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The use of multi-grain raw materials in the formulation of pasta from wheat baking flour

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Abstract

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Apart from conventional pasta recipes, producers offer products obtained using unconventional plant raw materials. The production of pasta using available multi-grain raw materials is of scientific interest. The purpose of the research was to determine the practical applicability of whole-grain multi-grain flour in the formulation of pasta from high-grade baking wheat flour. The objects of the research were: high-grade baking wheat flour, barley-rye-oat flour, model samples of dough and finished pasta for first courses (control and test samples with the substitution of 10% (experiment 1), 20% (experiment 2) and 30% (experiment 3) of wheat flour with a similar amount of whole-grain barley-rye-oat flour). We established a good compatibility of the studied raw material by the organoleptic indicators. We highlighted the superiority of the multi-grain flour by the content of lipids (by 4 times), dietary fiber (by 2.5 times), zinc (by 2.8 times), iron and magnesium (by 2.4-2.5 times), manganese and copper (by 1.6-1.7 times), phosphorus (by 64.6%) against the background of the low gluten content. According to the results of testing the organoleptic and physical and chemical parameters of the pasta dough, tasting assessment of the quality and cooking properties of the pasta, experiment 3 was chosen as the best experimental version. The substitution of 30% of wheat flour in pasta recipes for first courses with whole-grain multi-grain flour increases the content of lipids (by 2.7 times), dietary fiber (by 44.6%), micronutrients: copper (by 1.7 times), zinc (by 48%), iron (by 40%), manganese (by 21%), macronutrients: magnesium (by 47%) and phosphorus (by 10%) in the finished product due to the formation of a very good quality and acceptable cooking properties.

Keywords: pasta; wheat baking flour; multi-grain flour; quality; nutritional value

Introduction

Due to the lack of strong wheat pasta flour, in Russia most types of pasta are produced from baking flour (Malyutina & Turenko, 2016). Thus, the output of economy-class products from the high-grade wheat flour is 45% of the total production (Galitskova & Pokrovsky, 2015; Filippova, 2017). In recent years, in addition to conventional pasta recipes, producers offer improved quality products with an increased nutritional value, including through the use of unconventional plant raw materials (Galitskova & Pokrovsky, 2015; Osipova et al., 2018). There are known technologies of using powdered parsnip and pumpkin in the composition of homemade noodles, potato juice, spelt wheat, rye, beans flour, pea starch, etc. (Koroleva, 2017; Rodionov et al., 2017; Trotz & Blinova, 2017; Vershinina & Yurk, 2017). An important factor in this case is the preservation of traditional organoleptic quality indicators and the provision of a high nutritional, biological and functional value of the products. The production of pasta using available multi-grain raw materials is of scientific and practical interest. The purpose of the research was to establish the practical applicability of whole-grain multi-grain flour in the formulation of pasta from the high-grade baking wheat flour.

Materials and Methods

The objects of research were:

– high-grade baking wheat flour and whole-grain multi-grain flour (composition: oats – 40%, barley and rye – 30% each) produced by Soyuzpishcheprom Association LLC (Russia, Chelyabinsk region, Chelyabinsk);

– model samples of pasta dough and finished pasta, namely "Domashnyaya" noodles for first courses. The control samples were made according to the basic recipe (composition: high-grade baking wheat flour, drinking water, salt), the test samples – with the substitution of 10% (experiment 1), 20% (experiment 2) and 30% (experiment 3) of the wheat flour with a similar amount of whole-grain multi-grain flour. The used dosages are experimental and were selected taking into account the known results published in scientific papers by the leading experts in pasta production (Osipova, 2011; Malyutina & Turenko, 2016; Fedorova et al., 2017; Berestov, 2018).

The organoleptic characteristics of the raw materials, semi-finished products and finished products were determined visually and during testing. The tasting assessment of the model pasta samples was carried out after cooking, using a 100 point scale. The samples scoring 96–100 points were considered to be of a "very good" quality, 84–95 – "good" quality, 75–83 – "satisfactory" quality, 74 and less – "technical defect" (Agapkin, 2019).

