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MANUFACTURING APPROACHES TO MAKING MUFFINS OF HIGH NUTRITIONAL VALUE

The object of this study is the technology of baking muffins using beetroot fibers and wheat germ meal. Muffins are popular flour-based confectionery products with pleasant physical appearance and a variety of flavors, which are characterized by high energy and low food values. In addition, they are most often prepared using polycomposite mixtures, which does not make it possible to obtain products with a physiologically significant content of biologically active substances. It has been proposed while improving the technology of making muffins of high nutritional value to use such products of wheat germ and beet pulp processing as the additives «Beet fibers» and «Wheat germ meal» to serve the sources of physiologically functional ingredients. Beetroot fibers contain in their composition pectin-cellulose-hemicellulose complex of non-starch polysaccharides, polyphenolic compounds, and minerals (magnesium, calcium, sodium, etc.). The chemical composition of wheat germ meal is represented by a cellulose-hemicellulose complex, quite high content of vitamin E, polyphenolic compounds, and a significant amount of potassium, phosphorus, magnesium, calcium. The influence of wheat germ and beet pulp processing products has been investigated when partially replacing wheat flour, 25.0–75.0 % and 10.0–20.0 %, respectively. The formulation composition of muffins was optimized resulting in the substantiation of the amount of experimental additives (15.0 %, beet fibers; 50.0 %, wheat germ meal) and a decrease in the formulation content of sugar by 30.0 %. The organoleptic and physicochemical indicators of muffins have been determined, as well as the amount of physiologically functional ingredients in the products containing wheat germ and beet pulp processing products. The functional- technological scheme of muffin production has been built involving the addition of beet fibers and wheat germ meal. The improved muffin technology differs from conventional technologies by the application of natural raw materials, lack of food additives of synthetic origin, and the introduction of beet fibers and wheat germ meal, which makes it possible to make products with high nutritional value while maintaining the appropriate quality.

Keywords: *muffin technologies, beetroot fibers, wheat germ meal, optimization of formulation composition, quality indicators, nutritional value.*

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1. Introduction

Muffins that have an appealing taste and consumer properties [1] are very popular today. Muffins are cupcake-like baked products with a small mass [2]. They combine the crumbliness and porosity of cakes and the puffy and light structure of sponge cakes. They may include a variety of fillings (marmalade, jam, fillers) and various additives (seeds, nuts, dried berries and fruits, chocolate chips, etc.) [3, 4].

However, they have high energy and sugar indicators and low nutritional value [5, 6]. Muffins are prepared by the technology that involves a separate mixing of liquid and dry ingredients [7]. In the first stage, dry components are sieved and mixed; in the second stage, the liquid ingredients are mixed to bring them to uniformity. Next, these mixtures are combined while the batter undergoes a quick kneading as prolonged kneading leads to tightening of the batter due to the swell of gluten proteins, resulting in products with a compacted crumb structure. The dough is dosed in paper or silicate molds at 2/3 of their height, followed by baking at a temperature of 180–200 °C over 25–30 minutes [8].

To improve the efficiency of technology, muffins can be made from special poly component mixtures. They typically contain wheat flour, white sugar, gluten-free flour, milk powder, dry egg powder, modified starches, surface-active substances (emulsifiers) maltodextrin, flavorings, baking powders, etc. [9, 10]. Such mixtures for the manufacture of muffins simplify the technology, they are easy to use, thereby making it possible to significantly expand the range of products. Their advantages also include the reduced number of manufacturing operations and the amount of time necessary for the manufacture of products. However, it should be noted that muffins based on such multicomponent mixtures have low quality and nutritional value indicators, as well as do not contain substances useful to the body.

Making food products of high nutritional and biological value involving the use of unconventional secondary plant raw materials is a relevant area of industry development [11, 12]. Such types of raw materials include the products of processing wheat germ (wheat germ meal) and beetroot pulp (beetroot fibers) [13]. These additives are proposed to be used in muffin technology as a source of functional and physiological nutrients. Wheat germ meal (WGM) is a skimmed residue obtained after separating the appropriate oil. It contains a significant amount, up to 45 %, of protein, dietary fibers (cellulose – 12.1 %, hemicellulose – 11.2 %, lignin – 3.0 %, pectin substances – 1.0 %), as well as vitamin E, carotenoids, polyphenols, and minerals. Beet fiber (BF) is obtained from beet pulp, a by-product of sugar production. They are represented by a pectin-cellulose-hemicellulose complex of non-starch polysaccharides (up to 80 %), polyphenols, and minerals [14]. The use of these additives in muffin technology in optimal dosage would enrich the products with essential substances, which could improve the nutritional status of the population.

