1. Introduction
This article is based upon the relevance of development and production of personalized foods aimed at maintaining a healthy lifestyle. The theoretic and experimental research made it possible to develop a scientific outlook on the production of personalized foods based on foods of animal and plant origin, and also to develop a structural logistic scheme for the implementation of scientific and methodological principles of creating such technologies. We present a matrix method for the development of biotechnology and formulas of personalized foods. In order to implement the results of analytical and experimental research in practice, we have developed technical and regulatory documentation for manufacturing new products, which were tested under industrial conditions in dairy enterprises. The technologies of these foods have received high appraisal from the consumers.

We are the first to suggest using the matrix method for the development of a recipe on the example of confectionary such as chocolate because it is a foodstuff that plays an important role in human life. It helps people to satisfy their hunger, reduce aggressiveness, overcome depression and anxiety, and also to improve creative and job-related activity. Those who eat chocolate tend to have a more positive view of life.
The range of confectionary is very wide. There are several classifications of chocolate:

1. Classification based on product description – GOST R 53041-2008 “Confectionary and semi-processed materials for confectionary production. Terms and definitions” [1]. Due to this specification, chocolate is confectionary produced from cocoa products and sugar and containing a minimum of 35% of total dry solids of cocoa products, which includes a minimum of 18% of cocoa butter and a minimum of 14% of total dry solids of cocoa. This specification defines and introduces such terms as: unsweetened chocolate, bitter chocolate, dark chocolate, white chocolate, milk chocolate, powdered chocolate, aerated chocolate, chocolate product, filled chocolate, chocolate with addition of confectionary ingredients, chocolate with addition of fine confectionary ingredients.

2. According to GOST 31721-2012 “Chocolate. General specifications” [2], chocolate is classified into regular chocolate and fondant chocolate depending on the technology of its production and fineness degree. Depending on their content and structure both types in turn can be subdivided into aerated chocolate, chocolate with addition of confectionary ingredients, filled chocolate, chocolate with mixed ingredients.

The taste of chocolate mass depends on the ratio of the masses of powdered sugar and cocoa liquor in it. Cocoa liquor gives a peculiar bitter taste to the chocolate mass and sugar gives sweetness. The ratio between the masses of sugar and cocoa liquor is called the “sweetness coefficient” (C_s). According to the value of C_s all chocolate masses are subdivided into 5 groups: very sweet (C_s is more than 2); sweet (C_s is 1.6-2.0); semi-sweet (C_s is 1.4-1.6); semi-bitter (C_s is 1.0-1.2); bitter (C_s is less than 1).

2. Problem setting

Widening the range of chocolate products is done through introduction of several improvements: development of new flavor combinations, development of new formulas to produce specialized, functional chocolate having higher nutrition value. Present-day economic situation requires increased production efficiency, sustainable use of primary resources, modernized process design. The use of informational technologies plays significant role in the development of innovative technologies in food-processing industry and methods of economic analysis.

At the present time, recipe calculation in chocolate manufacturing is done according to the book of standardized recipes “Recipes of chocolate and cocoa powder”, which has been mandatory for use since 1986 [5, 6]. The raw ingredients and intermediate goods, that are included into the recipes, are time tested under factory conditions and given with consideration of processing losses.

Let us consider an example of calculation of a chocolate recipe given in a tutorial book by Professor Z.G. Skobelskaya [5, 6]. A standardized recipe of “Alionka” chocolate (№11, by volume) for producing 1 ton of chocolate with consideration of processing losses done in the Microsoft Excel environment is presented in Fig.1.

Composition of the chocolate product. The product must contain a minimum of 35.5% of fat, a minimum of 8% of protein, 54% of carbohydrates, 98.8% of dry solids.

The raw ingredients and intermediate goods are enumerated in column 1. The values of dry solids (DS) in raw ingredients weight ratio are enumerated in column 2. The figures of the standardized recipe of “Alionka” chocolate (recipe №11) that represent raw ingredients consumption per 1 t of finished product (the weight of package not included) are enumerated in columns 3 and 4.

