The technology for producing a high-protein additive from soy and its use in the formulation of dry mix for baking muffins

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Abstract. Introduction of additives to the formula of flour confectionery products that can increase nutritional and biological value, and positively affect the organoleptic characteristics is one of the main ways to expand the list of products for a healthy diet. This article presents a scientific data on the technology development of producing a new high-protein supplement from soy through its technological transformation together with natural cinnamon sticks and ascorbic acid. It has been found that the process of preparing combined flour largely depends on the amount of prepared cinnamon introduced into the mixture, formed for drying granules diameter, and the temperature of their drying. Compliance with the established cooking parameters contributes to the production of flour with high organoleptic characteristics. An experimental study of the chemical composition of combined soy-cinnamon flour made it possible to establish a high content of protein, fat, carbohydrates, primarily dietary fiber, minerals, vitamins C, vitamin E and vitamin PP. The obtained high-protein flour was introduced into food concentrates - semi-finished products of flour products - dry baking mixes for muffins, which allowed one to significantly enrich their composition with vegetable protein, dietary fiber, vitamins and minerals. In terms of chemical composition, the level of satisfaction of the daily needs for basic nutrients and organoleptic characteristics, muffins that were made of a baking developed mix formula are significantly superior to muffins that were made of a traditional mix formula. The results of the studies allow us to attribute a high-protein supplement in the form of soy-cinnamon flour and products with its use to products that have a positive effect on human health.

1. Introduction
Flour confectionery is an essential part of the human diet around the world. Consumer preferences for such kind of food require a continuous expansion of their range both through development of new formulas and through improvement current ones by adding new non-traditional additives in their composition.

Additive requirements are today very serious. In addition to safety, the additives should enrich chemical composition, increase the benefit of the flour confectionery use, at the same time have a positive effect on organoleptic characteristics and not to reduce the overall quality of the product. Fruit, vegetable and berry powders, various types of flour (rice flour, oat flour, corn flour, soy flour, amaranth flour, sesame flour, etc.) that have the properties of the functional food products, are added
to the flour confectionery as the enriching components. Cereal bran containing dietary fiber, secondary products of milk processing (whey, casein, buttermilk, etc.), wood (dehydroquercytin, coniferous pectin) and many more are also used for enrichment of the flour confectionery [1-7]. The use of these kind of components makes it possible to obtain functional and specialized products for everyday nutrition, which helps to maintain and improve public health.

The demand for various semi-finished products today is rapidly growing, because of the consumers' high mobility and tight schedule. Due to the fact that cooking semi-finished products doesn't take much time and effort, more consumers use food concentrates - semi-finished products of flour products (various dry mixes for baking cakes, muffins, cookies, many sorts of bread, etc.) Semi-finished product of flour confectionery is a mechanical mix of prepared components of the formula, where the main ingredient is a wheat flour.

Such mixture is the promising object to enrich the chemical composition to obtain healthy food products.

That’s why we have conducted studies to get an additive that can enrich the chemical composition, increase the nutritional value, and improve the quality of food concentrates - dry baking mixes.

Among the many directions of enrichment flour products with protein substances and dietary fiber, the most popular is still the use of processed soy products in combination with other types of vegetable raw materials [8-10].

One of the most popular flavoring additive for flour confectionery is a very common spice, a cinnamon. At the same time, the cinnamon is primarily used in the cooking as a spice. However, it is known that the cinnamon has an antimicrobial effect and could be used as a preservative, it also helps to normalize the blood sugar level, positively affects the vascular tone, nervous system, and refreshes the breath. Dietary fiber and cinnamon's calcium help to clean the body of harmful substances and stimulate the digestion. Also cinnamon sticks have better qualities than a ground spice, while grinding the cinnamon loses its useful properties and aromatic substances [9]. Therefore, the aim of the work is to develop a high-protein soy-cinnamon flour technology and formulas of food concentrates as dry baking mixes for muffins with the obtained flour to enrich chemical composition and increase the nutritional value of finished products.

2. Materials and methods

2.1 Materials

The objects of studies are the main types of used raw materials: soy grain varieties of the Amur selection Evgenia and Intriga, cinnamon sticks, ascorbic acid that meet the requirements of current regulatory documents in terms of quality and safety. The process of preparing combined soy-cinnamon flour and a baking mix for muffins is also the study object.

