Встановлена висока ферментна активність добавок амаранту багряного та позитивний вплив на хлібопекарні властивості пшеничного борошна. Визначено зміни стану білкових речовин у тістовому напівфабрикаті: присутність добавок у тісті інтенсифікує процес гідролізу крохмалю, що створює умови для скорочення строку дозрівання тіста. Запропонована нова методика порівняльної оцінки протеолітичної активності ферментної сировини шляхом вимірювання відносної в'язкості розчинів желатину

Ключові слова: пшеничне борошно, дріжджове тісто, якість, клейковина, амарант багряний, ферментна активність

Установлена высокая ферментная активность добавок амаранта багряного и положительное влияние на хлебопекарные свойства пшеничной муки. Определены изменения состояния белковых веществ в тестовом полуфабрикате: присутствие добавок в тесте интенсифицирует процес гидролиза крахмала, что создает условия для сокращения срока созревания теста. Предложена новая методика сравнительной оценки протеолитической активности ферментного сырья путем измерения относительной вязкости растворов желатина

Ключевые слова: пшеничная мука, дрожжевое тесто, качество, клейковина, амарант багряный, ферментная активность

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EXAMINING A POSSIBILITY OF USING PURPLE AMARANTH IN THE TECHNOLOGY FOR PRODUCTS MADE OF YEAST DOUGH

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1. Introduction

Grain flour products, especially products made of wheat dough, form at present the basis of human nutrition; these are the products of everyday consumption for the entire population. The most common type of flour products is the products made from yeast dough, which include several hundred items [1].

In this regard, the quality and nutritional value of flour products, including products made of yeast dough, are of paramount importance. The value of such products is determined primarily by the presence of proteins, essential amino acids, vitamins, and minerals. However, it would be absolutely wrong to assess the nutritional value of flour products only from the position of their chemical composition, without taking into account such properties of products as physical appearance, fragrance, taste, and crumb porosity of a product.

The task on searching for the ways to improve quality and nutritional value of products made of flour becomes particularly relevant when consumption of food products of animal origin, such as meat, fish, dairy and egg products, animal fats, decreases significantly [2]. Given this, the proportion of cereal products in the diet, primarily products made of flour, increases.

Under conditions of monotonous nutrition, the issue on improving the quality and nutritional value of products, made of yeast dough, is especially acute; the search for possible ways of improvement is becoming particularly relevant. This primarily concerns the products from top grade wheat flour, more common in everyday life and in the culinary practices, and the least valuable in biological terms [3].

Specialists in the industry face the tasks on improving the technology of products from yeast dough and obtaining competitive high-quality products by using the improvers and fortifiers of different origin. In the food industry, in particular baking industry, the use of additives of non-natural origin is gradually decreasing. That is why the application of natural additives from non-traditional plant raw materials can contribute to fortifying the products with nutrients that are necessary for the human organism, improving the quality and decreasing the energy value of the latter [4].

2. Literature review and problem statement

One of the most promising types of non-conventional raw material that can be used to fortify the products from yeast dough is purple amaranth (PA). PA is the plant that is common in many climatic zones, except for the Far North [5].

Comparing data on the chemical composition of PA grains to wheat grains [6], one can say that amaranth grains in many respects resemble wheat grains. However, there are twice as many minerals in amaranth grains. Paper [7] studied the content of iron and phosphorus in the mineralizates of amaranth grains as the elements that are essential for the life activity of the organism. The presence of these substances in food products is one of the main characteristics of their biological value. The obtained data on the content of the aforementioned substances in grains make PA an exception from the entire group of cereals. Thus, by the content of phosphorus (380 mg %), amaranth grains can be put in line with peas (329 mg %), millet (233 mg %), and buckwheat (298 mg %). By the content of iron (19.2 mg %), purple amaranth grains can be compared only to hips (28 mg %) while the content of iron in cereals is significantly lower [8].

Not less interesting are the data that were obtained in the process of studying the vitamin composition of ingredients. Vitamin A takes a special place among vitamins, playing a vital role in ensuring many vital functions of an organism. Because the grains of the studied plant have a colored shell, it is possible to assume the existence of provitamins A, although one cannot exclude an alternative reason for coloration – the content of tannins [9]. It should be noted that the content of carotenoids is uncharacteristic for cereals. The analysis showed the content of carotenoids is 0.19 mg % (comparatively, mg %: potato – 0.2...0.3; milk – 0.5...0.7) [10].

