Досліджено вплив нетрадиційної сировини рослинного походження та натуральних добавок на формування споживних властивостей кексів поліпшеного складу. Визначено та науково обґрунтовано рецептурний склад і запропоновано модельні зразки кексів на основі проведеного аналізу органолептичних, фізико-хімічних показників, харчової і біологічної цінності. Для оцінювання органолептичних показників розроблено шкалу оцінювання, враховуючи показники: смак, запах, вид у розломі, колір, поверхня, форма, консистенція із введенням показника флейвор та побудовано профілограми зразків. На основі проведеної органолептичної оцінки встановлено, що розроблені кекси із внесенням у рецептуру нетрадиційної сировини володіють приємними смаком, ароматом та високо оцінені дегустаційною комісією. Завдяки зміні рецептури вдалося знизити енергетичну цінність виробів на 16–39 ккал/100 г. Нові зразки характеризуються підвищеним вмістом білка на 18,9–31,8 % (кекси без начинки) та в 1,6–1,7 разів (кекси з начинкою), зменшенням кількості жиру на 3,1–20,1 % та вуглеводів – на 4,7–14,9 %. Вміст незамінних амінокислот визначали за допомогою автоматичного аналізатора амінокислот Т 339. У нових виробах зріс вміст амінокислот в 1,1–1,9 разів порівняно із контрольним зразком. Жирнокислотний склад кексів визначали методом газової хроматографії на газовому хроматографі HP 6890. Співвідношення частки ненасичених жирних кислот до насичених в нових виробах зросло в 1,22–1,55 разів. Мінеральний склад визначали методом атомно-абсорбційної спектрофотометрії на атомно-абсорбційному спектрофотометрі С-115 ПК. Вміст мінеральних елементів зріс в 1,1–2,7 раза, а вітамінів у 1,2–2,9 раза. На основі отриманих даних обґрунтована доцільність розширення асортименту борошняних кондитерських виробів новими видами кексів

Ключові слова: кекси з органічним борошном, харчова цінність, споживні властивості, амінокислоти, жирнокислотний, мінеральний склад

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STUDYING CONSUMER PROPERTIES OF THE DEVELOPED CUPCAKES USING NON-TRADITIONAL RAW MATERIALS

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1. Introduction

The leading role in a healthy diet belongs to the development and production of foods with the balanced composition, enriched with natural biologically valuable additives. Special attention is paid to finding effective means to correct food deficits based on developing new products using the sources of essential nutrients.

Flour-based confectionery products belong to the highly-caloric foods for mass consumption. Cupcakes are traditionally in demand, but their range in the market is rather limited. A significant disadvantage of cupcakes is almost

the total absence of important biologically active substances, specifically essential amino acids, essential fatty acids, macro- and micro elements, etc. The chemical composition of such products requires significant adjustment in terms of improving the composition, enhancing food value and reducing energy content of products.

The theoretical and practical aspects in the field of developing pastry products with improved composition and enhanced food value were tackled in papers [1, 2]. However, studying the process of enriching cupcakes with valuable macro- and micro nutrients while their reducing caloric content is still relevant. The use of plant-based supplements would make it possible to improve the nutritional value and decelerate the processes of oxidation and staling in cupcakes, thereby enhancing their consumer properties.

2. Literature review and problem statement

In order to enrich cupcakes with food fibers, Girija Vudugula and Kavita Waghray suggested the introduction of organic wheat flour (Atta) and whole wheat flour (Maida) [3] to the formulation of model samples. Based on the results from sensory analysis, a sample of cupcakes that contained organic wheat flour and a mix of oil:coconut milk (75:25) received 7.8 points, while the estimate of the reference sample was 7.9. For the sample made from organic whole wheat, the optimal ratio of the mix was oil:coconut milk (50:50) – 7.7 points. The energy value compared to the commercially available products decreased by 250 kcal per 100 g of the product. However, the specified ingredients considerably increase the price of the finished product.

Bioavailability is the key factor for the successful development of functional foods, especially when a food matrix is very different from a natural source of the target bioactive ingredient. Although basic products include xanthophylls, their amount is relatively low for attaining the desired beneficial effect for health; during baking the degradative reactions reduce their content. Adding a water-soluble composition of lutein to the formulation of cupcakes could increase the content of xanthophyll and provide for its stability in the process of baking. The bioavailability *invitro* achieved the adequate levels of efficiency, which were 30–80 % of the initial content of lutein. The activity of pancreatic lipase in relation to lutein esters was low but the hydrolyzed lutein fully participated in the aqueous phase [4].

The high physiological value of extracts of carcade and medicinal lemon balm has been confirmed in terms of the alternative procedures and the protocols approved by the State Pharmacopeia of Ukraine.

Carcade (*Roselle calyces*) is one of the popular plant crops rich in anthocyanins. The possibility of using the extract from calyces Roselley in the formulation composition of cupcakes has been investigated. Finished products are characterized by a high content of dietary fiber – 8 %, mineral substances – 4.2 %, and anthocyanins 465 mg/100 g of dry matter, which is 2 times larger than the minimum average daily consumption of anthocyanins for Americans [5].

Melissa (*Melissa officinalis L.)*) and its extracts have bioactive properties and are promising ingredients in the development of food products with additional functionalities. The antioxidant, antibacterial, and antifungal effects of the extract from lemon balm were examined, as well as its potential hepatoxicity. Its antioxidant properties were confirmed by the effect of absorbing free radicals EC 50=79±2 μg/ml and the decreased capacity EC 50=49±1 mg/ml; antimicrobial – resistant against 8 bacteria and 8 fungi, as well as the absence of toxicity (in cell lines). It is worth noting that there are many varieties of herbs, which is why exploring this field has remained relevant [6].

The duration of storage, chemical composition, color parameters, as well as the antioxidant effect of cupcakes, were investigated following the introduction of extract of lemon balm to them, compared with products that contain potassium sorbate. The results obtained indicate that among the phenolic compounds of the extract of lemon balm the main component is rosemary acid – 2.8±0.01 %, which produces antioxidant effect [7].

