples under study during their surface contact. The adhesive strength was established using the method of normal separation of the steel plate from the bean paste. The obtained data was statistically processed using the standard Microsoft Office software suite.

Model compositions of finishing processed products were studied according to the developed organoleptic scales. They are based on indicators of appearance, consistency, taste, smell, and moulding ability. Display of the appearance characteristics of colour descriptors provided a range of colours for semi-finished products. The coefficients of weighting by consistency indicator for CC (confectionery coating) are 0.1:0.1:0.7:0.1; MSP (modelling of shaped products) – 0.3:0.2:0.2:0.3; DC (decorative confectionery) – 0.2:0.2:0.3:0.3. Areas of technological use: CC – 0.4:0.2; DC – 0.3:0.3; MSP – 0.2:0.4. The search for the optimal value of the mass fraction of DWP and coconut oil in bean pastes was determined by a multi-factor experiment. Figure 1 shows the order of the research.

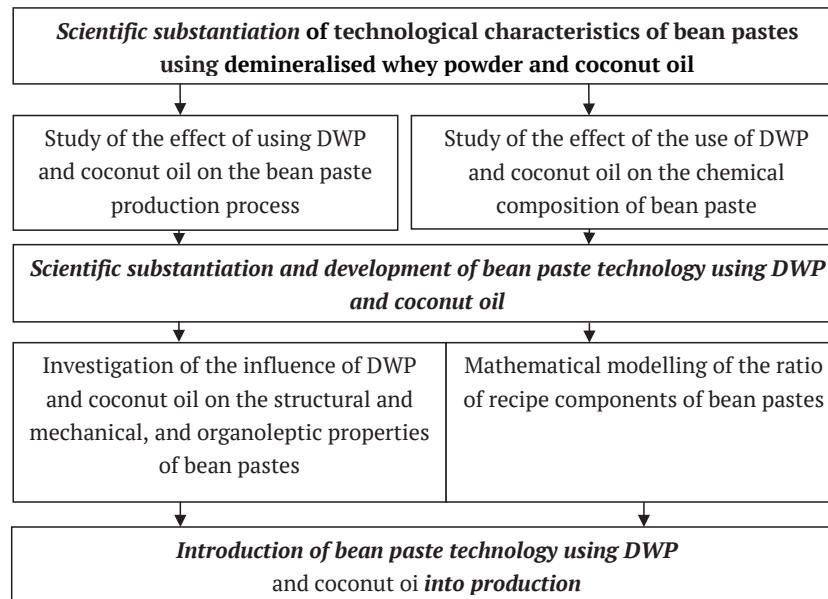


Figure 1. Scheme of the research procedure

The obtained results of the experimental array were statistically processed using correlation and regression analysis using MATHCAD-14 software suite. The obtained empirical regression equations allow qualitatively and quantitatively assessing the characteristics of the selection of matrix components [15; 16].

Defined variable factors: x_1 – coconut oil content, %; x_2 – DWP content, %. According to the design of the experiment, a full factorial experiment of type 2¹, with two factors, was implemented. Levels and intervals of factor variation (Table 2). The area for determining factors is found (Table 3).

Table 2. Level and interval of variation of the factor of complex rheological indicator of the consistency of bean pastes with DWP

| Factors | Code designations | Variable intervals | Factor level | | |
|------------------------|-------------------|--------------------|--------------|------------|-----------|
| | | | Main (0) | Upper (+1) | Lower(-1) |
| Coconut oil content, % | x_1 | 4 | 10 | 20 | 0 |
| DWP content, % | x_2 | 5 | 20 | 40 | 0 |

Table 3. Complex rheological indicator of the consistency of bean pastes with DWP

| Samples | Value | | | |
|---------|------------------|----------|----------------|---|
| | Moulding ability | Strength | Stretchability | Complex indicator |
| | Y_1 | Y_2 | Y_3 | Y |
| DC | 0.41 | 0.21 | 0.39 | $Y_{DC} = 0.39Y_1 + 0.22Y_2 + 0.39Y_3$ |
| CC | 0.14 | 0.16 | 0.69 | $Y_{CC} = 0.16Y_1 + 0.16Y_2 + 0.7Y_3$ |
| MSP | 0.59 | 0.26 | 0.15 | $Y_{MSP} = 0.59Y_1 + 0.24Y_2 + 0.14Y_3$ |

Note: Y_{CC} – complex rheological indicator of bean paste for CC, points; Y_{MSP} – complex rheological indicator of bean paste for MSP, points; Y_{DC} – complex rheological indicator of bean paste for DC, points

Using multivariate regression analysis, the response surface is constructed. The defined values of the response

functions for the specified rheological parameters are shown in Figures 2, 3.