The moisture content of the raw materials and finished products was determined by drying the weighted portion at 130°C for 40 minutes, the pasta dough – at 160°C for 10 minutes to a constant weight with a further calculation of the studied indicator. The protein content was determined by the sample mineralization according to Kjeldahl method; fat content – using the extraction method in the Soxhlet apparatus; ash content – by a complete burning of the organic part of the weighted portion followed by a gravimetric determination of the studied indicator; acidity – by titration with sodium hydroxide; phosphorus content – by the molybdenum-vanadium method; the content of other mineral elements – by the flame atomic absorption method; fiber content – by hydrolysis and removal of protein and starchy substances with enzymes (Skurikhin & Tutelian, 1998); microstructure of the weighted portions – using scanning electron microscopy (Pashkeev, 2015).

The amount of gluten in the raw material was determined by its washing from the dough manually, the quality of gluten was determined by measuring its elastic properties using a gluten deformation meter.

The preservation of the shape of the model samples of noodles after 5 minutes cooking was determined by a visual inspection with a subsequent calculation of the indicator. The dry matter transferred to the cook water from the noodles was determined in the remaining cook water dried (for 4 hours at a temperature of 100°C) to a constant mass with its subsequent cooling and processing of the results. The presence of metallomagnetic impurities was determined by a magnetic treatment in the longitudinal and transverse directions of the weighted portion of the noodles. The infection rate and contamination of the noodles with grain storage pests were determined by examining the noodle sample through a magnifier (Skurikhin & Tutelian, 1998).

The rates of the daily human demand for food and biologically active substances are taken from Methodical Recommendations "Norms of the physiological demands for energy and nutrients for various groups of the population of the Russian Federation" (Tutelian, 2009).

All the measurements were made in triplicate. A statistical analysis was performed using the software suite: Microsoft Excel XP, Statistica 8.0. The statistical error of the data did not exceed 5% (with a 95% confidence level).

Results and Discussion

At the first stage of the research, we studied the organoleptic characteristics of the used plant raw materials (Figure 1). High-grade baking wheat flour is a fine powder product characterized by a creamy white color; it has a slightly sweet taste and an inherent smell. Whole-grain multi-grain flour is light gray with interspersed grain shells with a brown-olive tone; it has a taste and smells typical of the grains included in its composition, without extraneous flavors and smells.

a) b)

Fig. 1. The appearance of the studied flour
a) wheat flour, b) multi-grain flour

It has been established that the baking wheat flour and the whole-grain multi-grain flour have a good compatibility by the organoleptic indicators, which determines their combined use in various ratios.

The physical and chemical tests of the analyzed raw materials allowed us to establish the advantage of the barley-rye-oat mixture over the wheat material by a number of indicators (Table 1).

Table 1. Chemical composition of the studied flour

Target indicator	Test results	
	wheat flout	multi-grain flour
Mass fraction of fat in terms of dry matter, %	1.1 ± 0.1	4.1 ± 0.1
Mass fraction of protein, %	13.7 ± 0.6	14.1 ± 0.5
Gluten quantity, %	31.2 ± 1.1	13.0 ± 0.4
Gluten quality, GDM units	66.1 ± 1.5	42.0 ± 0.7
Moisture content, %	12.9 ± 0.4	10.7 ± 0.3
Ash content in terms of dry matter, %	0.56 ± 0.03	1.30 ± 0.05
The content of dietary fiber, g/100 g, including:	3.42 ± 0.03	8.43 ± 0.04
– soluble	1.41 ± 0.04	1.62 ± 0.03
– insoluble	2.01 ± 0.02	6.81 ± 0.05

We have revealed a significant superiority of the multi-grain flour in the content of the following nutrients: vegetable lipids (4 times), which is due to the presence of oats in the composition of the three-component flour; dietary fiber (2.5 times) against the background of the prevailing insoluble fractions by 3.4 times. It is known that oat flour fat is a lipid of high biological activity (Vargach et al., 2017), and dietary fiber is of great importance for the human body. So, cellulose and hemicellulose have a stimulating effect on the vermicular motion, and pectins are sorbents and a nutrient substrate for the intestinal microflora (Kondrashina, 2017).

It has been found that the multi-grain flour slightly differs from the wheat flour by the moisture content. In addition, the presence of a significant amount of dietary fiber with a good water absorption capacity implies a reassessment of the water necessary for the formation of the pasta dough texture.

