Визначено показники амінокислотного СКОРу білкової системи, що представляє собою розчини різної концентрації гідролізату колагену у молочній сироватці (2 %, 4 %, 6 %). Показано, що всі розчини мають збалансований вміст незамінних амінокислот. Однак для досліджень вибрано харчову систему, що має концентрацію гідролізату колагену 4 %, що забезпечить добову потребу організму людини.

Досліджено піноутворення вуглеводно-білкової системи в залежності від співвідношення пектину яблучного та гідролізату колагену в молочній сироватці (0,5:1; 1:1; 1:0,5). Збивання проводили при температурі 10 °С в продовж 60 секунд. Отримані дані виявили оптимальне співвідношення основної вуглеводно-білкової сировини: концентрація гідролізату колагену 4 %, співвідношення пектин:гідролізат колагену 1:0,5.

За допомогою математичного моделювання розроблена рецептура аерованого смузі на основі молочної сироватки, фруктового соку, пектину яблучного та гідролізату колагену з підвищеним вмістом макронутріентів. Аналіз споживчої цінності розробленого продукту показав, що вміст основних макронутріентів склав 22,64 г на порцію (200 г) або 11,32 г на 100 г. Співвідношення основних мінеральних речовин кальцію, магнію та фосфору дорівнює 1:0,11:0,6. Аналіз амінокислотного СКОРу показав, що розроблений продукт має високий ступінь засвоюваності незамінних амінокислот, що пов'язано з відсутністю лімітуючої амінокислоти, СКОР якої менший ніж 100 %.

Визначення біологічної активності показало, що для готового смузі біологічна активність в середньому в 8,1 разів вища ніж у його складових, що свідчить про синергізм речовин антиоксидантної дії.

Оцінка сенсорних показників розробленого смузі показала високі якісні характеристики нового продукту, що є важливим для продукції закладів ресторанного господарства. Загальна оцінка за сенсорними показниками становить 33,8 бали з 35 можливих балів

Ключові слова: математичне моделювання рецептур продуктів, показники якості, аеровані напої, гідролізат колагену, піноутворення, харчові піни

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DEVELOPMENT OF A POLICOMPONENT COMPOSITION OF SMUZ USING BIOTECHNOLOGICAL AND MATHEMATICAL MODELING AND DETERMINATION OF ITS FOOD VALUE

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1. Introduction

Production of food plays a leading role in the provision of people with balanced nutrition products. Such products combine both plant and animal raw materials to create products of high nutritional and biological value for functional, dietary, and prophylactic purposes.

As we know, proteins of animal origin play an important role in the diet. There is a lack of proteins, which contain essential amino acids in the diet of Ukrainians over the past

10 years according to the Research Institute of Nutrition and other scientific and medical government institutions [1].

The use of whey for food production is reasonable due to its multicomponent biologically complete composition. Combining dairy raw materials with fruit and berry fillers, which are sources of vitamins, macronutrients, and microelements, with the used dietary fiber makes it possible to obtain new low-fat dietary and prophylactic foods of different textures with attractive parameters for a consumer.

One should note that the development of technologies for diary low-fat dietary and prophylactic foods with dietary fiber is a promising trend in the industry of production of food for restaurants. One should base technologies on knowledge about rational and balanced nutrition, which, in turn, will improve the quality of life of people of different population groups.

The range of dairy products with animal proteins and dietary fiber is not large at present, despite the wide interest in the problem.

It is necessary to study associative interactions in the system of "protein-polysaccharide" biopolymers for the development of milk-containing products with dietary fiber.

The development of innovative milk-containing aerated products using dietary fiber and animal protein is a relevant task.

2. Literature review and problem statement

The beverage market underwent significant changes and innovations in recent years, as the new way of life has a significant impact on health. Consumers expect beverage market operators to offer highly useful products with high-nutrient content as they are accepted transportation for nutraceuticals and biologically active substances.

Dairy based drinks, soy, fruit- or vegetable-based drinks, cocktails, sports, recreational and energy drinks can be sources of all nutrients needed for the modern body. Solubility, biological availability, pH, temperature, light and heat stability of ingredients, color and aroma of a finished beverage should be the main indicators of quality when we include fortifiers to such beverages [2].

Whey often plays a role of a basis for ready-to-drink protein drinks. The drinks have high quality, soft taste, easy digestibility and unique functionality due to whey protein. There are five common trends in the food and beverage industry: convenience, pleasure, ethnic composition, traditions and, most importantly, health.

Whey proteins may have antioxidant activity. Researchers studied beverages based on whey with high antioxidant parameters due to the presence of vegetable polyphenols, vitamins and astaxanthin. They used ABTS, FRAP (the presence of iron, which reduces energy of antioxidants) and ORAC (the capacity of absorption of oxygen radicals) for the studies on the antioxidant activity of beverages during storage. The combination of the whey with additional antioxidant ingredients increased bioactivity of products [3]. However, they did not study changes in the antioxidant activity for some individual formulation components and their effect on the overall antioxidant activity rate. They did not study an impact of introduction of plant raw material on rheological properties, which are important sensory indicators both for beverage production technology and for storage.

There are four main types of whey-based drinks:

– whey mixtures (treated or untreated, including permeates with fruit or vegetable juices;

– "thick" milk-type beverages (fermented or non-fermented);

– carbonated beverages, thirst quenchers and alcoholic beverages (beer, wine or liqueurs) [4].

