DETERMINATION OF THE OPTIMAL RATIO OF RECIPE INGREDIENTS IN THE PROCESS OF DESIGNING CONFECTIONERY PRODUCTS

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Abstract

The aim of this study was to develop new recipes of confectionery products for functional purposes in accordance with predetermined criteria of optimization.

The paper formulates the objective of recipe optimization relating to the class of multicriteria nonlinear programming problems, and shows the algorithm developed for its solution. As an example, the article gives the formulation and solution of the problem that involves designing candy recipes with mixed jelly-whipped body. The choice of ratio between layers of combined body enriched with functional ingredients was carried out according to four criteria (energy value, carotenoids, dietary fiber, and the cost price of the finished product) under the given constraints on technological and consumer product characteristics.

The solution of the multicriteria problem identified a number of effective points belonging to the area of Pareto. The final choice of possible options was made on the basis of the ratio “price–quality” tailored to meet the daily requirements of micronutrients and organoleptic evaluation of the product.

Adjustment of the layers provides a wide range of jelly-whipped candies with original organoleptic characteristics and a given set of micronutrients that can be recommended for different categories of the population. Varying the composition of recipe mixtures from possible set of raw ingredients, enriching them with micronutrients, can influence on the physiological effect of finished products.

The proposed approach can be recommended for recipe designs of complex multicomponent food systems with specified set of characteristics in terms of multiple alternatives of ingredient composition and interchangeability of raw materials.

Keywords: recipe calculations, multicriteria optimization.

Introduction

Increasing the competition in raw materials and food markets, the growing need for products of functional purposes, a variety of raw ingredients in the market foreground issues on the design of new recipes and their corrections depending on fluctuations in raw material parameters.

According to modern ideas the concept of „food design” includes the development of models describing the steps for creating products of specified quality and representing mathematical relationships which reflect different functional connections between technological, economic and other parameters of raw ingredients, desired characteristics of finished products (objective function) and a number of constraints arising from the requirements of normative documents (Киселев, Першина, 2009; Муратова, Толстых et al., 2010) .

One of the important objectives in the design of new types of functional foods for various categories of the population is to provide the optimal set of recipe ingredients and ratios in multicomponent food systems. The difficulty of solving this problem is related to the fact that:

- raw material base of the modern food industry employs thousands of ingredients that differ in functional, technological, physical, chemical and organoleptic characteristics;
- semi-finished products should have a given complex of technological properties;
- finished products must comply with the balanced nutrition formula, respond to medical and biological requirements, have high consumer properties and be affordable to the public.

The need to consider a variety of recipes, to take into account properties of semi-finished and finished products according to the criteria and limits for each stage of designing a new product requires the involvement of mathematical support, software algorithms and the use of automated systems as essential tools for solving the problem of determining the optimal ratio of recipe ingredients (Muratova et al., 2010; Дворецкий et al., 2012).

Materials and Methods

To maximize the use of micronutrient complex of different chemical nature that is a part of functional additives of plant origin, and to create a broad product line of candies a combination of candy mass that have different composition and colloid-chemical properties can be used. As functional additives we used powdered semi-finished products prepared from local plant raw materials with different dispersion from 0.14 to 0.5 mm. Pumpkin and carrot powders containing vitamins of groups A, B, C, E, carotenoids and other vitamin-like substances, dietary fibre, macro- and micronutrients (potassium, calcium, iron, magnesium) have been received through combined convective-vacuum impulse drying that allows to keep all biologically valuable substances included in raw.

For enriching products with functional additives we used whipped cream and jelly candy mass with gelatinous consistency and low, compared to other confectionery, energy value. The composition of ingredients for preparing the whipped mass included sugar, agar, syrup, egg white, carrot powder, and citric acid. The composition of jelly mass included sugar, syrup, pectin, pumpkin powder, citric acid, sodium citrate.

When creating recipes we considered the possibility of chemical interaction between ingredients and chose combinations and methods of application ensuring their maximum safety during production and storage as well their high bioavailability.

During the research we applied commonly used and special research methods for studying the properties of raw materials, semi-finished and finished products. The experimental data were processed by methods of mathematical statistics using software packages MS Office Exel, MathLab 7.1. When designing formulations used the method of multi-objective optimization using LPτ sequences (Соболь, Статников, 2006).

It is necessary to consider the problem of designing confectionary recipes based on combining jelly and whipped candy mass with gelatinous consistency and the same moisture content. As the functional ingredient we used pumpkin powder (3 wt.%) in the jelly mass and carrot powder (10 wt.%) in the whipped mass (Muratowa, Smolikhina, 2013).