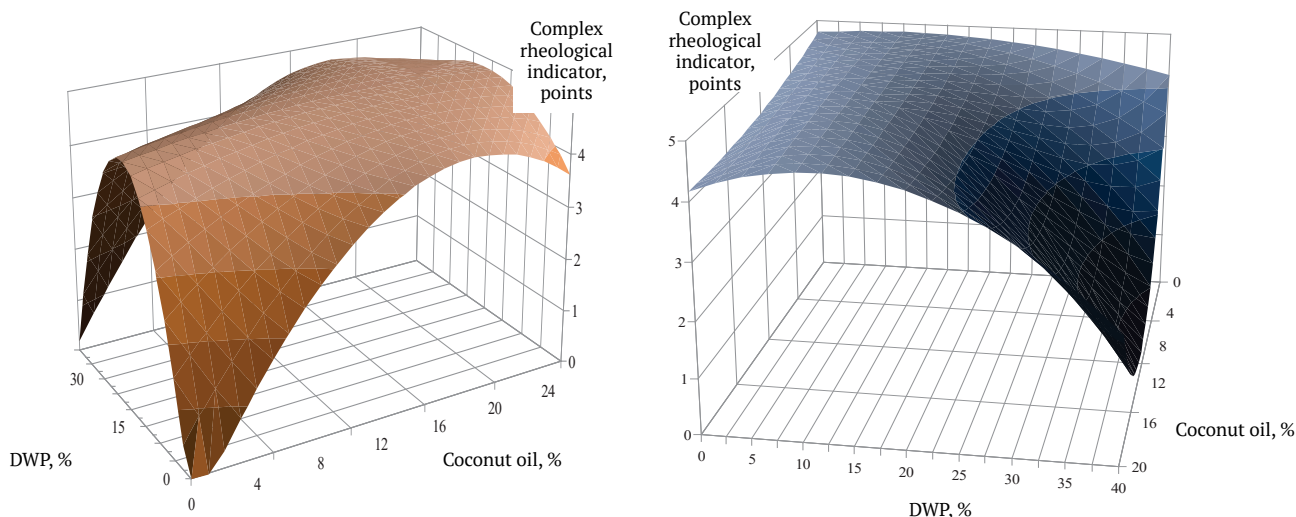


Figure 2. Response surface of the factor space of the complex rheological indicator: A – bean paste for CC; 2 – bean paste for DC

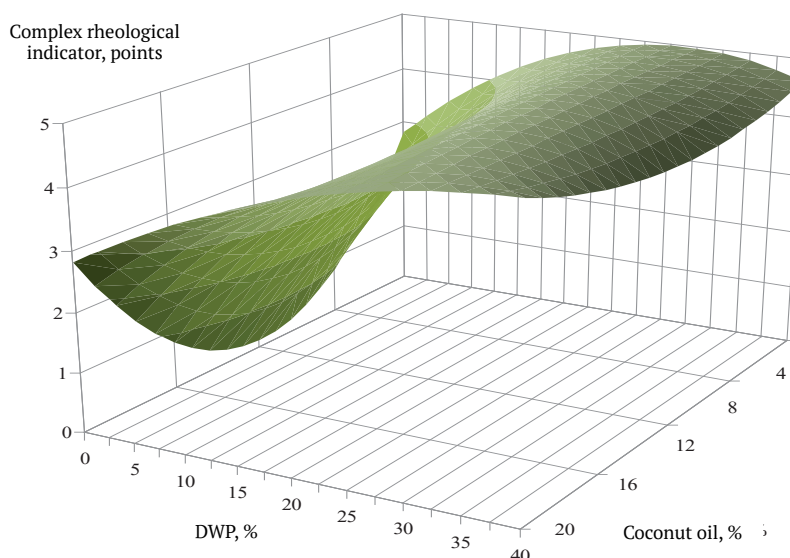


Figure 3. Response surface of the factor complex rheological space indicator for bean paste MSP

The dependences of the complex rheological indicator on the content of coconut oil and DWP are described

using the following mathematical models (1-3):

$$Y_{CC} = 3.3 \times 10^{-5} x_1^2 x_2^2 + 0.00136 x_1 x_2^2 + 0.00121 x_1^2 x_2 - 0.0106 x_1^2 - 0.0188 x_2^2 + 0.4423 x_1 + 0.6792 x_2 - 0.9208 \quad (1)$$

$$Y_{DC} = 2.92 \times 10^{-5} x_1^2 x_2^2 - 0.000515 x_1 x_2^2 - 0.000692 x_1^2 x_2 + 0.0131 x_1 x_2 - 0.00091 x_2^2 + 0.00841 x_1 - 0.072 x_2 + 4.856 \quad (2)$$

$$Y_{MSP} = 3.64 \times 10^{-5} x_1^2 x_2^2 - 0.002 x_1 x_2^2 - 0.00065 x_1^2 x_2 + 0.0373 x_1 x_2 - 0.0287 x_2^2 + 0.00597 x_1 - 0.546 x_2 + 4.917 \quad (3)$$

The obtained data allowed determining the optimal ratio of components of the developed bean pastes (Table 4). It is established that all factors are statistically significant. The

greatest statistical value in assessing mutual influence is their use. Based on the data, the optimal ratio of components of the developed bean pastes was determined (Table 4).

