Modeling of the cottage cheese products composition

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Abstract. Combined food products provide the human body with all the necessary nutrients in a balanced amount. The paper presents a technique for modeling the formulation of semi-finished products from cottage cheese using the Excel program. The main components of semi-finished products are: cottage cheese of 5% fat content, flour from unsteamed buckwheat, egg melange. The goal of modeling was to obtain the optimal ratio of the components of the formulation, which meets the established requirements for indicators of nutritional value, as well as the recommended intake of vitamins and minerals for the adult population. The goal function has selected the cost of the product for which the condition for obtaining the minimum value is set. As a result of the search for a solution, the program proposed several options for formulations, of which the most acceptable was selected. Thus, we can conclude that it is advisable to apply mathematical modeling methods to obtain a combined product with specified nutritional value indicators.

1. Introduction
The production of curd products using various plant components contributes not only to an increase in the range of products, but also allows the rational use of raw materials. The production of combined dairy products is aimed at providing the population with balanced, healthy food [1, 2].

Recently, there has been a tendency to develop food products with a composition optimized for the main nutrients [3, 4]. Nutrient-balanced foods are a source of vitamins, minerals, dietary fiber and other biologically active substances, provide the human body with energy.

Frozen semi-finished products are one of the most popular product groups among the population [5]. They are easy to prepare, and their wide assortment is able to satisfy the needs of the most fastidious consumer. Frozen semi-finished cottage cheese products are gradually occupying a niche in the semi-finished product market. It is possible to expand the range of these products by including in the formulation new interesting types of plant materials containing useful nutrients.

Green buckwheat flour is a promising type of plant material that can be used in frozen semi-finished cottage cheese products. It consists of ground buckwheat grains with minimal processing without steaming. Green buckwheat flour retains all the beneficial properties, in addition, it does not contain gluten, it has an excellent vitamin and mineral complex [6].

In world practice, to improve the technological process, to obtain optimized recipes for various products, methods of mathematical modeling and corresponding programs and applications are used. This allows you to quickly achieve your target with minimal raw material costs and time [7, 8].
The aim of the study is to model the recipe of semi-finished products from cottage cheese with the addition of flour from unsteamed buckwheat in terms of nutritional value.

2. Materials and Methods
The semi-finished products formulation from cottage cheese includes the following components: cottage cheese of 5% fat, flour from unboiled buckwheat, melange, salt, sugar.

The formulation was modeled in Microsoft Excel in the Solver application.

For the convenience of presenting the calculations, the following designations were introduced: \( j \) - index of different types of components (\( j = 1, 2, ..., n \)); \( i \) - nutrient index (\( i = 1, 2, ..., m \)); \( x_j \) - the required part of the content of the \( j \)-th component in the product unit; \( b_i \) is the required amount of the \( i \)-th nutrient in the formulation; \( a_{ij} \) is the content of the \( i \)-th nutrient per unit of the \( j \)-th type of component.

Taking into account the accepted designations, the mathematical model for optimizing the desired formulation to achieve the minimum production cost has the form (1):

\[
F(x) = \min \left\{ \sum_{j=1}^{n} c_j \cdot x_j \right\}
\]

For each component, its amount in the composition of the semi-finished products formulation was calculated according to the formula (2):

\[
b = \sum_{j=1}^{n} x_j a_{ij}
\]

To achieve an optimal composition, the following conditions must also be met:

1) the presence of the required ingredients in the composition:
   a) along the maximum border (3):
   \[
   \sum_{j=1}^{n} x_j a_{ij} \leq b_i
   \]
   b) along the minimum border (4):
   \[
   \sum_{j=1}^{n} x_j a_{ij} \geq b_i
   \]

2) obtaining a unit of mixture (5):
\[
\sum_{j=1}^{n} x_j = 1
\]

3) non-negativity of variables (6):
\[
x_j \geq 0, j = 1, 2, ..., n.
\]

At the first stage, a data table was formed on the content of nutrients (Tab. 1), as well as on the content of vitamins (Tab. 2) and minerals (Tab. 3) in the main components of the semi-finished products formulation.

| Component                        | Mass fraction, % |
|----------------------------------|------------------|
|                                  | protein | fat | moisture |
| Cottage cheese (5% fat)          | 21.0    | 5.0 | 69.0     |
| Unsteamed buckwheat flour        | 12.6    | 3.3 | 14.0     |
| Egg melange                      | 12.7    | 11.5| 74.0     |
Table 2. Vitamin content of component.

| Component                  | Content of vitamin, mg |
|----------------------------|------------------------|
|                            | B₁ | B₂ | B₆ | PP | E  |
| Cottage cheese (5% fat)    | 0.05 | 0.30 | 0.11 | 0.28 | 0.38 |
| Unsteamed buckwheat flour  | 0.40 | 0.20 | 0.40 | 4.2  | 6.7  |
| Egg melange                | 0.07 | 0.44 | 0.14 | 3.6  | 0.6  |

Table 3. Mineral content of component.

| Component                  | Content of mineral, mg |
|----------------------------|------------------------|
|                            | Ca | Mg | Zn | Fe | K   |
| Cottage cheese (5% fat)    | 150.0 | 23.0 | 0.39 | 0.46 | 112.0 |
| Unsteamed buckwheat flour  | 21.0 | 200.0 | 2.05 | 6.7  | 380.0 |
| Egg melange                | 55.0 | 12.0 | 1.11 | 2.5  | 140.0 |

The optimization took into account the content of protein, fat, vitamins and minerals. The content of vitamins and minerals in the product was set taking into account the recommended daily intake for an adult (Tab. 4).