Thus, the chosen *object of research* is the muffin technology involving the use of beet fibers and wheat germ meal. And the *purpose of the research* is to establish the optimal formulation composition of muffins with high nutritional value and to improve their manufacturing technology.

2. Methods of research

We estimated the organoleptic quality indicators of muffins (physical appearance, color, crumb status, taste, smell) according to [15].

The specific volume of muffin samples was calculated from the following formula:

$$V_{food} = V/m, \ \text{cm}^3/\text{g}, \quad (1)$$

where V is the sample volume, cm^3; m is the mass of a sample, g.

The moisture content of baked products was determined by drying to a constant mass, from the following formula:

$$W=(a-b)/(a-c)\cdot 100, \ \%, \quad (2)$$

where a is the weight of a container with a batch prior to drying, g; b is the weight of a container with the batch after drying, g; c is the mass of an empty container, g.

To determine the content of non-starch polysaccharides in the products, we degreased the samples. To this end, a batch of muffins was placed in a cartridge made of filter paper and dried at a temperature of 70–80 °C. A dried sample was placed in a flask with a capacity of 250 or 500 cm^3 with a section; we poured 30–40 cm^3 of ether and heated it in a water bath at a temperature of 40–50 °C with a reverse refrigerator (20–30)·60 s.

The content of free carbohydrates, water-soluble polysaccharides, and hemicellulose was determined by the modified Draywood method; the content of cellulose – by a nitrogen-alcohol method (Kürschner method); pectin substances – by a calcium-pectate method; lignin – the method by Wilshtetter and Zechmeister. The content of low molecular phenolic compounds was determined by a colorimetric method according to DSTU 4373:2005. The quantitative content of the sum of oxidized polyphenolic compounds was determined by a permanganatometry method according to the procedure DF XI (State Pharmacopeia of the USSR, XI edition). Carotenoids were determined by a colorimetric method according to DSTU 4305:2004. We determined the composition of tocopherols in the examined additives using the method of liquid chromatography according to DSTU EN 12822:2005 at the Smartline chromatographer (Knauer, Germany). The mineral composition of additives was determined by the method of atom-emission spectrography involving a photographic registration at the device DFS-8 (Russia).

The error value for all studies was σ=3–5 %; the experiment repeatability was n=5; the probability was $P \geq 0.95$.

3. Research results and discussion

The organoleptic and physicochemical characteristics of products, their nutritional and energy value are largely due to the ratio of formulation components. In order to reduce the energy value of confectionery flour-based products, the formulation amount of sugar is often reduced. At the same time, additional raw materials are introduced, which contain the necessary physiological and functional ingredients for the body [10]. In this regard, in our work, we explored the possibility of reducing the amount of sugar in the formulations of muffins, when using additives, by 10.0–30.0 %.

In the formulations of the experimental muffins, we optimized the amount of sugar and experimental additives using a mathematical method of the full factor experiment FFE2^2.

In the first stage, a quadratic mathematical model of the muffin production process was built. It reflects the dependence of the optimization criterion, the specific volume of finished products (Y, cm^3/g), on optimization factors. These were the amount of an additive (x_1, %) and the amount of sugar (x_2, %). The levels and intervals of variation of the experimental additives were chosen on the basis of the previously obtained research results and amounted to 10.0–20.0 % for beet fibers, and 25.0–75.0 % for wheat germ meal.

The task of optimization was to determine the values of the selected factors to maximize the criterion of optimality. The levels of factors and intervals of their variance are given in Table 1.

