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THE STUDY OF INDICATORS OF THE QUALITY TEST OF POLY-CEREAL WHOLE MEAL FLOUR FOR MAKING PASTA

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Abstract

The process of production of macaroni products of increased food and biological value on the basis of non-traditional poly-cereal raw materials is investigated. At the same time, the basis for the development of the formulation for the manufacture of poly-cereal pasta from composite flour mixtures of whole-grain cereals and cereals is the methodology for designing their composition, which allows to regulate the content of nutrients in the product that meet the requirements of rational and adequate nutrition, providing the finished product with a preventive orientation.

The elasticity of dough, characterized by the maximum resistance of the dough plate when it is blown into the bubble (P, mm) and the test extensibility, characterized by the maximum volume of the obtained dough bubble (L, mm), were studied. Along with the flour strength indicators, the P/L ratio (elasticity and extensibility) of the dough was also taken into account. The specific work spent on the deformation of the test (W, e.a.) while inflating the experimental sample of the test into a bubble was determined. The swelling index (G) of the experimental dough plate was measured. The coefficient of elasticity (Ie,%), characterized by the resistance of the test to stretching during deformation along two axes, was determined. To optimize the rheological properties of pasta dough and improve the quality of the finished product in a poly-cereal mixture consisting of corn flour (25 - 50%), oats (15 - 34%), buckwheat (16 - 28%), soy (15 - 17%), millet (15 - 17%) and peas (15 - 17%), dry wheat gluten (hereinafter - DWG) in the amount of 15, 25 and 35% was added. Rheology of the macaroni dough was determined by Farinograph.

Adding to the formulation of pasta dough DWG in an amount of 15 to 25% of its weight increases the value of the elasticity index, and a further increase in the percentage of DWG to 35% reduces the value of the elasticity index. This is due to the excessive amount of the introduced gluten frame, which consumes more water, and its deficiency gives the test an easily collapsing, tearing structure. The introduction of the percentage of DWG from 15 to 25% leads to a decrease in the elasticity coefficient of the prepared pasta dough from non-traditional poly-cereal raw materials. The structure of the test is crumbly, tearing at small values of deformation, and its elasticity is markedly different from the elasticity of the control sample. Increasing the DWG to 35% in the prepared test increases the values of the coefficient of elasticity.

The results of the study confirmed the expediency of increasing the nutritional value and consumer properties of traditional pasta using non-traditional poly-cereal raw materials.

***Key words**: Pasta from non-traditional raw materials, Poly-cereal raw materials, Flour mixture whole meal grains, Rheological properties of pasta dough technological properties poly-cereal mix, Dry wheat gluten, dietary and biological value of pasta.*

1. Introduction

Much attention in the policy of healthy nutrition is paid to the physiology of nutrition. Along with a balanced amino acid composition and high digestibility of proteins, food products should contain complex carbohydrates and ballast substances (dietary fibers) that ensure the normal functioning of the digestive organs [1 - 3].

Usually for the production of traditional pasta are used hard wheat varieties, which are "poor" in the chemical composition of the most important nutrients. In this regard, it is possible to increase the nutritional value of pasta by introducing natural ingredients such as: corn, millet, buckwheat, barley or oats, as well as other grains and legumes, which differ significantly in chemical composition from traditional raw materials. Therefore, the production of pasta on the basis of non-traditional raw materials poly-cereal is one of the promising areas for the creation of functional products [1 - 3].

The basis for the development of the formulation for manufacture of poly-cereal pasta from homogeneous composite flour mixtures of whole grain cereals and cereals, is emphasizing the methodology of construction of new compositions, allowing to regulate the content of nutrients in the product that meet the requirements of rational and adequate nutrition, and providing preventive orientation.

Thus, pasta from non-traditional raw materials, in comparison with other types of flour products, will have a number of advantages: high digestibility of basic nutrients, high consumer properties (each category of persons can satisfy their taste needs), long shelf life, low cost, and availability for all segments of the population. However, in Kazakhstan, such products are not produced, and manufacturers have to use baking flour from soft wheat, protein which has a shortage of essential amino acids.

At the same time, the modern macaroni industry is developing along the following path: reducing the production cycle and energy costs; reducing the time of cooking pasta and expanding the raw material base of pasta production through the use of non-traditional raw materials [3 - 5].

