

MATHEMATICAL MODELING OF THE COMPOSITION BASE OF PRODUCTS FOR BODY WEIGHT CONTROL

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Abstract

The problems of overweight and obesity have been analyzed, and the main ways to solve them have been investigated, one of which is the consumption of specially designed bran bars for body weight control. Based on the recommendations of experts, it has determined that the main components characterized by a high fiber content are oat and wheat bran, flax seed meal, in particular, the proposals of specialists on their content in the target products planned for development have been analyzed. Based on these data, 9 model compositions of the mentioned components have been created, their organoleptic properties have been assessed using a specially created point scale, on the basis of which, using the weight coefficients, their complex quality indicators has been determined. The information obtained was used to develop and build a mathematical model of the composition of the compositional base of bars for body weight control.

Keywords: mathematical modeling, body weight control, bran bars, organoleptic properties, complex quality indicator.

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1. Introduction

The problem of obesity and overweight in the world is one of the main factors of chronic diseases with serious social and psychological consequences. The obesity pandemic is negatively affecting virtually all age groups and socioeconomic groups.

According to the World Health Organization (WHO), more than 1.9 billion adults aged 18 and over are overweight, of which more than 650 million adults are obese.

Over the past four decades, the prevalence of obesity worldwide has increased dramatically. If this trend continues, by 2030 more than 50 % of the world's adult population will be overweight or obese [1].

In Ukraine, 35 % of women are overweight. More than 18 % of Ukrainian women suffer from obesity. More than 45 % of men are overweight. More than 13 % of Ukrainians are obese [2].

The global pandemic for the acute viral infection COVID-19 has exacerbated the issue of obesity and overweight. Forced isolation at home limits movement and activity, and this situation itself leads to a calorie surplus: a person continues to eat at the usual frequency, and en-

ergy consumption decreases due to constant stay in a confined space. People who are already obese or overweight have an increased risk of hospitalization, serious illness and death due to low-grade chronic inflammation, altered immune response to infection, and concomitant cardiometabolic disease. Thus, the forced isolation of the population as a result of pandemia additionally has a significant negative impact due to obesity of people.

Also, obese patients who are already sick with COVID-19 and need intensive care create problems with treatment, since obese and overweight patients are more difficult to intubate, it is more difficult to obtain diagnostic images (since there are weight restrictions on imaging machines), more difficult to transport by medical staff, they may feel bad when lying down [3, 4].

2. Literature review and problem statement

Despite the rapidly growing problem of overweight and obesity in the modern world, it is important to have a balanced human diet, the purpose of which in many cases is to control body weight, in particular, weight loss.

The introduction of special dietary products into the diet allows one to control body weight, and as a result, to purposefully affect the body.

Specialty weight management products represent a rapidly growing market segment. The global weight loss market is projected to show significant growth of 8.95 % between 2019 and 2025 and reach a market value of 408.36 billion USD by the end of 2024. The bar is gaining popularity due to its ease of consumption. The global market for weight control bars is expected to reach 16.9 billion USD by 2025, growing at a 6.17 % CAGR over the forecast period.

In Ukraine, the market for this group of goods is also developing very quickly – over the 9 months of last year, there is an increase in the share from 4.8 % to 9 %. Such an increase in sales of food products for weight control is due to the trend of conscious nutrition of health and natural food products and, accordingly, the expansion of the circle of buyers [5, 6].

In the process of solving the problem of overweight a person, one of the main places is occupied by the consumption of products characterized by a high content of fiber, in particular bran. The use of these food components, which are by-products of grain processing, due to their functional properties, has become widespread in the production of dietary foods. It should be noted that bran contains carbohydrates without starch (arabinoxylan, beta-glucan), flavonoids (anthocyanin), provitamins (carotenoids), phenolic acids (ferulic acid), oils (γ -oryzanol), oligosaccharides. All this and additionally their physicochemical properties make them desirable for food fortification. They are known to be involved in the body's fight against oxidative stress, prevent the risk of obesity by inducing satiety, decrease insulin resistance, and alleviate cardiovascular complications [7].

3. The aim and objectives of research

The aim of research was to determine a mathematical model of the composition of the compositional base of bars for body weight control, based on the organoleptic indicators that determine their integrated quality indicator.

To achieve this aim, a study was conducted, including the solution of the following objectives:

- to analyze scientific sources containing recommendations for the main components that are characterized by a high fiber content;
- to develop model versions of samples of bran bars on the basis of the data obtained and to assess their organoleptic quality indicators using the developed point scale;
- to determine the complex indicators of the quality of the organoleptic properties of the samples, taking into account the established weight factors;
- to develop a mathematical model of the composition of the compositional base of bars for body weight control.