Table 4. Optimisation parameters for recipe components of bean pastes

| Sample indicators | Coconut oil, % | | | DWP, % | | |
|-------------------|----------------|---------------|---------------|---------------|---------------|--------------|
| | Minimum value | Maximum value | Optimal value | Minimum value | Maximum value | Optimal data |
| CC | 9.7 | 10.2 | 9.0 | 19.5 | 22.6 | 21.0 |
| DC | 9.8 | 10.13 | 9.0 | 10.0 | 10.8 | 10.0 |
| MSP | 9.7 | 10.12 | 9.0 | 28.9 | 30.9 | 31.0 |

Optimal values are selected by rounding the optimised values within compromise areas to facilitate the dosing of recipe components of bean pastes in a production environment.

Results and Discussion

The results of studies [15; 16] on the organoleptic, and structural and mechanical characteristics of bean pastes allowed determining the zone of rational concentrations of DWP and coconut oil in the developed formulations by a planned experiment.

Clearly, an increase in the concentration of DWP in bean pastes increases the adhesive and cohesive strength, which makes it difficult to work with them. A possible solution to this problem is to use coconut oil, which contains saturated fatty acids – lauric and myristic and a small amount of volatile acids: caprylic and capronic. Therefore, in the production of products made from bean pastes, the selection of the optimal composition of ingredients according to the recipe is an urgent issue.

Some studies [10; 17] were aimed at finding the optimal ratio of structure-forming components of bean taste and aroma. On their basis, harmonious taste and aroma compositions are created. Therefore, the effectiveness of using DWP in the technology of bean paste should be aimed at eliminating the taste and aroma properties of beans with the creation of their harmonious compositions.

The properties of demineralised whey powder (DWP) and its high moisture-binding and moisture-retaining ability in the technology of bean pastes are described in sufficient detail in [18], which allowed taking the data into account in this study. The assistance of DWP in the creation of a

stronger structure was also established, which is conditioned by the emergence and development of the spatial framework. Therefore, in the continuous phase of the dispersion medium, stronger hydrogen bonds appear and the frame acquires static shear strength, which gives certain structural and mechanical properties to bean pastes.

It is proved [19] that a different ratio of DWP can be used to regulate these qualitative indicators. It was found [20; 21] that the DWP concentration of 11-31% affects changes in the structural characteristics of bean pastes, improving technological and functional properties. At the same time, this dosage of DWP provides the best rheological characteristics of pastes and, accordingly, gives them optimal moulding ability.

Consequently, the formation of the structure of bean pastes is caused by oppositely directed processes: destruction of the enzymatic cell structure and aggregation of protein particles in the spatial framework due to dehydration of the system. In addition, strong covalent bonds appear, and this is an improvement in the structural and mechanical properties of the paste.

The chemical composition was studied and the protein quality of bean pastes with DWP was evaluated (Tables 5, 6). The protein content is 9.8-10.3%, sucrose is reduced by 1.2 times, which indicates an increase in the quality of protein in the developed pastes. The fat content is 10%. The results of studies of carbohydrate composition reflected a decrease in sucrose, starch, and food fibres by 1.25-1.45 times compared to the control. There was also an increase in the amount of lactose by 11-16% of the total carbohydrate composition.