The set of alternative raw ingredients and main production stages of candies with combined whipped-jelly bodies for functional purposes are well known. By varying the composition of recipe mixtures and enriching them with micronutrients we can achieve certain physiological effects. For designing multicomponent food products object-oriented approach is offered to use. A distinctive feature of the object-oriented approach to recipe design of multicomponent food systems is presenting the recipe in a hierarchical structure.

Results and Discussion

It is important to determine the recipe $x = (x_1, x_2, ... x_n)$ of the finished product in which the basic consumer characteristics (food, biological and energy value, etc.) and cost price of the finished product $F(x) = (f_1(x), f_2(x), ..., f_m(x))$ reach the optimal values, and other consumer characteristics (microbiological indicators, shelf life, safety performance) $g_j(x), j = \overline{1,\gamma}$ satisfy the requirements of the technical specification for developing new food recipes, i.e. $g_j(x) \le 0, j = \overline{1,\gamma}$.

The problem of mathematical formulation of optimal recipe design is as follows:

$$x^* = \arg\min_{x \in X} \{F(x)\} \qquad (1)$$

Restrictions on other consumer characteristics of the finished product:

$$g_j(x) \le 0, j = \overline{1,\gamma} \qquad (2)$$

and the ratio of raw ingredients and semi-finished products:

$$\underline{x_i} \le x_i \le \overline{x_i}, i = \overline{1,n} \qquad (3)$$

The formulated problem belongs to the class of multiobjective problems in nonlinear programming. The problem was solved on the basis of the most-informative presentation of the searched area for compromise solutions by points filling the area X according to the method of I.M. Sobol. Algorithm for solving this problem is presented in the paper (Дворецкий et al., 2012).

Solving the problem of optimal recipe design of jelly-whipped candies enriched with functional ingredients (1)-(3) supposes using the applied criteria: carotenoids, $f_1(\gamma, x)$; dietary fibre content, $f_2(\gamma, x)$; energy value $f_3(\gamma, x)$, cost price of the finished product $f_4(\gamma, x)$.

Characteristics of the whipped and jelly layers are shown in Table 1.

Objective functions are calculated by the formula:

$$f_i(x) \equiv \sum_{j=1}^{2} c_{ij} x_{j,} i = \overline{1,4} \qquad (4)$$

where $x_{j,}\ j = \overline{1,2}$ – percentage of the whipped and jelly layer, respectively; $c_{1,j,}\ j = \overline{1,2}$ – energy value of constituent layers, kcal; $c_{2,j,}\ j = \overline{1,2}$ – carotenoids, mg; $c_{3,j,}\ j = \overline{1,2}$ – dietary fiber, g; $c_{4,j,}\ j = \overline{1,2}$ – cost price, rubles.

Table 1

Characteristics of jelly and whipped layers

Range of admissible values, wt.%	Energy, kcal	BAS content		Cost, rubles
		Carotenoids, mg	Dietary Fiber, g	
Jelly layer, 10.0–90.00	20.1–321.0	0.01–0.56	0.40–6.20	6.60–58.90
Whipped layer, 10.0–90.00	28.4–463.0	0.50–7.50	0.02–0.38	11.60–103.50

As a result of solving the multicriteria problem (1)–(3) many effective points (γ, x) of Pareto area (F) were built, which may be recommended for different recipes of jelly-whipped candies with high nutritional value taking into account consumer preferences:

1) γ= 2,3, F = (2,6; 11,76; 363,0; 80,29) – low energy value and high content of dietary fibre – can be recommended for the diet;
2) γ= 1, F = (4,09; 8,22; 380,0; 91,1) – balanced composition and average cost – for mass consumption;
3) γ= 0,4, F = (5,38; 4,6; 386,0; 100,35) – high energy value and high antioxidant content – can be recommended for sports nutrition.

The final choice of the above mentioned options was made on the basis of the ratio “price–quality” tailored to meet the daily requirement of micronutrients and organoleptic evaluation of the product. Adjustment of the layers provides a wide range of jelly-whipped candies with original organoleptic characteristics and a given set of micronutrients (Figs. 1 and 2).