Vegetables occupy an important place in healthy human nutrition and are the main source of vitamins, amino acids, mineral elements, organic acids, whose consumption has a positive effect on the human body. Many plant-based products demonstrate phytoncidal, antiseptic, antioxidant, radioprotective properties, and their proper use contributes to normalizing metabolism and is an effective method of rehabilitation and treatment-and-prophylactic effects on the body. The antioxidant properties, physical and organoleptic characteristics of cupcakes, enriched with phenolic aqueous microwave extract from three species of vegetables – broccoli, Chinese cabbage, and spinach, were investigated. The highest ability to inhibit the radical activity was detected in cupcakes enriched with Chinese cabbage, spinach, and broccoli. The highest average score of 7.0 in terms of general eligibility was established for the cupcakes enriched with spinach, lower scores were given to samples with Chinese cabbage and broccoli. The cupcake with the highest consumer properties is the product enriched with an aqueous extract from spinach [8]. Vegetables can be used in flour products in different combinations, which extends the areas of and prospects for research.

A possibility to make fat-free cupcakes from the flour of baru (*Dipteryx alata Vog*) – *BF* was examined. Four different formulations of cupcakes were made from wheat flour (*WF*) containing 30 % of *BF*, with a reduced (by 50, 75, and 100 %) content of margarine, compared with control sample made form 100 % of *WF* with a 100 % content of margarine. The cupcakes baked from a mixture of 70 % *WF*+30 % *BF* and with the reduced content of margarine, by 75 and 100 %, can be considered "light", and the highest organoleptic score for acceptance was given to the sample with a reduced (by 75 %) content of margarine [9].

One of the indicators, which attests to the balanced nutrition of people, is the presence of proteins. Flour-based confectionery products are not the main source of their intake. However, the use of flour from pumpkin seeds in the formulation of cupcakes, by replacing 50 % of wheat flour, makes it possible to prepare cupcakes with the increased (almost by 2 times) content of plant protein and without significant changes to the starting characteristics for products [10].

The organoleptic indicators for five samples of cupcakes were investigated, including control, which were made using different concentrations of syrup from the flowers pf mahua (*Madhuca Longifolia*) at different temperatures. The results of sensory evaluation clearly demonstrate that the cupcakes that were baked with the use of the syrup from the flowers of mahua in the amount of 55 g at a baking temperature of 175 °C, over 14 minutes, demonstrate the highest properties in terms

of sensory characteristics. Increasing the concentration of this syrup (above 55 g) gives rise to a poor aftertaste [11]. However, the specified ingredient is rare, which makes it difficult to make products based on this formulation.

Thus, studies into improvement of consumer properties of flour-based pastry products have been reported in a significant number of scientific publications. However, the unresolved issues remain that are related to reducing caloric value and increasing the share of essential amino acids, unsaturated fatty acids, macro- and micronutrients and vitamins.

3. The aim and objectives of the study

The aim of this study is to scientifically substantiate the extension of product range of cupcakes using alternative raw materials and to practically confirm the results from examining the amino acid, fat-acid, mineral, and vitamin composition.

To accomplish the aim, the following tasks have been set:

– to estimate, based on experimental study, the impact of applied enriching agents on the formation of consumer properties of the new product range of cupcakes and to determine their nutritional value;

– to explore the impact of alternative raw materials on the amino acid composition of new cupcakes;

– to analyze the composition of fractions of fatty acids in the developed cupcakes;

– to study the vitamin and mineral composition of new cupcakes.

4. Methods to study consumer properties of new cupcakes

The objects of our research are the cupcakes with improved composition “Kunzhutnyi”, “Moryachok”, “Mitsnyi Gorishek”, “Osinny Aromat”, “Chornychnyi”, “Medok”, and “Elitnyi”. Control sample that was selected is the cupcake “Stolychnyi”, baked in line with a classic formulation.

Limit on the total content of ingredients in the formulations for cupcakes was determined from formula (1):

$$\sum_{i=1}^{j} x_i = 1000, \quad (1)$$

where x_i, i=1, 2, ..., j is the unknown amount of raw materials of the i-th kind (g).

Technological conditions for providing the required moisture content in products were determined from formula (2):

$$0{,}05\sum_{i=1}^{j} x_i \le \sum_{i=1}^{j} \lambda_i x_i \le 0{,}1\sum_{i=1}^{j} x_i, \quad (2)$$

where x_i, i=1, 2, ..., j is the unknown amount of raw material of the i-th kind (g); λ_i is the water content per 1 g of the i-th ingredient (g).

Additional conditions for enriching a would-be product with nutrients were defined by percentage relative to a daily need. The objective function should be chosen from formula (3):

$$Z = \sum_{i=1}^{j} a_i x_i \to \max, \quad (3)$$

where x_i, i=1, 2, ..., j is the unknown amount of raw material of the i-th kind (g); a_n is the content of a nutrient of the n-th type per 1 g of the i-th ingredient (g).

Solution to the problem on designing the optimization of the content of ingredients in new cupcakes from new product range was derived by a simplex method in the software Mathcad (Prime 3.0) [12].

To study the consumer properties of cupcakes with the proposed formulations and changes in their quality in the process of product promotion, the current work employed the organoleptic, physical-chemical, and microbiological analysis methods. Experiments were repeated three and five times.

The product-specific evaluation of the developed cupcakes with new formulations was carried out in accordance with the European technical regulations for food products [13].

Amino acid composition of the cupcakes was determined using the method of ion exchange liquid-column chromatography at the automated amino acid analyzer T 339 made by Mikrotehna from the Czech Republic (Fig. 1) [13].