There were beverages developed based of on whey obtained in the process of production of solid and fermented milk cheese, as well as retentate obtained by concentrating whey by the nanofiltration method. There were "Apple pear" and "Strawberry-cherry" directly pressed juices (purees), which did not contain sugar, used in formulations of drinks. The beverages obtained had an average energy value of 20.9 kcal in whey-based drinks and 65.1 kcal in retentate-based drinks [5]. The researchers took into account only taste indicators in the investigation of beverage formulations. They did not take into consideration a change in consistency due to pectic substances of pear, apple, cherry and strawberry purees.

There were studies on the effect of a type and concentration of pectin substances on probiotic properties of beverages for development of pectin-containing beverage formulations and technologies [6]. Researchers used the dried Unipectin OV 700 pectin and the pectin apple extract produced by SunLand (Hungary) as pectin supplements. They investigated dynamics of biomass accumulation by lactic acid cultures. They developed formulations for beverages with balanced micronutrient composition using mathematical modeling. However, authors of the study did not show the effect of pectin-containing additives on rheological parameters of a finished beverage and their change during storage.

There was a study conducted on the effect of addition of xylooligosaccharide (XOS, 1.25 g/100 ml) on pH, physical-and-chemical composition, functional properties, volatile profile, rheological properties and sensory perception of a flavored strawberry drink based on the whey [7]. Addition of polysaccharide led to obtaining of drinks with high antioxidant activity, high viscosity and improved volatile profile. However, the issue of determination of the dynamics of syneresis of finished beverages during storage remained unresolved.

Authors of paper [8] used Lactobacillus acidophilus LA-5 or Bifidobacterium animalis ssp. Lactis BB-12 probiotic cultures for production of beverages. The beverage formulation included pasteurized acid whey with milk, unsweetened condensed milk or non-fat milk powder. They stored the products under refrigeration (5±1 °C) for 21 days. The obtained data showed that whey beverages are a good environment for probiotic bacteria; a number of bacteria exceeded 10^8 CFU/ml during the storage period. The number exceeded the minimum therapeutic dose significantly. However, they did not investigate changes in the amino acid profile of beverages during fermentation.

Authors of work [9] studied an effect of the addition of high-methoxylated pectin and carboxymethyl cellulose with different combined ratios on stability of acidified non-fat milk and whole milk beverages [9]. The results of experiments showed that the stability of beverages improved when a number of polymeric polysaccharides increased in the ratio of polysaccharides, emphasizing the importance of molecular properties of polysaccharides. However, the authors did not pay enough attention to the combination of polysaccharides and influence on organoleptic and rheological properties of the finished products, when they selected the ratio of polysaccharides.

There was high-methoxylated pectin used to stabilize dairy drinks to prevent milk protein flocculation. Particle diameter, viscosity, sedimentation and viscosity-elastic properties were parameters for estimation of the amount of pectin needed to stabilize a beverage. The study showed that a certain amount of pectin was strongly irreversibly bounded with casein aggregates, which made it possible to state that there was formation of a multilayer pectin layer on casein aggregates [10]. However, the issue of determination of stability of obtained drinks during storage remained unresolved.

Authors of paper [11] studied the effect of orange fibers rich with pectin on rheological, sensory, and tribological properties of yogurt gels. More specifically, the study evaluated an effect of fiber particle size (coarse and fine) and fiber concentration (0.1 and 1.0 %). Addition of fiber caused changes in sensory perception. Tribological data showed that friction increased mainly due to the reduced ability of coarse-fiber yogurt to immobilize water at high deformation and that the protein (casein) network dominated among lubrication properties in an ordinary yogurt. The authors carried out addition of orange fibers based on tribological data only, but they did not take into account recommendations of nutritionists regarding an amount of dietary fiber in the daily diet.

Authors of work [12] used whey obtained during production of Cheddar cheese and paneer to produce a lemon-based whey drink [12]. They hydrolyzed lactose, which was in the whey, by the Maxilact L-2000 enzyme of lactase. They obtained the most acceptable beverage using a lemon base, which contained 8, 4, 0.1 and 0.05 % of sugar, lemon juice, lemon aroma and carboxymethylcellulose, respectively. They paid considerable attention to rheological parameters during production of a drink, but the study did not show how sensory and rheological parameters of drinks changed at different ratios of whey and lemon base.

Thus, the issue of creation of finished products with a balanced nutrient composition remains unresolved, despite current research in the field of beverage technology. In terms of technology, there are problems in improvements of the aeration process of milk-vegetable mixtures to obtain beverages with a whipped structure and beverages enriched with active oxygen. Vegetable raw materials are rich in structure-forming polysaccharides, so they are widely used for production of beverages. But their effect on rheological parameters of beverages under various technological modes of production and storage remains unresolved. It is necessary to meet needs of modern man and meet requirements of nutrition in terms of nutritional composition in production of competitive beverages in production of competitive drinks.

Therefore, it is important to develop an integrated approach to the development of aerated beverages, taking into account an effect of hydrocolloids on rheological parameters during production and storage. In addition, a comprehensive approach to beverage production should include modeling of formulations according to requirements of dietarians and nutritionists.

3. The aim and objectives of the study

The objective of this study is to develop a composition of an aerated smoothie with high solids content.

We set the following tasks to achieve the objective:

– substantiation of selection of raw materials for production of aerated smoothies;

– mathematical optimization of compositions of aerated smoothies;

– investigation of nutritional and energy values and antioxidant activity of a new product;

– study of sensory indicators of a finished product under production conditions.

4. Materials and methods for the development of the smoothie composition

We performed our studies in the following laboratories:

– Healthy Nutrition Consulting Laboratory (Odessa, Ukraine);

– Research laboratory of microbiological studies named after O. A. Kirilenko (Odessa, Ukraine).