The value of dry solids in the finished product (98.8%) is inserted into line C15 - Output.

In cell D14 we determine the sum of the weights of ingredients:

\[ =\text{SUM(D7:D13)} \]

and we obtain 1018.6 kg.

In cell D15 – Output we determine the weight of chocolate as 1000 kg.

In column 4 we do the calculation of the values of dry solids in every line, for example in cell E7 – 98.85*431.3/100 = 430.7, according to the formula:

\[ =\text{C7*D7/100} \]
In cell E14 we determine the sum of the values of dry solids in column 4.

=SUM(E7:E13)

Here we obtain the total weight of 1004.1 kg.

In cell E15 we obtain the weight of dry solids per 1 t of finished product which is 988 kg. Hence, in columns 1, 2, 3, 4 we have the data that are needed for recalculation of the weights of ingredients in order to produce any other amount of the chocolate product.

The formulation for producing 200 kg of the chocolate is presented in fig. 2.

**Figure 1.** Standardized recipe of “Alionka” chocolate

**Figure 2.** Calculation of the recipe of “Alionka” chocolate for producing 200 kg of the finished product using a standardized recipe
The calculation of the weight of the raw ingredients for producing 200 kg of the finished product is presented in column 5. For example, the consumption of powdered sugar presented in cell F7 is equal to the result of multiplication of the corresponding value per 1 t of finished product by the recalculation coefficient 0.2. Thus we have $431.3 \times 0.2 = 86.3$ kg etc. The total sum of raw ingredients consumption is 203.8 kg, the output of the chocolate product is 200 kg.

To calculate the consumption of all raw ingredients in dry solids, the recalculation coefficient is determined in advance $C_c = \frac{200.8}{1004.1} = 0.19998$.

The consumption of every single raw ingredient in dry solids is calculated by multiplying the values of every line in column 4 by the coefficient $C_c$ within an accuracy of 0.1 kg.

• for powdered sugar: $430.7 \times 0.19998 = 86.1$ kg;
• for cocoa liquor: $136.5 \times 0.19998 = 27.3$ kg etc.

Correctness of the recipe calculations can be checked by comparison of the obtained sum with the total value which was obtained earlier in column 6, $988.0 \times 0.2 = 197.6$ kg.

Conventional calculations of chocolate products output using a standardized recipe are done according to the described technique. As can be noted, this technique requires a series of calculations that are time consuming, because one must calculate the consumption of raw ingredients and intermediate goods, caloric and nutritional values of the product. Also the cases when a new ingredient is introduced into the recipe require recalculation of all values.

3. Materials and methods
The production plan for manufacturing of chocolate comprises the following stages: development of a recipe; mixing the ingredients, refining the mixed chocolate mass; dilution, homogenization and conching of the chocolate mass; filtering and tempering of the chocolate mass; molding of the chocolate mass; cooling and extraction from the molds; wrapping; packaging; marking; transportation and storage.

The recipe for manufacturing is developed taking into consideration the approved recipe recipes, characteristics of the intermediate goods used, the operating volume of equipment.

The ratio of the basic ingredients in the chocolate mass may vary considerably, but the percentage of cocoa butter must be 32-36% in order to provide ample liquidity of the mass during molding. Cocoa liquor contains 52-54% of cocoa butter. When cocoa liquor is mixed with powdered sugar this amount of cocoa butter cannot provide adequate liquidity. Therefore, pure cocoa butter is additionally introduced into the mass. The content of cocoa butter in the chocolate mass is determined as the sum of the cocoa butter introduced and the cocoa butter contained in the cocoa liquor.

Any recipe may be determined by the equation:

$$S + L + B = 100,$$

where $S$, $L$, $B$ are the percentages of the sugar, the cocoa liquor and the cocoa butter respectively.