(0.4) (89.7) (68.2) (43.3)

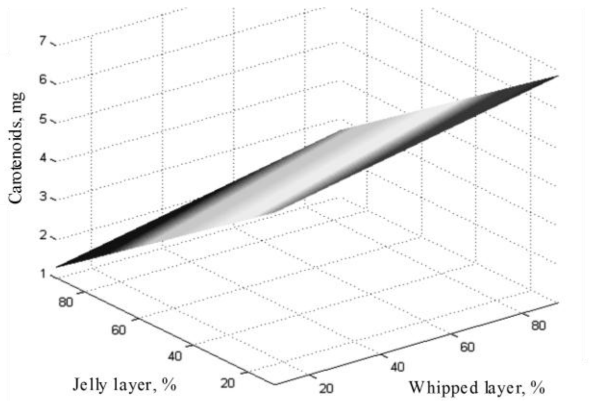

Figure 1. Dependence of the carotenoid content on the ratio of body layers

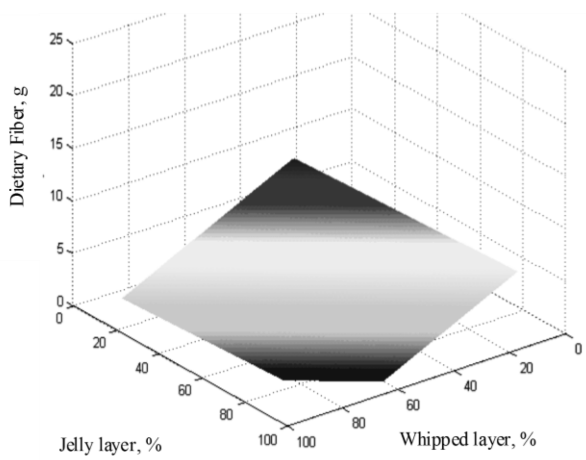

Figure 2. Dependence of the pectin content on the ratio of body layers

Table 2

Food and energy value of jelly-whipped candies

Indicator	Food value			
	Control	With the addition of vegetable powders and the ratio of the body layers		
		30:70	**50:50**	**70:30**
Energy value per 100g of candies, kcal (kJ)	400.0 (1676.0)	386.0 (1617.3)	380.0 (1592.2)	363.0 (1520.9)
Proteins, g	1.80	2.08	1.85	1.61
Fat, g	15.18	17.71	15.17	12.64
Carbohydrates, g	62.99	54.29	58.28	62.27
BAS	Per 100g (satisfying the norm of physiological needs, %)			
Dietary fibre, g	0.4 (7.7)	4.6 (21.3)	8.2 (41.1)	11.8 (58.8)
Vitamin C, mg	0.4 (0.54)	12.8 (18.2)	10.0 (14.2)	6.7 (9.6)
Carotenoids, mg	0.02	5.3	4.1	2.6

Taking into account the established and well-known rules of biologically active substances norm losses during technological processing and storage we calculated food and energy value of jelly-whipped candies with the addition of vegetable powders and different ratios of the body layers (Table 2).

For the calculation of multi component food recipes we used an automated system „Multifaz” based on the object-oriented approach (registration number 2011616793) and developed by the staff of Tambov State Technical University.

A distinctive feature of the object-oriented approach to the recipe design of multicomponent food systems is presenting the recipe as a hierarchical structure (Fig. 3).

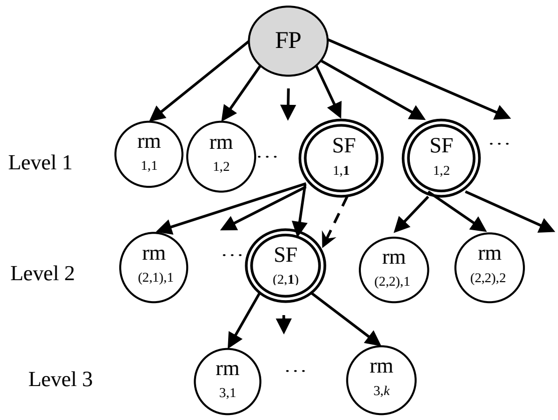

Figure 3. Diagram of program modes for calculating the single-phase recipe

Each of the top in the hierarchical structure is an object (the finished product, semi-finished product, raw materials). Every hierarchy level corresponds to a specific stage of manufacturing the food product and may have its own individual number of tops positioned lower in the hierarchy. Figure 3 shows a three-level hierarchy of calculating recipes, where the first index – the level number, the second index – the number of recipe component mixture. If on one or another recipe level several semi-finished products are used, their first index becomes composite and is denoted as a list (*i*, *j*), where *i* – the level number; *j* – the serial number of the semi finished product on the *i* level. This composite index is used below in the hierarchy (shown by the dashed arrow).