The following equipment was used for the studies:

– a blender (PHILIPS HR-1633/80, China), a refrigerating chamber (SHK-0,4 MS, Republic of Mariy El, Russia), a wash bath and electric scales (Rotex RSK 10-P, China) for the preparation of smoothies;

– a KFK-2MP photo-calorimeter ("ZOMZ" opto-mechanical plant production association, USSR) for determination of antioxidant activity;

– a Hitachi 835 ion exchange liquid chromatograph (Japan) for determination of an amino acid composition;

– a Biolam P15 microscope (Lomo, Russia) with a ScopeTek DCM-130 E 1.3 Mp digital eyepiece camera (Hangzhou Scopetek Opto-Electric Co., China) for microscopy of samples [13].

The following raw materials were chosen for the production of a smoothie: whey, cherry juice, apple pectin and collagen hydrolysate.

We performed mathematical modeling of the smoothie composition by macronutrient content [14]. Linear programming was employed using MS Excel 2010 software for the implementation of mathematical modeling of formulations [14, 15].

5. Results of modeling a smoothie composition and determining its quality parameters

5. 1. Substantiation of selection of raw materials for the production of the smoothie

The main parameters for selection of raw materials for establishments of the restaurant industry are indicators of compliance with safety standards and requirements of HACCP, taking into account constancy of useful properties in culinary processing. Therefore, we chose available, inexpensive and high-quality raw materials with high biological parameters as raw materials for production of smoothie.

Whey contains more than 200 microelements, vitamins, and vital substances. Daily use of whey satisfies 2/3 of the daily need of the body in calcium, 1/2 – in potassium, 80 % – in vitamin B_2, 1/3 – in vitamins B_1, B_6, B_{12}.

There is an optimal balanced amount of fats, proteins and carbohydrates in whey. It does not overload the sensitive baby's digestive system and helps to cope with excessive gas formation and dysbacteriosis. It also stimulates the body's protective functions.

Cherry juice improves metabolic processes in the body and has a restorative effect due to its pronounced antioxidant properties. The high content of folic acid and iron makes it a useful for people suffering from anemia. It eliminates the number of streptococci, staphylococci, and causative agents of dysentery. It helps heal wounds and relieves inflammation of joints faster than some anti-inflammatory drugs. There are many coumarins in cherry juice. Coumarins are active substances, which that have different effects, such as antispasmodic, calming, diuretic, soothing, antimicrobial, and other effects. There are many compounds of the P-vitamin complex in cherry juice [16].

Pectin is a natural polysaccharide. Pectins act in the human body as follows:

– envelop the mucous membrane of the stomach and intestines, protecting against damage and harmful bacteria;

– strengthen intestinal peristalsis and help to cope with constipation;

– increase absorption of calcium and magnesium in a body;

– remove aggressive substances, toxins and salts of heavy metals from the gastrointestinal tract;

– help to restore the beneficial microflora in dysbiosis (apple pectin works best for this matter);

– bind harmful cholesterol and remove it from the body and prevent formation of atherosclerotic plaques;

– accelerate tissue regeneration after surgery, burns or peritonitis [17].

97 % of collagen hydrolysate (CH) is protein. The composition of the animal collagen and the hydrolysate produced on its basis is very close to the protein produced by the human body. Collagen hydrolysate has the following meaning for the human body: it is responsible for tissue elasticity; it stimulates cell growth; it retains moisture in cells; it gives attractive appearance to hair, nails, and skin; it prevents flabbiness of skin.

We determined the prerequisites of an influence of technological parameters on rheological parameters of a mixture of selected components for mathematical optimization of compositions of aerated smoothies.

As more than 50 % of the composition of the smoothie will consist of protein raw materials, we calculated the amino acid SCORE of protein raw material with its different ratio.

The studies went as follows. We prepared solutions of collagen hydrolysate in whey with different concentrations. The whey concentration of collagen hydrolysate was 2, 4 and 6 %, based on the recommendations of nutritionists regarding the use of collagen hydrolysate (5 g – maintenance therapy, 10 g – therapeutic therapy).

Table 1 gives the qualitative composition of essential amino acids. Table 2 presents calculations of amino acid SCORE.

All solutions had sufficiently high rates in terms of amino acid SCORE for further studies. However, we chose a sample, which contained 4 % of collagen hydrolysate, because the content of a finished product will meet recommendations of nutritionists at this concentration of collagen hydrolysate. In addition, an increase in the content of collagen hydrolysate in the whey will not lead to a more homogeneous structure and the food system will have an increased sticky effect, which will worsen its product parameters significantly.

Table 1

Content of essential amino acids in the investigated protein solutions

Amino acids	Concentration of CH in whey								
	2 %	4 %	6 %	2 %	4 %	6 %	2 %	4 %	6 %
	g of a/c g per 100 ml of solution			g of a/c g per 1 g of protein			mg of a/c per 1 g of protein		
valine	0.60	0.63	0.66	0.28	0.18	0.13	283.84	180.64	135.60
isoleucine	0.59	0.61	0.62	0.27	0.17	0.128	277.69	173.16	127.54
leucine	1.15	1.18	1.21	0.537	0.33	0.24	536.554	334.76	246.70
lysine	1.04	1.07	1.10	0.48	0.30	0.22	485.73	304.17	224.93
methionine	0.22	0.22	0.23	0.10	0.06	0.04	104.43	64.59	47.21
threonine	0.61	0.64	0.66	0.28	0.18	0.13	287.02	181.66	135.68
tryptophan	0.23	0.23	0.22	0.11	0.06	0.04	109.66	65.27	45.90
phenylalanine	0.40	0.42	0.44	0.19	0.12	0.09	190.41	120.92	90.59