Table 5. Chemical composition of bean pastes with DWP

| Indicators | Control | CC | Difference, units | DC | Difference, units | MSP | Difference, units |
|---------------------------|---------------|---------------|-------------------|---------------|-------------------|---------------|-------------------|
| Protein, % | 10.1 ± 0.4 | 10.2 ± 0.2 | 0.1 | 9.8 ± 0.5 | -0.3 | 10.3 ± 0.2 | 0.2 |
| Fats, % | 1.0 ± 0.5 | 10.9 ± 0.3 | 9.9 | 10.9 ± 0.4 | 9.9 | 10.9 ± 0.4 | 9.9 |
| Carbohydrates, % | 75.3 ± 0.4 | 68.6 ± 0.4 | -6.7 | 68.5 ± 0.5 | -6.8 | 68.9 ± 0.2 | -6.4 |
| incl. Sucrose, % | 51.6 ± 0.1 | 39.2 ± 0.4 | -12.4 | 44.4 ± 0.5 | -7.2 | 34.1 ± 0.2 | -17.5 |
| Lactose, % | – | 11.4 ± 0.1 | 11.4 | 3.8 ± 0.2 | 3.8 | 19.2 ± 0.4 | 19.2 |
| Starch, % | 21.7 ± 0.1 | 16.5 ± 0.1 | -5.2 | 18.7 ± 0.3 | -3.0 | 14.3 ± 0.3 | -7.4 |
| Dietary fibre, % | 1.9 ± 0.4 | 1.5 ± 0.1 | -0.4 | 1.7 ± 0.4 | -0.2 | 1.3 ± 0.1 | -0.6 |
| <i>Macronutrients, mg</i> | | | | | | | |
| Potassium (K) | 550.0 ± 0.1 | 608.5 ± 0.3 | 58.5 | 536.5 ± 0.1 | 13.5 | 1395 ± 0.1 | 845.5 |
| Calcium (Ca) | 75.0 ± 0.2 | 283.5 ± 0.3 | 208.5 | 140.0 ± 0.2 | 65.0 | 524.5 ± 0.5 | 449.5 |
| Magnesium (Mg) | 51.5 ± 0.1 | 76.6 ± 0.1 | 25.1 | 56.8 ± 0.4 | 5.3 | 163.4 ± 0.1 | 111.9 |
| Phosphorus (P) | 271.5 ± 0.1 | 396.8 ± 0.1 | 125.3 | 296.9 ± 0.4 | -25.4 | 849.6 ± 0.1 | 578.1 |
| <i>Microelements, mcg</i> | | | | | | | |
| Iron (Fe) | 2,970.0 ± 0.1 | 2,656.2 ± 0.1 | -313.8 | 2,687.2 ± 0.2 | -282 | 2,625.0 ± 0.1 | -345.0 |
| Iodine (I) | 6.1 ± 0.1 | 14.8 ± 0.5 | 11.4 | 8.6 ± 0.1 | 2.5 | 20.9 ± 0.2 | 14.9 |
| Manganese (Mn) | 670.0 ± 0.2 | 510.7 ± 0.1 | -159.3 | 576.7 ± 0.3 | -93.3 | 444.7 ± 0.1 | -225.3 |
| Copper (Cu) | 290.0 ± 0.1 | 220.4 ± 0.5 | -69.6 | 249.4 ± 0.3 | -40.6 | 191.4 ± 0.5 | -98.6 |
| Molybdenum (Mo) | 19.7 ± 0.2 | 14.9 ± 0.4 | -4.7 | 16.9 ± 0.1 | -2.8 | 13.0 ± 0.5 | -6.7 |
| Fluorine (F) | 22.0 ± 0.3 | 16.7 ± 0.1 | -5.3 | 18.9 ± 0.4 | -3.1 | 14.5 ± 0.5 | -7.5 |
| Zinc (Zn) | 1,605.0 ± 0.5 | 1,534.8 ± 0.1 | -70.2 | 1,485.3 ± 0.1 | -119 | 1,584.3 ± 0.1 | -20.7 |

| Indicators | Control | CC | Difference, units | DC | Difference, units | MSP | Difference, units |
|---------------------------|------------|------------|-------------------|------------|-------------------|------------|-------------------|
| <i>Vitamins</i> | | | | | | | |
| Tocopherol (E), mg | 1.92 ± 0.1 | 1.45 ± 0.2 | -0.47 | 1.65 ± 0.1 | -0.27 | 1.27 ± 0.4 | -0.65 |
| Ascorbic acid (C), mg | – | 0.75 ± 0.2 | 0.75 | 0.25 ± 0.1 | 0.25 | 1.25 ± 0.1 | 1.25 |
| Pyridoxine (B6), mg | 0.45 ± 0.2 | 0.44 ± 0.1 | -0.01 | 0.41 ± 0.1 | -0.04 | 0.45 ± 0.5 | – |
| Cobalamin (B12), mcg | – | 0.36 ± 0.1 | 0.36 | 0.12 ± 0.3 | 0.12 | 1.56 ± 0.5 | 1.56 |
| Biotin (B7), mcg | – | 5.55 ± 0.3 | 5.55 | 1.85 ± 0.1 | 1.85 | 9.25 ± 0.1 | 9.25 |
| Niacin (B3,PP), mg | 1.05 ± 0.1 | 0.91 ± 0.4 | -0.14 | 0.94 ± 0.3 | -0.11 | 0.85 ± 0.1 | -0.2 |
| Pantothenic acid (B5), mg | 0.6 ± 0.4 | 1.29 ± 0.5 | 0.69 | 0.79 ± 0.2 | 0.19 | 1.79 ± 0.4 | 1.19 |
| Riboflavin (B2), mg | 0.09 ± 0.4 | 0.25 ± 0.1 | 0.19 | 0.13 ± 0.2 | 0.04 | 0.37 ± 0.3 | 0.28 |
| Thiamine (B1), mg | 0.25 ± 0.1 | 0.22 ± 0.5 | -0.03 | 0.22 ± 0.1 | -0.03 | 0.21 ± 0.1 | -0.04 |
| Folacin (B9), mcg | 45.0 ± 0.3 | 35.9 ± 0.3 | -9.1 | 38.3 ± 0.4 | -6.7 | 32.6 ± 0.2 | -12.4 |
| Choline (B4), mg | – | 15.0 ± 0.1 | 15.0 | 5.0 ± 0.5 | 5.0 | 25.0 ± 0.2 | 25.0 |
| Energy value, kcal | 331 | 376 | 45 | 372 | 41 | 361 | 30 |
| Glycaemic index | 53 | 49 | -4 | 50 | -3 | 47 | -6 |