4. Methodological base of experimental research

Based on the analysis of scientific literature sources [8–10], it was found that the following ratio of components characterized by a high fiber content is optimal for the base of bran bars, % – oat bran:wheat bran:flax seed meal – 50 – 65:25 – 35:4 – 27. In particular, during the period of body weight control with systematic physical activity, the ratio is considered optimal, % – 46.6 – 63.2:26.7 – 32.8:4 – 26.7.

To obtain the optimal composition of products, a two-level system of structural-parametric optimization of the composition of the compositional base of bars was used to control body weight for quantitative and qualitative (organoleptic) criteria, as well as further enrichment with a functional composition in accordance with recommendations for ensuring control of human body weight [11, 12]. The organoleptic assessments of the quality indicators determined by the optimal at the first stage of the samples of bars were carried out according to the 5-point scale developed and prepared by the authors, taking into account the weighting factors, which were determined by the expert commission from representatives of scientific KNUTE and specialists of the manufacturer.

5. Discussion of research results

On the basis of the considered recommendations of experts in the field of dietetics and dietic nutritionology, the authors calculated the recommended previously mentioned components, characterized by high fiber content, % (Table 1).

Table 1

Results of calculating fiber content

Total fiber	Recommended content in a composite base, %
Oat bran	46.6–63.2
Wheat bran	26.7–32.8
Flax seed meal	4.0–26.7

The obtained values for the recommended fiber content in the product for special dietary consumption for persons controlling body weight became the basis for creating 9 prototypes corresponding to the specific physiological processes of the human body being in the active phase of controlling excess body weight under conditions of physical systematic stress.

According to the concept of rational nutrition, when overweight, it is necessary to take into account the following components: energy intake with food, its reserves in the body and energy costs. Energy intake into the human body is regulated by a complex system directed by such physiological manifestations as appetite and satiety. Therefore, to carry out a comprehensive organoleptic assessment of prototypes, characterized by high compliance with the needs of the human body, which controls body weight, a point scale was developed (Table 2).

In order to obtain data for mathematical modeling of the fiber composition of bars for persons controlling body weight, the organoleptic properties of 9 developed samples were assessed, characterized by a high correspondence to the characteristics of needs, according to the developed score scale. Based on these data, their complex quality indicator was calculated, which was determined taking into account the rejection and reference values according to the formula:

$$\sum_{i=1}^n a_i \frac{P_i - P_i^{rej}}{P_i^{ref} - P_i^{rej}},$$

where P_i – i -th quality indicator in natural form; P_i^{ref} – reference (better acceptable) value of the i -th indicator; P_i^{rej} – rejection (worse permissible) value of the i -th indicator; a_i – weighting coefficient of the i -th indicator, which is determined by the ranging method; n – the number of assessed indicators.

According to the research results, it was revealed that the highest integrated quality indicator is characterized by sample 7 (54.9 % wheat bran, 26.7 % oat bran, 18.4 % flax seed meal), the lowest – sample 6 (46.6 % oat bran , 32.8 wheat bran, 18.4 flax seed meal).

Table 2

A point scale for evaluating the organoleptic properties of products for special dietary consumption for persons who control body weight

Indicators	Weight factor	Scores	Characteristic
Appearance and consistency	0.3	5	Rectangular elongated tiles with equal cuts. Separate tiles with broken corners or cracks are allowed no more than 3 % by count in one group package. Embossed, rough, with or without shallow cuts. Elastic, crispy, slightly viscous. Vitreousness not allowed
		4	Rectangular elongated tiles with slight cuts. Embossed, rough with shallow cuts. Elastic, crispy, slightly viscous.
		3	Rectangular elongated tiles with uneven cuts and cracks. Embossed, rough with deep cuts. Inelastic, not crunchy, slightly viscous.
		2	Non-rectangular elongated tiles with uneven cuts and cracks. Embossed, glossy with deep cuts. Inelastic, non-crunchy, viscous.
		1	Products of irregular shape, deformed, disproportionate, with deep cracks and breaks. Unsuitable for this type of product.
Colour	0.1	5	From light yellow to golden, corresponding to the color of the applied raw materials.
		4	Yellow, corresponding to the color of the applied raw material
		3	Dark yellow, insufficiently pronounced, little matches the color of raw materials
		2	Various shades, does not match the color of the introduced raw materials
		1	Not typical for this type of product
Taste	0.2	5	Sweet, pleasant, balanced, pronounced characteristic of this type of product, without foreign aftertaste
		4	Sweet, pleasant, balanced, insufficiently expressed, with a slight aftertaste
		3	Sweetish, unpleasant, unbalanced, insufficiently expressed, with an aftertaste
		2	Expressed taste with aftertaste
		1	Does not correspond to this type of product, foreign taste
Smell	0.15	5	Nice, pronounced, appropriate for the given species. No foreign smell
		4	Pleasant, pronounced, appropriate for the given species. No foreign smell
		3	poorly expressed
		2	pronounced
		1	Unsuitable for this type of product
Aftertaste	0.25	5	Pleasant, sweetish, balanced, sufficiently long-lasting, without any foreign aftertaste
		4	Pleasant, sweetish, unbalanced, short-lived, without any foreign aftertaste
		3	Expressed, without any foreign aftertaste
		2	Unpleasant, mild, short-lived, with a slight aftertaste
		1	Harsh, unpleasant, persistent and long-lasting, with significant aftertaste