2.2 Methods

In these studies we used standard and special methods. The chemical composition of the main raw materials, semi-finished products and finished products was studied by spectrometry near infrared area on the IR-scanner "FOSSNIRSystem 5000”. We studied the amino acid composition of raw materials and products by using the AAA 400 amino acid analyzer. Mass fraction of moisture in raw materials and finished products was obtained by drying to constant weight, mass fraction of fat by infusion with a solvent. We studied acidity through alkali titration, and pH through potentiometric method. The total amount of carbohydrates was determined by the permanganate method, and the fiber content by the method of Kürschner and Ganek, based on the oxidation, destruction and dissolution of all chemical compounds that are part of the product, except fiber, was determined by the mix of acetic and nitric acids. We studied the content of Vitamin C by titrimetric method with potentiometric titration, the content of mass fraction of vitamin E was obtained by using highly effective liquid chromatography, and total amount of vitamin PP was got by colorimetry. The energy value of the obtained products was determined by using the Rubner coefficients. Organoleptic analysis of products was carried out.
according to the current regulatory documentation for specific products. To evaluate organoleptic indicators, there were developed five-point scales with an exact characteristics of the evaluated indicators. Evaluation was carried out at tasting meetings. We used modern statistical analysis methods to process the experimental data [11-12].

2.3 Methodology of the studies

The experiment on obtaining combined soy-cinnamon flour was carried out on two soybean varieties Evgenia and Intriga, which have a comparatively different protein content and relatively low trypsin-inhibiting activity [13].

We soaked soy grains and cinnamon sticks to make them swell and soft. Then, wet cinnamon sticks were cut into pieces to the size that matches a soy grain. Further, we mixed the grain and cinnamon and added them into the water in a quantity of 800 g per 100 g of the mix, then loaded into the grinder-extractor. During the processing, the mix components were fine powdered, the mix was heated, and soluble components were going into the water to form a soy-cinnamon suspension. Later we added an aqueous solution of the ascorbic acid in concentration of 5 % to the produced suspension to coagulate protein and other substances of the suspension. At the end of the process, whey was separated from the produced soy-cinnamon clot. A certain granules diameter were formed from obtained soy-cinnamon clot and sent to dry. The granules which has been dried to a dry substance content of 90-92% were subjected to the fine grinding to obtain flour.

The amount of cinnamon in the soy-cinnamon mix, the granules’ diameter and the drying temperature were the main factors that affected the organoleptic characteristics of soy-cinnamon flour. We recorded the data on the results of the experiments in the planning and experiment results matrix. In the experiments, we reproduced 4 parallel determinations according to the Box and Draper technique [11], evaluated the reliability of the experimental data and the reproducibility of the experiments according to the method of E.E. Rafaless - Lamarck and V.G. Nikolaev. The numerical values in the tables are the arithmetic mean, which reliability is $P = 0.95$, and the confidence interval is $\pm 5.0 \%$.

The experiment that explains the ideal parameters was carried out on the basis of techniques proposed by a number of authors. The techniques analysis made it possible to determine that the researchable processes are described by a second-order mathematical model [11, 12].

These mathematical models are characterized the process of obtaining soy-cinnamon flour. Then, we studied the chemical composition of the flour that was obtained by complying with the ideal technology parameters.

We used a soy-cinnamon flour to develop a model formula of the baking muffins mix. The flour was added to the standard formula of the baking mix in a 9.8% of overall mass. We undertook a comparative analysis of the chemical and amino acid composition of the mixtures, and of the level of satisfaction from people in nutrients while using the mix. After baking, we evaluated the organoleptic characteristics of the finished muffins.

3. Discussion of the results

The most significant factors of the process that affect the organoleptic characteristics of soy-cinnamon flour are mass fraction of additives (cinnamon) - A, % ($X_1$); granules’ diameter - B, mm ($X_2$); drying temperature - C, °C ($X_3$) (table 1).

| Table 1. Levels and intervals of variation of the factors |
|----------------------------------------------------------|
| **Factors** | **Factors** | **Factors** |
| X₁ | X₂ | X₃ |
| Top level | 75 | 3 | 100 |
| Basic level | 50 | 2 | 80 |
| Lower level | 25 | 1 | 60 |
| Interval of variety | 25 | 1 | 20 |
The organoleptic evaluation of quality indicators is taken as the optimization criterion - $P$, points ($Y$).