Note: (dry matter content per 100 g), $p \leq 0.05$

Table 6. Protein quality assessment of bean pastes with DWP

| Essential amino acid | Control | | CC | | DC | | MSP | |
|--------------------------|---------|-------|-----|-------|-----|-------|-----|-------|
| | C | ΔAASD | C | ΔAASD | C | ΔAASD | C | ΔAASD |
| Lysine | 205 | 145 | 189 | 132 | 149 | 98 | 161 | 107 |
| Threonine | 118 | 58 | 120 | 63 | 125 | 74 | 132 | 78 |
| Valine | 140 | 80 | 132 | 75 | 130 | 79 | 126 | 72 |
| Methionine+Cystine | *60 | 0 | *57 | 0 | *51 | 0 | *54 | 0 |
| Leucine | 180 | 120 | 164 | 107 | 150 | 99 | 135 | 81 |
| Isoleucine | 155 | 95 | 142 | 85 | 135 | 84 | 122 | 68 |
| Tyrosine + Phenylalanine | 118 | 58 | 108 | 51 | 102 | 51 | 93 | 39 |
| Tryptophan | 130 | 70 | 110 | 53 | 120 | 69 | 110 | 56 |
| ΣΔAASD | – | 626 | – | 566 | – | 554 | – | 501 |
| AASDF | – | 78 | – | 70 | – | 69 | – | 62 |

Improvement of the vitamin and mineral composition of the developed bean pastes was established. The content of macronutrients increases significantly, in particular, K by 59-846 mg, Ca by 209-450 mg, and P by 126-579 mg. The vitamin composition was supplemented with vitamin C (0.75 – 1.25 mg), B₁₂ (0.36 – 1.56 mcg), B₇ (5.55-9.25 mcg), B₄ (15-25 mg), vitamin B₅ increased by 0.69-1.19 mcg, B₂ by 0.19-0.28 mg (Table 5).

The developed bean pastes belong to products with an average GI (glycaemic index), which is 47-50 units, but the energy value increases by 15-20% compared to the control.

As a result of the research, an increase in the colour intensity of model compositions of bean pastes was found with an increase in the concentration of DWP, which approaches a light cream colour and, accordingly, contributes to the disappearance of transparency of the consistency inherent in traditional bean pastes. This allows expanding the areas of their technological use. Thus, the resulting paste becomes suitable for covering confectionery products and modelling of various shapes.

The presence of DWP in the amount of 11-31% in bean pastes increases the saturation of milk taste and smell, and also helps to “mask” the bean taste and aroma. DWP at a concentration of 10-30% creates a harmonious, balanced taste and aroma composition.

The introduction of DWP in the formulation of bean pastes improves their consistency. Increased density and strength indicators while reducing softness optimise the product moulding. However, an increase in the concentration of DWP leads to an increase in stickiness indicators by 10%, which is the main disadvantage.

The results of organoleptic analysis of the developed descriptors indicate that CC pastes have the best indicators. Thus, at an DWP concentration of 20%, the total score is 4.64. For DC paste, the highest overall score is set at a DWP concentration of 30%, but the recommended DWP concentration is 10%. This is substantiated by the optimal score when evaluating appearance indicators, since only bean pastes have a unique transparency, which is optimally preserved only at a DWP concentration of 10%. This typical

transparency allows making flowers from bean paste as a decorative element for finishing confectionery products as realistic as possible. For MSP paste, the best values are observed at a DWP concentration of 30%.

The process of making compositions of bean pastes with demineralised whey powder with the addition of coconut oil is essentially mixing the components. In the

process, the formulation mixture undergoes physicochemical transformations and interacts with each other to form various bonds. The mixed mass of the paste belongs to a visco-plastic structured system [20]. Accordingly, the effect of bean pastes with a concentration of DWP and coconut oil in the amount of 4-12% on the adhesive strength indicators was established. The data is summarised in Table 7.

Table 7. Adhesive strength ($\omega\alpha$) of bean paste compositions with DWP and coconut oil

| Designation | Samples with coconut oil concentration, % | | | | | |
|--|---|-------|-------|-------|-------|-------|
| | 0 | 4 | 6 | 8 | 10 | 12 |
| ($\omega\alpha$), H/m ² , DWP 21% | 65.1 | 42.1 | 35.3 | 27.9 | 24.2 | 23.5 |
| Difference, % | – | -22.2 | -29.1 | -36.4 | -43.2 | -41.1 |
| ($\omega\alpha$), H/m ² , DWP 11% | 56.3 | 37.0 | 31.5 | 26.2 | 22.0 | 22.4 |
| Difference, % | – | -18.6 | -24.2 | -29.5 | -33.6 | -33.9 |
| ($\omega\alpha$), H/m ² , DWP 31% | 7.2 | 55.5 | 48.0 | 39.9 | 26.2 | 25.1 |
| Difference, % | – | -18.3 | -30.8 | -25.8 | -47.6 | -48.7 |

Note: ($n = 5, p \leq 0.05$)

Table 7 shows that the adhesive strength of bean pastes decreases from 65.1 to 23.5 H/m² at a DWP concentration of 20%, from 56.3 to 22.4 H/m² at a DWP concentration of 11%, and from 73.8 to 25.2 H/m² at a DWP concentration of 31%. The presence of coconut oil reduces the adhesive strength of bean paste with DWP by three times compared to the control sample. The concentration of 11% of coconut

oil in the composition of bean pastes with DWP brings the adhesive strength closer to the characteristics of prepared pastes using conventional technologies. The components of the paste have different effects on the deformation characteristics of model compositions. The effect of coconut oil concentration on the deformation characteristics of model compositions of bean pastes with DWP is shown in Table 8.