As a result of the analysis of patent research, it should be noted that at the current level of development of the macaroni industry, the range is regularly replenished with new types of products that differ in a rich chemical composition, as well as in the ratio of amylase and amylopectin, in the temperature of gelatinization and the size of granules. At the same time, a promising direction in the development of pasta production is the use of coarse flour varieties of various cereals and legumes. Various combinations of them will give new varieties of pasta with therapeutic and preventive properties, and the consumption of new pasta will give a functional status in the prevention of a number of chronic diseases.

In this regard, the main idea of our study is to increase the nutritional value and consumer properties of traditional pasta through the use of non-traditional raw materials poly-cereal [1 - 9].

2. Materials and Methods

The general program and methodology of research work included information-analytical and laboratory parts of the study with the use of experiment planning, analytical processing of the results of technological experiments with the use of modern laboratory equipment and computer programs.

To study the rheological properties of dough from composite poly-cereal flour, were used instruments such as: Alveo-consistograph (Chopin Technologies - France), Farinograph (Brabender - Russia) and Infrared Spectroscopy (Russia). For the manufacture of pasta from non-traditional poly-cereal raw materials laboratory press machine (Germany) was used.

Analytical studies were conducted on the basis of "Kazakh national agrarian University" (KazNAU), namely in the conditions of research laboratories of the educational research and production Center "Technology of processing industries" and Agrotechnological HUB.

3. Results and Discussion

In order to calculate recipe nutritional value of poly-cereal flour we used specially developed for us computer program called "Calculation of the formulation poly-cereal mixture for the production of high degree of readiness" [1, 10]. As a result of the calculation, three formulations of pasta from non-traditional raw materials were selected. The estimated values of the selected formulations are shown in Table 1.

Next, we determined the calculated (theoretical) caloric content of the formulation by the formula:

$$E_v = 4{,}0 \cdot x_p + 9 \cdot x_f + 3{,}75 \cdot x_c$$

Where: x_p, x_f and x_c - accordingly, the contents of protein, fat and carbohydrates (cellulose + starch).

Caloric value for each recipe is as follows:

- Recipe 1: $E_v = 4 \times 18.028 + 9 \times 8.61 + 3.75 \times (60.256 + 8.076) = 72.112 + 77.49 + 256.245 = 405.847$ kcal.
- Recipe 2: $E_v = 4 \times 17.824 + 9 \times 8.348 + 3.75 \times (63.076 + 6.684) = 71.296 + 75.132 + 261.6 = 408.028$ kcal.
- Recipe 3: $E_v = 4 \times 18.5 + 9 \times 7.76 + 3.75 \times (56.7 + 13.23) = 74 + 69.84 + 262.23 = 406.07$ kcal.

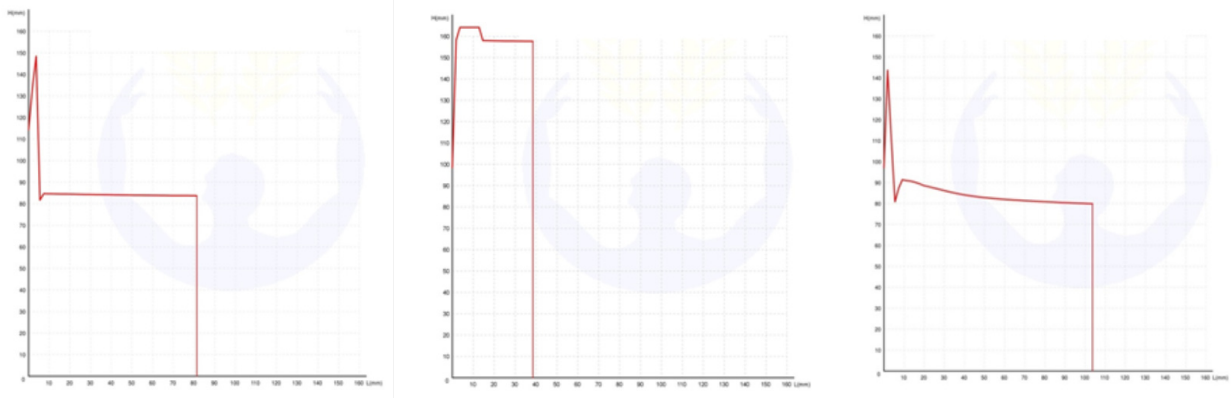
Weight dosages of various cereals and legumes on the main components of the poly-cereal flour mixture influenced: rheological properties, the duration of mixing and the speed of pressing pasta dough.

