TECHNOLOGICAL SCHEMES FOR THE PROCESSES OF PREPARATION AND MILLING BINARY GRAIN MIXTURES AND BIOCHEMICAL EVALUATION OF PRODUCED PRODUCTS

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KEY WORDS: wheat, flax, binary grain mixture, grinding technological scheme, wheat-flax flour, biochemical assessment.

ABSTRACT
A study of the preparation and milling of a grain mixture containing 7% of flax seeds has been carried out in order to obtain a composite wheat-flax flour, in which the entire biopotential of flax seeds was preserved. It was revealed that the preparation of the components of the grain mixture should be carried out independently, in parallel flows. During the wheat grain preparation the cold conditioning was carried out, the modes of which were the following: humidity — 15.5%, dwell time in the water — 24 hours. The optimal conditions for milling the wheat-flax mixture have been determined, which are the following: yield (%) / ash content (%) in 3 break systems (in terms of the 1st break system — grain) for the first break system — 53.5 / 1.00; for the second break system, — 22.2 / 1.11; totally for the first and the second break systems — 75.7 / 1.055; totally for the first, the second and the third break systems — 81.0 / 1.1. The technological schemes have been developed and the new varieties of wheat-flax flour with predetermined technological properties and increased nutritional value have been formed. The approximate indices of yield and quality of the new wheat-flax flour varieties are the following: Flour A — yield 45–50%, lipids 3.6–4.0%, protein 13–15.5%, ash 0.55–0.70%, whiteness — 50–55%; Flour B — yield 20–25%, lipids 5.5–6.0%, protein 14–14.5%, ash 0.9–1.25%, whiteness — 22 conventional units; Flour C — yield 70–75%, lipids 4.5–5.0%, protein 15.6–14.0%, ash 0.75–0.90%, whiteness — 36 conventional units. It was indicated that the total lipids content in flour from two-component mixtures increases by about 4 times, and the total protein content in the studied samples increases by 1–2%. The content of linoleic acid (ɷ-6) in wheat-flax flour samples is 1.6...3.3 times higher than in wheat flour; the content of linolenic acid (ɷ-3) in wheat-flax flour samples is 36.8...57.2 times higher than in wheat flour (taking into account the total lipids content in the samples). The enrichment of wheat flour due to flax seeds allows to make up the deficiency of PUFA family in the diet of a modern person and to obtain products on a grain basis of a balanced composition.

FUNDING: The article was published as part of the research topic No. 0585–2019–0002 of the state assignment of the V. M. Gorbatov Federal Research Center for Food Systems of RAS

1. Introduction
The enrichment of the products of wheat grain processing with proteins, minerals, and dietary fiber is achieved by introducing the milling products of some cereal crops into wheat flour. This solution has found a wide application in the bakery production in the form of so-called composite flour mixtures. However, in recent years the demand of grain products enrichment with essential fatty acids, especially with linolenic acid (the ɷ-3 family of fatty acids), the deficiency of which negatively affects human health, has emerged [1,2,3,5,6].

Analysis of the lipid composition of various oilseeds shows that linseed oil, as a source of unsaturated fatty acids of the ɷ-3 family, has an absolute advantage. The main fatty acid of the oil from flax seeds is linolenic acid, the relative content of which varies according to different sources from 47.5% to 68.1% [3,5,7].

The problem of flour enrichment with essential fatty acids is currently solved by using crushed linseed cake (flax meal). The use of linseed cake has several disadvantages. First of all, according to various authors’ studies the content of such flax meal in the composite mixture should be 15–25% to provide essential fatty acids in the required amount, but such content significantly degrades the consumer properties of bread [4,5]. The direct use of flax seeds will allow one to significantly (3–4 times) reduce the content of products of flax seeds processing in the composite mixture at maintaining the amount of unsaturated fatty acids, primarily of essential linolenic acid, necessary in terms of composition balance [4,8].

The introduction of flax seeds in the mixture sets the task of developing technology for processing mixtures. First of all, it is necessary to determine the milling conditions of such mixtures (parameters and milling modes), each component of which has its own specific features.