Fig. 1. Automated analyzer of amino acids T 339 (Mikrotehna, Czech Republic)

Underlying the work of an automated amino acid analyzer is the principle of carrying out all operations in a continuous stream of eluent. The principle of operation implies that the eluent is passed, from a container, by a dispensing pump, through the chromatographic column. At the outlet from the column the eluate is constantly added, using a micro pump, with a ninhydrin reagent at the predefined ratio to the eluate. A mixture of eluate and ninhydrin reagent is sent along a capillary tube to the reactor, which is heated to a temperature of 95–98 °C and is fed then to a flow-through cuvette. The intensity of the emerging coloration is measured by photocolorimetry using a photoelement, which perceives the light from the source through the walls of the cuvette. The photoelement’s signals are amplified and recorded by a self-recording potentiometer in the form of a chromatogram. The area of peaks at a chromatogram is calculated and compared to the area of peaks from amino acids with a known concentration. Comparing these areas is applied to compute the absolute amount of an amino acid in the analyzed sample.

Biological value of proteins from food is characterized by the amino acid score. The amino acid score is calculated in per cents as the ratio of content of amino acids in the exam-

ined protein to their content in a conditionally perfect protein that meets the needs of the body [14]. When developing food products of elevated nutritional value, an important aspect is to increase the amount of limited amino acids whose score is less than 100 %.

The amino acid score was determined from the ratio of the amount of a respective essential amino acid per 1 g of protein to its regulated content in an "ideal protein" based on the scale by FAO/WHO [15].

Amino acid score (AAS) of each essential amino acid is calculated according to the recommendations for the scale by FAO/WHO, adopted for the classification of a protein from formula (4):

$$C_j = \frac{AK_j}{AK_c} \cdot 100\,\%, \qquad (4)$$

where C_j is the amino acid score of the j-th amino acid of protein, %; AK_j is the content of an essential amino acid per 1 g of the examined protein, mg/g of protein; AK_c is the content of an essential amino acid per 1 g of a reference protein, mg/g of the reference protein.

Fat-acid composition of the cupcakes was determined by gas chromatography at the gas chromatograph HP 6890 (Agilent, United States) (Fig. 2).

Fig. 2. Gas chromatograph HP 6890 (Agilent, United States)

A gas chromatograph is designed to analyze the gas and liquid multi-component mixtures of organic and inorganic origin with a boiling point up to 350 °C. Separation of components may occur under isothermal or programmed heating modes of chromatographic columns. Detection of components involves the flame-ionization detectors, heat-conductance detectors, mass spectrometers, as well as detectors of other types. A signal from the detector is converted by using the appropriate interface into a digital format for further computer processing.

The gas chromatograph HP 6890 has two channels. A capillary evaporator, a capillary column, and a flame ionization detector form the chromatograph's front channel, whereas the evaporator for packing columns, a faucet for dispensing gas samples, a packing column and a katharometer form the back channel. The device can control the gas flows at evaporators, detectors, and three auxiliary flows, by means of the system of electronic control over gas flows (ECGF). ECGF implies setting the flows and pressures, as well as programming them in the course of analysis.

The systems of ECGF in the evaporator maintain such behavior of a gas carrier over the entire analysis, even when changing the temperature of the column [16].

Mineral composition of the cupcakes was determined by the method of atomic absorption spectrophotometry at the atomic-absorbing spectrophotometer C-115M1-PK (Semy, Ukraine) [17].

5. Results of research into consumer properties of cupcakes with the new formulations

Ingredient composition was chosen based on the rational ratio. By adjusting the formulations we reduced the content of flour and margarine. It should be noted that the production of the examined cupcakes involved raw materials manufactured at the territory of Ukraine, and certified in accordance with acting legislation.

The content of separate formulation components is given in Table 1. Model formulations of the cupcakes are described in [18–22].

Raisins in the cupcake "Osinny Aromat" were completely replaced with candied fruits (apple-cherry) and partially replaced in the cupcake "Mitsnyi Gorishek" with walnut kernels (22.9 kg/t), in the cupcake "Chornychnyi" – with blueberries (22.9 kg/t). The cupcakes with fillings contain 150.6 kg/t of filling from natural honey with pollen for "Medok" and natural honey with propolis for "Elitnyi".

Table 1

Features of the formulation composition of new cupcakes

Alternative raw materials and natural supplements	Amount of raw materials in the formulation of cupcakes, kg/t						
	«Kunzhutnyi»	«Moryachok»	«Mitsnyi Gorishek»	«Osinny Aromat»	«Chornychnyi»	«Medok»	«Elitnyi»
Wheat	rye (57.2)	oatmeal (38.1)	buckwheat (19.06)	corn (57.2)	buckwheat (15.25)	corn (53.06)	oatmeal (35.52)
Powders and their mixtures	blueberry leaves (1.9), black currant leaves (3.8), chamomile flowers (1.9)	leaves of thick-leaved bergenia (0.95). raspberry leaves (1.9), coltsfoot (19.1), deep-sea tangles (0.95)	peppermint leaves (1.91), walnuts (1.91)	perforate St John's-wort (1.91), heart linden flowers (1.91), purple echinacea (0.95)	chicory roots (0.95), tricolor violet flowers (5.7)	heart linden flowers (1.77), flower pollen (4.42)	peppermint leaves (1.77), haricot (13.69), propolis (3.69)
Whey	38.1	–	38.12	–	–	53.05	53.29
Dry skimmed milk	–	–	–	38.12	57.2	–	–
Vegetable oils	sesame (21.0)	pumpkin seeds (16.3)	walnuts (21.0)	–	–	pumpkin seeds (15.12)	–

We performed sensory evaluation of the developed samples of cupcakes with improved composition using the profiling method to compare with controls "Kunzhutnyi" and "Moryachok" (Fig. 3), "Osinny Aromat", "Mitsnyi Gorishek", "Chornychnyi" (Fig. 4) and "Medok" and "Elitnyi" (Fig. 5).