Determination of operating modes of technological equipment, as well as the development and adjustment of the formulation of pasta production are performed due to the rheological properties of processed food biopolymer masses, semi-finished products and finished products.

The rheological properties of macaroni dough (as a biopolymer mass) [1, 2, 11 - 13] on the basis of non-traditional raw materials were studied. Alveogramms are presented in Figures 1 - 3.

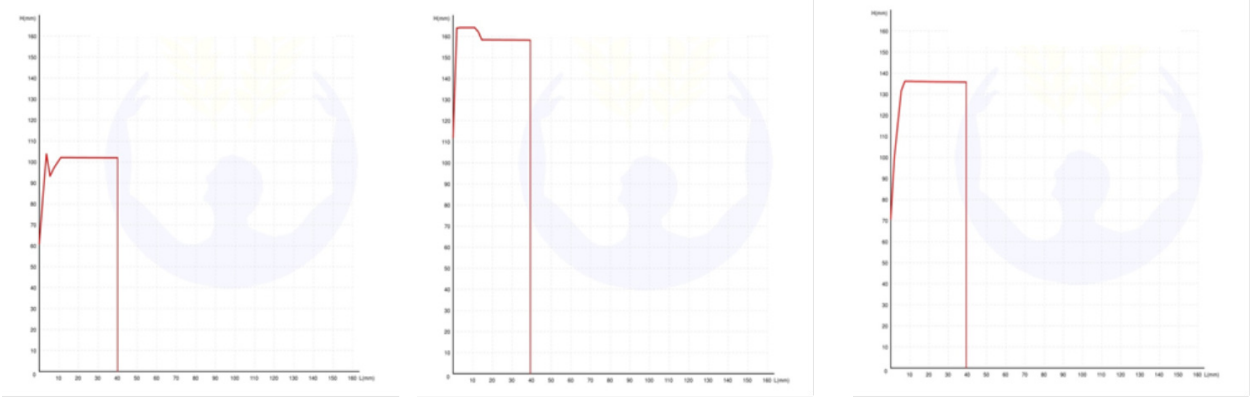
Table 1. Recipes of pasta from non-traditional raw materials

Name of ingredient	(%) in:		
	Recipe 1	Recipe 2 (%)	Recipe 3 (%)
Barley	0	0	16
Corn	33.33	50	25
Qat	33.33	16.66	15
Buckwheat	0	16.66	27,33
Millet	16.66	0	0
Pea	0	0	16.66
Soy	16.66	16.66	0
Protein	18.028 (discrepancy in protein - 4.248)	17.824 (discrepancy in protein - 3.654)	18.5
Starch	60.256	63.076	56.7
Cellulose	8.076 (discrepancy in the carbs -0.008)	6.684 (discrepancy in the carbs - 0.0299)	13.23
Fats	8.610 (discrepancy of fats - 9.27)	8.348 (discrepancy of fats - 7.692)	7.76
Ash	3.664	2.946	5.34