The aim of the research is the development of technological schemes for the preparation and grinding of binary grain mixtures based on wheat and flax seeds and a biochemical assessment of the newly formed varieties of wheat-flax flour obtained by joint grinding of a wheat-flax mixture.

2. Materials and methods
The object of the study was wheat grain and seeds of white and brown seed flax. Table 1 and Table 2 show the technological properties and chemical composition of the initial components of the grain mixture.

The components of the grain mixture are characterized by an average level of values both in chemical composition and technological properties and can be considered as quite representative. The content of flax seeds in the mixture was determined based on the recommended levels of consumption of food and biologically active substances [9,10] and averaged about 7%.

To study the milling and production of wheat and wheat-flax flour, the RSA-5 reduction and sorting unit with corrugated roll-
ers for break systems (P -10 \( \bar{1} \)% and microrough surface rollers for reduction systems, the laboratory plan sifter and the laboratory bran finisher were used. The whiteness of flour (WF) was determined by measuring the reflectivity of a densely smoothed flour surface using a photovoltaic device (GOST 26561–2013), ash content (Z) — by burning flour and bran, followed by determination of the fireproof residue mass (GOST 27494–2016). The total protein content was determined by the Kjeldahl method (N x 6.25) (GOST 10846–91); lipids content — according to Soxhlet (GOST 29033–91); fiber content — according to Kuschner and Hanek; starch content — according to Evers (GOST 31675–2012); reducing sugars according to the Bertrand method; soluble protein — according to the Lowry method. The scheme of the two-factor experiment for determining the optimal conditioning parameters is presented in Table 3.

### Table 1

**Technological properties of the initial components of the grain mixture**

| Agricultural crop | Moisture, % | Mass of 1000 seeds, g | Test weight, g/l | Vitreousness, % | Medium geometric size, mm | Joint processing | Ash content, % | Protein, % | Fat, % | Starch, % | Cellulose, % | Gluten, % |
|------------------|-------------|-----------------------|-----------------|----------------|-------------------------|----------------|---------------|-------------|----------|-----------|--------------|----------|
| Wheat            | 12/2        | 44.66                 | 769             | 52            | a = 3.6                 | b = 2.9        | 1 = 6.5       | 13.43       | 1.83      | 66.8      | 2.2         | 24.7      |
| Flax seeds: white | 5.2        | 8.40                   | 668             | —             | a = 2.5                 | b = 1.2        | 1 = 5.2       | 24.68       | 39.80     | 5.2       | 15.0        | —         |
| Flax seeds: brown | 5.1        | 8.37                   | 667             | —             | a = 2.5                 | b = 1.2        | 1 = 5.1       | 24.42       | 37.33     | 5.1       | 15.1        | —         |

The analyses were performed in the samples of wheat-flax flour, presenting the results as average arithmetic ones. The discrepancy between parallel assays did not exceed 3% of the average arithmetic value with the confidence probability P = 0.95.

### Table 2

**The chemical composition of the initial components of the grain mixture**

| Agricultural crop | Protein, % | Fat, % | Starch, % | Cellulose, % | Gluten, % |
|------------------|------------|--------|-----------|--------------|-----------|
| Wheat            | 13.43      | 1.83   | 66.8      | 2.2          | 24.7      |
| Flax seeds: white | 24.68    | 39.80  | 5.2       | 15.0         | —         |
| Flax seeds: brown | 24.42   | 37.33  | 5.1       | 15.1         | —         |

### Table 3

**Estimated and actual moisture content of the original wheat grain**

| Milling number | Estimated moisture, % | Actual moisture, % | Dew time in the water, hour |
|----------------|-----------------------|--------------------|-----------------------------|
| 1 (control)    | 16.0                  | 14.7               | 24                          |
| 2              | 16.5                  | 15.2               | 24                          |
| 3              | 16.5                  | 14.9               | 12                          |
| 4              | 15.0                  | 14.4               | 18                          |
| 5              | 14.5                  | 13.6               | 12                          |
| 6              | 14.5                  | 15.7               | 24                          |