Table 1

Optimization factor levels

Optimization factor	Zero level	Variance level	Low level	Upper level
Muffins with added WGM				
Additive amount (x_1, %)	50	25	25	75
Sugar amount (x_2, %)	80	10	70	90
Muffins with added BF				
Additive amount (x_1, %)	15	5	10	20
Sugar amount (x_2, %)	80	10	70	90

The result of the implementation of the experiment matrix and data treatment is the derived adequate regression equations:

– for muffin technology with WGM:

$$Y1(x_1,x_2)= 5.401+80.4\cdot10^{-3}x_1-78.3\cdot10^{-3}x_2-$$
$$-3.32\cdot10^{-3}x_1^2+0.42\cdot10^{-3}x_2^2+0.24\cdot10^{-3}x_1x_2;$$

– for muffin technology with beetroot fibers:

$$Y2(x_1,x_2)= 3.443+30.6\cdot10^{-3}x_1-30.5x_2-$$
$$-21.28\cdot10^{-5}x_1^2+17.0\cdot10^{-5}x_2^2-0.1\cdot10^{-3}x_1x_2;$$

The graphic interpretation of the mathematical models for muffins with beetroot fibers is shown in Fig. 1, 2; for those with wheat germ meal – Fig. 3, 4.

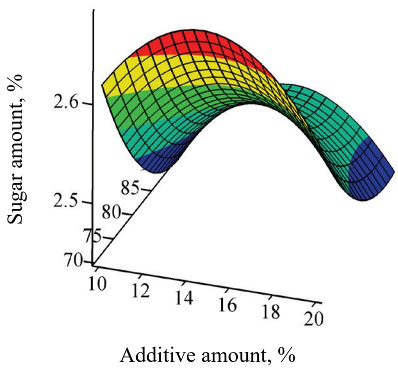

Fig. 1. Surface of the optimization criterion response to a change in the variance factors of muffins with beetroot fibers

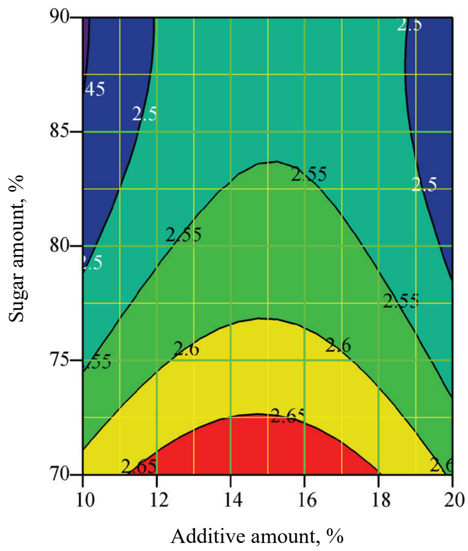

Fig. 2. Isolines of beetroot fiber influence

The regression equations were used to find the optimal values of factors x_1 and x_2. According to our results, muffins with beetroot fibers have the following intervals of optimization parameters: a dosage of the experimental additive (x_1) is 11.0–18.0 % with flour replacement and reduction of sugar (x_2) by 27.5–30.0 % of the amount in the basic formulation.

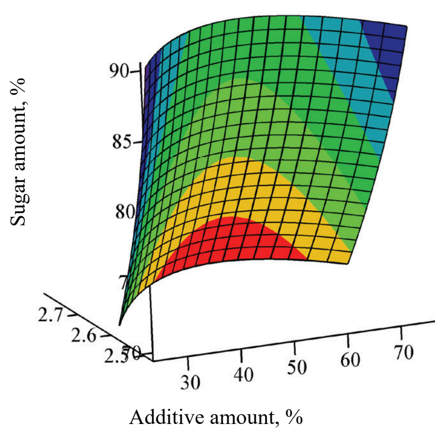

Fig. 3. Surface of the optimization criterion response to a change in the variance factors of muffins with wheat germ meal