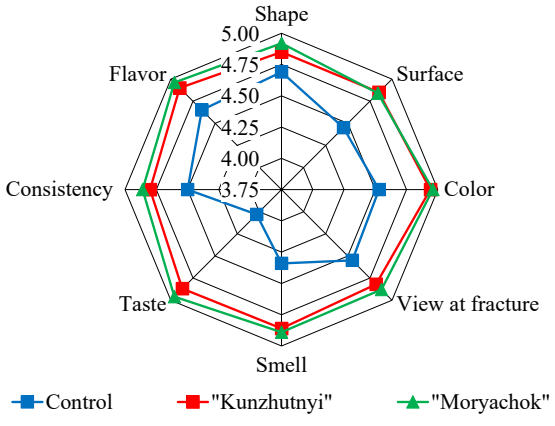

Fig. 3. Profilograms of organoleptic indicators for cupcakes "Kunzhutnyi" and "Moryachok"

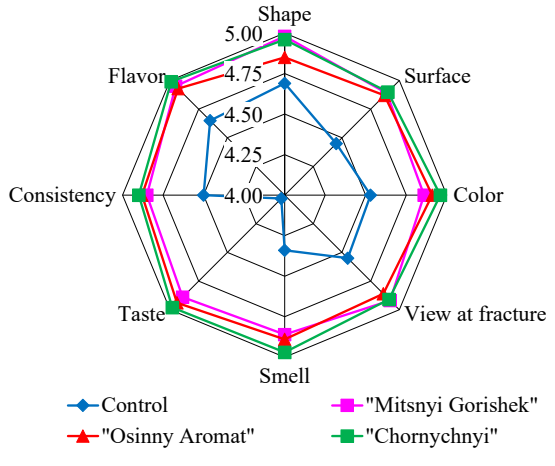

Fig. 4. Profilograms of organoleptic indicators for cupcakes "Osinny Aromat", "Mitsnyi Gorishek" and "Chornychnyi"

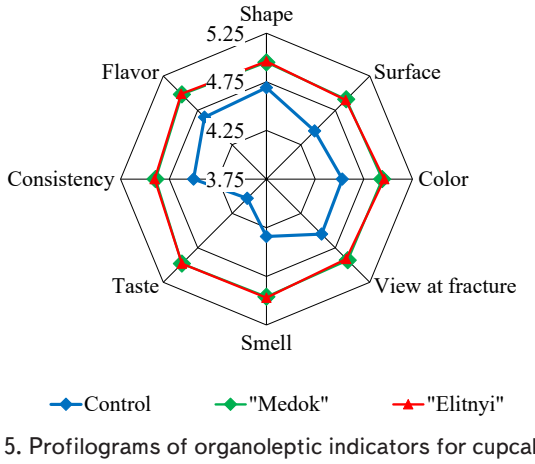

Fig. 5. Profilograms of organoleptic indicators for cupcakes "Medok" and "Elitnyi"

Visual comparison of organoleptic indicators for cupcakes testify to the considerable advantages of samples over control, particularly taste (4.87–4.98 points compared with 4.03 points), smell (4.86–4.97 points against 4.34) and color (4.86–4.96 against 4.53 points). The developed formulations for cupcakes "Medok" and "Elitnyi" are characterized by a high value of comprehensive quality indicator – 0.99, for the rest of the samples it was 0.97–0.98, confirming the appropriateness of the use of a given formulation composition compared with control sample; it is 11.6 % higher than the control sample.

The use of alternative raw materials predetermined adjusting the chemical composition, thereby improving the nutritional value and reducing the caloric content of the new cupcakes (Table 2).

Table 2

Nutritional value and caloric content of new cupcakes, $p \leq 0,05$; $n=3$

Cupcake title	Content, g/100 g of product				Caloric content, kcal/100 g
	proteins	fats	carbohydrates	ash	
Control sample	4.91	20.27	55.77	1.02	425.15
«Kunzhutnyi»	6.15	19.61	52.11	1.90	409.53
«Moryachok»	6.02	17.14	53.15	1.70	390.94
«Mitsnyi Gorishek»	6.47	20.66	49.05	1.77	408.02
«Osinny Aromat»	5.93	19.31	51.76	1.94	404.55
«Chornychnyi»	5.84	19.65	47.45	1.96	390.01
«Medok»	8.10	16.20	52.12	1.68	386.68
«Elitnyi»	7.80	18.70	50.16	1.53	400.14

It was experimentally proven that products with the chosen set of ingredients are characterized by the elevated content of protein, by 18.9–31.8 % (cupcakes without filling) and by 1.6–1.7 times (cupcakes with filling), a decrease in the amount of fat, by 3.1–20.1 %, and carbohydrates – by 4.7–14.9 % compared with control sample. The result of using the proposed formulation supplements is the reduced energy value of the new cupcakes, by 16–39 kcal/100 g.

Nutritional value of the new cupcakes improved, in particular through the improvement of the amino acid composition. Introduction to the formulation of cupcakes of the protein enriching agents (whey, skimmed milk powder, non-traditional types of flour) predetermined an increase in the content of essential amino acids.

The ratio of essential amino acids to nonessential in the developed cupcakes was 0.47 ("Medok") – 0.44 ("Elitnyi"), whereas in control sample it was only 0.42. Owing to the properly selected raw materials, the new products demonstrated an increase in the content of phenylalanine, by 24.6–90.1 %, isoleucine – 8.7–75.1, leucine – 7.7–70.6, and valine – by 5.0–66.1 %, as well a significant increase in the content of lysine, threonine, and methionine (Fig. 6).

Aminograms of control sample of the cupcake, as well as cupcakes "Moryachok", "Mitsnyi Gorishek" and "Medoc", are shown in Fig. 7.

The amino acid score for cupcake "Kunzhutnyi" for all amino acids except isoleucine and valine exceeded control. Although the essential amino acids, except for leucine (score equals 110 %) and phenylalanine+tyrosine (138 %), in a given sample are limited, the value for this indicator for threonine increased by 10 %, lysine – by 13 %, methionine with cystine – by 22 % (Table 3).

For cupcake "Moryachok" the amino acid score for valine reached 103 %, isoleucine – 100 %. Limited are lysine,

threonine, and methionine+cystine. However, there was an increase in the score for leucine, lysine, and threonine, compared with control.

For cupcake “Mitsnyi Gorishek”, limited amino acids are only lysine and methionine+cystine. There was an increase in the score for amino acid valine (by 12 %), isoleucine (by 6 %), lysine (by 16 %) and threonine (by 29 %).