**Yield (Y) flour and bran, %**

| Technologiesystem | Milling No 2 | Milling No 3 | Milling No 4 | Milling No 5 | Milling No 6 |
|-------------------|--------------|--------------|--------------|--------------|--------------|
| Break I            | 8.4          | 11.9         | 8.3          | 8.3          | 9.5          |
| Break II           | 10.8         | 11.9         | 7.7          | 7.7          | 8.8          |
| Break III          | 3.6          | 3.3          | 4.3          | 4.0          | 3.8          |
| Reduction system 1 | 35.6         | 35.4         | 31.4         | 30.7         | 32.1         |
| Reduction system 2 | 5.2          | 2.5          | 11.0         | 11.7         | 8.4          |
| Reduction system 3 | 2.4          | 2.9          | 5.0          | 6.0          | 3.8          |
| Flours            | 66.0         | 67.9         | 67.7         | 68.4         | 66.4         |
| Bran from break systems | 23.2      | 18.5         | 19.0         | 16.3         | 19.5         |
| Bran from reduction systems | 10.8      | 13.6         | 13.3         | 15.3         | 14.1         |
| Bran from break systems / bran from reduction systems | 2.15     | 1.36         | 1.43         | 1.07         | 1.38         |
| Whiteness (WF), units |
|-------------------|--------------|--------------|--------------|--------------|--------------|
| Break I            | 73           | 69           | 69           | 67           | 66           |
| Break II           | 56           | 52           | 55           | 51           | 51           |
| Break III          | 37           | 31           | 31           | 30           | 29           |
| Reduction system 1 | 55           | 51           | 50           | 50           | 50           |
| Reduction system 2 | 36           | 29           | 36           | 35           | 33           |
| Reduction system 3 | 28           | 23           | 24           | 21           | 25           |

The study of the processes of preparation and milling of a grain mixture containing flax seeds was carried out using 95% wheat grain and 7% flax seeds content. The conditions for the joint processing of wheat grain and flax seeds are the separate preparation and thorough mixing of the components immediately before milling. The content of flax seeds in the mixture was determined in accordance with the "Recommended levels of consumption of food and biologically active substances", it averaged about 7%. During the wheat grain preparation the cold conditioning was carried out, the modes of which corresponded to "The rules of organization and process control at flour mills", humidity — 15.5%, dwell time in the water — 24 hours.

Analysis of the geometric sizes of flax seeds and wheat grain shows the impossibility of their joint cleaning. The preparation scheme should consist of independent preparation flows.

3. Results and discussion

Processing of grain mixtures, the components of which have significant differences in physical and chemical properties, is a rather complicated task [12,13,14,15]. The study of the processes of preparation and milling of a grain mixture containing flax seeds was carried out using 95% wheat grain and 7% flax seeds content. The conditions for the joint processing of wheat grain and flax seeds are the separate preparation and thorough mixing of the components immediately before milling. The content of flax seeds in the mixture was determined in accordance with the "Recommended levels of consumption of food and biologically active substances", it averaged about 7%. During the wheat grain preparation the cold conditioning was carried out, the modes of which corresponded to "The rules of organization and process control at flour mills", humidity — 15.5%, dwell time in the water — 24 hours.

Analysis of the geometric sizes of flax seeds and wheat grain shows the impossibility of their joint cleaning. The preparation scheme should consist of independent preparation flows.

The scheme of the two-factor experiment for determining the optimal conditioning parameters is presented in Table 3.

### Table 4

**Yield (Y) flour and bran, %**

| Technologiesystem | Milling No 2 | Milling No 3 | Milling No 4 | Milling No 5 | Milling No 6 |
|-------------------|--------------|--------------|--------------|--------------|--------------|
| Break I            | 8.4          | 11.9         | 8.3          | 8.3          | 9.5          |
| Break II           | 10.8         | 11.9         | 7.7          | 7.7          | 8.8          |
| Break III          | 3.6          | 3.3          | 4.3          | 4.0          | 3.8          |
| Reduction system 1 | 35.6         | 35.4         | 31.4         | 30.7         | 32.1         |
| Reduction system 2 | 5.2          | 2.5          | 11.0         | 11.7         | 8.4          |
| Reduction system 3 | 2.4          | 2.9          | 5.0          | 6.0          | 3.8          |
| Flours            | 66.0         | 67.9         | 67.7         | 68.4         | 66.4         |
| Bran from break systems | 23.2      | 18.5         | 19.0         | 16.3         | 19.5         |
| Bran from reduction systems | 10.8      | 13.6         | 13.3         | 15.3         | 14.1         |
| Bran from break systems / bran from reduction systems | 2.15     | 1.36         | 1.43         | 1.07         | 1.38         |

