STUDY OF PROPERTIES OF WHEAT GERMINS AND MEALS AND THEIR USE IN THE PRODUCTION OF DIETARY HARDTACKS

Pavlo Pyvovarov[1], Tetiana Cheremskaya[2], Maryna Kolesnikova[3], Svitlana Iurchenko[4], Svitlana Andrieieva[5]

[1]Department of Food Technology in the Restaurant Industry, Kharkiv State University of Food Technology and Trade, Kharkiv, Ukraine
ORCID: https://orcid.org/0000-0001-9119-12252
[2]Department of Food Technology in the Restaurant Industry, Kharkiv State University of Food Technology and Trade, Kharkiv, Ukraine
ORCID: https://orcid.org/0000-0001-6518-3889
[3]Department of Food Technology in the Restaurant Industry, Kharkiv State University of Food Technology and Trade, Kharkiv, Ukraine
ORCID: https://orcid.org/0000-0002-6223-7105
[4]Department of Food Technology in the Restaurant Industry, Kharkiv State University of Food Technology and Trade, Kharkiv, Ukraine
ORCID: https://orcid.org/0000-0003-1286-081X
[1]Department of Food Technology in the Restaurant Industry, Kharkiv State University of Food Technology and Trade, Kharkiv, Ukraine
ORCID: https://orcid.org/0000-0003-2981-481X
✉Corresponding author: Svitlana Andrieieva, e-mail: svetana783@ukr.net

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ABSTRACT

Object of research: technology of production of dietetic hardtacks using germs and meal of wheat germ, by defatting them.

Investigated problem: the process of defatting wheat germ meal not only reduces the total amount of lipids, but also contributes to a change in the ratio of individual fatty acids.

Main scientific results: in order to use wheat germ meal as the main raw material, together with wheat germ in the production of dietetic hardtacks, their amino acid composition, biological value and balance of essential amino acids were studied in comparison with the FAO/WHO standard. The mineral, vitamin and fatty acid composition of the germ and meal of wheat germ has been determined. The results obtained were used in the development of the recipe composition and the technological process for the production of dietetic hardtacks.

The results obtained (calculation of the balance according to the "tryptophan" and "threonine" indices) confirm that wheat germ meal is a valuable raw material that can be used in technologies for the production of high-protein food products.

The moisture-absorbing capacity of wheat germ and meal was studied in order to determine their ability to form dough. It has been established that the best performance is characterized by a mixture of wheat germ meal and wheat germ in a ratio of 80:20.

The ability of digestion by enzymes of the gastrointestinal tract "in vitro" of wheat germ meal proteins has been investigated, which determines the biological value of food products and makes it possible to predict the degree of their utilization by the body.

The field of practical use of the research results: production of dietetic hardtacks in restaurant enterprises, in specialized confectionery shops, as well as within the boundaries of food production

An innovative technological product: the possibility of using valuable secondary raw materials in food production technology – wheat germ and meal, which is a source of high-quality protein, vitamins and minerals. This will make it possible to adjust the nutritional and biological value of flour confectionery products, as well as improve the nutritional structure of consumers of these products.

Scope of application of an innovative technological product: dietetic hardtacks.

1. Introduction

1. 1. The object of research

Development of technology for dietetic hardtacks using wheat germ and meal.

1. 2. Problem description

It is known that nutrition is one of the most important factors determining the health status of the population. Proper nutrition ensures normal growth and development, contributes to the prevention of human diseases, and affects the quality of life. It should be noted that in recent years, the structure and chemical composition of the diet of the population has changed significantly, which is associated with the deterioration of their financial and economic condition. Therefore, the urgent issue is the problem of adjusting the structure of nutrition.

The food industry is actively developing: new sources of raw materials are used, as well as technologies that make it possible to process agricultural raw materials without losing valuable components. These are the processes of development and implementation of innovations that make it possible to provide the population with high-quality food products that can compensate for nutrient deficiencies and become a source of necessary regulators of all functions of organs and systems of the human body.