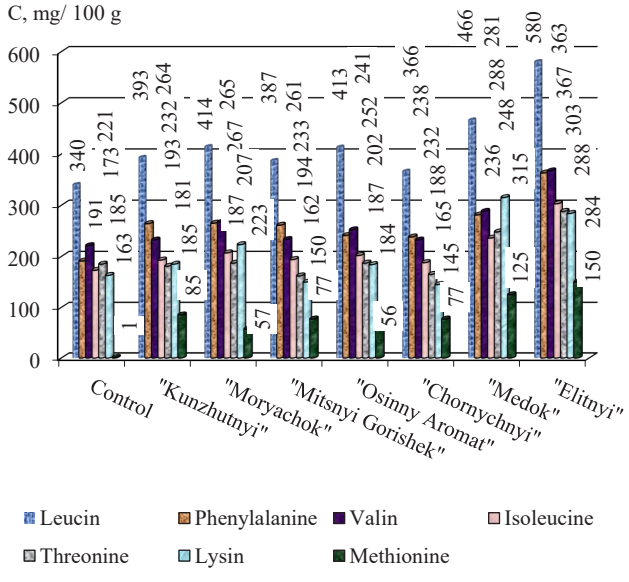

Fig. 6. Content of essential amino acids in the new cupcakes

Cupcake “Osinny Aromat” is characterized by a noticeable growth of the amino acid score for valine, isoleucine, leucine, lysine, and threonine.

An increase in the amino acid score for valine (100 %), isoleucine (100 %), leucine (112 %) was noted for cupcake “Chornychnyi”.

The cupcakes “Medok” and “Elitnyi” demonstrated the most noticeable increase in the score for lysine (respectively, by 41 and 14 %), and particularly methionine+cystine (to 105 %) and threonine (to 101 and 94 %, respectively).

Replacing 8–10 % of margarine with unconventional kinds of vegetable oils in the new products predetermined an increase in the proportion of unsaturated fatty acids, particularly polyunsaturated. The composition of fractions of fatty acids in the studied samples of cupcakes was markedly improved (Fig. 8).

In accordance with recommendations by the European Bureau of WHO, the ratio of saturated, mono unsaturated and polyunsaturated fatty acids should equal 1:1:1. This indicator for the fat-acid spectrum turned out to be the best for cupcake “Mitsnyi Gorishek” – 0.9:1.2:1.0: it is close to the optimal ratio. The ratio of the total amount of unsaturated fatty acids to saturated in control sample was 1.8, and in the cupcakes with new formulations equaled: “Kunzhutnyi” – 2.8, “Mitsnyi Gorishek” – 2.5, “Moryachok” and “Medok” – 2.2.

Fig. 9 shows chromatograms of control sample of the cupcake, as well as cupcakes “Moryachok”, “Mitsnyi Gorishek” and “Medok”.

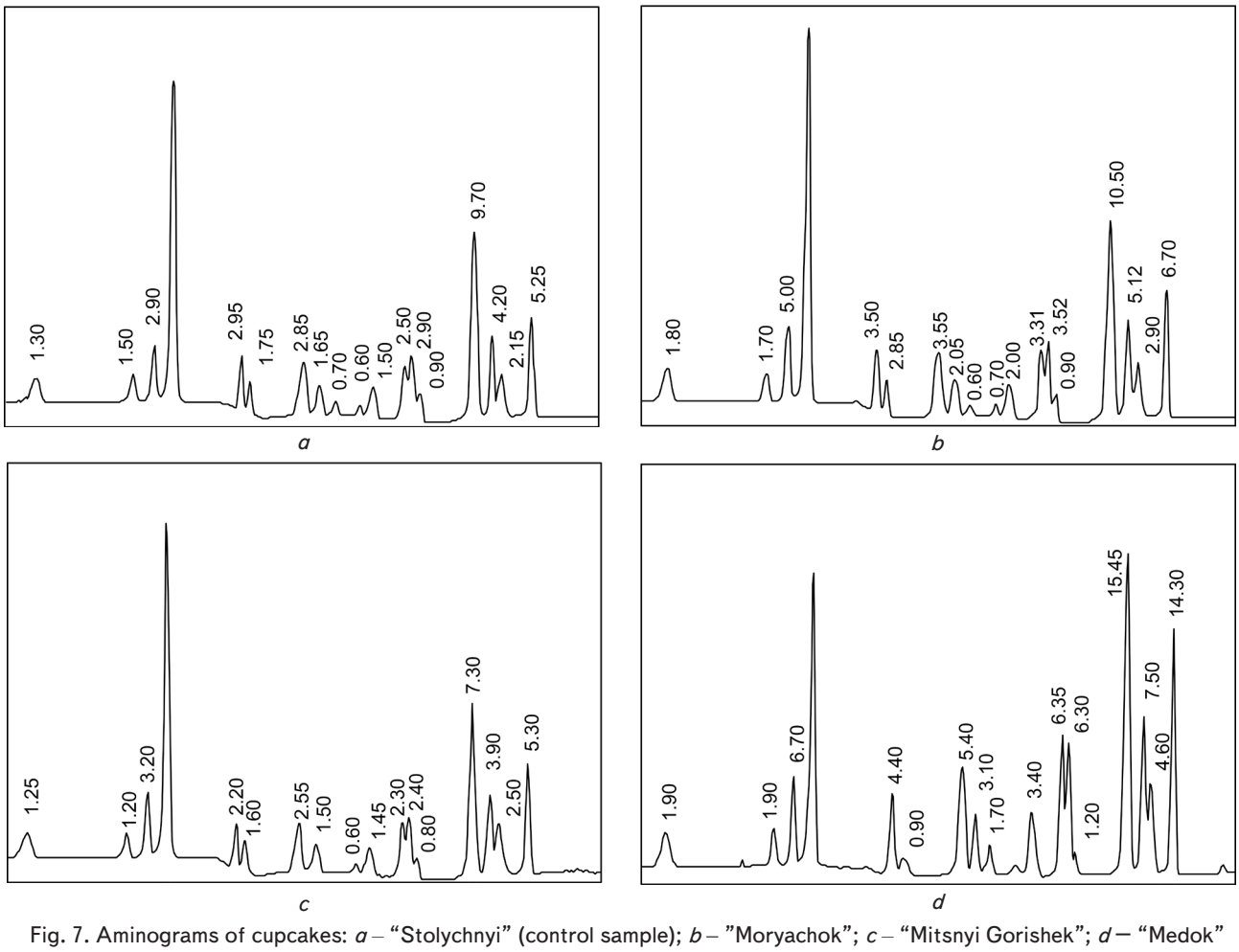

Fig. 7. Aminograms of cupcakes: *a* – “Stolychnyi” (control sample); *b* – ”Moryachok”; *c* – “Mitsnyi Gorishek”; *d* – “Medok”