### Table 5

**Whiteness (WF), units**

| Technologiesystem | Milling No 2 | Milling No 3 | Milling No 4 | Milling No 5 | Milling No 6 |
|-------------------|--------------|--------------|--------------|--------------|--------------|
| Break I            | 73           | 69           | 69           | 67           | 66           |
| Break II           | 56           | 52           | 55           | 51           | 51           |
| Break III          | 37           | 31           | 31           | 30           | 29           |
| Reduction system 1 | 55           | 51           | 50           | 50           | 50           |
| Reduction system 2 | 36           | 29           | 36           | 35           | 33           |
| Reduction system 3 | 28           | 23           | 24           | 21           | 25           |
Statistical analysis of laboratory milling results using the MINITAB14 program revealed statistically significant linear regression equations. The result of statistical processing of the dependence of flour whiteness on conditioning parameters (Table 3) is presented below.

Regression Analysis: WF2 versus Y2
The regression equation is
WF2 = 72,45–0,2759 Y2
S = 2,39544 R-Sq = 91,0%  R-Sq(adj) = 88,8%

Regression Analysis: WF3 versus Y3
The regression equation is
WF3 = 67,16–0,3066 Y3
S = 1,92102 R-Sq = 95,3%  R-Sq(adj) = 94,2%

Regression Analysis: WF4 versus Y4
The regression equation is
WF4 = 69,93–0,2675 Y4
S = 1,95255 R-Sq = 95,2%  R-Sq(adj) = 91,5%

Regression Analysis: WF5 versus Y5
The regression equation is
WF5 = 67,16–0,3066 Y5
S = 2,26688 R-Sq = 93,1%  R-Sq(adj) = 91,3%

Regression Analysis: WF6 versus Y6
The regression equation is
WF6 = 67,16–0,3051 Y6
S = 2,26688 R-Sq = 93,1%  R-Sq(adj) = 91,3%

Regression Analysis: WF1 versus Y1
The regression equation is
WF1 = 75,00–0,09554 Y1
S = 0,369080 R-Sq = 98,8%  R-Sq(adj) = 98,3%

The number of samples and the mass of the sample were determined in accordance with the recommendations [13] and amounted to — the number of samples — 8, the mass of the sample according to calculation — 5 g, in fact — 50 g.

Comparison of the mixing methods showed that the passive method is significantly inferior to the active one. So with equal mixing cycles, the coefficient V is 57.4% for the drum mixer and 15.9% for the screw mixer. Subsequently, the active mixing method was used, which ensured satisfactory quality. The basic scheme for the grain mixture preparing for milling includes: separate cleaning of wheat grain flow and flax seeds flow from impurities, cleaning of the surface (shelling) of wheat grain, wheat grain conditioning, wheat grain and flax seeds mixing, forming of a grain mixture flow.

The program of experimental studies of milling modes in the first, the second and the third break systems provided for a wide range of yield indices, which was achieved by a corresponding variation of the roll space: for the first break system from 0.75 mm to 0.20 mm, providing yield index from 25 to 70%, for the second break system from 0.20 mm to 0.05 mm, which corresponded to yield indices from 48 to 66%; for the third break system from 0.05 mm to 0.00, and the yield indices range was from 22 to 45%.

Analysis of the grain-size composition shows that the better part of the intermediate products lies in the size range of 600–150 microns (Figure 1).

Figure 1. Grain-size composition of dunst products and flour obtained from I — III break systems with varying degrees of extraction: black color — 66%; red color — 72%; green color — 79%

The fractional composition of grains is shown in Figure 2.

Figure 2. Fractional composition of grains obtained with I — III break systems with a total grains yield: a) — 43%; b) — 48%, c) — 52%
The bulk of the grains is characterized by a size of 250–560 microns, according to the classification [13] — this is a mixture of small and medium grains.