Table 2 presents the results of experiments conducted on the standard matrix of the full factorial experiment.

| Experiment No. | $X_1$/A, % | $X_2$/ B, mm | $X_3$/C,°C | Organoleptic evaluation (points) |
|----------------|------------|--------------|-------------|----------------------------------|
| 1              | -1         | -1           | +1          | 20,0                             |
| 2              | +1         | -1           | -1          | 18,0                             |
| 3              | -1         | +1           | -1          | 20,0                             |
| 4              | +1         | +1           | +1          | 19,5                             |
| 5              | -1         | -1           | -1          | 21,0                             |
| 6              | +1         | -1           | +1          | 19,4                             |
| 7              | -1         | +1           | +1          | 20,0                             |
| 8              | +1         | +1           | -1          | 18,2                             |
| 9              | -1,215     | 0            | 0           | 21,5                             |
| 10             | +1,215     | 0            | 0           | 21,0                             |
| 11             | 0          | -1,215       | 0           | 21,5                             |
| 12             | 0          | +1,215       | 0           | 22,0                             |
| 13             | 0          | 0            | -1,215      | 20,5                             |
| 14             | 0          | 0            | +1,215      | 20,5                             |
| 15             | 0          | 0            | 0           | 23,5                             |

Regression analysis of the dependence $Y = f (X_1; X_2; X_3)$ allowed us to obtain an adequate mathematical model (Fisher's calculated criterion is more than tabular) of the organoleptic evaluation of combined soy-cinnamon flour:

- in coded form:

$$Y = 23.085 - 0.5942 \cdot X_1 + 0.4625 \cdot X_1 \cdot X_3 - 1.1513 \cdot X_2^2 - 0.8126 \cdot X_3^2 - 1.6590 \cdot X_3^2 \rightarrow 25 \text{ points}$$

- in decoded form:

$$P = -6.4313 + 0.0864 \cdot A + 3.2504 \cdot B + 0.6175 \cdot C + 0.0009 \cdot A \cdot C - 0.0018 \cdot A^2 - 0.8126 \cdot B^2 - 0.0041 \cdot C^2 \rightarrow 25 \text{ points}$$

The model analysis showed that the ideal parameters values are the mass fraction of cinnamon in the mix – 52.5 %; granules’ diameter – 2.3 mm; drying temperature – 84.2 °C, where organoleptic evaluation (P) is 23.16 points.

Three-dimensional graphical interpretation of these models is shown in figures 1-3. It gives a visual representation of the impact of a combination of three factors on the organoleptic characteristics of combined soy flour.

The next phase of the study we identified the chemical composition and energy value of the combined soy-cinnamon flour. The results are presented in table 3.

During the tasting we discovered that the combined soy-cinnamon flour has a great looking and color, pretty good taste and aromatic characteristics (figure 4).

The obtained combined flour has high organoleptic characteristics and nutritional value due to the presence of protein, minerals, biologically active substances of cinnamon, vitamin C, vitamin E and soy isoflavonoids which have antioxidant properties in it. The presence of dietary fiber in the flour formed by insoluble okara and cinnamon components is particularly important for obtaining healthy food.
Table 3. Chemical composition and energy value of soy-cinnamon flour

| Indicators                     | The standard (\( \bar{X} \pm m ; m \leq 0.05 \)) |
|-------------------------------|--------------------------------------------------|
| Humidity, % no more than      | 8.0                                              |
| Protein, % no less than       | 29.0                                             |
| Fat, % no less than           | 12.9                                             |
| Carbs, % no less than         | 37.8                                             |
| Dietary fiber, % no less than | 16.2                                             |
| Minerals, % no less than      | 12.3                                             |
| Vitamin C, mg/100g           | 70.0                                             |
| Vitamin E, mg/100g           | 5.5                                              |
| Vitamin PP, mg/100g          | 3.2                                              |
| Energy value, kcal/100g       | 383.3                                            |

Figure 1. Response surface and its section \( Y=f(X_1=0.27;X_2;X_3) \)

Figure 2. Response surface and its section \( Y=f(X_1;X_2=0.0;X_3) \)

Figure 3. Response surface and its section \( Y=f(X_1;X_2;X_3=-0.04) \)

We used soy-cinnamon flour in the food concentrates formula - a baking muffin mix - to expand the range of flour confectionery and to obtain healthy food. To create a model formula we chose the traditional formula of the muffin mix "Vanilla" where the part of the wheat flour was replaced by soy-cinnamon flour. Traditional and model formulas are presented in table 4.