Taking into account the indicated problems, in this work the use of wheat germ meal obtained as a result of cold pressing of oil, together with wheat germ in the production of dietetic hardtacks, is substantiated.

1. 3. Suggested solutions to the problem

Hardtacks are flour products that resemble lingering cookies, made from wheat flour and water with or without other raw materials, which satisfy hunger well and are suitable for daily consumption, including instead of bread.

Wheat germ is a unique natural concentrate that contains (in % on dry matter): proteins 33…45, sugars 21…30, lipids 13…19, minerals 4…7, fats 8…17, fiber 2…3, vitamins, enzymes.

It has been established that wheat germ contains 21 macro- and microelements, including calcium, phosphorus, iron, as well as magnesium, potassium, iodine, selenium, zinc, etc. The vitamin composition of wheat germ is also unique, which is practically a multivitamin concentrate. In terms of tocopherol content (12...33 mg %), wheat germ exceeds most food products. 12 vitamins have been identified, in particular, tocopherols, thiamine, provitamin A (carotene), niacin (PP), riboflavin (B2), ergocalciferol (D2), pyridoxine (B6), pantothenic acid (B3), folic acid [1–3].

The embryo contains phytohormones (auxin, heteroauxin, etc.), it is an energy base for living cells and the production of immunocytes in the body, which reduce the toxic effect of harmful factors on the human body. In addition, wheat germ is a promising phytoenterosorbent. As a result of the consumption of wheat germ, an increase in the content of proteins in the blood was noted, there is a normalization of metabolic processes in the liver and throughout the body, an improvement in blood composition and the function of the thyroid and pancreas [4–6].

Wheat germ meal is a valuable secondary raw material, which is a source of high-quality protein, the content of which is about 43 %, carbohydrates – 47 %, fiber – 13.2 %, vitamins of group B, PP, D_2, carotene, tocopherol, thiamine, folic acid. It also contains macro- and microelements calcium, phosphorus, iron, as well as magnesium, potassium, iodine, selenium, zinc, etc. [7–9].

It can be concluded that the use of germs and meal of wheat germ in the recipe composition of dietetic hardtacks is a promising direction in the production of health food products. However, despite the high nutritional and biological value, the technological properties of wheat germ meal are rather low. In this regard, it is necessary to search for effective ways of processing wheat germ meal in order to use it in the technology of health food products.

2. Materials and methods

The protein content in the raw material was determined by the Lowry method modified by Miller [10].

The lipid content was determined by the gravimetric method according to E. Bligh and W. Dyer [11].

The fatty acid composition of lipids was determined using gas chromatography of methyl esters of fatty acids [12]. The studies were carried out on a GC-14BPF gas chromatograph with the following parameters: the injector temperature was 200 °C, the detector temperature was 200 °C, the evaporator temperature was 180 °C, and the carrier gas was argon. Calculation of the amount of free fatty acids [12, 13] was carried out using the calibration graph of a standard mixture of fatty acids.

The content of vitamins was determined according to the methods [13].

The mineral composition was determined on a PAZh-3 flame spectrophotometer with appropriate light filters [14].

The amino acid score of raw proteins and the degree of amino acid balance were determined by the method proposed by FAO/WHO [14].

Enzymatic hydrolysis of proteins in vitro was determined by the method of A. Pokrovsky and E. Ertanov [15]. Let's use the enzymes pepsin, trypsin, and chymotrypsin produced by Biopharma (Kyiv, Ukraine). Enzymatic hydrolysis of proteins was determined under conditions of sequential action of pepsin at pH 1.2 and t=37 °C and a mixture of trypsin and chymotrypsin at pH 8.2 and t=37 °C. In the products of enzymolysis, the degree of protein degradation was calculated by the Lowry color reaction and expressed in arbitrary units (μg of tyrosine per 1 mg of protein).