The content of fat in the chocolate mass ($M_{ch}$, 1%) is the sum of the cocoa butter added and the cocoa butter contained in the cocoa liquor.

$$M_{ch} = M + m \times L,$$

where $m$ is the content of fat in the cocoa liquor, %.

The percentage of the pure cocoa butter added depends on the percentage of the cocoa butter in the cocoa liquor:

$$M = M_{ch} - m \times L.$$

The above equations combined give the following equation:

$$M_{ch} - m \times L + L + S = 100.$$

This equation makes it possible to calculate the weight of the cocoa butter that must be additionally introduced into the mass, when the percentage of the cocoa butter in the cocoa liquor is known, and the fat content in the chocolate mass is predetermined.

When developing new recipes of multicomponent food systems, as a rule, approaches based on the linear programming theory are used, the simplex method being its general method.

Use of the simplex method when optimizing the recipes of foods allows finding the extremum of a linear objective function within linear technological limitations of the sought variables. The optimization
problem is solved with respect of the chosen parameters (for example chemical, vitamin, mineral composition and caloric value). The calculations take into account the objective function, the boundary conditions of technological variables and the limitations of the content of specific nutrients.

The difficulty of the multicomponent recipe problem lies in the fact that at present it involves many ingredients (more than 5). In this case, the recipe calculation that is done without use of present-day digital technologies is extremely time-consuming (with possible human errors) which leads to loss of efficiency in production control.

The mentioned disadvantages of the conventional method may be successfully solved by using present-day digital technologies, i.e. such computer software like MathCAD, Excel, Maple, Statistica etc. The use of digital technologies saves time of doing calculations and eliminates human errors. It also facilitates developing functional multicomponent foods having such predefined composition and properties as nutritional and caloric value and also considering economic component.

The main principle of recipe calculation is the fundamental law of mass conservation. Its implementation here is done through solving a system of linear equations using the balance method. The mathematical technique for solution of a classic recipe problem is the simplex method, developed by a Nobel prize winner mathematician L.V. Kantorovich and American scientist G. Dantzig. From the mathematical standpoint, the solution of linear equations using the balance method may have three variants: the system has no solution; the system has one solution; the system has many solutions [7–11].

From the standpoint of education, research and production those variants of the solution of linear equations are of interest that give either one positive solution or many non-negative ones. From the standpoint of technology this means existence of either one recipe or many variants of a product recipe. The task of a food process engineer is choosing a variant of a recipe having the required composition.

4. Results and discussion

Let us consider an example of a parametric structural analysis of nutritional value of chocolate products based on recipe optimization using a matrix method [12–14].

Six structural modules are formed for the implementation of the matrix method:

1. The information module of data bank including the following four elements: type, chemical composition, wholesale prices of the ingredients and the standard contents of a developed multicomponent chocolate product.

2. The module of linear balance equations of the product chemical composition – fat, protein, carbohydrates, dry solids, moisture, mass.

3. The module of technological limitations of the use of specific ingredients depending both on their type and their percentage in the product mixture.

4. The module of the objective function for recipe optimization.

5. The module of recipe problem solution in a computer mathematic system.

6. The module of analysis of recipe variants and determination of the recipe that satisfy the set objective.

The methods of research. The analytical and experimental method on the basis of computer modelling was used in this research.

Let us consider an example of implementation of the matrix method in calculation of nutritional value of “Alionka” milk chocolate. The type and composition of raw ingredients and intermediate goods included into this recipe fully correspond the ones in the standardized recipe.

According to the requirements of regulatory production documentation the percentages of the ingredients in chocolate must be a minimum of: 35.5% fat; 8% protein; 54% carbohydrates; 1.8% food fibers (FF). Caloric value of chocolate must be 2290/550 kJ/kcal. Weight fraction of total cocoa dry solids must not be less than 29.8%. Weight fraction of cocoa nonfat solids must not be less than 5.7%.