The high ash content of the multi-grain flour (outnumbers by a ratio of 2 to 1) is due to the presence of the aleuronic layer particles and seed shells in its composition, which undoubtedly positively influences the level of mineral elements in it.

The quantity and quality of the gluten flour is an important technological indicator characterizing in this case the ability of pasta to take shape during pressing and to preserve it after cooking (Malyutina & Turenko, 2016; Koroleva, 2017; Rodionov et al., 2017). It has been determined that the analyzed wheat flour has an average (good) gluten quality, which belongs to the first quality group. In the multi-grain raw materials, we managed to obtain quantitative characteristics of gluten at the level of 13.0±0.4% by means of washing, but it is impossible to interpret its quality according to GOST 27839-2013 “Wheat flour. Methods for determining the quantity and quality of gluten”. Thus, it has been revealed that the main role in the formation of the products’ gluten network will be played by the wheat flour containing 2.4 times more gluten than the multi-grain flour.

It is known that 80% of protein substances of the wheat flour are composed of high molecular weight prolamins and glutelins (Marx et al., 2017); oat protein is characterized by a high content (43.4%) of low molecular weight albumin and globulin (Vargach et al., 2017); in barley, the content of low molecular weight and high molecular weight fractions can vary in wide ranges: 17-33% – albumins, 18-19% – globulins, 14-24% – prolamins, 23-26% – glutelins, depending on the plant genetics, weather conditions, agricultural cultivation parameters, etc. (Ganieva et al., 2019). Proteins of

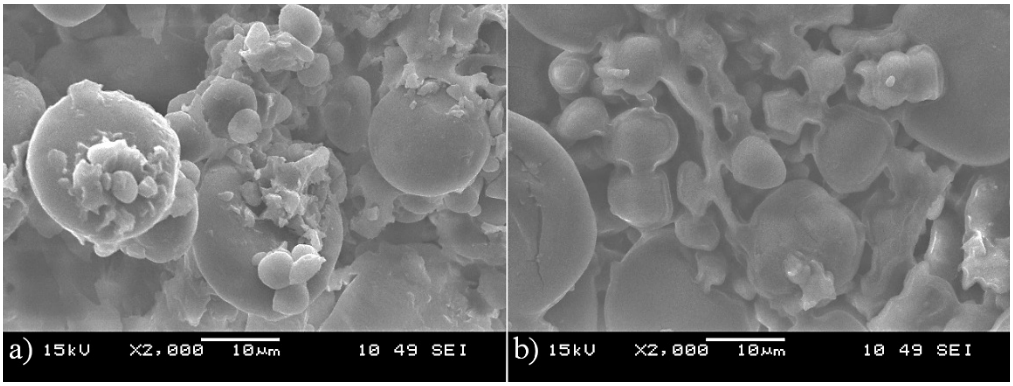

Fig. 2. The microstructure of the studied flour
a) wheat flour, b) multi-grain flour

rye flour are mainly represented by prolamins and glutelins (Dremucheva et al., 2016). The microscopic examination of the studied raw materials allowed us to establish (Figure 2) the morphological features of their protein structures, which determine the properties of the dough and influence the quality of the finished products.

The final stage in the study of various types of flour was the study of the mineral composition, the results of which are presented in Table 2.

Table 2. The content of mineral elements in the studied flour

Target element	Test results, mg/kg	
	wheat flour	multi-grain flour
Copper	2.36 ± 0.22	4.14 ± 0.43
Iron	32.94 ± 3.16	78.09 ± 7.24
Magnesium	391.58 ± 33.81	965.98 ± 91.55
Manganese	14.25 ± 1.21	23.04 ± 2.09
Calcium	211.60± 19.06	164.51 ± 13.46
Zinc	6.52 ± 0.44	18.12 ± 1.54
Phosphorus	1111.21 ± 97.55	1829.31 ± 130.04
Selenium	0.64 ± 0.07	0.54 ± 0.03

It has been determined that whole-grain multi-grain flour has a significant prevalence over the wheat raw materials by the content of most minerals, which is primarily preconditioned by the presence of circumferential parts of single seeds in its composition. So, the amount of zinc in it exceeds the level of its content in the wheat raw material by 2.8 times, iron and magnesium – by 2.4-2.5 times, manganese and copper – by 1.6-1.7 times, phosphorus – by 64.6%. However, the tested wheat flour compares favorably with the three-component raw materials by the content of calcium and selenium, since the level of these elements in it is 1.3 times and 18.5% higher, respectively.