3. Results

The chemical composition, as well as the functional and technological properties of wheat germ meal depends on many factors that make up the technological background of the processed raw materials, methods and conditions for its production, etc. [16, 17]. The influence of the defatting process on the chemical composition of the wheat germ meal is presented in **Table 1.**

Studies have shown that wheat germ is characterized by variability in the content of lipids and poliosis. The content of nitrogen-containing components is characterized by relative stability in terms of quantitative indicators and amino acid composition (**Table 2**).

Table 1

Chemical composition of wheat germ and meal, %

Object name	Moisture content	Lipid content	Content of protein and nitrogen-containing substances	Carbohydrate content		Ash content	Unidentified fractions
				hexoses	polyoses		
Wheat germ	4.2±0.01	12.3±0.02	39.0±0.3	3.6±0.03	37.5±0.3	0.7±0.01	2.7±0.02
Wheat germ meal	3.9±0.03	1.1±0.05	42.5±0.5	4.1±0.01	43.7±0.5	0.9±0.02	3.9±0.03

Table 2

Amino acid composition of wheat germ and meal

Amino acid name	Sample			
	Wheat germ		Wheat germ meal	
	Amount of amino acids, mg %	Amino acid content, %	Amount of amino acids, mg %	Amino acid content, %
Essential amino acids, including:	15,901.3	40.8	17,724.9	41.7
valine	1,950.1	5.0	2,857.0	6.7
methionine	1,182.8	3.0	1,369.9	3.2
leucine+isoleucine	5,560.8	14.3	5,452.9	12.8
lysine+histidine	1,971.1	5.1	2,280.1	5.4
threonine	1,439.3	3.6	1,866.6	4.4
tryptophan	419.7	1.1	430.9	1.0
phenylalanine	3,377.5	8.7	3,467.5	8.2
Essential amino acids, including:	23,102.5	59.2	24,727.2	58.3
alanine	5,011.4	12.8	5,144.9	12.1
arginine	1,736.7	4.5	1,782.3	4.2
aspartic acid	2,216.6	5.6	2,780.3	6.5
glutamic acid	1,384.2	3.6	1,421.1	3.4
proline	5,154.3	13.2	5,544.2	13.1
serine	4,465.4	11.5	4,837.0	11.4
tyrosine	2,230.1	5.7	2,289.6	5.4
cystine	903.8	2.3	927.8	2.2
Total amino acids	39,003.8	100.00	42,452.1	100.00

These data indicate that defatting does not entail a significant change in the amino acid composition of the embryos, but leads to a relative increase in the content of the total number of amino acids from 39.0±0.3 % to 42.5±0.5 %. The share of essential amino acids is also increasing, the increase is almost 1.8 %.

The biological value of wheat germ and wheat germ meal in comparison with the amino acid score of reference proteins is given in **Table 3** [18], the balance according to "tryptophan" and "threonine" indices – in **Table 4.**

Table 3

The biological value of wheat germ and meal of wheat germ by amino acid score

Amino acid name	FAO/WHO scale	Wheat germ		Wheat germ meal	
	mg/per gram of protein	mg/per gram of protein	amino acid score	mg/per gram of protein	amino acid score
Leucine+Isoleucine	110	142.6	129.6	128.5	116.8
Lysine+histidine	55	50.5	91.9	53.7	97.7
Valine	50	50.0	100.0	67.3	134.6
Tryptophan	10	10.8	108.0	10.6	108.0
Threonine	40	36.9	92.3	44.0	109.9
Phenylalanine+Tyrosine	60	143.9	239.7	135.6	226.0
Methionine+cystine	35	53.5	152.9	54.1	154.6

From the **Table 3** it is possible to see that the limiting values for wheat germ are lysine with histidine (score 91.9 %) and threonine (score 92.3 %). Probably, during defatting, a relative increase in the threonine content occurs due to the removal of fats, as a result of which lysine with histidine is limiting for proteins in wheat germ meal (score 97.7 %).