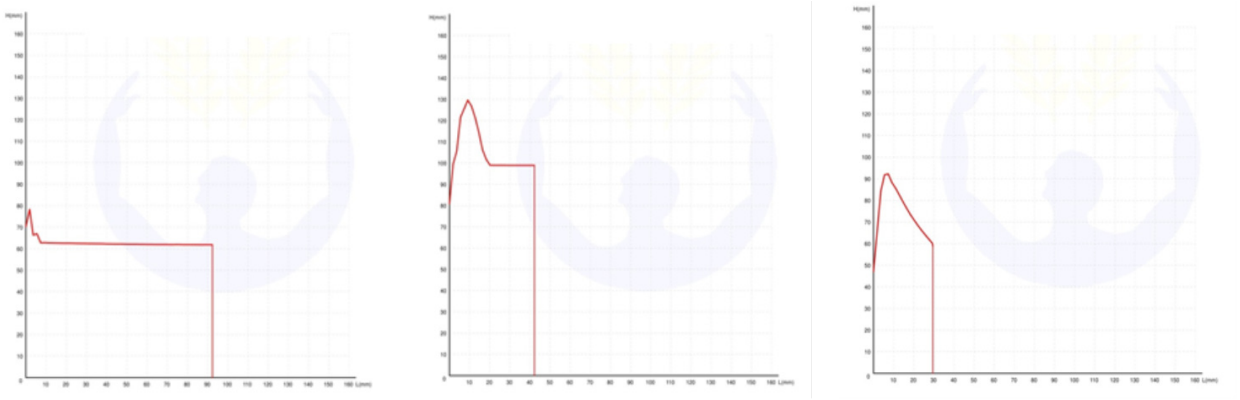
(a) **(b)** **(c)**

Figure 1. Alveogramm pasta dough according to the recipe 1, where: a) 15% DWG, b) 25% DWG, c) 35% DWG



(a) **(b)** **(c)**

Figure 2. Alveogramm pasta dough according to the recipe 2, where: a) 15% DWG, b) 25% DWG, c) 35% DWG



(a) (b) (c)

Figure 3. Alveogramm pasta dough according to the recipe 3, where: a) 15% DWG, b) 25% DWG, c) 35% DWG

In the course of experimental studies we studied the elasticity of the test, characterized by the maximum resistance of the test plate when it is inflated into a bubble (P, mm). Also, we studied the extensibility of the test, characterized by the maximum volume of the resulting test bubble (L, mm). Along with the indicators of the strength of the flour it should be also take into account the data of alveogramm describing the relation of P/L (elasticity and extensibility) of the dough. We determined the specific work spent on the deformation of the test (W, e. a.) when inflating the experimental test sample into a bubble. The coefficient of elasticity (Ie, %) characterized by the resistance of the tensile test at deformation along two axes was also determined.

Experimental data showed that the plates of macaroni dough from non-traditional raw materials had the worst rheological properties, which were not simply recognized by Chopin's Alveo-consistograph, and which is explained by the high content of a water-soluble protein fraction that is not able to bind water. The structure of the test sample was crumbly, disintegrating even at low values of deformation. Only the control sample of the dough plate based on the first grade flour was characterized by a high characteristic of rheological properties, due to the fact that the protein fraction of grain crops is represented mainly by water-insoluble gliadin and gluten, a characteristic feature of which is weak solubility in water and therefore in the test they are able to bind water. The results of experimental studies to determine the rheological properties of the control test sample are given in Table 2.

Further, experimental studies were conducted in order to improve the rheological properties of pasta dough from non-traditional raw materials. To optimize the rheological properties of pasta dough and improve the quality of the finished product was introduced into the poly-cereal flour mixture of DWG in an amount of 15, 25, 35%, respectively, for the three selected recipes. The results were compared with a control sample of the dough from flour of the first grade. The results of the studies are presented in Tables 3 - 5.

Table 2. Rheological properties of the dough from flour of the first grade (control sample)

Name of indicator	Control (wheat flour of the 1st grade)
Test elasticity, R, mm·H_2O	137
The extensibility of the dough, L, mm	84
Specific work, W, e.a.	455
The ratio of elasticity to extensibility, P/L	1.63
Elasticity coefficient, Ie, %	68.9

Table 3. Rheological properties of pasta dough from poly-cereal flour mixture, formulation 1

Name of indicator	Introduction of DWG,%		
	15	25	35
Test elasticity, R, mm·H_2O	181	253	188
The extensibility of the dough, L, mm	81.4	38.5	103.6
Specific work, W, E. A.	132	193	330
The ratio of elasticity to extensibility, P/ L	13.66	17.01	7.09
Coefficient of elasticity, Ie, %	12.4	9.3	29.5
Flour humidity, %	8.47	8.3	8.2

Table 4. Rheological properties of pasta dough from poly-cereal flour mixture, formulation 2

Name of indicator	Introduction of DWG, %		
	15	25	35
Test elasticity, R, mm·H_2O	121	238	168
The extensibility of the dough, L, mm	40	41.01	40.1
Specific work, W, E. A.	79	162	162
The ratio of elasticity to extensibility, P/ L	16.59	22.33	19.81
Coefficient of elasticity, Ie, %	92.9	9.1	36.2
Flour humidity, %	10.38	8.09	8.12