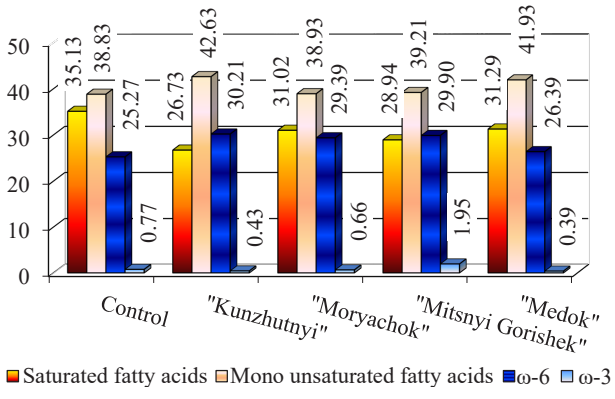

Fig. 8. Composition of fractions of fatty acids in cupcakes, %

Introduction to the formulation of products from the new range of alternative raw materials and natural additives also contributed to the improvement of their mineral composition. By adding the skimmed milk powder, the highest increase in the amount of calcium was demonstrated by cupcakes "Osinnyi Aromat" and "Chornychnyi" (Fig. 8); it exceeds control sample by 4.0 and 3.9 times. The increase in the content of magnesium in the new cupcakes ranges from 1.3 to 2.1 times compared with control. A significant growth of phosphorus was also observed (Fig. 10).

The highest iron content was found in cupcakes "Chornychnyi" and "Moryachok": it exceeded the value for this indicator in controls by 1.6–1.9 times (Table 4).

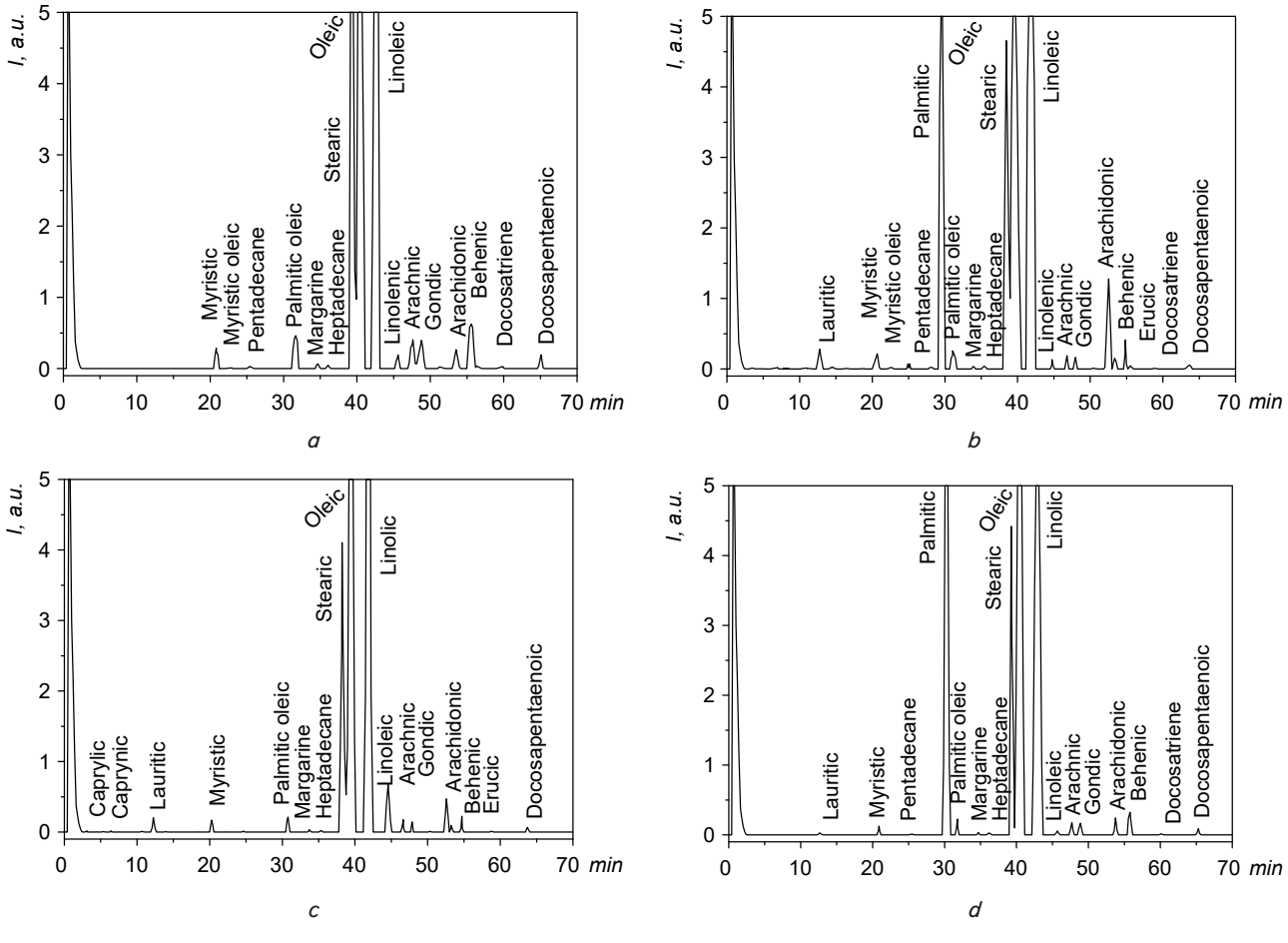

Fig. 9. Chromatograms of cupcakes: *a* –"Stolychnyi" (control sample); *b* –"Moryachok"; *c* – "Mitsnyi Gorishek"; *d* – "Medok"