Thus, we have proved the effectiveness of substituting a part of the high-grade bakery wheat flour with the whole-grain multi-grain flour to increase the mineral value, the content of dietary fiber and vegetable fats in pasta.

At the next stage of the experiment, we studied the influence of experimental dosages of the multi-grain flour on the pasta dough quality. It has been established that the use of the whole-grain barley-rye-oat raw materials did not significantly influence the organoleptic characteristics of the semi-finished product (Figure 3a), which in appearance was a loose mass of moistened grayish-cream flour lumps, without spots and stripes, with an inherent taste and smell. A light brown-olive tone was characteristic of test sample 3. The model samples of the pasta dough filled well the receiving windings of the extrusion worm.

The moisture content of the semi-finished product is an important indicator that determines the rheological properties of the dough. We have revealed a consistent increase (by 1.4–7.1%) in the moisture content of the experimental samples of the pasta dough with an increase in the dosage of the multi-grain flour in the semi-finished product (Table 3), which is a consequence of an increase in the content of dietary fiber in it, as well as the change in the fraction composition of proteins (Malyutina & Turenko, 2016). In parallel, we have observed an increase in the acidity of the pasta dough when we added the multi-grain raw materials. The maximum value of the indicator was in experiment # 3, which is primarily preconditioned by an increase in the content of free fatty acids in the experimental samples due to the presence of oat raw materials (Malyutina & Turenko, 2016; Koroleva, 2017).

The organoleptic characteristics of the model pasta samples were evaluated for the compliance of their quality with the requirements of GOST 31743-2017 "Pasta. General Specifications". The appearance of the control and experimental noodle samples before cooking is shown in Figure 3b. It has been established that the use of the whole-grain multi-grain flour in the studied dosages influenced only the color scale of the products. So, with an increase in the content of the unconventional raw materials, there is an increase in the gray tones in the pasta, and a light brown gamma already appears in experiment 3 due to the presence of visible particles of grain seed shells. The remaining organoleptic characteristics (shape, taste, smell) in all the pasta samples were within one acceptable grade regulated by the requirements of the applicable standard.

To obtain more objective results on a comparative assessment of consumer properties of the model pasta samples, we used a numerical score of the products after cooking (Figure 3c, Table 4).

It has been revealed that all the samples of noodles had a smooth surface, a regular shape; the products did not stick together in bulk. A plain solid color was typical of the control sample with a maximum score of 15.0 points, which decreased slightly with an increase in the content of the whole-grain multi-grain flour, and it was 12.0 points in experiment 3. No differences were found in the taste, smell and texture of the model samples of noodles. The taste and smell were typical, very well expressed; the texture was elastic, without a flour kernel. However, the quality assessment of the cook water allowed us to establish some features typical of each experimental sample: with an increase in the content of the barley-rye-oat flour, the turbidity of the cook water slightly increases due to the presence of suspended particles and, accordingly, the score for this indicator gradually decreases from 10.0 to 9.1. However, this did not prevent all the samples from meeting the high quality level.

Fig. 3. Model samples of the semi-finished and finished pasta
a) pasta dough, b) pasta before cooking, c) pasta after cooking

Table 3. Physical and chemical indicators of the model samples of the pasta dough

Target indicator	Test results			
	control	experiment 1	experiment 2	experiment 3
Moisture content, %	35.2 ± 0.5	35.7 ± 0.3	36.5 ± 0.4	37.7 ± 0.3
Acidity, degrees	2.03 ± 0.03	2.09 ± 0.04	2.20 ± 0.02	2.52 ± 0.05