Table 2

Amino acid SCORE of protein solutions

Amino acids	2 % CH solution	4 % CH solution	6 % CH solution
valine	567.7	361.3	271.2
isoleucine	694.2	432.9	318.9
leucine	766.5	478.2	352.4
lysine	883.2	553.0	409.0
methionine	298.4	184.6	134.9
threonine	717.5	454.2	339.2
tryptophan	1096.6	652.8	459.1
phenylalanine	317.4	201.5	151.0

We used apple pectin as a stabilizer of the aerated structure. Therefore, the next step was to substantiate the pectin:collagen hydrolysate ratio to obtain a more whipped structure of the food system.

We prepared carbohydrate-protein solutions in the whey for our study. The pectin:collagen hydrolysate ratio was 0.5:1; 1:1; 1:0.5.

We carried out whipping at 10 °C and 20 °C. We chose such temperatures according to the technological process of cocktails preparations in restaurants.

The whipping time was 30 to 120 seconds with 30 sec pauses.

Fig. 1, 2 show comparison of foaming of samples.

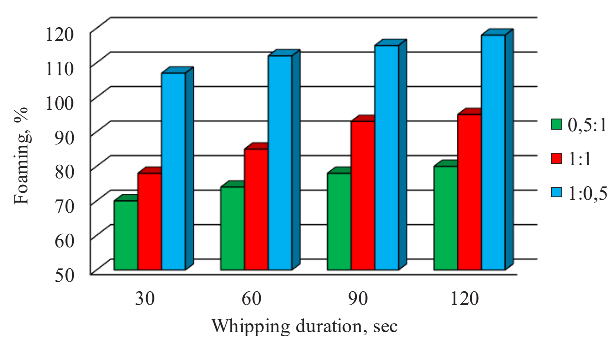

Fig. 1. Foaming of the carbohydrate-protein food system at 10 °C

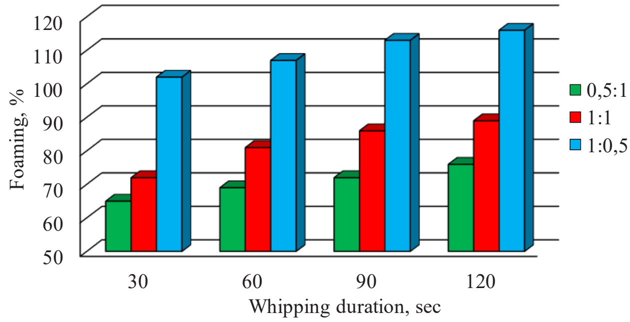

Fig. 2. Foaming of the carbohydrate-protein food system at 20 °C

The dynamics of foam growth (Fig. 1, 2) is the same for all samples. An increase in duration of whipping led to an increase in foaming by 3 to 10 % on average. An increase in the content of collagen hydrolysate in solution led to a decrease in foaming due to its properties to hydration and swelling, which is correlated with previous studies [18].

The obtained data (Fig. 1, 2) made it possible to identify the most effective ratio of the main carbohydrate-protein raw material: the concentration of collagen hydrolysate – 4 %, the ratio of pectin:collagen hydrolysate – 1:0.5.

The main indicator of the quality of the aerated product for a consumer is its ability to maintain a stable consistency for time of consumption. Therefore, the basic prerequisite for mathematical modeling became verification of ability of model carbohydrate-protein systems to maintain a stable foam structure.

We carried out the studies at 10 °C and 20 °C, taking into account the temperature mode of obtaining of foam and its realization (Fig. 3, 4).

The obtained data (Fig. 3, 4) showed high rates of foam resistance obtained at different temperatures. The foams obtained at 10 °C were more stable than the foams obtained at 20 °C. A decrease in aging temperature of foams from 20 °C to 10 °C showed an increase in the indicator of foam stability by 3.5 % on average.

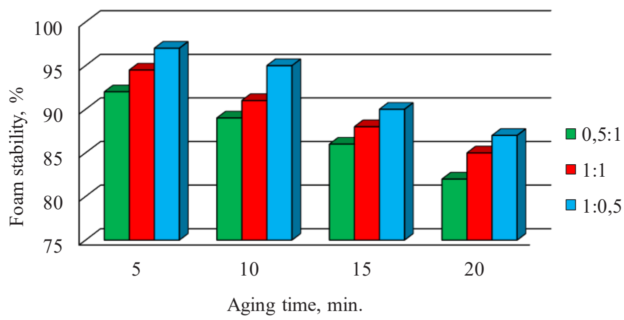

Fig. 3. Foam stability of the carbohydrate-protein food system obtained at a whipping temperature of 10 °C

We selected a sample of the food system, which contained apple pectin and collagen hydrolysate in a ratio of 1:0.5, for the study of foam multiplicity.

Fig. 5 shows the dynamics of change in foams multiplicity, depending on temperature and time of their formation.

The obtained data (Fig. 5) showed that the foaming ratio of the food system at a temperature of 10 °C was higher than at a temperature of 20 °C almost in 2 times.

We know that the foam multiplicity increases with a size of bubbles and their number, and thickness of walls decreases accordingly. Therefore, the optimal foam whipping duration is 90 minutes. It is at this time that the foaming of the foam acquires the maximum multiplicity, and further increase of the time of the foaming does not increase the multiplicity of foam due to the fact that the process of mechanical destruction of the cellular structure of the foam begins.