Judging by the fact that PA grains, resembling wheat in many respects, are more advantageous than the latter by the content of provitamins A and mineral substances, it would be necessary to pay attention to the green mass of amaranth. This primarily concerns its foliage. It is likely that quite rich vitamin and mineral composition of amaranth grains is a consequence of the high capacity of its leaves to synthesize the mentioned substances. Due to detection of a rich vitamin composition of foliage, it would be possible to use PA successfully as an additive to familiar food products, fortifying them with the complex of natural biologically active substances. However, unlike amaranth grains, the chemical composition of the leaves should vary depending on the age of a plant.

Paper [11] investigated a gradual steady increase in the content of essential vitamins and minerals in the foliage depending on the age. Purple amaranth in the period of its maturity at the age of 5 months seems to be the most promising for both subsequent studying and later application.

Analyzing data in the articles [11, 12], one should pay attention, first of all, to an unusually high content of protein in the foliage of PA of this age (5.8 %), which in terms of dry substance is 31.1 %. For comparison, it is 3.7 in parsley; it is 1.3 % in paprika and 5.0 % in green pea [13]. This allows recommending fortification of wheat flour carbohydrates with preparations from dry foliage of purple amaranth.

Quite a large amount of ash in amaranth leaves indicates an increased content of mineral substances [14]. Indeed, there is as much phosphorus and iron in the foliage of the plant as in its grains. It is impossible to compare amaranth to any salad vegetable by the content of phosphorus and iron (for comparison, mg %: parsley (P – 26, Fe – 0.8).

But the most interesting results relate again to the vitamin composition of raw material [15]. By the content of vitamin C (338.2 mg %), amaranth is second only to hips (1,500...2,000 mg %) and can be compared with black currant (300 mg %). Other fruits and vegetables contain much less amount of vitamin C. A leaf of amaranth is closest to carrot by the content of carotenoids (8.6 mg %) and has no analogues among vegetable raw materials by the content of vitamin E (9.5 mg %), with the exception of corn and wheat germs [16].

The results of analysis of the chemical composition of grains and green mass of purple amaranth prove huge prospects of the latter as an additive, improving nutritional value of food products. However, there is one very serious objection to the direct use of green mass of the plant, specifically, the difficulty in laying-in and storing this raw material. In the case of the possible use of this additive in a dry form, that drawback would be eliminated.

The studies of the change in the chemical composition of amaranth foliage in the process of drying and long storage were conducted [17]. As it is known, of all the studied biologically active substances, vitamin C, which is easily oxidized, even at the most insignificant influences on the substrate, is the most unstable. Vitamins A and E are fairly stable, not to mention protein and mineral substances. As the obtained results show, soft drying and storage of received flour have virtually no impact on the content of biologically active substances, except for, as expected, vitamin C. In the process of foliage drying, vitamin C is destroyed, but not completely – a sufficient amount (138.2 mg %) remains and is retained during a long-term storage.

As a result of the analysis, it is evident that PA is the richest source of valuable biologically active substances, which was supposed judging from historical experience of being used in food by many peoples [18]. However, although this experience indirectly indicates full safety and non-toxicity of this plant, it is necessary to prove this.

Studies of toxicity of both flour from amaranth grains and flour from dry foliage were carried out [19]. The tests were conducted by the suspension method. The preparations were suspended in the aprotic solvent – dimethylsulfoxide (DMSO). Vegetative and spore test-culture (E. Coli and Bac. Cerens) were used for tests. Control was performed with the use of a solvent and saline solution. The data obtained indicate the absence of toxicity of the tested preparation in respect to both vegetative and spore microorganisms.

All the above results taken together make it possible to consider PA, first and foremost, flour from dry foliage, promising as a concentrated protein and vitamin additive to top grade wheat flour. Thus, for fortification of yeast dough products, it is advisable to use flour from dry foliage of PA, which is a valuable source of vitamins, minerals, and protein. It should be noted that there is virtually no research aimed at improving the nutritional and biological values of yeast dough products with the help of flour from dry PA foliage directly in wheat flour. Such method of using this non-conventional raw material could open the new ways of improving the quality and nutritional value of the products made of yeast dough.