Table 4. Tasting evaluation of the model samples of pasta

Target indicator	Weight coefficient	Tasting evaluation results, points			
		control	experiment 1	experiment 2	experiment 3
Appearance	5.0	25.0 ± 0.0	25.0 ± 0.0	25.0 ± 0.0	25.0 ± 0.0
Color	3.0	15.0 ± 0.0	14.5 ± 0.1	13.2 ± 0.1	12.0 ± 0.0
Smell	2.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
Taste	5.0	25.0 ± 0.0	25.0 ± 0.0	25.0 ± 0.0	25.0 ± 0.0
Texture	3.0	15.0 ± 0.0	15.0 ± 0.0	15.0 ± 0.0	15.0 ± 0.0
Condition of the cook water	2.0	10.0 ± 0.0	9.8 ± 0.1	9.5 ± 0.2	9.1 ± 0.2
Total score	–	100	99	98	96
Conclusion on the quality	–	very good			

The use of the measuring research methods allowed us to study in more detail the quality of the model samples of noodles after cooking (Table 5). The above turbidity of the cook water of the experimental samples was confirmed by measuring the indicator – the dry matter transferred to the cook water, which also tended to increase with an increase in the content of the multi-grain flour. At the same time, all the studied samples of noodles had the same cooking period – 5 minutes, they retained their shape well after cooking, but gained weight with different intensities. It has been determined that the use of the multi-grain raw materials contributes to an increase in the weight gain coefficient of the noodles during the cooking process, which may be preconditioned both by an increase in the content of dietary fiber in the finished product and a quantitative and qualitative change in the starch grains and protein structures due to the substitution of the wheat raw materials with the unconventional mixture. It is known that the weight gain of quality products is in the range from 1.5 to 2.5. Thus, according to this indicator, the quality of the experimental samples of the noodles increases.

Taking into account the positive results of the preliminary tests, further we analyzed the quality and nutritional value of the control sample and the experimental sample with the maximum substitution of the wheat baking flour with the multi-grain raw materials (experiment 3).

It has been revealed (Table 6) that the moisture content of the products made using the oat-barley-rye flour mixture was 18.3% higher (but within the normal range), which is explained by a 44.6% increase in the content of dietary fiber, which has a good water absorption ability. The content of ballast substances in 100 g of the noodles of the test sample is able to satisfy 22.5% of the adult's daily demands, while in the noodles of the control sample it is only 15.5%. Moreover, the increased total fiber content is firstly preconditioned by an increase in the "coarse fibers" level by 2.3 times due to the presence of the oat and barley raw materials in the multi-grain flour (Osipova, 2011; Berestov, 2018).

The content of lipids in the products made from the four grains exceeds the indicator level of the products made from the mono-component wheat raw materials by 2.7 times. It is known that the gluten structure depends on the presence of lipids, which, interacting with gluten proteins, determine its plastic and elastic properties (Zheng et al., 2016; Rizzello et al., 2017).

The acidity of the pasta with a modified composition was 33.5% higher than that of the traditional formulation products,

Table 5. The quality of the model samples of pasta after cooking

Target indicator	Standard as per GOST 31743-17	Test results			
		control	experiment 1	experiment 2	experiment 3
Retention of the shape of the cooked products, %	no less that 100	100	100	100	100
Dry matter transferred to the cook water, %	no more than 6.0	5.40 ± 0.05	5.40 ± 0.03	5.51 ± 0.04	5.81 ± 0.05
Cooking time, min.	not regulated	5	5	5	5
Weight before cooking, g		50			
Weight after cooking, g		134	152	158	172
Gain weight coefficient		1.68	2.04	2.16	2.44

Table 6. Physical and chemical indicators and chemical composition of pasta

Target indicator	Standard as per GOST 31743-17	Test results	
		control	experiment 3
Moisture content of the products, %	no more than 13	9.3 ± 0.3	11.0 ± 0.4
Acidity, degrees	no more than 4	1.52 ± 0.05	2.03 ± 0.05
Metallomagnetic impurity, mg per 1 kg of the product	no more than 3	not found	
Infection rate and contamination with grain storage pests	not allowed	not found	
Mass fraction of fat in terms of dry matter, %	not regulated	0.51 ± 0.03	1.40 ± 0.05
Mass fraction of protein in terms of dry matter, %		13.0 ± 0.4	13.1 ± 0.5
Ash content in terms of dry matter, %		1.52 ± 0.03	2.01 ± 0.02
The content of dietary fiber, g/100 g, including:		3.14 ± 0.04	4.54 ± 0.03
– soluble		1.61 ± 0.05	1.02 ± 0.02
– insoluble		1.53 ± 0.03	3.52 ± 0.04

but did not go beyond the regulated requirements. The ash content of the experimental pasta sample was 32.2% higher than that of the basic recipe noodles, which was reflected in the results of studying the mineral composition of the products. The quantitative characteristics of other regulated quality indicators of both model samples of noodles corresponded to the standards of this GOST.