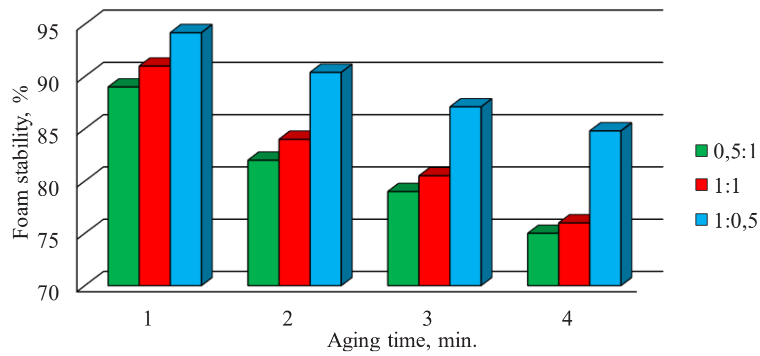

Fig. 4. Foam stability of the carbohydrate-protein food system obtained at a whipping temperature of 20 °C

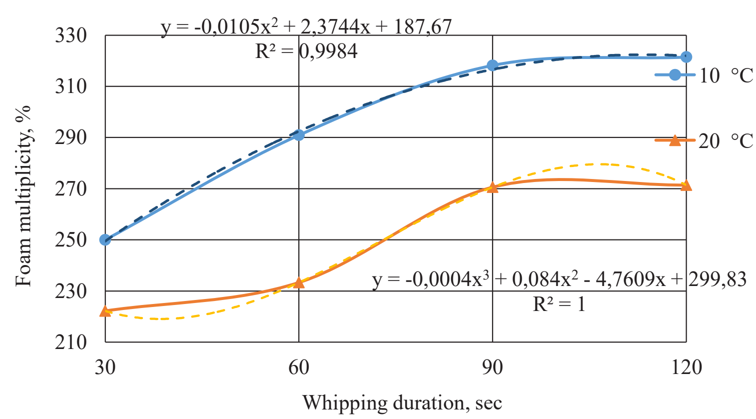

Fig. 5. Dependence of the foam multiplicity of carbohydrate-protein mixture on whipping duration

5. 2. Mathematical optimization of the composition of aerated smoothies

The purpose of mathematical modeling of the composition of the smoothie was to obtain a finished product with a high content of macronutrients.

Table 3 shows a matrix of characteristics of formulation ingredients (FI) for the design of the smoothie formulation. We took the range of variation of pectin content and collagen hydrolysate based on previously obtained data on obtaining a food system with maximum foaming and foam stability.

The table gives the content of macronutrients in selected FI.

We optimized formulations in Excel using a Search for Solution tab.

Table 3

Information matrix of data for mathematical modeling of the smoothie composition

Formulation ingredient	Index, X_i	FI macronutrient content, %	Range of FI variation, g/serving
Whey	X_1	5.97	92–100
Cherry juice	X_2	10.26	88–96
Apple pectin	X_3	36	7–9
Collagen hydrolysate	X_4	70	3–5

The objective function for the development of the smoothie was as follows:

$$F(x)=\frac{5.97\cdot x_1+12.3\cdot x_2+36\cdot x_3+70\cdot x_4}{100}\rightarrow \max.$$

Based on the information matrix (Table 3) and the content of macronutrients (Table 4), we built a system of linear balance equations by the content in a composition of proteins, fats and carbohydrates, respecting restrictions, according to the physiological need of a man.

Table 4

The content of RI macronutrients for the manufacture of strips

Formulation ingredients Nutrients, g/100 g	Whey	Cherry juice	Apple pectin	Collagen hydrolysate
Proteins	0.76	0.7	0.5	70
Fat	0.09	0.2	0.5	0
Monocarbohydrates	5.12	11.4	35	0
Total	5.97	12.3	36	70

The system of equations for the development of the smoothie was as follows.

The protein content was not less than 2 g per 100 g and not more than 5 g per 100 g:

$$0.76\cdot x_1+0.7\cdot x_2+0.5\cdot x_3+70\cdot x_4\geq 2,$$

$$0.76\cdot x_1+0.7\cdot x_2+0.5\cdot x_3+70\cdot x_4\leq 5.$$

The fat content was not less than 0.1 g per 100 g and not more than 0.4 g per 100 g:

$$0.09\cdot x_1+0.2\cdot x_2+0.5\cdot x_3\geq 0.1,$$

$$0.09\cdot x_1+0.2\cdot x_2+0.5\cdot x_3\leq 0.4.$$

The carbohydrate content was not less than 5 g per 100 g and not more than 15 g per 100 g:

$$5.12\cdot x_1+11.4\cdot x_2+35\cdot x_3\geq 5,$$

$$5.12\cdot x_1+11.4\cdot x_2+35\cdot x_3\leq 15.$$

The protein:carbohydrate ratio was not less than 0.25 and not more than 0.33:

$$\frac{0.76\cdot x_1+0.7\cdot x_2+0.5\cdot x_3+70\cdot x_4}{5.12\cdot x_1+11.4\cdot x_2+35\cdot x_3}\geq 0.25,$$

$$\frac{0.76\cdot x_1+0.7\cdot x_2+0.5\cdot x_3+70\cdot x_4}{5.12\cdot x_1+11.4\cdot x_2+35\cdot x_3}\leq 0.33.$$