Bran bars “Effect”, which are based on the following ingredients: oat bran, wheat bran, flax seed meal and the functional composition of the same name “Effect”, which consists of coenzyme Q10, lipoic acid, guarana and conjugated linoleic acid in an optimal ratio and safe concentration. The bars have a targeted effect on the intensification of lipid metabolism, antioxidant effect, and have a positive effect on the physical performance of athletes.

Bran bars “Chocolate effect”, which contain oat bran, wheat bran, cocoa powder, extrusion buckwheat flour and functional composition Effect, which contains coenzyme Q10, lipoic acid, guarana and conjugated linoleic acid in an optimal ratio and safe concentration (dose) increase the metabolic rate, accelerate the complete recovery of the athlete’s body after physical exertion, also have a positive effect on the mechanisms of the body’s antioxidant defense against the damaging effects of lipid peroxidation, which is known to be activated during intense muscular activity.

Table 3

The results of sensory assessment and calculation of the integrated quality indicator

Sample No.	Recipe composition, %			Appearance and consistency					Colour					Taste					Smell					Aftertaste					Comprehensive quality indicator					
				weight factor																														
	0.3					0.1					0.2					0.15					0.25													
	Expert					Expert					Expert					Expert					Expert													
			Average value of the indicator					Average value of the indicator					Average value of the indicator					Average value of the indicator					Average value of the indicator											
			No. 1	No. 2	No. 3	No. 4	No. 5	No. 1	No. 2	No. 3	No. 4	No. 5	No. 1	No. 2	No. 3	No. 4	No. 5	No. 1	No. 2	No. 3	No. 4	No. 5	No. 1	No. 2	No. 3	No. 4	No. 5							
1	63.2	26.7	10.1	5	5	4	4	5	4.6	5	4	5	4	5	4.6	4	5	5	4	5	4.6	5	4	5	5	4	4.6	4	4	5	5	5	4.6	0.9
2	63.2	29.7	7.1	4	4	4	5	4	4.2	4	4	4	4	5	4.2	4	5	4	4	4	4.2	4	4	4	4	4	4	4	4	4	4	4	4	0.78
3	63.2	32.8	4	3	4	4	4	4	3.8	3	4	4	3	3	3.4	3	4	3	3	4	3.4	3	4	4	3	3	3.4	3	4	3	4	4	3.6	0.6425
4	46.6	26.7	26.7	5	4	5	4	5	4.6	4	5	4	5	5	4.6	5	4	5	4	5	4.6	4	4	5	5	5	4.6	4	5	5	4	5	4.6	0.9
5	46.6	29.7	23.7	4	5	4	4	4	4.2	5	4	4	4	4	4.2	4	4	4	4	4	4.2	4	4	4	4	3	3.8	4	4	4	3	4	3.8	0.76
6	46.6	32.8	20.6	4	3	4	4	3	3.6	3	4	4	3	4	3.6	4	4	3	4	4	3.8	3	4	3	4	3	3.4	3	3	3	3	3	3	0.615
7	54.9	26.7	18.4	4	5	5	5	5	4.8	5	5	4	5	5	4.8	5	5	4	5	5	4.8	5	5	5	5	4	4.8	4	5	5	5	5	4.8	0.95
8	54.9	29.7	15.4	4	4	4	4	4	4	4	4	5	4	4	4.2	4	5	4	4	4	4.2	4	4	4	4	5	4.2	4	4	4	4	5	4.2	0.785
9	54.9	32.8	12.3	4	5	4	3	3	3.8	5	3	4	3	4	3.8	5	3	3	4	3	3.6	4	3	3	4	3	3.4	3	4	3	3	3	3.2	0.6375

Bran bars “Sport Slim” and “Sport Slim Chocolate” for people who control body weight in conditions of systematic physical exertion include a functional composition “Sport Slim”. The functional composition consists of coenzyme Q₁₀, conjugated linoleic acid, L carnitine and green tea extract. Systematic consumption of bran bars contributes to the correction of body weight, manifests itself in a significantly reduced body weight and percentage of fat in the body of athletes, has an antioxidant effect, affects the increase in physical performance of athletes, strengthening the immune system [13, 14].