The mass fraction of protein in both noodle samples was at the same level. Given that the use of the oat-barley-rye flour mixture in the modified formulation noodles is based on the substitution of a certain amount of the wheat raw materials rich in gluten proteins with a low-gluten composition, it was interesting to study the influence of this technological solution on the microstructure of protein molecules of the finished product. It has been revealed (Figure 4) that the amount, structure, and size of the proteins of the experimental sample of noodles remained unchanged with regard to the conventional formulation products.

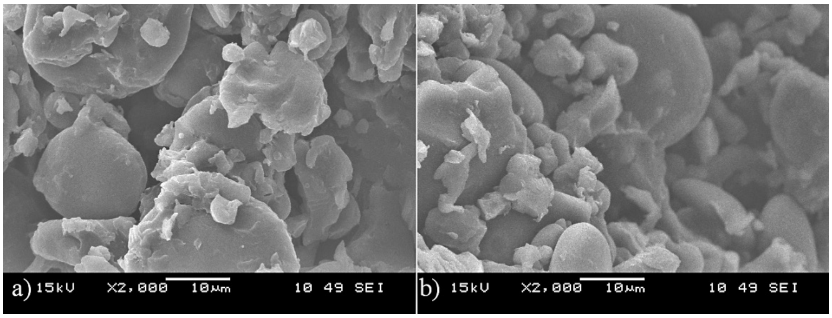

Fig. 4. The microstructure of pasta
a) control, b) experiment 3

Table 7. The content of mineral elements in pasta

Target element	Test results, mg/kg (% of satisfying the daily demand per 100 g of dry product)	
	control	experiment 3
Copper	2.40 ± 0.90 (24 %)	4.10 ± 0.71 (41 %)
Iron	28.10 ± 2.11 (28 % – for male, 15 % – for female)	39.32 ± 3.12 (39 % – for male, 22 % – for female)
Magnesium	400.44 ± 31.72 (10 %)	591.05 ± 54.33 (15 %)
Manganese	13.79 ± 1.26 (68 %)	16.64 ± 1.57 (83%)
Calcium	199.15 ± 18.22 (2 %)	183.51 ± 17.76 (2 %)
Zinc	6.88 ± 0.62 (6 %)	10.20 ± 0.88 (9 %)
Phosphorus	1117.10 ± 97.44 (14 %)	1227.30 ± 101.22 (15 %)
Selenium	0.54 ± 0.04 (77 % – for male, 98 % – for female)	0.51 ± 0.05 (72 % – for male, 94 % – for female)

The study of the mineral value of pasta has shown an increased content of individual elements in the experimental sample (Table 7). As for micronutrients, there is more copper (by 1.7 times), zinc (by 48%), iron (by 40%), manganese (by 21%), as for macronutrients – there is more magnesium (by 47%) and phosphorus (by 10 %). The content of calcium and selenium in the studied noodle samples was in the same quantitative range, without significant fluctuations. A standard serving of pasta is considered to be 100 g of the dry product. In terms of this amount, the consumption of the test sample of noodles can satisfy a larger percentage of the adult's demand for certain minerals: manganese – by 83%, copper – by 41%, iron – by 39% (for male), magnesium – by 15%, zinc – by 9%.

Conclusions

Using the practical means, we have established the possibility and proved the effectiveness of substituting 30% of the high-grade bakery wheat flour in the formulation of pasta for first courses with the whole-grain multi-grain flour. The use of this technological solution allows us to make very good quality products, with acceptable cooking properties and a high content of essential nutrients – manganese, copper and iron in addition to magnesium, phosphorus and dietary fiber.

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