Table 8. Deformation characteristics of model compositions of bean pastes with DWP and coconut oil

| Name of the indicator | Designation | Samples with coconut oil concentration, % | | | | | | |
|--|------------------|---|-------|-------|-------|-------|-------|-------|
| | | 0 | 4 | 6 | 8 | 10 | 12 | |
| Reverse deformation, 10 ⁻³ | γ_{rev} | CC | 340.0 | 325.7 | 302.9 | 301.0 | 287.1 | 281.4 |
| | | DC | 358.6 | 348.6 | 337.1 | 328.6 | 305.2 | 291.1 |
| | | MSP | 334.3 | 328.1 | 312.9 | 305.0 | 289.1 | 276.4 |
| Irreversible deformation, 10 ⁻³ | γ_{irr} | CC DC MSP | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 |
| | | CC | 352.9 | 338.6 | 325.7 | 319.9 | 311.0 | 294.3 |
| Total deformation, 10 ⁻³ | γ_{total} | DC | 371.4 | 361.4 | 350.0 | 341.4 | 320.0 | 300.1 |
| | | MSP | 347.1 | 337.1 | 315.7 | 312.9 | 304.2 | 277.3 |
| | | | | | | | | |

Note: ($n = 5, p \leq 0.05$)

Data from the table indicate a gradual decrease in the total deformation by 25-30% relative to the control. The irreversible deformation is stable for all prototypes, regardless of the concentration of DWP and is 12.9 c.u. A decrease was established in the DC deformation index – from 358.6 to 291.1 c.u.; CC – from 340.0 to 281.4 c.u.; MSP – from 334.3 to 276.4 c.u. This trend of change indicates a significant effect of coconut oil on the consistency of bean pastes with DWP.

Based on comparisons of bean paste with marzipan, the strength character is established. Therefore, coconut oil, which has certain crystallisation properties, is a promising component. In general, the experiments described above indicate the feasibility of using coconut oil in bean

paste technology. The results of the analysis confirm a decrease in the stickiness of model bean pastes CC, MSP, DC with an increase in the concentration of coconut oil. It also creates conditions for increasing strength and density with a decrease in stretchability indicators.

The results of organoleptic studies showed the best consistency of the compositions of bean pastes with DWP was observed with the 11% concentration of coconut oil. The total score of the developed descriptors was 2.97 for CC, 2.93 for DC, and 2.94 for MSP. Therefore, the impact that is carried out on improving the overall assessment of bean pastes is conditioned primarily by the properties of coconut oil. Evaluating the organoleptic quality indicators of the studied bean pastes, the appearance should be noted,

namely, a unique transparent colour with a light yellow hue, which allows them to be used in the production of decorative elements for finishing confectionery.

Conclusions

Thus, the results of the conducted studies confirmed the prospects of using DWP in the technologies of bean pastes in a concentration of 11-31% and coconut oil in an amount of 10%. The established dosage allows obtaining the desired structural and mechanical properties of finishing processed products in accordance with the area of their technological use. The developed technology of semi-finished products provides high-quality and low-calorie finishing processed products for confectionery.

It has been experimentally confirmed that the developed technologies of semi-finished products with 11-31% DWP in bean pastes significantly improve the mineral and vitamin composition. The balanced chemical composition of

bean confectionery pastes based on DWP and coconut oil contributes to the expansion of the range of low-calorie finishing processed products. The nutritional and biological value of the developed bean pastes is experimentally confirmed.

The solution of the research tasks provided the following scientific results:

1. Stabilisation of the rheological characteristics of the bean paste is achieved due to the properties of DWP and coconut oil.

2. Technological basis of the conducted research is an important area for expanding the range of confectionery products. In addition, the proposed recipe composition of processed products improves their organoleptic quality indicators and helps to ensure dietary nutrition conditions.

The prospect of further research is aimed at expanding the investigation of the rheological properties of bean pastes in relation to the use of non-conventional plant raw materials to improve their chemical composition.