Table 5. Rheological properties of pasta dough from poly-cereal flour mixture, formulation 3

Name of indicator	Introduction of DWG, %		
	15	25	35
Test elasticity, R, mm·H_2O	96	162	103
The extensibility of the dough, L, mm	92.4	42.2	29.5
Specific work, W, E. A.	129	164	124
The ratio of elasticity to extensibility, P/ L	8.91	8.07	6.01
Coefficient of elasticity, Ie, %	61.6	11.2	40
Flour humidity, %	8.05	8.2	7.7

The results of studies to determine the rheological properties of the test from poly-cereal flour raw materials, namely the elasticity and extensibility of the test, the specific work of the deformation of the test, the elasticity coefficients of the experimental samples of the prepared pasta dough with the introduction of DWG, as well as the results of studies of the rheology of the pasta dough (Figures 1 - 3 and Tables 3 - 5). Also, the results of studying the duration of kneading and pressing speed of pasta dough from non-traditional raw materials. For example, the analysis of the presented data shows that in the formulation of pasta dough leads to an increase in the duration of mixing and processing intensity of the prepared pasta dough.

To determine the feasibility of using unconventional poly-cereal raw materials in order to increase the nutritional and biological value of pasta, the chemical composition of the mixtures with different percentages of DWG (15, 25, and 35%) was studied by near infrared spectroscopy. The results of the analysis and the calculation of nutritional value are presented in Table 6.

Analysis of the presented data (see Table. 6) indicates that an increase in the percentage of DWG from 15% to 35% in the formulation of pasta dough leads to an increase in the caloric content of the flour mixture. However, DWG, because of its chemical composition, significantly reduces the heating value of the original poly-cereal mixture.

We also conducted experimental studies on farinograph. Analysis of the obtained farinograms indicates that the maximum values of the water absorption index correspond to the recipe 3, which amounted to 60.6 - 65.1%. The minimum values corresponded to formulation 1 and amounted to 57.1% - 52.6%. At the same time, the time of formation of the test, according to experimental data, was 9.2 minutes for formulation 1; for recipe 2 - 6 min.; and for formulation number 3 - 1.8 minutes.

The stability of the test corresponded to the following values: formulation 1 - 11.8 minutes; for formulation 2 - 5 min.; formulation number 3 - 0.5 minutes. The degree of dilution dough - for formulation number 1 - 70 units; for formulation number 2 - 163 units; and for formulation number 3 - 257 units. Dough liquefaction time was as follows: formulation 1 - 9.3 minutes; for formulation 2 - 6.1 min., and for formulation number 3 - 1.8 minutes. The degree of quality according to farinograph: formulation number 1 - 93 units; for formulation 2 - 61 units; formulation number 3 - 18 units.

The data presented indicate that the best technological properties has pasta dough made according to recipe 1. The resulting dough has a low water absorption, but a long dough formation, has a high dough stability, low degree of liquefaction, and high quality values according to farinograph.

Table 6. Values of the chemical composition of the formulation is composed of pasta dough made with the DWG

Recipe 1 + 15% DWG		Recipe 2 + 25% DWG		Recipe 3 + 35% DWG	
Protein,%	16.68	Protein,%	18.31	Protein,%	26.25
Fat,%	3.96	Fat,%	3.96	Fat,%	4.88
Cellulose,%	1.35	Cellulose,%	1.37	Cellulose,%	1.5
Ash,%	0.51	Ash,%	0.6	Ash,%	0.89
Calorific value, kcal	107.4	Calorific value, kcal	114.01	Calorific value, kcal	154.54
Recipe 1 + 15% DWG		**Recipe 2 + 25% DWG**		**Recipe 3 + 35% DWG**	
Protein,%	17.12	Protein,%	18.91	Protein,%	22.7
Fat,%	3.10	Fat,%	3.25	Fat,%	3.65
Cellulose,%	1.29	Cellulose,%	1.40	Cellulose,%	1.45
Ash,%	0.42	Ash,%	0.48	Ash,%	0.59
Calorific value, kcal	101.20	Calorific value, kcal	110.1	Calorific value, kcal	129.08
Recipe 1 + 15% DWG		**Recipe 2 + 25% DWG**		**Recipe 3 + 35% DWG**	
Protein,%	13.08	Protein,%	15.99	Protein,%	20.29
Fat,%	2.35	Fat,%	2.73	Fat,%	3.13
Cellulose,%	1.19	Cellulose,%	1.25	Cellulose,%	1.34
Ash,%	0.35	Ash,%	0.42	Ash,%	0.55
Calorific value, kcal	77.93	Calorific value, kcal	93.21	Calorific value, kcal	114.35