However, it is not enough to find an additive that would ensure the content of the most important biologically active substances in wheat flour, thereby enhancing its nutritional value and, consequently, the value of the products. It is essential that the proposed additive should not worsen the consumer qualities of the products from this flour. For example, it should not affect elastic-stretching properties of gluten, fragrance and coloration of products' crusts. That is why before recommending PA additives, which are rich in vitamins, protein and minerals, for fortification of wheat flour, it is necessary to study thoroughly their influence on baking quality of the latter.

3. The aim and objectives of the study

The aim of present study is to examine the influence of additives of purple amaranth (APA) on baking properties of wheat flour for its possible use in the technology of products from yeast dough.

To accomplish the aim, the following tasks have been set:

– to explore amylolytic activity of APA;

– to determine rational concentration of APA, which will contribute to the improvement of qualitative composition and baking properties of wheat flour;

– to explore the impact of APA on amylolytic and proteolytic activity of wheat flour, as well as the state of its protein complex.

4. Materials and methods of research

Materials of research:

– top grade wheat flour;

– flour from dry foliage of PA (Fig. 1, *a*);

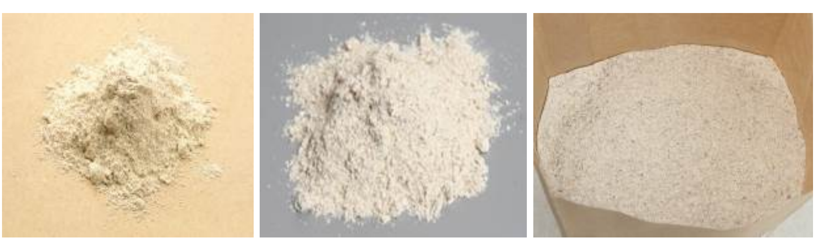
– flour from amaranth malt (Fig. 1, *b*);

– flour from barley malt (Fig. 1, *c*);

– water extracts from dry foliage of AP, amaranth and barley malts;

– gluten, separated from the samples of top grade wheat flour.

Preparation of materials and the methods of research are described in more detail in [7].



a *b* *c*

Fig. 1. Materials of research: *a* — flour from dry PA foliage; *b* — flour from amaranth malt; *c* — flour from barley malt

5. Results of study of the impact of additives of purple amaranth on baking properties of wheat flour

Before considering the possibility of adding APA, which is rich in vitamins, mineral substances and protein [11], to wheat flour, it is necessary to carefully explore the impact on its amylolytic activity. If the flour has low amylolytic activity, not enough maltose will be formed in its dough semi-finished product. The fermentation process will occur with low intensity, the product will turn out to be of poor quality, with an insufficiently porous, fluffy crumb. Sugar formation capability of flour also affects getting a crunchy brown crust when baking products. Under the influence of high temperature, proteins and reducing sugars interact with formation of melanoidins, giving coloration to the crust of the baked product, and aldehydes and ketones included in its aromatic complex (the Meyer reaction) [3]. With insufficient amount of sugars, the product turns out to be with a pale crust and weak fragrance.

First of all, it was necessary to examine amylolytic activity of APA themselves. Amylolytic activity of flour from dry PA foliage was explored using the model substrate (2 % solution of starch, partially dextrinirated). Activity of the enzyme preparation was assessed by the amount of formed maltose (the product of deep starch hydrolysis) in the reaction mixture. Flour from dry foliage of PA and its 5 % water extract were used. In the beginning, separate activity of α- and β-amylases, existing in enzymatic raw materials, was determined. Now, great attention is paid to α-amylase, because it is α-amylase that hydrolyzes 1.4-gluconic bonds in the molecule of polysaccharide. Depolymerization of starch occurs, its molecules split into large shards. A characteristic sign of the effect of α-amylase is rapid dilution of glutenized starch [9]. Under conditions of high temperature of baking products, starch decomposition flows especially intensively at the high activity of α-amylase, which can cause dramatic worsening of crumb quality. β-amylase splits every other glycoside bond from the end of the polysaccharide chain, in this case maltose is split. At the very beginning of the action of β-amylase, reducing sugar, which creates beneficial conditions for dough fermentation, is produced in the reaction mixture. In our situation the increased β-amylase activity of APA may negatively affect positive qualities. Thus, it is necessary to carry out determining of α- and β-amylases of APA in a differentiating way to make sure that high total amylolytic activity will not affect deterioration of the crumb quality of finished products.