The ingredients used as components for chocolate are presented in fig. 3. The information matrix of chocolate recipe data consists of five structural elements: type and composition of the ingredients; wholesale prices; content of the chocolate product; indexed variables (defined as $X_i$ in Figure 3).
The system of linear balance equations and limitations based upon the information matrix is presented in table 1.

**Table 1. The system of linear balance equations and limitations**

| Balance of: | Equations, limitations |
|-------------|------------------------|
| fat         | (25\cdot X_2 + 99.9\cdot X_3 + 15\cdot X_4 + 42\cdot X_5 + 80\cdot X_6 + 0.1\cdot X_7)/100 \geq 35.5 |
| protein     | (24.2\cdot X_2 + 24.3\cdot X_4 + 19\cdot X_5 + 0.1\cdot X_7)/100 \geq 8.0 |
| carbohydrates | (99.95\cdot X_1 + 55\cdot X_2 + 10.2\cdot X_4 + 30.2\cdot X_5 + 13\cdot X_6 + 87.6\cdot X_7)/100 \geq 54.0 |
| FF          | (35.3\cdot X_4)/100 \geq 1.8 |
| DS          | (99.85\cdot X_1 + 96\cdot X_2 + 100\cdot X_3 + 97.8\cdot X_4 + 96\cdot X_5 + 99\cdot X_6 + 99\cdot X_7)/100 \geq 98.8 |
| mass of chocolate | X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 = 100.00 |
| Limitations | X_6 = 0.4; X_7 = 0.1 |

The objective function, which is the minimum cost of “Alionka” chocolate recipe, may be expressed as a sum of products of every ingredient cost and the corresponding indices $X_i$:

$$ F(X_i) = 45\cdot X_1 + 156\cdot X_2 + 180\cdot X_3 + 254\cdot X_4 + 220\cdot X_5 + 120\cdot X_6 + 267\cdot X_7 \rightarrow \min $$

A system of linear balance equations with the objective function can be solved using MS Excel software with the help of the “Solver” Add-In. The window “Solver Parameters” for the recipe problem is presented in Figure 4.

Thus the coordinates of the objective function can be selected in the edit box “Set Objective”, in our case it is cell J14, which is the minimum cost of 100 kg of the recipe mixture.

In the edit box “By Changing Variable Cells” we select the cells that define the weights of the ingredients of the product, calculated in accordance with the technological limitations of the product.

Then we click on the “Solve” button and the Solver returns a recipe for “Alionka” chocolate.

The results of recipe optimization with the minimum cost of the chocolate product are shown in Figure 5.

For recipe calculation with account of dry solids weight loss we take into the consideration the loss coefficient equal to 1.6%. Relative yield here is: 1 – 0.016 = 0.984 (see The book of standardized recipes).
At the present time, one of the prospective lines of development of food processing industry is the use of up-to-date software for mathematic modelling of compositional systems. Successful implementation of innovative solutions is the basis for sustainable development of food industries under the conditions of market economy. Mathematic modelling is the key technique for the solution of the set task. Development of adequate mathematic models of technological processes on the basis of forming the principles for development of management system makes it possible to create differentiated technologies for production on the basis of forecasting the characteristics of primary resources. The efficiency of primary resources utilization increases under such conditions because the whole processing chain is being evaluated in terms of resource saving.

Specific nature of mathematic modelling is in the fact that it can be used in forecasting and organizing of any process, including technological one. Mathematic modelling makes it possible to investigate and...
describe various technological processes using innovative techniques of raw ingredients processing, that help to achieve the required quality standards of the studied products. The processes of formulation of chocolate products have been investigated in this paper. On the basis of literature data, we can calculate the loss of primary and auxiliary raw materials for any technological process and by that we can find effective production conditions. The recipe components determined by mathematic modelling make it possible to achieve the required quality standards of food products [15–20].

The recipe of the chocolate product with account of ingredients weight loss is shown in Figure 5 in cells K4-K10. The total sum of ingredients weights is 101.86 kg.