The optimal zone of the milling mode is determined, first of all, by the maximum endosperm content (minimum ash content) in the grains of break systems (Figure 3).

The optimal milling conditions were characterized by the following values (yield / ash content): in terms of the first break system — 53.5 / 1.00; the second break system — 22.2 / 1.1; totally the first and the second break systems — 75.7 / 1.03 and the third break system — 5.3 / 2.07. Totally for the first, second and third break systems — 75.7 / 1.03. Totally for the first and the second break systems — 75.7 / 1.03 and the third break system only the dust was selected. The flow of medium grains was directed to the sizing system, small grains were directed to the second reduction system. It represents the crushed peripheral parts of the grain with a yield of 20–25% and a whiteness of 22 units.

Variety B grade was obtained by mixing flour flows: third break system, the scratch system, the fourth reduction system, the fifth reduction system. It represents the crushed peripheral parts of the grain with a yield of 20–25% and a whiteness of 22 units.

Variety of flour C was obtained as a result of combining all flows of flour with a yield of 70–75% and a whiteness of 36 units.

The optimal zone of the milling mode is determined, first of all, by the maximum endosperm content (minimum ash content) in the grains of break systems (Figure 3).

In addition, considering the non-uniform lipids distribution between individual flows, namely that the lipids content increases with the turn from the first to the last milling systems, and also taking into account the principle of the formation of flour varieties, which is based on the fact that the individual flows belong to different anatomical parts of the grain, flour varieties A, B and C were formed.

Variety A included flour flows from the central part of the endosperm — the first break system, the second break system, the sizing system, the first reduction system, the second reduction system, the third reduction system, — are characterized by low ash content and high whiteness value. Its yield was 45–50%, whiteness 50 units.

Variety B grade was obtained by mixing flour flows: third break system, the scratch system, the fourth reduction system, the fifth reduction system. It represents the crushed peripheral parts of the grain with a yield of 20–25% and a whiteness of 22 units.

Variety of flour C was obtained as a result of combining all flows of flour with a yield of 70–75% and a whiteness of 36 units.

The chemical composition of the formed flour varieties A, B, C, presented in Table 6, indicates the enrichment of wheat flour with protein and fat components, as well as fiber due to the inclusion of flax seeds in the binary grain mixture.

An analysis of the chemical composition of the formed flour varieties indicates an increase in the mass fraction of protein mass fraction by 1.0–2.0%, fat mass fraction in 1.5–3.5 times; fiber mass fraction by 3.4–4.0 times and a decrease in the mass fraction of starch by about 2–4%.

The fractional composition of soluble proteins, the ratio of different fractions is important both for evaluating technological properties (gluten formation, its quantity and quality), and for the biological value of proteins, their assimilation degree [4,8,16,17,18,19]. The data presented in Table 7 demonstrate the ratio of soluble proteins fractions in the formed varieties of wheat-flax flour.

The fractional composition of soluble proteins of the formed varieties of flour from a grain mixture based on wheat grain and flax seeds.

| Sample                        | albumins % | globulins % | prolamin % | glutelins % | reducing sugar % |
|-------------------------------|------------|-------------|------------|-------------|------------------|
| Wheat-flax flour, A variety   | 15.8       | 18.8        | 30.8       | 28.6        | 26.8             |
| Wheat-flax flour, B variety   | 13.2       | 18.5        | 29.6       | 29.8        | 29.8             |
| Wheat-flax flour, C variety   | 14.8       | 20.2        | 28.8       | 30.2        | 30.2             |
| Wheat flour top grade (control) | 8.4       | 17.0        | 35.8       | 30.8        | 8.0              |

Figure 3. The dependence of the ash content of grains on the total yield (break I system)

Figure 4. Cumulative curves of whiteness of flour: red color — wheat grain milling, black color — wheat + flax brown, green color — wheat + flax white