Table 4

Balance of essential amino acids of germ and wheat germ meal in comparison with the FAO/WHO standard

Amino acid name	Balance of amino acids according to the «tryptophan» index			Balance of amino acids according to the «threonine» index		
	FAO/WHO scale	Wheat germ	Wheat germ meal	FAO/WHO scale	Wheat germ	Wheat germ meal
Threonine	2…3	3.4	4.4	1.0	1.0	1.0
Lysine+histidine	3…5	4.7	5.3	1.1	1.4	1.2
Valine	4	4.6	6.7	1.5	1.4	1.5
Leucine+Isoleucine	7…10	13.2	12.7	3.1	3.9	2.9
Phenylalanine	2…4	8.0	8.1	1.1	2.4	1.9
Methionine	2…4	2.8	3.2	0.7	0.8	0.7
Tryptophan	1,0	1.0	1.0	0.25	0.3	0.2

Balance calculations based on indices indicate that the proteins of wheat germ and wheat germ meal are overloaded with threonine (when calculating the balance using the "tryptophan" index), leucine, isoleucine and phenylalanine. The results obtained confirm that, taking into account the given data, wheat germ meal is a valuable raw material that can be used in technologies for the production of high-protein food products.

The mineral and vitamin composition of wheat germ and wheat germ meal is presented in **Tables 5, 6.**

The given data (**Table 5**) testifies that the degreasing process does not significantly affect the qualitative composition of mineral elements, relatively increasing their content in terms of 100 g of natural product. This is the result of the fact that minerals are practically not included in the lipid fractions.

The results obtained (**Table 6**) show that defatting significantly affects the vitamin composition of wheat germ. Along with fats, fat-soluble vitamins are removed during the extraction process, reducing their content in the meal. The content of water-soluble vitamins is also reduced: pyridoxine, nicotinic acid by 8 times, biotin, choline – by 6, thiamine – by 5 times, which may be the result of exposure to organic solvents or the selected defatting parameters.

Table 5

Mineral composition of wheat germ and wheat germ meal

Name of mineral substances	Mineral composition, mg/ %	
	Wheat germ	Wheat germ meal
Calcium (Ca^{2+})	29.0±0.2	37.0±0.2
Magnesium (Mg^{2+})	96.0±0.4	154.0±0.6
Potassium (K^{+})	252.0±0.8	312.0±0.8
Sodium (Na^{+})	5.0±0.03	8.0±0.04
Iron ($Fe^{2+/3+)}$)	20.6±0.1	7.5±0.04
Copper (Cu)	0.25±0.001	0.32±0.001
Chlorine (Cl^{-})	112.0±0.8	144.0±0.8
Phosphates	196.0±0.9	216.0±0.9
Zinc (Zn^{2+})	0.37±0.001	0.44±0.001
Manganese (Mn)	0.18±0.001	0.27±0.001
Cobalt (Co)	0.009±0.001	0.015±0.002
Nickel (Ni)	0.005±0.001	0.009±0.001
Chromium (Cr)	0.001±0.005	0.002±0.001
Total	711.0±1.0	879.0±1.0

Table 6

Vitamin composition of wheat germ and wheat germ meal

Name of vitamins	Vitamin content, µg/g	
	Wheat germ	Wheat germ meal
Biotin (vitamin H)	0.86±0.01	0.14±0.001
Thiamin (vitamin B_1)	51.2±0.3	10.3±0.05
Riboflavin (vitamin B_2)	15.5±0.2	4.5±0.03
Pyridoxine (vitamin B_6)	152.8±0.8	19.3±0.1
Tocopherols (vitamin E)	164.6±0.8	0.137±0.001
Niacin (vitamin PP, niacin)	359.9±0.9	47.2±0.3
Carotenoids (provitamin A)	56.7±0.3	1.0±0.05
Folacin (folic acid)	3.8±0.03	0.97±0.01
Pantothenic acid (Vitamin B_3)	34.7±0.1	2.0±0.02
Choline	939.0±1.0	148.0±0.9

In the process of defatting wheat germ, the total amount of lipids is significantly reduced (**Table 7**), which affects the nutritional value of raw materials.