The method of differential determining of amylases by inactivation of one of them is quite common in the research practice. In the process of heating the enzyme mixture for 15 minutes at t=70 °C, α-amylase is almost completely preserved. To stabilize α-amylase in this method of β-amylase inactivation, it is recommended to add a small amount of calcium acetate. The amount of reducing sugars, determined in this way, characterizes activity of α-amylase, while activity of β-amylase is determined as the difference between the total activity and activity of α-amylase. Data on determining activity of α- and β-amylases, as well as on the total amylase activity are given in Table 1.

Table 1

Determining activity of α- and β-amylases of flour from dry foliage of PA

No. of entry	Enzyme preparation	Maltose number, % of maltose
1	5 % water extract from dry foliage of PA with non-inactivated β-amylase	12.31±0.36
2	5 % water extract from dry foliage of PA with inactivated β-amylase	1.12±0.09
3	Estimated value of activity of β-amylase	11.23±0.34

According to data from Table 1, activity of α-amylase in flour from dry PA foliage is extremely low, which is fully consistent with the literature data about low activity of α-amylase in plant raw materials [5]. Subsequently, exploring the effect of the studied enzyme preparation on various substrates, α-amylase can be neglected without any harm, when performing total determining of activity of amylase complex. Detailed experimental results are given in Table 2.

Data from Table 2 show that amylase complex of PA foliage is somewhat less active compared with barley malt, chosen as the comparator. However, activity of the amylase complex can be increased using small additives of Ca^{2+} ions, which take part in the formation and stabilization of the active center and the whole tertiary structure of the enzyme. They contribute to formation of the most beneficial configuration of the enzyme and the active enzyme-substrate complex [5, 20].

Addition of $CaCl_2$ to the reaction mixture significantly increases amylolytic activity of the preparation and puts it at one level with barley malt.

Table 2

Impact of amylases of flour from dry PA foliage on starch hydrolysis

No. of entry	Substrate	Enzyme preparation	Maltose number, % of maltose
1	2 % starch solution	5 % water extract of barley malt	17.21±0.37
2	–//–	5 % water extract from dry PA foliage	12.31±0.36
3	–//–	5 % water extract from dry foliage of PA on solution of calcium chloride (Ca^{2+}=0.01 g/l)	16.0±0.35

To study enzyme activity of raw materials on the model substrates, specific rules, requiring the use of 5 % water extract of enzyme raw materials, were established [21]. But before exploring the impact of the dry preparation on amylolytic activity of wheat flour, it was necessary to choose the optimal concentration of the additive.

Three provisions were taken as the basis when selecting a concentration of flour from dry PA foliage:

– the amount of the additive should be sufficient to produce a significant effect on the vitamin and mineral composition of wheat flour;

– it is necessary that the additive should not worsen rheological indicators of dough;

– the introduced additive should not make a significant impact of the color of flour and crumb of the product.

Data on the impact of APA concentration on the content of the main biologically active substances in wheat flour are shown in Table 3 (data were obtained by calculation).

As can be seen from data in Table 3, low concentrations of APA to wheat flour practically do not affect its qualitative composition and only starting with the 1 % concentration, the additive has a significant impact on the biological value of the substrate.

As a criterion for bread making quality of wheat flour, we selected its gluten quality, determined by running of a ball from 10 g of gluten after 1-hour lying [20]. Data on running a ball of gluten, washed away from wheat flour, containing various APA concentrations, are shown in Table 4.

Table 3

Impact of APA concentration on the content of basic biologically active substances in wheat flour

No. of entry	Concentration of additive, %	Content of biologically active substances					
		protein, %	vitamin C, %	Carotenoids, mg %	Vitamin E, mg %	P, mg %	Fe, mg %
1	0	12.7±0.3	–	–	1.1±0.1	86.0±0.7	1.2±0.1
2	0.25	12.7±0.5	0.4±0.2	0.1±0.1	1.2±0.1	88.0±0.6	1.4±0.1
3	0.5	12.8±0.4	0.7±0.3	0.2±0.1	1.3±0.1	90.0±0.5	1.7±0.2
4	0.75	12.9±0.3	1.0±0.4	0.3±0.2	1.5±0.2	92.2±0.7	1.8±0.1
5	1.0	13.1±0.6	1.4±0.3	0.5±0.2	1.6±0.1	94.2±0.9	2.2±0.2
6	2.0	13.3±0.5	2.8±0.4	1.0±0.3	2.1±0.2	102.4±0.8	3.2±0.1