Table 6

| Sample                        | Protein (N × 6.25), % | Lipids, % | Starch, % | Cellulose, % | Reducing sugar, % |
|-------------------------------|-----------------------|-----------|-----------|--------------|------------------|
| Wheat-flax flour, A variety   | 13.16                 | 3.6       | 69.52     | 1.60         | 0.16             |
| Wheat-flax flour, B variety   | 14.38                 | 5.6       | 64.85     | 1.92         | 0.18             |
| Wheat-flax flour, C variety   | 15.58                 | 4.3       | 68.11     | 1.86         | 0.16             |
| Wheat flour top grade (control) | 12.65                | 1.6       | 72.10     | 0.46         | 0.14             |

Table 7
The significant increase of the ratio of the albumin-globulin fraction content in wheat-flax flour samples to alcohol and alkalinsoluble proteins content, as well as to its content in wheat flour, in which the part of gluten proteins prevails, should be marked.

When grain is processed into flour, the cell structure is destroyed, and as a result, oxidative and hydrolytic processes are enhanced [20]. In this regard, it is of interest to evaluate the activity of the main hydrolytic enzymes in samples of the formed varieties of wheat-flax flour. Thus, the value of proteolytic activity, along with other biochemical parameters, has fundamental importance, as proteinases are able to actively hydrolyze their own proteins, including the gluten ones, which, ultimately, affects the technological process and the finished product. In addition, proteolytic enzymes are involved in the regulation of the activity of other enzyme systems, for example, of amylases.

Amylases also assume major significance in assessing the quality of flour and products made from it. High amylolytic activity negatively affects its baking advantages.

In wheat flour, the substrate for the action of lipases is the flour’s own lipids, the content of which can reach up to 1.5–2% of its mass, and in the studied samples of wheat-flax flour up to 3.6–5.6%. It is known that the use of lipase specimen leads to an improvement of the rheological properties of the dough, an increase of the specific volume of products, and an improvement of the crumb structure and color [4,5]. There is also evidence that lipases contribute to the retardation of the bread crumb, which can be explained by the action of hydrolysis products — monoglycerides and fatty acids, which, forming complexes with amylose, slow down its retrograde. It is supposed that lipases modify the interactions between proteins and lipids of flour, improving the gluten quality [19].

Moreover, lipolytic enzymes indirectly affect the oxidation processes in the dough during kneading, which is due to an increase of the availability of unsaturated fatty acids for the action of the lipoperoxidase enzyme that is present in flour or introduced into the dough as part of improving agents.

Plant lipases are characterized by an optimum pH: cereal lipases mainly show their activity in the alkaline region — pH 8.0; oilseed lipases — in the acid region — pH 4.7 [21].

The fatty acid composition of the formed varieties of flour from a two-component grain mixture consisting of 95% of wheat grain and 7% of flax seeds is presented in Table 8.

| Indicator         | The content of high fatty acids, % | wheat flour, top grade | wheat-flax flour, grade A | wheat-flax flour, grade B | wheat-flax flour, grade C |
|-------------------|------------------------------------|------------------------|---------------------------|---------------------------|---------------------------|
| C 14: 0 myristic  | < 0.1                              | < 0.1                  | < 0.1                     | < 0.1                     |
| C 16: 0 palmitic  | 19.64 ± 1.57                       | 18.79 ± 7.50           | 12.54 ± 1.00              | 15.44 ± 1.24              |
| C 16: 1 palmitoleic | < 0.1                           | < 0.1                  | < 0.1                     | < 0.1                     |
| C 17: 0 margarine | < 0.1                              | < 0.1                  | < 0.1                     | < 0.1                     |
| C 17: 1 margaroleic | < 0.1                           | < 0.1                  | < 0.1                     | < 0.1                     |
| C 18: 0 stearic  | 1.21 ± 0.15                        | 5.79 ± 0.46            | 4.81 ± 0.53               | 5.26 ± 0.42               |
| C 18: 1 oleic    | 17.54 ± 1.40                       | 28.50 ± 1.43           | 22.54 ± 1.8               | 25.15 ± 0.02              |
| C 18: 2 linoleic | 57.95 ± 2.90                       | 41.21 ± 3.06           | 55.57 ± 2.78              | 49.97 ± 2.46              |
| C 18: 3 linolenic | 2.95 ± 0.32                       | 48.80 ± 0.54           | 39.23 ± 0.43              | 45.10 ± 0.45              |
| C 20: 0 arachin | 0.25 ± 0.03                        | 0.17 ± 0.02            | < 0.1                     | < 0.1                     |
| C 20: 1 gondoin | 0.73 ± 0.08                        | 0.58 ± 0.06            | 0.59 ± 0.04               | 0.31 ± 0.03               |
| C 20: 2 eicosodienoic | < 0.1                           | < 0.1                  | < 0.1                     | < 0.1                     |
| C 22: 0 behenayaya | < 0.1                           | 0.29 ± 0.03            | 0.15 ± 0.02               | 0.15 ± 0.02               |
| C 22: 1 erucia  | < 0.1                              | < 0.1                  | < 0.1                     | < 0.1                     |
| C 22: 2 docosodienic | < 0.1                           | < 0.1                  | < 0.1                     | < 0.1                     |