Table 7

Fatty acid composition of lipids of wheat germ and wheat germ meal

Name of fatty acid, index	Fatty acid content, % of the total	
	Wheat germ	Wheat germ meal
Myristic, $C_{14:0}$	0.2±0.001	–
Palmitic, $C_{16:0}$	17.9±0.1	18.2±0.1
Stearic, $C_{18:0}$	14.5±0.1	16.0±0.1
Arachidonic, $C_{20:0}$	0.1±0.001	0.1±0.001
Palmitoleic, $C_{16:1}$	1.5±0.02	–
Oleic, $C_{18:1}$	57.7±0.3	56.7±0.3
Linoleic, $C_{18:2}$	6.1±0.03	8.2±0.03
α-Linolenic, $C_{18:3}$	2.0±0.02	–
Not identified	–	0.8±0.01
The total amount of lipids in the samples, %	12.3±0.2	1.1±0.05

From the data presented (**Table 7**) it can be seen that defatting not only reduces the total amount of lipids, but also contributes to a change in the ratio of individual fatty acids in lipids. It is found that the meal of wheat germ is characterized by more stable physicochemical parameters in comparison with wheat germ (**Table 8**).

Table 8
Physicochemical parameters of wheat germ lipids

Index	Value
Acid number, mg KOH/g	1.8±0.02
Peroxide number, 1/2 O mol/kg	1.7±0.02
Mass fraction of non-saponifiable substances, %	1.1±0.02
Mass fraction of tocopherols, mg %	175.0±0.9

Based on the studies carried out, it is advisable to use wheat germ meal as the main raw material, since its nutritional and biological value is not significantly inferior to wheat germ. In order to enrich hardtacks with lipids, wheat germs were additionally introduced into their recipe composition. On the basis of preliminary studies and analysis of organoleptic indicators, the optimal concentration of adding wheat germ to dietetic hardtacks in an amount of 20 % of the mass of dry prescription components has been established.

Considering the fact that the technological properties of wheat germ meal are rather low, it was important to determine the moisture absorption capacity (MAC) of meal, wheat germ and a mixture of meal and wheat germ (**Fig. 1**). The studies were carried out at a temperature of 20 °C.

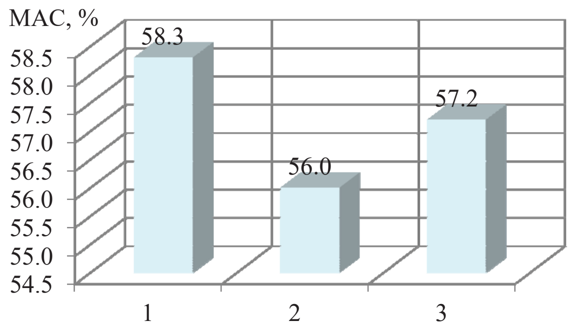

Fig. 1. Moisture absorption capacity, %: 1 – a mixture of wheat germ meal and wheat germ (80:20); 2 – wheat germ; 3 – wheat germ meal

It has been established that the highest moisture absorption capacity is characteristic of a mixture of germs and wheat germ meal.

The influence of the defatting process on the ability of digestion by enzymes of the gastrointestinal tract "in vitro" of wheat germ meal proteins has been investigated. The rate of protein digestion in the gastrointestinal tract by proteolytic enzymes is one of the important indicators; therefore, the results of protein digestion in "in vitro" conditions can be used to predict the degree of their utilization by the body [19, 20].

From the obtained experimental data on the accumulation of products of enzymatic hydrolysis of protein (**Fig. 2**), it can be seen that at the stage of pepsinolysis, the depth of hydrolysis of wheat germ meal is 1.2 times higher than that of wheat germ.

The digestibility of wheat germ is 118.2 μg/mg, a similar indicator of wheat germ meal is slightly higher – 148.2 μg/mg, and a mixture of meal and wheat germ is 142.2 μg/mg, which confirms their use in technology.

Taking into account analytical and experimental studies, a recipe composition and a technological scheme for the production of dietetic hardtacks using germs and wheat germ meal have been developed (**Fig. 3**).