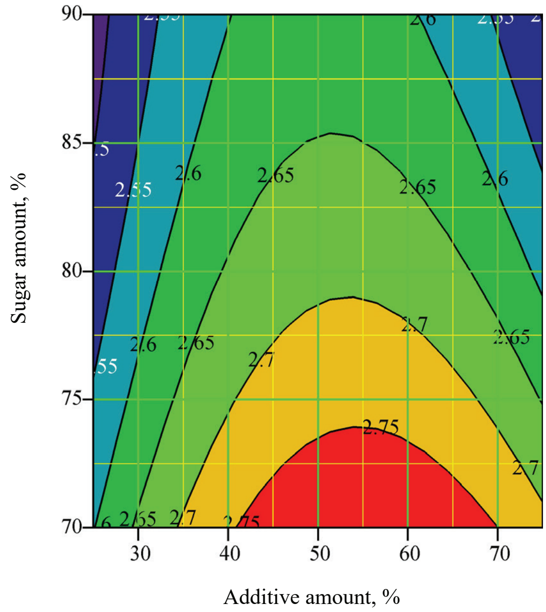

Fig. 4. Isolines of wheat germ meal influence

The best indicator of the specific volume of muffins with wheat germ meal is observed when the dosage of the experimental additive (x_1) is in the interval of 40.0–70.0 % with the replacement of flour and a decrease in the amount of sugar (x_2) by 26.0–30.0 % of the amount in the basic formulation.

Optimization data have made it possible to choose in the formulations of muffins the amount of experimental additives (15.0 % beet fibers; 50.0 % wheat germ meal) and reduce the formulation amount of sugar by 30.0 %.

The organoleptic and physicochemical characteristics of control and muffin samples made using the optimal doses of additives and sugar are given in Table 2.

Table 2

Muffin quality indicators

Indicator	Muffins without additives (control)	Muffins with added	
		BF	WGM
Physical appearance	Products of the correct shape, without breaks, cracks available		
Color – crust – crumb	golden light yellow	beige creamy	golden creamy
Crumb state	Well loose, fragile	Loose, with BF inclusions, more fragile	Well loose, with WGM inclusions, more fragile
Smell and taste	Inherent in a given product, no foreign inclusions	Inherent in a given product, light pleasant aftertaste and aroma of BF	Inherent in a given product, with light nutty aftertaste and aroma
Moisture content, %	28.0	29.2	29.5
Specific volume, cm^3/g	2.50	2.45	2.70

Muffins are characterized by the presence of cracks at their surface. Table 2 shows this typical attribute persists when adding beetroot fibers and wheat germ meal. The products with additives retain their shape well, have no breaks. The color of the developed products is somewhat intensified – they acquire a cream color. The crumb of the products is well loosened; the cut demonstrates the inclusion of the corresponding additives while it becomes more fragile.

The smell and taste of muffins with additives are pleasant. If one adds meal, the products have a light nutty taste; when using beetroot fibers – a light taste of this additive.

Compared to the control sample, the moisture content of muffins with the addition of BF increases by 5.0 %; of those with WGM – by 5.5 %. The specific volume of muffins with BF decreases slightly; those with meal – increases by 8.0 %. This may be due to the fact that the meal has larger particle sizes, which contribute to obtaining a looser structure of the muffin crumb.

We examined the content of nutrients and biologically active substances in the developed muffins with the addition of beet fibers and wheat germ meals (Table 3).

Table 3 shows that muffins with BF, when compared to the control sample, have a 21.0 % lower carbohydrate content and 12.3 % less energy value. Products with WGM have 2.0 times higher amounts of protein, 24.8 % less carbohydrate content, and the energy value reduced by 9.1 % compared to muffins without additives.

In products with BF, the content of non-starch polysaccharides increases by 10 times; the low molecular phenolic compounds – by 1.9 times compared to control. The content of tannins in muffins with beet fibers is significantly greater than that in products without additives. In turn, products with wheat germ meal are also characterized by a much higher content, compared to control, of non-starch polysaccharides, by 11 times, and of low molecular phenolic compounds, by 12.5 times. They also have a higher content of carotenoids, by 1.4 times, and tocopherol, by 6.3 times, compared to control. Muffins with wheat germ meal significantly surpass products without additives in the content of tannins.

Fig. 5 shows an improved manufacturing scheme of muffin production with the addition of beetroot fibers and wheat germ meal.

The advantages of the proposed technology are the use of natural raw materials and the absence of synthetic food additives. The application of wheat germ and beetroot meal processing products makes it possible to prepare muffins of high nutritional value while maintaining good quality.