Table 4
Characteristics of the components of functional compositions

Functional composition	Nutritional problem for weight controllers	Component of functional composition	Physiological action in practice of the program for controlling body weight in conditions of systematic physical exertion
Functional composition for a special product for dietary consumption «Effect»	Intensification of lipid metabolism, increasing efficiency, enhancing the antioxidant defense system of the body.	Conjugated linoleic acid	A direct antioxidant that has anti-carcinogenic effects, improves cardiovascular function, and decreases insulin resistance to prevent adult diabetes and facilitate weight control
		Coenzyme Q ₁₀	Promotes an increase in muscle strength, power, local endurance, an increase in muscle energy reserves, supports the immune system. slows down the human aging process, has a pronounced antioxidant activity. Activates the regenerative processes of all fast-growing tissues
		Guarana	supports the body's resistance to physical and mental fatigue, accelerates the conversion of fats into energy, improves blood circulation, improves performance, enhances endurance, supports cognitive functions
		Lipoic acid	Antioxidants, restores other oxidized forms of antioxidants, has lipotropic properties, improves liver function, provides intracellular and extracellular protection
Functional composition for a special product for dietary consumption «Sport Slim»	Acceleration of thermogenesis, restoration of immune dysfunction, increase in the adaptive potential of athletes, supports cognitive function	Conjugated linoleic acid	Reduces insulin resistance. Reducing insulin resistance has been shown to help prevent adult diabetes and facilitate weight management
		Coenzyme Q ₁₀	Promotes resistance to muscle fatigue, has a beneficial effect on the nervous system, restores immune dysfunction
		L carnitine	Increases physical and mental performance, normalizes blood circulation
		Green tea extract	Neutralizes the action of free radicals in body tissues

5. Discussion of the results of organoleptic assessment and calculation of the integrated quality indicator

Based on the data on the fiber content and the complex quality indicators calculated from the results of the organoleptic assessment using the MS Excel 2003 software, a mathematical model of the complex quality indicator was developed:

$$y=0,047672435x_1+0,00248866x_2+0,04671862x_3-2,560681668 (R_2=0.9833),$$

where x_1 – oat bran; x_2 – wheat bran; x_3 – flax seed meal.

Based on the studies carried out and the calculation of a complex quality indicator based on organoleptic quality indicators in the established range of fiber content, the following dependence was established with their amount in the test samples, Fig. 1.

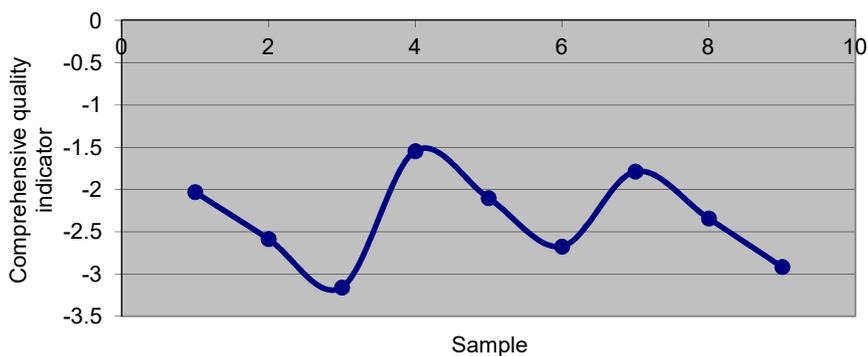


Fig. 1. Change in the comprehensive quality indicator of the test samples

6. Conclusions

On the basis of the performed mathematical modeling of the composition of the compositional base of bars for control of body weight, the optimal ratios of fiber in bran bars for persons controlling body weight have been established. In particular, as a result of the organoleptic assessment, it was determined which samples are characterized by the best organoleptic properties, and a mathematical model of the composition of the fiber of the product was developed to control body weight. The components of the functional compositions, which were included in bran bars, have the following properties: conjugated linoleic acid is a direct antioxidant, has an anticarcinogenic effect, improves the functioning of the cardiovascular system, reduces insulin resistance helps prevent adult diabetes and simplifies weight control; coenzyme Q_{10} – helps to increase muscle strength, power, local endurance, increase muscle energy reserves, supports the immune system; slows down the aging process of a person, has a pronounced antioxidant activity, activates the regenerative processes of all fast-growing tissues of guarana – supports the body’s resistance to physical and mental fatigue, accelerates the conversion of fats into energy, improves blood circulation, improves performance, enhances endurance, supports cognitive functions; lipioic acid is an antioxidant that reduces other oxidized forms of antioxidants, has lipotropic properties, improves liver function, and provides intracellular and extracellular protection; L carnitine – increases physical and mental performance, normalizes blood circulation green tea extract - neutralizes the action of free radicals in body tissues.

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