Standardization conditions (200 g serving yield):

$$x_1+x_2+x_3+x_4=200.$$

Lower restrictions of variables (formulation ingredients):

$$x_1\geq 92;\quad x_2\geq 88;\quad x_3\geq 7;\quad x_4\geq 3.$$

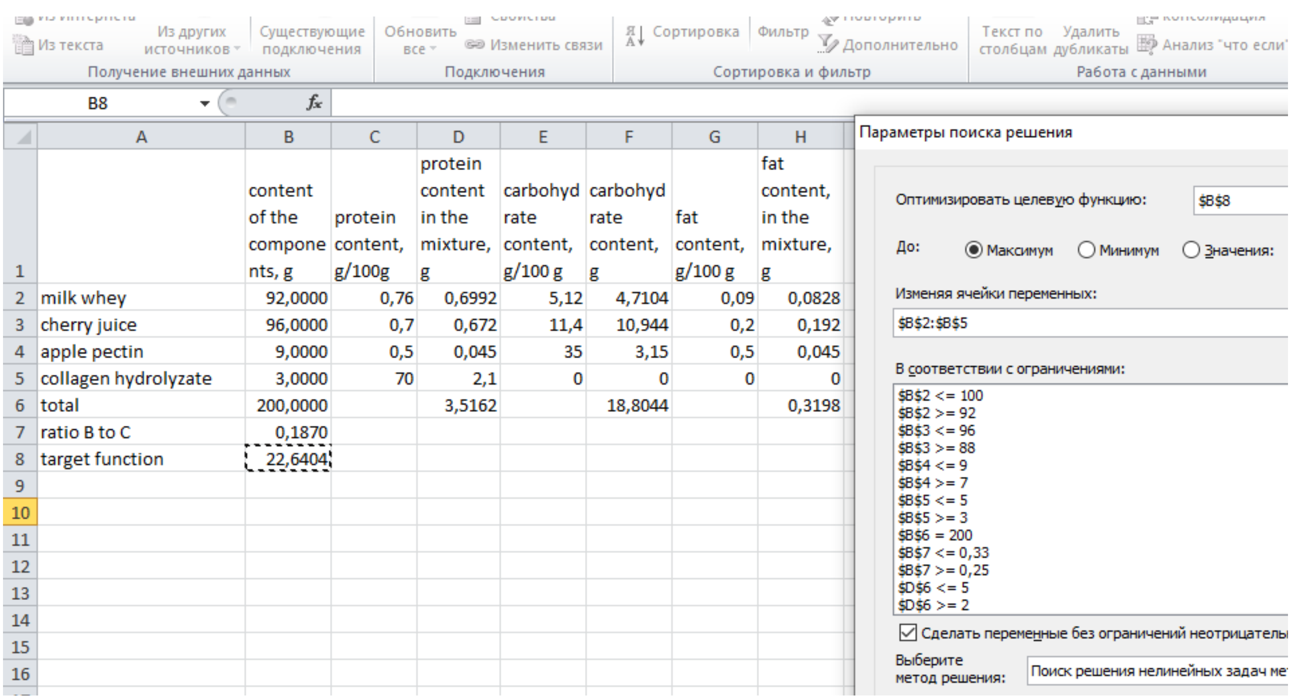

Fig. 6. Progress of planning calculations in "Search for Solution"

Upper restrictions of variables (formulation components):

$$x_1 \le 100;\quad x_2 \le 96;\quad x_3 \le 9;\quad x_4 \le 5.$$

We applied mathematical programming and we made the optimal solution: we found the extremum of the linear objective function with restrictions on variables, which we need to find.

Fig. 6 shows the progress of calculations in a Search for Solution tab.

The software calculated the following formulation ingredients:

$$x_1 = 92;\quad x_2 = 88;\quad x_3 = 7;\quad x_4 = 3,$$

and

$$F(x) = \frac{5.97\cdot 92 + 12.3\cdot 96 + 36\cdot 9 + 70\cdot 3}{100} = 22.64.$$

Thus, the content of basic macronutrients was 22.64 g per serving (200 g).

In accordance with the obtained results we created formulation of the smoothie and the norms of raw material for production of 1 serving (Table 5).

Table 5

Formulation and the norm of use of raw materials for production of smoothies

Raw material	Losses, %	Gross, g	Net, g
Whey	0.2	92.18	92.0
Cherry juice	0.5	96.48	96.0
Apple pectin	0.7	9.06	9.0
Collagen hydrolysate	0.5	3.02	3.0
Total, g/serving (200 g)			200.0

5. 3. Analysis of nutritional and energy value and antioxidant activity of the new product

Tables 6, 7 present data on the nutritional and energy value of the smoothie with increased mass fraction of protein of animal origin.

Table 6

The nutrient composition of the smoothie

Micro-nutrients	Daily need, mg	Smoothie, mg	Satisfaction of a daily need (serving), %	Satisfaction of a daily need (per 100 g of smoothie), %
Na	400	92.100	23.03	11.51
K	2500	381.280	15.25	7.63
Ca	300	114.680	38.23	19.11
Mg	400	16.220	4.06	2.03
P	400	91.290	22.82	11.41
Fe	18	0.533	2.96	1.48
A	0.1	0.009	8.60	4.30
B1	1.5	0.046	3.09	1.55
B2	1.8	0.148	8.22	4.11
B6	0.2	0.075	37.60	18.80
E	15	0.192	1.28	0.64
PP	20	0.317	1.59	0.79
C	80	7.104	8.88	4.44

Table 7

The energy value of the smoothie

Energy components	Content per 100 g
Proteins, g	1.76
Fats, g	0.16
Carbohydrates, g	9.4
Energy value, kcal	46.7

As we modeled the smoothie formulation based on amino acid SCORE, we calculated it in the finished product (Table 8).