Table 3

Amino acid score of new cupcakes, %

Amino acid title	FAO/WHO scale, g/100 g protein	Cupcake title							
		Control	«Kunzhutnyi»	«Moryachok»	«Mitsnyi Gorishek»	«Osinny Aromat»	«Chornychnyi»	«Medok»	«Elitnyi»
Valin	5.0	91	91	103	103	102	100	94	96
Isoleucine	4.0	95	95	100	101	103	100	96	99
Leucine	7.0	108	110	114	114	120	112	109	108
Lysine	5.5	53	66	78	69	68	56	94	67
Methionine+cystine	3.5	71	93	59	34	65	75	105	105
Threonine	4.0	79	89	90	108	95	88	101	94
Phenylalanine+ tyrosine	6.0	134	138	136	127	138	140	118	125

Table 4

Contents of microelements in new cupcakes, mg/100 g, $p \leq 0.05$; $n=3$

Titles of cupcakes samples	Mineral elements					
	Iron	Copper	Zink	Magnesium	Iodine, μg/kg	Selenium, μg/kg
Control	1.38	0.13	0.38	0.28	0.001	0.01
«Kunzhutnyi»	1.60	0.24	0.46	0.38	*	*
«Moryachok»	2.27	0.34	0.49	0.59	0.150	3.68
«Mitsnyi Gorishek»	2.58	0.42	0.40	0.42	0.175	5.29
«Osinnyi Aromat»	1.50	0.15	0.40	0.26	*	*
«Chornychnyi»	2.68	0.24	0.50	0.57	0.004	*
«Medok»	2.00	0.39	0.41	0.40	0.030	6.57
«Elitnyi»	1.82	0.39	0.46	0.14	0.016	2.61

** – indicator was not defined*

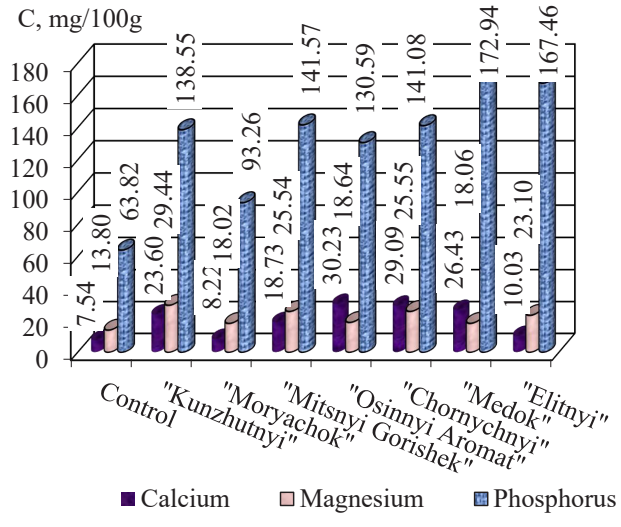

Fig. 10. Content of macro elements in the new cupcakes

Cupcakes "Moryachok" and "Mitsnyi Gorishek" were enriched with iodine through the use in the formulation composition of samples of deep-sea tangles, as well as kernels, leaves and oil from walnut. The developed cupcakes demonstrated a marked increase in the content of selenium due to introducing to the formulation of cupcakes "Moryachok" the powder of deep-sea tangles, coltsfoot, oil from pumpkin seeds, to "Mitsnyi Gorishek" – oil and kernels of walnut, to "Elitnyi" – the powder of haricot, to "Medok" – the powder of flower pollen.

The use of alternative raw materials in the new formulations of cupcakes helped enrich products with vitamins (Table 5).

Table 5

Content of vitamins in new cupcakes, mg/100 g, p≤0.05; n=3

Titles of cupcakes	Content, μg/100 g					
	Retinol	Thiamine	Riboflavin	Nicotinic acid	Ascorbic acid	Tocopherol
Control	0.025	0.044	0.047	0.206	0.25	0.10
«Kunzhutnyi»	0.033	0.061	0.097	0.397	1.9	0.25
«Moryachok»	0.035	0.075	0.069	0.408	3.3	1.2
«Mitsnyi Gorishek»	0.036	0.078	0.093	0.421	4.1	1.6
«Osinnyi Aromat»	0.031	0.080	0.096	0.477	2.4	0.8
«Chornychnyi»	0.031	0.078	0.081	0.4–6	2.6	0.5
«Medok»	0.059	0.129	0.119	0.514	3.0	1.2
«Elitnyi»	0.048	0.114	0.107	0.492	2.7	0.8

A significant increase in the content of retinol was achieved in cupcake "Medok": it exceeded control sample by 2.4 times, vitamin B_1 – by 2.9 times. The content of riboflavin increased by 1.5–2.5 times, vitamin PP – by 2.3–2.5 times. In terms of the content of vitamin C, one can note the cupcakes "Mitsnyi Gorishek" and "Moryachok". In addition, owing to the use of plant-based raw materials and natural additives the content of β–carotene reached, for cupcake "Medok", 0.968, for "Moryachok", 0.950, and for "Elitnyi", 0.737 mg/100 g.

6. Discussion of results of studying consumer properties of the new cupcakes

We have proven a positive impact of the applied raw materials and additives (rye flour, oatmeal flour, buckwheat flour, corn flour, the powdered blueberry leaves, blackberry leaves, heartleaf bergenia, raspberry, coltsfoot, peppermint, walnut, heart linden flowers, chamomile, tricolor violet flowers, deep-sea tangles, Hypericum perforatum, chicory roots, purple echinacea, haricot, natural honey, flower pollen, propolis, dry whey, skimmed milk powder, sesame oil, pumpkin seeds oil, walnut oil, walnut kernels, candied apple-cherry and blueberry fruit) on the formation of consumer properties (organoleptic indicators, nutritional and biological value) of the new cupcakes.