Table 3

Food and energy value per 100 g of muffins

Indicator	Muffins without additives (control)	Muffins with experimental additives	
		BF	WGM
Proteins, g	5.4	4.8	10.7
Fat, g	13.3	13.0	13.2
Carbohydrates, g	53.0	41.8	39.8
Non-starch polysaccharides, g	0.4	3.9	4.6
including cellulose	0.040	1.42	2.3
hemicellulose	–	1.2	2.1
pectin substances	–	1.25	0.15
Lignin, g	–	0.45	0.55
Tannins (tannin), mg	0.68	83.7	276.6
Low molecular weight phenolic compounds (by rutin), mg	0.20	0.37	2.50
Carotenoids, mg	0.25	–	0.350
Tocopherol, mg	–	–	0.62
Iron, mg	0.46	3.42	1.33
Silicon, mg	1.52	13.50	traces
Phosphorus, mg	32.68	2.90	117.8
Aluminum, mg	399.0	1.71	traces
Manganese, mg	traces	0.85	6.84
Magnesium, mg	6.08	5.7	41.8
Calcium, mg	6.84	13.65	21.8
Zinc, mg	traces	0.59	4.15
Sodium, mg	1.14	10.2	1.37
Potassium, mg	46.36	1.71	416.1
Energy value, kcal	362	318	329

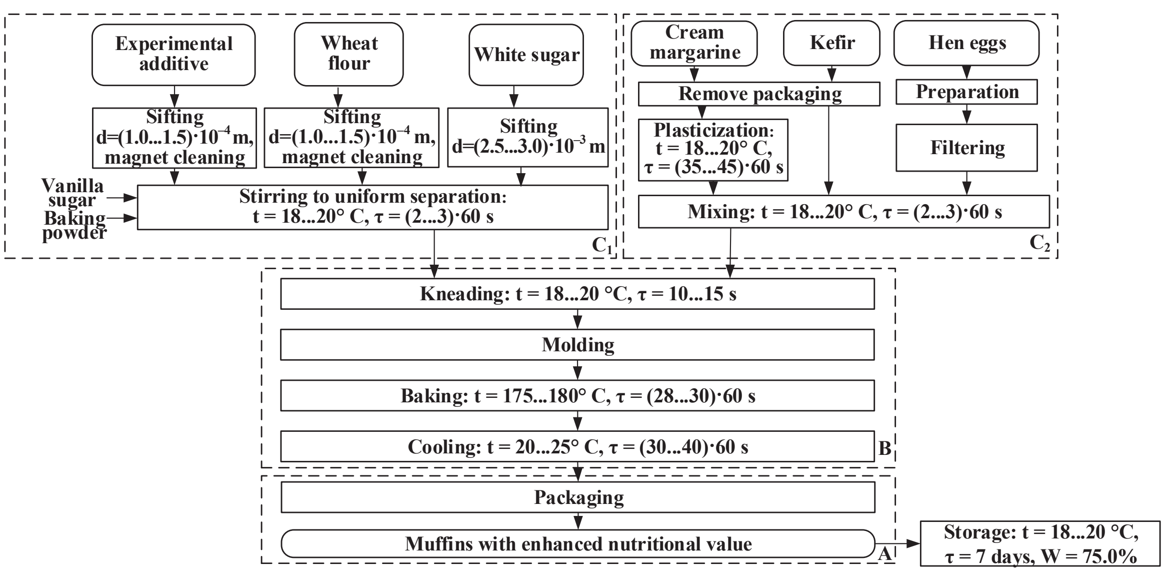

Fig. 5. Manufacturing scheme of muffins with experimental additives

4. Conclusions

In the course of the study, using mathematical modeling of the formulation composition of muffins, it has been determined that the optimal amount of beet fibers is 15.0 %, wheat germ meal is 50.0 %, while the amount of sugar is reduced by 30.0 %. The addition of experimental additives contributes to the improvement of organoleptic indicators and the physicochemical characteristics of muffins. In addition, the products demonstrate an increase in the content of food fibers such as cellulose, hemicellulose, pectin substances, as well as polyphenolic compounds, magnesium, calcium, sodium, phosphorus, and potassium.

The improved muffin technology differs from conventional technologies by the use of natural raw materials, the lack of food additives of synthetic origin.