Table 4. Recommended daily requirement for vitamins and minerals for an adult.

| Vitamins | Recommended daily requirement, mg | Minerals | Recommended daily requirement, mg |
|----------|----------------------------------|----------|----------------------------------|
| B₁       | 1.5                              | K        | 2500                             |
| B₂       | 1.8                              | Ca       | 1000                             |
| B₆       | 2.0                              | Mg       | 400                              |
| PP       | 20.0                             | Zn       | 12                               |
| E        | 15.0                             | Fe       | 10                               |

To draw up the balance equations, the following designations are adopted: \( x₁ \) - cottage cheese content (5% fat), \( x₂ \) - content of flour from uncooked buckwheat, \( x₃ \) - melange content, \( x₄ \) - edible salt content, \( x₅ \) - sugar content; \( x₁–5 \) is the sought-for specific gravity of the components of the semi-finished product formulation.

The following balance equations were compiled for optimization:
1) in accordance with the Technical Regulations of the Customs Union “On the safety of milk and dairy products” (TR CU 033/2013), the developed semi-finished product from cottage cheese must contain at least 35% fat in terms of dry matter:

\[
(5x₁ + 3.3x₂ + 11.5x₃) * 100 / (100 – (69x₁ + 14x₂ + 74x₃)) \geq 35;
\]

2) the presence in the produced product of the daily intake of vitamins, the proportion of units:
   a) vitamin E

\[
0.38 \cdot x₁ + 6.7 \cdot x₂ + 0.6 \cdot x₃ \geq 15;
\]

   b) vitamin B₁

\[
0.05 \cdot x₁ + 0.4 \cdot x₃ + 0.07 \cdot x₃ \geq 1.5;
\]

similar to other vitamins

3) the presence in the produced product of the daily intake of minerals, the proportion of units:
a) Ca
\[ 150 \cdot x_1 + 21 \cdot x_2 + 55 \cdot x_3 \geq 1000; \]
b) Mg
\[ 23 \cdot x_1 + 200 \cdot x_2 + 12 \cdot x_3 \geq 400; \]
similar to other minerals
4) receiving a unit of a product:
\[ x_1 + x_2 + x_3 + x_4 + x_5 = 1; \]
5) obtaining non-negative variables, since all components must be present in the recipe:
\[ x_1, x_2, x_3, x_4, x_5 \geq 0. \]

The goal function is the cost of the product, the value of which tends to a minimum. The cost of the product was calculated as follows:
\[ 170 \cdot x_1 + 89 \cdot x_2 + 110 \cdot x_3 + 14 \cdot x_4 + 42 \cdot x_5 \rightarrow \text{min}. \]

3. Results and Discussion
The program offered several options for compositions for semi-finished products, taking into account all the established restrictions and requirements. The most acceptable composition is shown in Table 5.

| Component                        | Content of component, % |
|----------------------------------|-------------------------|
| Cottage cheese (5% fat)          | 68,0                    |
| Unsteamed buckwheat flour        | 10,0                    |
| Egg melange                      | 10,0                    |
| Edible salt                      | 2,0                     |
| Sugar                            | 10,0                    |

The found results of the calculation of nutrients are presented in Table 6, vitamins and minerals in Table 7.

| Indicator                                      | Calculation results |
|------------------------------------------------|---------------------|
| Content of protein, %                         | 16.8                |
| Content of fat (in terms of dry matter), %    | 4.9 (38.0)          |
| Content of moisture, %                        | 55.7                |

| Vitamin or mineral | Calculation result, mg | Percentage of the daily value in 100 g, % |
|--------------------|------------------------|------------------------------------------|
| B1                 | 0.081                  | 5.4                                      |
| B2                 | 0.268                  | 14.9                                     |
| B6                 | 0.129                  | 2.6                                      |
| E                  | 0.988                  | 6.6                                      |
| PP                 | 0.980                  | 4.9                                      |

| Vitamin or mineral | Calculation result, mg | Percentage of the daily value in 100 g, % |
|--------------------|------------------------|------------------------------------------|
| Ca                 | 117.3                  | 11.7                                     |
The calculation results showed that when using 100 g of semi-finished product from cottage cheese with the addition of flour from unboiled buckwheat, the daily requirement for these vitamins is covered up to 14.9%, and in minerals - up to 12.3%.

4. Conclusion
As a result of modeling, the formulation of the semi-finished products from cottage cheese with the addition of flour from unboiled buckwheat was obtained. Due to the enrichment of semi-finished products with this plant component, the content of vitamins and minerals amounted to 14.9% of the daily intake. Thus, we can conclude that it is advisable to use mathematical modeling methods to obtain a product with specified nutritional value indicators.

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