References

- [1] Kuryata, V.G., & Golunova, L.A. (2018). Peculiarities of the formation and functioning of soybean-rhizobial complexes and the productivity of soybean culture under the influence of retardant of paclobutrazol. *Ukrainian Journal of Ecology*, 8(3), 98-105.
- [2] Honcharuk, I., & Pantsyreva, H. (2020). Efficiency of growing legumes crops in Ukraine. In *Integration of traditional and innovation processes of development of modern science* (pp. 42-65). Latvia: Baltija Publishing.
- [3] Cifu, D.X., Carne, W., Pushkin, H., & Cifu, I. (2020). The basics of nutrition: A primary rehabilitation intervention. *Physical Medicine and Rehabilitation Clinics*, 31(4), 665-684. doi: 10.1016/j.pmr.2020.07.001.
- [4] Mutari, B., Sibiya, J., Bogweh Nchanji, E., Simango, K., & Gasura, E. (2021). Farmers' perceptions of navy bean (*Phaseolus vulgaris* L.) production constraints, preferred traits and farming systems and their implications on bean breeding: A case study from South East Lowveld region of Zimbabwe. *Journal of Ethnobiology and Ethnomedicine*, 17(1), 1-19. doi: 10.1186/s13002-021-00442-3.
- [5] Didur, I., Chupshuk, O., Pantsyreva, H., Olifirovych, S., Olifirovych, V., & Tkachuk, O. (2021). Effect of fertilizers for *Phaseolus vulgaris* L. productivity in Western Forest-Steppe of Ukraine. *Ukrainian Journal of Ecology*, 11(1), 419-424. doi: 10.15421/2021_61.
- [6] Ntatsi, G., Karkanis, A., Yfantopoulos, D., Olle, M., Travlos, I., Thanopoulos, R., Bilalis, D., Bebeli, P., & Savvas, D. (2018). Impact of variety and farming practices on growth, yield, weed flora and symbiotic nitrogen fixation in faba bean cultivated for fresh seed production. *Acta Agriculturae Scandinavica, Section B – Soil & Plant Science*, 68(7), 619-630. doi: 10.1080/09064710.2018.1452286.
- [7] Stadnyk, I., Piddubnyi, V., Kravchenko, M., Rybchuk, L., Balaban, S., & Veselovska, T. (2021). The effect of dry demineralized whey (DDW) and coconut oil on the rheological characteristics of the legume butter. *Potravinarstvo Slovak Journal of Food Sciences*, 15, 318-329. doi: 10.5219/1578.
- [8] Yong, H., Wang, X., Sun, J., Fang, Y., Liu, J., & Jin, C. (2018). Comparison of the structural characterization and physicochemical properties of starches from seven purple sweet potato varieties cultivated in China. *International Journal of Biological Macromolecules*, 120, 1632-1638. doi: 10.1016/j.ijbiomac.2018.09.182.
- [9] Li, Z., Rui, J., Li, X., Li, J., Dong, L., Huang, Q., Chen, F. (2017). Bacterial community succession and metabolite changes during doubanjiang-meju fermentation, a Chinese traditional fermented broad bean (*Vicia faba* L.) paste. *Food Chemistry*, 218, 534-542. doi: 10.1016/j.foodchem.2016.09.104.
- [10] Kilara, A. (2015). Whey and whey products. In *Dairy processing and quality assurance* (pp. 349-366). Malden: Wiley-Blackwell. doi: 10.1002/9781118810279.ch15.
- [11] Kolyanovska, L., Palamarchuk, I., Sukhenko, Y., Mussabekova, A., Bissarinov, B., Popiel, P., Mushtruk, M., Sukhenko, V., Vasuliev, V., Semko, T., & Tyshchenko, L. (2019). Mathematical modeling of the extraction process of oil-containing raw materials with pulsed intensification of heat of mass transfer. In R.S. Romaniuk, A. Smolarz, & W. Wójcik (Eds.), *Optical Fibers and Their Applications: Society of Photo-Optical Instrumentation Engineers*, article number 11045. doi: 10.1117/12.2522354.
- [12] Mushtruk, M., Bal-Prylypko, L., Slobodyanyuk, N., Boyko, Y., & Nikolaienko, M. (2022). Design of reactors with mechanical mixers in biodiesel production. In *Design, simulation, manufacturing: The innovation exchange* (pp. 197-207). Cham: Springer.
- [13] Erem, E., Icyer, N.C., Tatlisu, N.B., Kilicli, M., Kaderoglu, G.H., & Toker, Ö.S. (2021). A new trend among plant-based food ingredients in food processing technology: Aquafaba. *Critical Reviews in Food Science and Nutrition*, 1-18. doi: 10.1080/10408398.2021.2002259.
- [14] Pycarelle, S.C., & Delcour, J.A. (2021). The role and impact on quality of exogenous and endogenous lipids during sponge cake making. *Trends in Food Science & Technology*, 114, 158-166. doi: 10.1016/j.tifs.2021.05.015.