Table 8

Calculation of amino acid SCORE of the smoothie

amino acids	g/3.5 g of protein (serving – 200 ml)	g/1 g of protein	mg/g of protein	Ideal protein	SCORE
valine	0.097	0.03	27.71	50	554.28
isoleucine	0.078	0.02	22.28	40	557.14
leucine	0.144	0.04	41.14	70	587.75
lysine	0.142	0.04	40.57	55	737.66
methionine	0.022	0.006	6.28	35	179.59
threonine	0.093	0.026	26.57	40	664.28
tryptophan	0.018	0.005	5.14	10	514.28
phenylalanine	0.067	0.019	19.14	60	319.04

Table 9 presents satisfaction with amino acids at consumption of 1 serving of the smoothie.

Table 9

Satisfaction with essential amino acids

amino acids	Daily яneed in g	Content, g/1 serving	Satisfaction, %
valine	3	0.097	3.23
isoleucine	3	0.078	2.60
leucine	5	0.144	2.88
lysine	4	0.142	3.55
methionine	3	0.022	0.73
threonine	2	0.093	4.65
tryptophan	2	0.018	0.90
phenylalanine	3	0.067	2.23
arginine	6	0.155	2.58
histidine	2	0.031	1.55

Experimental data on the determination of the biological activity (BA) of the used raw material and the developed smoothie indicated that the biologically active substances of the smoothie components are capable of oxidation of $NAD \cdot H_2$ to NAD differently (Fig. 6). The study showed that smoothie components exhibited the effect of synergism of the interaction of biologically active substances in terms of antioxidant action (amino acids-antioxidants: methionine, tyrosine, cysteine and other vitamins).

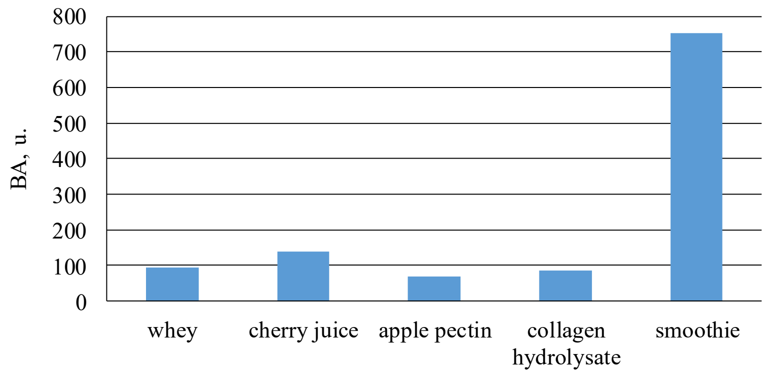

Fig. 7. Study on biological activity of raw materials and the developed smoothie

5. 4. Determination of the sensor indicators of the finished product under production conditions

We performed a tasting evaluation for introduction into production in the establishments of the restaurant industry, which was evidenced by the act of introduction at "Garlic" cafe (Odessa) and a temporary card.

A tasting committee performed sensory evaluation. The committee consisted of 10 people immediately after making the smoothie.

Table 10 shows the data on the evaluation of sensory indicators of the obtained products. We performed or-ganoleptic evaluation by the sensory method according to DSTU 2781-98 indicators, such as appearance, consisten-cy, color, aroma, and taste. Fig. 8 shows the smoothie's rate.

Table 10

Sensory indicators of the developed smoothies

Beverage name	Smoothie
Appear-ance	Homogeneous, uniform throughout the volume, glossy surface
Color	Light-red
Aroma	Characteristic to this type of products, pleasant, sour-milk aroma
Consis-tency	Homogeneous, whipped, bubbles evenly distributed throughout the volume
Taste	Sour milk with a cherry tinge, moderately sweet

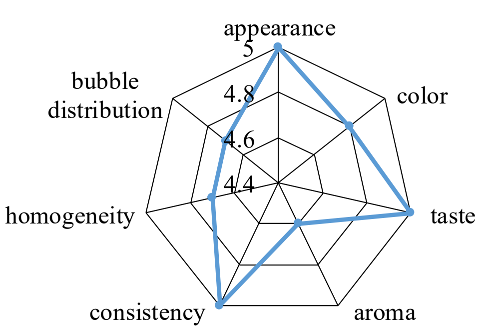

Fig. 8. Profilogram of organoleptic indicators of the smoothie

The tasting showed that the smoothie had high taste properties. We can offer it in the restaurant.

We studied a change in the microbiota of the finished smoothies within 4 hours. We stored them in a closed glass container at (4±2) °C.

Table 11 shows data on the studies of changes in microbiological biomass during storage.

The data given in Table 11 make us recommend the implementation of the develo-ped smoothie for 4 hours, if it is stored in a refrigera-tor in a glass container at (4±2) °C.

Table 11

Microbiological indicators of the smoothie quality

Indicator	Storage, hours			
	1	2	3	4
E. coli coliforms bacteria, CFU per 0.01 g of product	Not detected			
Pathogenic microorganisms, Salmonella, per 25 g of product	Not detected			
Amount of molds, CFU per 1 g of product, not more than	$2.3\cdot10^2$	$2.7\cdot10^2$	$2.9\cdot10^2$	$3.1\cdot10^2$
Amount of yeast, CFU per 1 g of product, not more than	$2.4\cdot10^1$	$2.7\cdot10^1$	$2.9\cdot10^1$	$3.1\cdot10^1$
Staphylococcus aureus, per 0.01 g of product	Not detected			

6. Discussion of results of modeling the smoothie composition

The calculation of the amino acid content (Table 1) and the SCORE showed (Table 2) that all the samples contained all the essential amino acids in sufficient amount. Their SCORE was more than 100, so the body will absorb them fully. The absence of an amino acid with a SCORE less than 100 indicated that there were no limited amino acids. However, the amino acid SCORE of methionine was the lowest, as the mentioned amino acid is completely absent in collagen hydrolysate.