The amount of introduced soy-cinnamon flour, first of all, was determined by the impact on the dough formation and organoleptic indicators. When we added more soy-cinnamon flour to the baking mix, an intrusive spicy taste of cinnamon appeared, the surface structure and the consistency of the pastry are significantly inferior to the analogue because of the increased acidity of the dough. At the same time, the introduction of a smaller amount of combined soy-cinnamon flour into the baking mix does not affect the nutritional and biological value of the finished products.

The technological process of the food concentrates preparation - semi-finished products of flour confectionery consists in preparing the components and mixing them according the formula. First we mixed combined soy-cinnamon flour with wheat flour, after that dosed into the mixer.
Table 4. The food concentrates formula - semi-finished flour products "Muffin", %

| Components                     | Muffin “Vanilla” (analogue) | Muffin with soy-cinnamon flour (formulation) |
|--------------------------------|----------------------------|---------------------------------------------|
| High-grade wheat flour         | 54.6                       | 44.9                                        |
| Granulated sugar               | 34.0                       | 34.0                                        |
| Soy-cinnamon flour             | -                          | 9.8                                         |
| Powdered eggs                  | 6.6                        | 6.6                                         |
| Milk powder                    | 3.5                        | 3.5                                         |
| Table salt                     | 0.2                        | 0.2                                         |
| Sodium bicarbonate             | 0.7                        | 0.7                                         |
| Citric acid                    | 0.3                        | 0.3                                         |
| Vanillin                       | 0.1                        | -                                           |
| In total:                      | 100.0                      | 100.0                                       |

The results of a comparative assessment of the chemical composition and the level of satisfaction of the daily human nutritional requirements are presented in table 5.

Table 5. The chemical composition and the level of satisfaction of the daily requirement for nutrients of the baking mix “Muffin”

| Indicators                  | Muffin “Vanilla” (analogue) | Muffin with soy-cinnamon flour (formulation) |
|-----------------------------|------------------------------|---------------------------------------------|
|                             | Content | Satisfaction, % | Content | Satisfaction, % |
| Water, g                    | 10.0    | -               | 10.0    | -               |
| Protein, g                  | 9.1     | 12              | 13.2    | 18              |
| Fat, g                      | 2.8     | 3               | 4.1     | 5               |
| Carbs, g                    | 73.7    | 20              | 65.8    | 18              |
| Dietary fibers, g           | 2.9     | 10              | 4.3     | 14              |
| Vitamin E, mg               | 1.1     | 11              | 1.7     | 17              |
| Vitamin C, mg               | 0       | 0               | 14.0    | 20              |
| Minerals:                   | 1.5     | -               | 2.6     | -               |
| Potassium, mg               | 104.0   | 3               | 357.0   | 10              |
| Phosphorus, mg              | 90.0    | 9               | 169.0   | 17              |
| Calcium, mg                 | 33.0    | 3               | 97.0    | 10              |
| Magnesium, mg               | 13.0    | 3               | 71.0    | 18              |
| Energy value, kcal          | 356.4   | -               | 352.9   | -               |

Figure 4. Combined soy-cinnamon flour

Figure 5. Muffins with soy-cinnamon flour
According to the results, the baking mix with soy-cinnamon flour surpasses the analogue in protein content by 4.1 %, fat by 1.3 %, dietary fiber by 1.4 %, vitamin E by 0.6 %, and vitamin C 14 %.

In the new type of baking mix, the level of satisfaction the daily needs for minerals increases: potassium by 3 %, phosphorus by 8 %, calcium by 7 %, magnesium by 15 %.

The results of the organoleptic evaluation showed that the soy-cinnamon muffins are not inferior in appearance and quality to the analogue, and the crumb's taste, smell, color and tenderness significantly exceed it (figure 5).

4. Conclusion

The studies substantiated the technological parameters of the obtaining soy-cinnamon flour process, which can be the fundamental basis of production the corrective additives for combined foods. The study results of the chemical composition and properties of the combined soy-cinnamon flour obtained by the developed technology indicate its high nutritional and biological value.

The introduction of the obtained additive to the composition of food products will contribute to enriching their chemical composition.

Introduction of soy-cinnamon flour to the formula of a food concentrate - a semi-finished product of flour products allows enriching finished products with protein, fat, dietary fiber, vitamins and minerals.

Given the high nutritional and biological value of enriched mixtures, the resulting product can be attributed to healthy nutrition products, and because of the growth in the consumption of flour confectionery products, the introduction of combined soy-cinnamon flour into their composition will improve the public health.

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