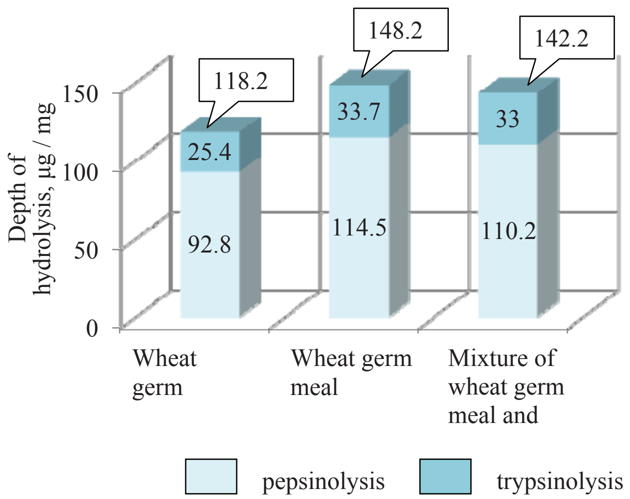

Fig. 2. Enzymatic hydrolysis of germ protein, wheat germ meal and their mixture by proteolytic enzymes

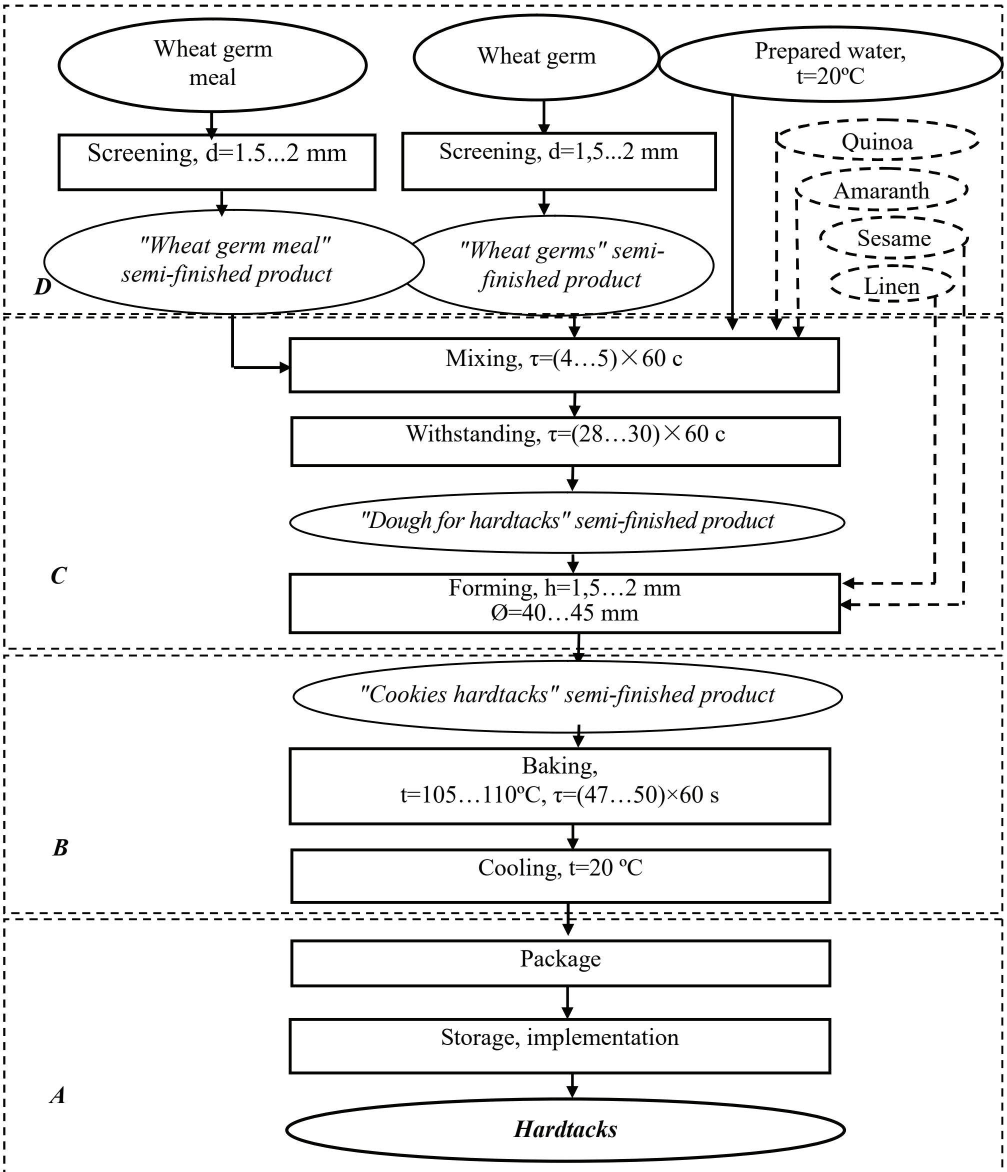

Fig. 3. Technological scheme for the production of dietetic hardtacks using wheat germs and wheat germ meal

4. Discussion

In the course of research, it has been determined that the process of defatting wheat germ for hardtacks does not lead to a change in the total amino acid composition of wheat germ, but the proportion of essential amino acids increases. Also, scientists [21] have developed the technology of butter cookies for patients with diabetes mellitus using wheat germ. The technological process for the production of hardtacks implies pre-roasting of wheat germ in order to reduce the characteristic bean flavor, however, heat treatment has reduced the composition of essential amino acids.

In the course of studies of enzymatic hydrolysis, it has been determined that a mixture of meal and wheat germ can be digested by enzymes of the gastrointestinal tract. Similar studies were also carried out by scientists [22], which confirm the presence of a harmonious enzyme system (lipase, lipoxygenase, catalase) in wheat germ. The presence of these enzymes affects their quality indicators during storage and thereby complicates their industrial use on a large scale.

Based on the results of physicochemical studies, it has been determined that the highest moisture absorption capacity of 58.3 % is characterized by a mixture of germs and wheat germ meal. In [23], a technology was developed for obtaining cake from wheat germ, the moisture absorption properties of which depended on the degree of dispersion of the cake. So, the authors determined that during grinding, the surface area of the particles increases, which contributes to an increase in the amount of adsorbed-bound moisture. When grinding wheat germ cake to an