4. Conclusions

- As a result of studies on the chemical composition of selected samples of grain of domestic breeding varieties, the percentage content of protein, carbohydrates (starch + fiber) and fat was established. The research results allowed to determine the varieties of cereals with the highest nutritional value, which must be considered when developing formulations of poly-cereal mixtures for the production of pasta from non-traditional grain raw materials. The calculation with the use of modern information systems allowed us to develop formulations of three poly-cereal flour mixtures for the preparation of pasta dough.

- The rheological properties of pasta dough have been studied. As a result of experimental studies, it was found that when DWG is added to the pasta dough recipe in an amount from 15 to 25%, the values of the elasticity index increase, and a further increase in the percentage of DWG to 35% reduces the values of the elasticity index, and this is explained by the fact that the excessive amount of the introduced gluten frame should consume more water, and its deficiency gives the test an easily collapsing, tearing structure.

- As a result of the experimental studies, the numerical values of the specific work index (W, e.a.) were established macaroni dough from non-traditional raw materials with the introduction of DWG, which indicate that an increase in the dosage of DWG from 15 to 25% (and in the formulation 3 DWG increases to 35%) in the flour mixture of cereals and legumes in the experimental dough plates led to an increase in the specific work on the deformation of the dough. This indicator can be directly related to the energy costs of pressing pasta dough in the preparation of new types of pasta.

- The analysis of the presented diagrams shows that the introduction of DWG additives from 15 to 25% leads to a decrease in the elasticity coefficient of the prepared pasta dough from unconventional grain and leguminous raw materials. The structure of the test is crumbly, tearing at small values of deformation. The elasticity of the test is markedly different from the elasticity of the control sample. A further increase in the percentage of DWG to 35% in the prepared test increases the value of the coefficient of elasticity.

- As a result of the research DWG influence on change of rheological properties of the prepared pasta dough from non-traditional grain and leguminous raw materials is established. In flour mixtures with the addition of 15% and 25% DWG, an increase in elasticity was observed, a further increase in DWG to 35% reduces elasticity, and worsens other rheological characteristics of pasta dough. Thus, to maximize the rheological properties of pasta dough is recommended 25% introduction of DWG in the dough formulation, which will increase the nutritional value of finished products

without significant deterioration of the rheological properties of the test. This means that the resulting products will have high consumer properties and uniform structure. The study of the rheological properties of dough according to farinograph indicates that the best technological properties are possessed by pasta dough made according to recipe 1. Possessing a low water absorption, but a long dough formation, it has a high dough stability, a low degree of liquefaction, and high quality values according to farinograph.

- The duration of mixing is studied. The analysis of the presented data shows that with an increase in the percentage of DWG from 15% to 35% in the formulation of pasta dough leads to an increase in the duration of mixing and processing intensity of the prepared pasta dough.

- Pressing speed of pasta dough is studied. The analysis of the presented data shows that the pressing speed depends on the plasticity of the dough. With increasing moisture content of the dough increases the speed of pressing, but to a certain moisture content, namely, to 31.5%. Further increase in the humidity of the dough leads to the formation of lumps (pasta stick together, forming lumps), poorly passes through the outlet of the screw chamber. Wetter raw pasta require more heat consumption for drying, so it is advisable to increase the productivity of the press by increasing the temperature of the dough.

- The chemical composition of the compiled mixtures with different percentages of DWG by the method of near infrared spectroscopy was studied. Analysis of the data presented suggests that an increase in the percentage of the DWG from 15% to 35% in the recipe for pasta dough leads to an increase in the caloric content of the flour mixture. However, the DWG, by virtue of its chemical composition, significantly reduces the caloric value of the original poly-cereal mixture.

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