It should be mentioned that “Alionka” chocolate meets the regulatory requirements. It contains 35.5% fat, 8% protein, 54% carbohydrates, 98.6% dry solids, 1.8% food fibers, 32.2% cocoa. Caloric value of the chocolate is 554 kcal (2321 kJ).

We suggest using the following six special dimensionless indices for evaluation of ingredients balancing in multicomponent chocolate products:

1. **IPRB** – the index of product recipe balance (Ur);
2. **IVCB** – the index of vitamin content balance (Uv);
3. **IMCB** – the index of mineral content balance (Um);
4. **IFCB** – the index of amino-acid content balance (Ua);
5. **ICVB** – the index of fatty-acid content balance (Uf);
6. **ICVB** – the index of caloric value balance (Ue)

These indices will make it possible to evaluate the ingredient balance at every stage of food product design. The calculation of specific indices is done as the calculation of the geometric mean, for instance the formula for IVCB (Uv) is:

\[
U_v = \sqrt[n]{\prod_{j=1}^{n} \left( \frac{B_j}{B_{ej}} \right)}, \quad (6)
\]

where \(B_j\) is the weight ratio of the \(j^{th}\) vitamin in the product, mg%; \(B_{ej}\) is the weight ratio of the \(j^{th}\) vitamin equal to the required daily intake of this vitamin, mg%; \(n\) is the number of vitamins in the product.

The specific index of product recipe balance:

\[
U_r = \sqrt[n]{\prod_{j=1}^{n} \left( \frac{P_j}{P_{ej}} \right)}, \quad (7)
\]

where \(P_j\) is the weight ratio of the \(j^{th}\) ingredient (fat, protein, carbohydrate) in the product, mg%; \(P_{ej}\) is the weight ratio of the \(j^{th}\) ingredient (fat, protein, carbohydrate) equal to the required daily intake of this ingredient, mg%; \(n\) is the number of ingredients in the product (n=3).

The specific index of mineral content balance IMCB:

\[
U_M = \sqrt[n]{\prod_{j=1}^{n} \left( \frac{M_j}{M_{ej}} \right)}, \quad (8)
\]

where \(M_j\) is the weight ratio of the \(j^{th}\) mineral in the product, mg%; \(M_{ej}\) is the weight ratio of the \(j^{th}\) mineral equal to the required daily intake of this mineral, mg%; \(n\) is the number of minerals in the product.

The specific index of amino-acid content balance IACB:
\[
U_A = \sqrt[n]{\prod_{j=1}^{n} \left( \frac{A_j}{A_{ej}} \right)},
\]

where \(A_j\) is the weight ratio of the \(j^{th}\) amino-acid in the product, mg%; \(A_{ej}\) is the weight ratio of the \(j^{th}\) amino-acid equal to the required daily intake of this amino-acid, mg%; \(n\) is the number of essential amino-acids in the product.

The calculations of vitamin and mineral contents of the chocolate are shown in Figures 6, 7.

The fatty-acid content of “Alionka” milk chocolate is shown in Figure 8.

The target values of the amino-acid score of the chocolate are shown in Figure 9.

It must be noted that the bioavailability of “Alionka” milk chocolate fails to meet the requirements of recommended dietary allowance for schoolchildren because six essential amino-acids out of eight are limiting ones. The numeric data concerning the ingredients of “Alionka” milk chocolate calculated using two different methods with consideration of the weight loss is presented in Table 2.

**Figure 6.** The vitamin content of “Alionka” milk chocolate

**Figure 7.** The mineral content of “Alionka” milk chocolate
The proposed matrix method for the calculation of recipe of “Alionka” milk chocolate in the MS Excel environment is very simple and informative. This method has never been used for recipe calculation of chocolate. The method has such name because the data base for the calculation is presented in the form of a matrix having lines and columns.