average particle size of 0.12 mm, the moisture absorption capacity increases to 78.3 %, which provides a homogeneous and monolithic structure in the finished product. However, the authors of [24] confirmed the opposite, that a finer grinding of wheat germ (particle size 0.8 … 0.12 mm) significantly impairs the organoleptic characteristics of the product.

To obtain a finely dispersed system of wheat germ meal mixtures, technological equipment are necessary that will grind raw materials with certain dimensional characteristics. To date, grinding is carried out by the method of dry mechanical activation, however, in the process of mechanical activation, significant destruction occurs, as well as the formation of various integral violations of the feedstock. Therefore, the selection of technological equipment, as well as the determination of the degree of dispersion, using the methods of modern photo-microscopy, is one of the main limitations of the study.

Thus, the prospect of further research will be based on the study and research, the degree of dispersion of the mixture of seed meal of wheat germ meal and wheat germ.

5. Conclusions

The effect of the defatting process on the chemical composition of wheat germ meal has been studied: the total amount of lipids decreases, the ratio of individual fatty acids changes, and there is a relative increase in the content of the total number of amino acids from 39.0±0.3 % to 42.5±0.5 %. The content of fat-and water-soluble vitamins decreases, which affects the nutritional value of raw materials.

The results of the general digestibility of wheat germ and wheat germ meal have the advisability of using a mixture of meal and wheat germ in a ratio of 80:20 in the recipe composition of dietetic hardtacks, which will make it possible to obtain finished products with a predictably high degree of digestion.

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