The novelty of technical solutions was confirmed by five patents for the useful model in Ukraine: cupcake "Kunzhutnyi" No. 68297, cupcake "Moryachok" No. 66891, cupcake "Mitsnyi Gorishek" No. 65758, cupcake "Osinnyi Aromat" No. 66890, cupcake "Chornychnyi" No. 69064.

Replacing wheat flour with rye flour, oatmeal flour, buckwheat flour, corn flour, haricot powder, dried dairy whey, skimmed milk powder influenced the increase in the content of protein, by 18.9–31.8 % (cupcakes without filling) and by 1.6–1.7 times (cupcakes with filling) compared with control sample (Table 2).

Owing to replacing flour with powders made from medicinal technical raw materials (powders from blueberry leaves, black currant, heartleaf bergenia, raspberry, coltsfoot, peppermint, walnut, the flowers of heart linden, chamomile, tricolor violet, deep-sea tangles, the herbs from Hypericum perforatum, chicory roots, purple echinacea, haricot) the amount of carbohydrates decreased by 4.7–14.9 %; the

amount of fat decreased by 3.1–20.1 % compared with control sample (Table 2).

A change to the formulations of cupcakes and the introduction of non–traditional raw materials helped reduce the calorie content of products by 16–39 kcal/100 g.

The use in the cupcakes' formulation of whey, skimmed milk, rough rye flour, oatmeal flour, buckwheat flour and corn flour, as well as the haricot powder, affected the increase in the content of essential amino acids in the new products by 1.1–1.9 times compared with control sample (Fig. 6).

Replacing the fat base (margarine) in the formulations of cupcakes with non-traditional types of vegetable oils (sesame oil, pumpkin seeds oil, walnut oil, walnut kernels) influenced the increase in the amount of unsaturated fatty acids. As a result of the replacement, the ratio of proportion of unsaturated fatty acids to saturated in the new products equaled 2.2–2.8, and in control sample – 1.8 (Fig. 8).

Through the use of alternative raw materials, we have successfully improved the mineral composition of the developed products. The applied raw materials and additives influenced the growth of calcium by 1.1–3.5 times, magnesium – by 1.3–2.1, phosphorus – by 1.5–2.7, potassium – by 1.1–1.5, iron – by 1.1–1.9 times owing to the introduction to the formulation of flour rye, oatmeal flour, buckwheat flour, corn flour, dry skim milk, whey, deep-sea tangles, walnut leaves, purple echinacea, propolis, natural honey, flower pollen. The cupcake "Stolychnyi" demonstrated its traces (0.001 μg/100 g), while "Moryachok" and "Mitsnyi Gorishek" were enriched with iodine through the use in the formulations of, respectively, deep-sea tangles and oil, leaves, and walnut kernels. Control contains traces of selenium, and the new cupcakes demonstrate a significant increase in a given element due to the introduction to the formulation of cupcake "Moryachok" of deep-sea tangles, coltsfoot, oil from pumpkin seeds, "Mitsnyi Gorishek" – oil and kernels from walnut, "Elitnyi" – the haricot powder, "Medok" – the powdered flower pollen (Table 4).

Introducing alternative raw materials to the new formulation of cupcakes increased the content of vitamins. The amount of thiamine rose by 1.4–2.9 times, riboflavin – by 1.5–2.5, vitamin PP – by 1.9–2.5 times due to introducing rye flour, oatmeal flour, buckwheat flour, corn flour, powdered leaves of walnut, chicory roots, haricot, fruits of blueberries, as well as pollen and propolis. The increase in the content of retinol, by 1.2–2.4 times, is explained by introducing changes to the formulation of the new products in the form of dry whey, skimmed milk powder, deep-sea tangles (Table 5).

The advantage of this study is that the results obtained make it possible to develop and devise not only the cupcakes with new formulations, but other pastry, bakery products, as well as food concentrate products. In addition, the data obtained in the course of our research could be used for extending a range of products with improved composition and the predefined consumer properties.

A serios drawback of the current study is that the production of such products is associated with difficulties concerning the high cost of alternative plant-based raw materials and the necessity to certify them.

Further studies will address determining the influence of various factors on the quality and safety of finished products during storage, as well as slowing down the processes of staling.

7. Conclusions

1. The new products that contain selected ingredients are characterized by a higher content of protein, by 18.9–31.8 % (cupcakes without filling) and by 1.6–1.7 times (cupcakes with filling), a decreased amount of fat, by 3.1–20.1 %, and carbohydrates, by 4.7–14.9 %, compared with control sample. The result of using the proposed formulation supplements is the reduced caloric value of cupcakes, by 16–39 kcal/100 g.

2. The application of alternative raw materials in the new products had an impact on the increased content of essential amino acids, by 1.1–1.9 times, compared with control sample.

3. Replacing margarine in the formulations of cupcakes with non-traditional types of plant-derived oils has increased the ratio of proportion of unsaturated fatty acids to saturated to 2.2–2.8, whereas in control sample it was only 1.8.

4. The applied raw materials and additives have improved the mineral composition of the developed products. The content of calcium increased by 1.1–3.5 times, magnesium – by 1.3–2.1, phosphorus – by 1.5–2.7, potassium – by 1.1–1.5, iron – by 1.1–1.9 times. Control sample lacks iodine (0.001 μg/100 g), while cupcakes "Moryachok" and "Mitsnyi Gorishek" have been significantly enriched with iodine; the same trend was observed as regards the growth in the content of selenium. Introducing alternative raw materials to the new formulations of cupcakes has increased the contents of vitamins. The amount of retinol increased by 1.2–2.4 times, thiamine – by 1.4–2.9, riboflavin – by 1.5–2.5, vitamin PP – by 1.9–2.5 times. At the same time, the new product range of cupcakes has demonstrated a growth in the content of tocopherol.

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