The data presented in Fig. 1 showed that the maximum foaming occurred after 120 min of whipping. The foaming made up 118 % at a pectin:collagen hydrolysate ratio of 1:0.5 after 120 minutes of whipping, which was 2.6 % higher than after 90 seconds of whipping. We compared the whipped mixtures with the ratios of pectin:collagen hydrolysate of 1:1 and 1:0.5, and saw that the foaming increased by almost 24 % at a lower content of collagen hydrolysate. The foaming of the carbohydrate-protein system with the pectin:collagen hydrolysate ratio of 0.5:1 had the lowest indicators.

The foam stability decreased after 5 minutes at aging at 10 °C. Thus, the foam stability decreased by 8 %, 5.5 %, and 3 %, respectively, at the apple pectin to collagen hydrolysate ratio of 0.5:1, 1:1, 1:0.5.

The foam stability decreased by 11 %, 9 % and 5.8 % for the respective solutions at 20 °C.

The foam stability obtained at 10 °C decreased by 18 %, 15 %, 13 %, respectively, for food systems with a mixture of pectin and collagen hydrolysate of 0.5:1, 1:1, 1:0.5, respectively, after 20 minutes of aging. The foam stability decreased by 25 %, 24 %, 15.2 % for the respective solutions at aging the foam at a temperature of 20 °C on average. The foam stability decreased by 3 % on average every 5 minutes at 10 °C. The foam stability decreased by 5.5 % on average at 20 °C.

An increase of whipping duration led to an increase in the foam multiplicity from 250 % to 321.43 % at a temperature of 10 °C, and whipping at 20 °C made it possible to increase the multiplicity from 222.22 % to 271.43 %.

Designing the smoothie composition using mathematical programming made it possible to obtain the optimum fractions of components, such as: whey – 92 ml, cherry juice – 96 ml, apple pectin – 9 g, collagen hydrolysate – 3 g.

Analysis of the nutrient composition of the smoothie (Table 6) showed that consumption of 1 serving of the smoothie satisfied the need for calcium by 19.11 %, sodium – 11.51 %, phosphorus – 11.41 %.

The data given in Table 9 showed that consumption of 1 serving of the developed smoothie satisfied the need for essential amino acids at the low level. We observed the maximum satisfaction for threonine and it was 4.65 %, and the minimum satisfaction for the daily requirement was for tryptophan (0.90 %).

Determination of biological activity showed that the rate of electron transfer in the NAD·H2-K3[Fe(CN)6] system for the finished smoothie was on average 8.1 times higher than in its components, which indicated the synergism of antioxidant substances (Fig. 2).

Evaluation of the sensory indicators of the developed smoothie showed high quality characteristics of the new product, which is important for products for restaurants. The total score by the sensory indicators was 33.8 points out of 35 possible points.

The data on determination of the dynamics of a microbiota change of the smoothie showed high safety indices and possibility of realization of the developed smoothie for 4 hours, if it was stored in a refrigerator in a glass container at (4±2) °C.

Any market operator can use the developed functional approach to beverage production to produce not only beverages but various food products also.

Market operators plan to perform a SWOT-analysis of the obtained product and to make up Hazard Analysis and Critical Control Points to start production. The next study should determine the integrated quality index of the developed smoothie and the calculation of the competitiveness indicator.

7. Conclusions

1. According to the requirements of the HACCP and food safety standards, we selected available, inexpensive and high-quality raw materials with high biological properties for production of smoothies, such as whey, cherry juice, apple pectin and collagen hydrolysate. Studies showed that there was the recommended daily consumption norm achieved in the whey at using of a 4 % solution of collagen hydrolysate, but such a concentration produced a slight sticky effect.

2. We selected a dose of collagen hydrolysate recomemended by nutritionists as a limitation for mathematical programming. We performed the mathematical modeling of the smoothie composition to obtain a product with a high solids content using the MS Excel 2010 table processor. The smoothie formulation consisted of the following components: whey – 92 g, cherry juice – 96 g, apple pectin – 9 g, collagen hydrolysate – 3 g. The content of basic macronutrients was 22.64 g per serving (200 g) or 11.32 g per 100 g.

3. We studied the nutrient composition of the obtained smoothie and proved the balanced nutrient content. The ratio of basic minerals of calcium, magnesium and phosphorus was 1:0.11:0.6. It is possible to correct magnesium deficiency by consumption of smoothies with flavor additives, such as cocoa powder, sesame seeds and dates. Analysis of the amino acid SCORE showed that the developed product had a high degree of absorption of essential amino acids due to the absence of a limiting amino acid with the SCORE less than 100 %. We established the effect of synergism of interaction of biologically active substances of all components of the smoothie by the indicator of antioxidant action. The tasting evaluation of the sensory indicators of the developed smoothie produced at the production facilities of the modern market operator ("Garlic" cafe, Odessa) showed high quality indicators. The total score by the sensory indicators was 33.8 points. It is necessary to calculate the competitiveness of the new product to introduce the developed composition into real conditions.

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