The algorithm for calculating multiphase food product recipe begins with the calculation of the final level in the longest branch of the hierarchical structure of the calculation. The initial data for calculation of the last level are: the consumption on downloading all kinds of raw materials and semi-finished products in kind; the loss of dry substances; the predetermined amount of finished products equal to 1 t.

Functional diagram of the automated information system is presented in Figure 4 (Муратова, Толстых, 2010). The system consists of information database including recipe components and semi-finished products, calculation and optimization modules. Information module is a collection of data for recipe components and semi-finished products.

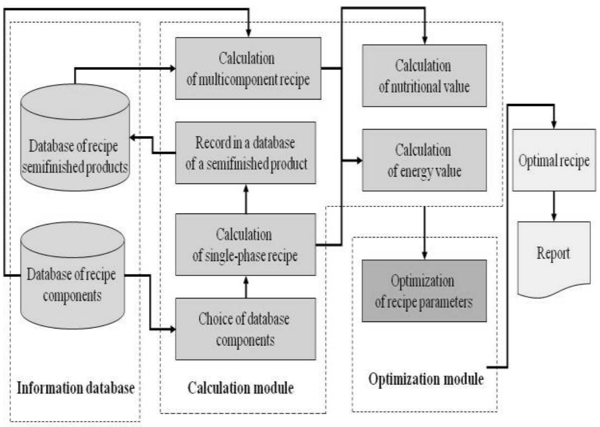

Figure 4. Functional diagram of the system „Multifaz"

The calculation module is used for selecting and recording components into the database information module, making calculations of single-phase and multiphase recipes, as well as food and energy value. The optimization module performs the selection of recipe components according to food and energy value in terms of restrictions on the cost price (Figure 5)

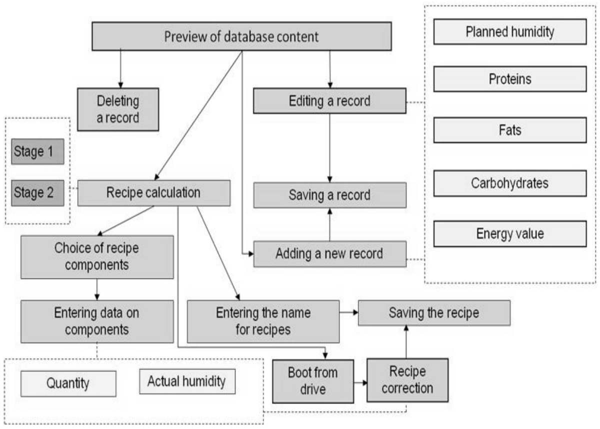

Figure 5. Diagram of program modes for the calculation of single-phase recipe

To construct the recipe hierarchy from the list of raw semi-finished components it is necessary to select semi-finished products from which the product is made and set the amount for the load. Then each recipe of semi-finished products is prepared with indicating solids content and the possibility of adding new recipe components to the list. Next the loading characteristic is set for each component of the raw material. The general hierarchy view of the wafers recipe for functional purposes is shown in Figure 6.

Pressing the button „Calculation" we get raw material consumption for cooking semi-finished products in accordance with this recipe, as well as a summary recipe of the designed product.

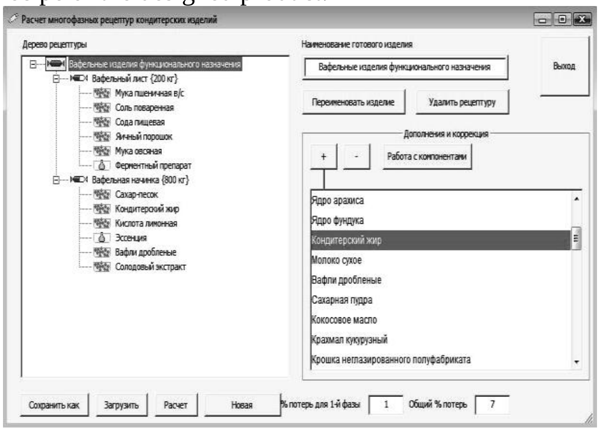

Figure 6. General view of the recipe tree of products for functional purposes

Calculation module of the automated system "Multifaz" has been tested and used in the educational process during the study of the discipline „Design of combined food" and during performing the final qualification work of bachelors, specialists and masters. The development of software module for optimizing recipes on food and energy value is now in progress.

Conclusions

Computer-aided recipe design noticeably allows to accelerate the calculation and optimization of complex multi component food products, to create products with predetermined chemical composition, nutritional value and functional orientation, to respond quickly to changes in the properties and types of raw ingredients.

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