The unit activity of the main hydrolytic enzymes in the samples of the formed varieties of flour from a grain mixture based on wheat and flax seeds is presented in Table 8.

| Sample                      | UA* protease, units / mg protein | UA amylase units / mg protein | UA lipases, units / g |
|-----------------------------|---------------------------------|-------------------------------|-----------------------|
| Wheat-flax flour grade A    | 0.110                          | 0.080                         | 0.45                  | 3.8                  | 5.2                  |
| Wheat-flax flour grade B    | 0.120                          | 0.090                         | 0.60                  | 3.8                  | 6.0                  |
| Wheat-flax flour grade C    | 0.110                          | 0.080                         | 0.55                  | 3.8                  | 5.6                  |
| Wheat flour top grade (control) | 0.100                          | 0.070                         | 0.50                  | 3.8                  | 0                   |

* UA — unit activity

The unit activity of proteases and amylases in the studied samples of wheat-flax flour changes, but not significantly, and the activity of alkaline lipases (cereal lipases) remains unchanged, while the activity of acid lipases (oilseed lipases) is approximately 1.5 times higher than the activity of alkaline lipases in the studied samples of wheat-flax flour. As noted above, it occurs due to the presence of flax seed milling products and may affect the shelf life of this type of flour. However, the test samples storage in the laboratory at 4–6 ºC for 14 weeks led to an insignificant increase of the acid lipases activity by 1.8–2.5%.

The fatty acid composition data (Table 9) of the formed flour varieties from a two-component grain mixture consisting of 93% of wheat and 7% of flax seeds allows us to draw the following conclusion: the content of linoleic acid (ɷ-6) in the wheat flour sample is 1.6 ... 3.3 times less than in the wheat-flax flour samples (0.95% against 1.51 ... 3.14%, taking into account the total lipids content in the samples); the content of linolenic acid (ɷ-3) in the wheat flour sample is 36.8 ... 57.2 times less than in the wheat-flax flour samples (0.047% against 1.73 ... 2.69%, taking into account the total lipids content in the samples).
Conclusions

Technological schemes for the preparation and milling of two-component grain mixtures based on wheat grain and flax seeds are developed. The patterns of preparation and milling of binary grain mixtures to obtain composite types of flour with specified technological properties and increased nutritional value on account of the enrichment of the traditional types of grain by adding flax seeds with valuable nutritional components such as PUFA, essential amino acids, and other irreplaceable nutritional factors are revealed.

The use of whole flax seed in a binary grain mixture, consisting of 95% of wheat and 7% of flax seeds, allowed to balance the chemical composition of composite wheat-flax flour by the protein and lipids components, and also to enrich it with fiber, which means to use the entire phytopotential of flax seeds. Primarily, as the studies showed, the obtained wheat-flax flour contains the sufficient amount of PUFA in accordance with the recommended standards for consumption of grain-based food products [10], and the products made from it will help to make up the deficiency of ω-3 family PUFA in the diet of a modern person.

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All authors bear responsibility for the work and presented data.

All authors made an equal contribution to the work.

The authors were equally involved in writing the manuscript and bear the equal responsibility for plagiarism.

The authors declare no conflict of interest.

Received 06.07.2020 Accepted in revised 25.08.2020 Accepted for publication 15.09.2020