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References

1. Rahman, R., Hiregoudar, S., Veeranagouda, M., Ramachandra, C. T., Kammar, M., Nidoni, U., Roopa, R. S. (2015). Physicochemical, textural and sensory properties of muffins fortified with wheat grass powder. *Karnataka Journal of Agricultural Sciences, 28* (1), 79–82.
2. Dizlek, H. (2015). Effects of Amount of Batter in Baking Cup on Muffin Quality. *International Journal of Food Engineering, 11 (5),* 629–640. doi: http://doi.org/10.1515/ijfe-2015-0066
3. Ureta, M. M., Olivera, D. F., Salvadori, V. O. (2014). Quality Attributes of Muffins: Effect of Baking Operative Conditions. *Food and Bioprocess Technology, 7 (2),* 463–470. doi: http://doi.org/10.1007/s11947-012-1047-7
4. Saulsbury, C., Rose, R. (2010). *750 Best Muffin Recipes: Everything from Breakfast Classics to Gluten-Free, Vegan and Coffeehouse Favorites.* Incorporated, 512.
5. Ortega-Heras, M., Gómez, I., de Pablos-Alcalde, S., González-Sanjosé, M. L. (2019). Application of the Just-About-Right Scales in the Development of New Healthy Whole-Wheat Muffins by the Addition of a Product Obtained from White and Red Grape Pomace. *Foods, 8 (9),* 419. doi: http://doi.org/10.3390/foods8090419
6. Żbikowska, A., Kupiec, M., Szymanska, I., Osytek, K., Kowalska, M., Marciniak-Lukasiak, K., Rutkowska, J. (2020). Microbial β-glucan Incorporated into Muffins: Impact on Quality of the Batter and Baked Products. *Agriculture, 10 (4),* 126. doi: http://doi.org/10.3390/agriculture10040126
7. Weinstein, B., Scarbrough, M. (2012). *The Ultimate Muffin Book: More Than 600 Recipes for Sweet and Savory Muffins.* London: HarperCollins, 272.
8. Nilsson, M. (2019). *Röstbaserade Instruktioner-Vad som krävs för att göra sig förstådd.* Available at: https://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1481703&dswid=-7703
9. Dorokhovich, A. N., Liman, N. P. (2009). Maffin – novii vid muchnykh konditerskikh izdelii na rynke Ukrainy. *Produkty i ingredienty, 10,* 12–13.
10. Bhaduri, S., Mukherjee, A. K. (2016). Rheology of Muffin Batters by Line Spread Test and Viscosity Measurements. *International Journal of Food Science, Nutrition and Dietetics, 5 (9),* 325–329. doi: http://doi.org/10.19070/2326-3350-1600058
11. Ghinea, C., Leahu, A., Prisacaru, A. E., Cojocaru, M., Ladariu, V. (2019). Physico-chemical and sensory analyzes of muffins obtained with almond flour and coconut oil. *International Multidisciplinary Scientific GeoConference: SGEM, 19 (6.3),* 165–172.
12. Tufeanu, R. E., Tiţa, M. A., Tiţa, O. (2018). Muffins Obtained with Some Vegetal Powders as Fat Replacers. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. *Animal Science and Biotechnologies, 75 (1),* 21. doi: http://doi.org/10.15835/buasvmcn-asb:000317
13. Samokhvalova, O. V., Oleinik, S. G., Kasabova, K. R., Bolkhovitina, E. I, Stepankova, G. V. (2020). Perspektivy ispolzovaniia novykh istochnikov pischevykh volokon v tekhnologii muchnykhkonditerskikh izdelii. *Kadry dlia APK.* Belgorod: ID «BelGU» NIU «BelGU», 301.
14. Tan, C., Wei, H., Zhao, X., Xu, C., Peng, J. (2017). Effects of dietary fibers with high water-binding capacity and swelling capacity on gastrointestinal functions, food intake and body weight in male rats. *Food & Nutrition Research, 61 (1),* 1308118. doi: http://doi.org/10.1080/16546628.2017.1308118
15. Samokhvalova, O. V., Kasabova, K. R. (2012). *Tekhnichni umovy 10.7-01566330-272:2012. Vyroby kondyterski boroshniani z kharchovymy voloknamy. Vved. 05.07.2012.* Kharkiv: Derzhspozhyvstandart Ukrainy, 21.

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