- [15] Kumar, A., Sehrawat, R., & Saxena, D.C. (2019). Development of *Pakoda* using semi-automatic pakoda-making machine: Thermal, rheological, physicochemical and sensory properties. *Journal of The Institution of Engineers (India): Series A*, 100(4), 593-599. doi: 10.1007/s40030-019-00385-9.
- [16] Stadnyk, I., Piddubnyi, V., Kravchenko, M., Rybchuk, L., Kolomiets, O., & Danylo, S. (2020). Adhesion of marzipan pastes based on dry demineralized whey. *Potravinarstvo Slovak Journal of Food Sciences*, 14, 1149-1160. doi: 10.5219/1351.
- [17] Savini, F., & Bertolini, L. (2019). Urban experimentation as a politics of niches. *Environment and Planning A: Economy and Space*, 51(4), 831-848. doi: 10.1177/0308518X198260.
- [18] Kovalyshyna, H., Dmytrenko, Y., Makarchuk, O., Slobodyanyuk, N., & Mushtruk, M. (2020). The donor properties of resources resistance against the exciter of wheat rust wheat. *Potravinarstvo Slovak Journal of Food Sciences*, 14, 821-827. doi: 10.5219/142.
- [19] Su, H.L., & Chang, K.C. (1995). Physicochemical and sensory properties of dehydrated bean paste products as related to bean varieties. *Journal of Food Science*, 60(4), 794-797. doi: 10.1111/j.1365-2621.1995.tb06231.x.
- [20] Saini, D., Rawat, N., Negi, T., Barthwal, R., & Sharma, S.K. (2021). Utilization, valorization and functional properties of wild apricot kernels. *Journal of Pharmacognosy and Phytochemistry*, 10(4), 119-126.
- [21] Zobel, H.F. (1984). Gelatinization of starch and mechanical properties of starch pastes. In *Starch: Chemistry and technology* (pp. 285-309). Cambridge: Academic Press. doi: 10.1016/B978-0-12-746270-7.50015-X.
- [22] Caridi, F., Acri, G., Belvedere, A., Crupi, V., D'Agostino, M., Marguccio, S., Majolino, D. (2021). Evaluation of the radiological and chemical risk for public health from flour sample investigation. *Applied Sciences*, 11(8), article number 3646. doi: 10.3390/app11083646.

Вплив концентрації кокосової олії із МССД на властивості бобових паст

Ігор Ярославович Стадник¹, Володимир Антонович Піддубний²,
Галина Вікторівна Карпик¹, Людмила Анатолівна Бейко¹,
Христина Юрїївна Кравченко¹

¹Тернопільський національний технічний університет ім. І. Пулюя
46001, вул. Руська, 56, м. Тернопіль, Україна

²Київський національний торговельно-економічний університет
02156, вул. Кіото, 19, м. Київ, Україна

Анотація. В раціоні харчування людини спостерігається нестача білкових продуктів, тому актуальним завданням сьогодення залишається збалансування нутрієнтного складу продуктів. Метою досліджень є розроблення та визначення структурно-механічних характеристик оздоблювального напівфабрикату із пасти бобової, молочної сироватки сухої демінералізованої та кокосової олії для кондитерських виробів. Розроблено основні напрями технологічного використання кондитерських паст: для нанесення на поверхню виробів в якості шару; для розроблення квітів та фігурних модельних виробів, як декоративного елементу для борошняних кондитерських виробів. Використано квасолю білу продовольчого сорту «Мавка», молочну сироватку сухої демінералізовану, виготовлену із підсирної сироватки з 90 % ступенем демінералізації відповідно ТУ У 15.5-00413890-089:2014. Реологічні властивості (пружність, еластичність, пластичність) визначали плоскопаралельним еластопластометром Толстого. Поверхневі характеристики паст вивчали динамометром, підключеним до вимірювального приладу MIG-1.3. Адгезійну міцність визначали відривом від бобової пасти пластинки сталеві. Одержано емпіричні рівняння регресії методом кореляційного та регресійного аналізу з використанням програми MathCAD-14. Визначено хімічний склад бобових паст з молочною сироваткою сухою демінералізованою, їх органолептичні показники якості та структурно-механічні властивості з метою оптимізації рецептурного складу для покращення функціонально-технологічних властивостей кондитерських паст. Встановлено позитивний ефект взаємного використання квасолі, молочної сухої сироватки демінералізованої на структурно-механічні властивості нових оздоблювальних напівфабрикатів. Доведено покращення показників формульної здатності за концентрації 10...30 % молочної сироватки сухої демінералізованої та 8 % кокосової олії в рецептурному складі. Встановлено зменшення липкості у композиціях бобових паст для моделювання фігурних виробів, покриття кондитерських виробів та виготовлення квітів, як декоративних кондитерських виробів, при концентрації олії кокосової до 10 %. Відповідно, загальні бали розроблених дескрипторів становили: 2,92 для декоративних кондитерських виробів, 2,98 для покриття кондитерських виробів та 2,95 для моделювання фігурних виробів. Встановлено зміну інтенсивності забарвлення композицій паст бобових у разі збільшення концентрації молочної сироватки сухої демінералізованої, що дозволяє розширити технологічні прийоми виготовлення фігурних виробів. Розроблена технологія та рецептурний склад дають змогу отримати якісні, з високою біологічною цінністю та низькокалорійні оздоблювальні напівфабрикати для кондитерських виробів.

Ключові слова: білок, квасоля, адгезійна міцність, реологічні властивості, оптимізація, рецептурний склад, композиція паст