Projection of this method on another types of food products also gives positive results. The basis of methodology for achievement of research objective when calculating any recipe is formed by the accomplishments of nutriology that deal with the present-day views on physiological requirements of individuals depending on their age, activities, health status and other factors. Specifically, healthy nutrition is determined by the conditions under which an individual eats food, the component composition of food, and the physical condition that facilitates nutrient intake [21, 22].

The use of such method involving digital systems is an integral part of designing multicomponent products, which recipes may include various bioactive agents. The vital and essential components used...
in the recipe are an integral part of healthy nutrition that includes dietary regime, the conditions under which an individual eats food, the component composition of food, and the physical condition, and also generally facilitates digestion of nutrients [23, 24].

Table 2. Comparative evaluation of standardized recipe of “Alionka” milk chocolate and the recipe calculated using the matrix method (with consideration of the weight loss)

| Ingredients                      | Standardized recipe, kg | Recipe calculated using the matrix method, kg |
|----------------------------------|-------------------------|---------------------------------------------|
| Powdered sugar                   | 43.13                   | 42.61                                       |
| Dry whole milk                   | 10.78                   | 22.68                                       |
| Cocoa butter                     | 19.84                   | 23.43                                       |
| Cocoa liquor                     | 13.96                   | 12.03                                       |
| Cream powder                     | 13.65                   | 9.01                                        |
| Emulsifier (soy lecithin)        | 0.4                     | 0.44                                        |
| Flavour «Vanilla»                | 0.1                     | 0.11                                        |
| Total, kg                        | 101.86                  | 101.86                                      |
| Yield, kg                        | 100.00                  | 100.00                                      |
| Cost, rubles                     | 13817.27                | 11539.21                                    |
| Weight ratios, %                 |                          |                                             |
| fat                              | 35.5                    | 35.5                                        |
| protein                          | 8.0                     | 8.0                                         |
| carbohydrates                    | 54.0                    | 54.0                                        |
| dry solids (DS)                  | 98.6                    | 98.6                                        |

As a result of theoretical and experimental research conducted by the Department of foods and food technology of Omsk SAU a scientific conception has been developed that allows designing of functional and diabetic confectionery products, which includes the sequence of their designing and management through regulation of technological variations of the component composition and its subsequent supplementation with functional and necessary ingredients, for example, for any type of personalized foods.

The methodology of designing of these innovative foods based on the following scientific methodological principles:

- Forming of functional and special characteristics of confectionery products is done through scientific justification and optimization of ingredients using mathematic modelling methods. These methods help to correlate fatty acid and/or protein and carbohydrate content and/or vitamin and mineral content, and also biologic, nutrition, caloric values of new foods meant for physically active people.
- Production schemes of confectionery products were developed with the aim at full complex use of the components of various origin;
- Determination of shelf life duration for confectionery products must be carried out using up-to-date functional and technical ingredients, including natural food fibers ant antioxidants [17, 18]. Every experiment is repeated five times and their results undergo statistical processing with the use of correlation and regression analyses in "MathCAD-14 Professional" software. The investigated objects are fully characterized using up-to-date research methods. After checking the main quality indicators, the recipe data is fed into the software for calculation of general technological characteristics, which will make it possible to draw a conclusion concerning economic feasibility.

5. Conclusion
Having conducted a complex analysis of scientific and practical achievements of Russian and foreign researchers in the development of a definite logistic chain of the matrix model, we found out that one of the most important directions in the design and production of personalized foods is the production of foods for people following a healthy lifestyle and doing amateur or professional sports. Research and
experimental substantiation of the possibility of using the matrix method for processing the recipes of personalized foods is based on the general trends that promote domestic manufacture, achievement of high quality of the products and preservation of health of variously-aged people.

The technologies of all the foods have been tested under industrial conditions and received high appraisal from the consumers that do active sports. Including optimization operators (like objective function) into the matrix method it is possible to develop a recipe having predetermined characteristics and content, for example having a minimum prime cost of the product. Application of this method in education, research and production processes will make it possible to design new chocolate products having functional properties.

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