Table 4

Impact of APA concentration on the running of wheat flour gluten

No. of entry	Concentration of additive, %	Diameter of a ball, mm
1	0	40
2	0.25	40
3	0.5	42
4	0.75	44
5	1.0	47
6	2.0	106

As data in Table 4 show, insignificant addition of the preparation practically does not weaken flour gluten flour up to 1 % concentration. A subsequent increase in the concentration of the preparation leads to a dramatic deterioration of gluten quality.

To establish the influence of APA on the flour whiteness, the whiteness and the color shade of flour with different concentrations of the additive were determined at the device FPM-1.

a *b* *c* *d* *e* *f*

Fig. 2. Samples of flour with different APA concentration, %: *a* – 2, *b* – 0; *c* – 0,25; *d* – 0,5; *e* – 0,75; *f* – 1

Data on determining are given in Table 5.

Table 5

Impact of APA on indicators of whiteness and shade of color of wheat flour (in conditional units based on the scale of the device FPM-1)

No. of entry	Concentration of additive, %	Readings of measurement at light filter		Shade of color of flour (by nomogram)
		SZS-7	OS-14	
1	0	18	28	white
2	0.25	19	29	white
3	0.5	19	29	white
4	0.75	20	29	grayish
5	1.0	21	30	creamy
6	2.0	35	53	yellow

According to the acquired data, we can conclude that APA in small concentrations (up to 0.5 %) has almost no effect on the color shade of wheat flour – its color does not differ from the color without the additives. Starting with the concentration of 0.75 % and up to 1 % of the additive in flour, the grayish color shade appears, but this color does not go beyond the requirements for top grade wheat flour [5]. An increase in APA up to 2 % causes a rather abrupt darkening of flour, which in the scale units of the device indicates creamy and yellow colors. Thus, the obtained data on the color of wheat flour with APA show toward a 1-% concentration.

The experimental data made it possible to carry out the research into amylolytic activity of flour from dry PA foliage on wheat flour. The data on amylolytic activity of wheat flour with APA and its water extract are shown in Table 6.

Table 6

Impact of APA on amylolytic activity of wheat flour

No. of entry	Enzyme preparation	Maltose number, % of maltose
1	Dry barley malt (flour)	9.81±0.35
2	Dry PA foliage (flour)	7.82±0.32
3	5 % water extract from dry PA foliage (distilled water)	8.31±0.33
4	5 % water extract from dry PA foliage (tap water)	9.42±0.34
5	Without preparation (control)	3.93±0.28

The patterns, obtained in the model systems of starch, are fully preserved in this case.

Given the high amylolytic activity of flour from dry PA foliage, we made steps (by analogy with barley malt) to study amylolytic activity of amaranth malt, derived from two-day germination and cautious drying of PA grains. The studies were carried out using different substrates: top grade wheat flour, dry potato starch and 2 % starch solution that was partially dextrinated. Enzyme activity of the preparation was determined by the amount of maltose, formed in the reaction mixture. The flour, obtained from grinding amaranth malt and its 5 % water (or salt) extract, was used as enzyme preparations.

Results of research into the influence of amaranth malt on amylolytic activity of wheat flour are shown in Table 7. It was known [19] that the influence of amylases on unchanged or even partially damaged starch grains is very weak compared to the influence on starch gelatin. This is evident from comparison of the data, given in Table 7. However, activity of amaranth malt can be enhanced with the use of insignificant adding of Ca^{2+} ions as it was described above for the case of amaranth foliage.

The obtained results gave grounds to undertake research into amylolytic activity of amaranth malt to wheat flour, the data of which are shown in the same table. The patterns, described above, are fully preserved.

Table 7

Impact of amaranth malt on amylolytic activity of wheat flour

No. of entry	Substrate	Enzyme preparation	Concentration of Ca^{2+}, g/l	Maltose number, % of maltose
1	2 % starch solution	5 % water extract of barley malt	–	17.21±0.36
2	–//–	5 % water extract of amaranth malt	–	13.51±0.29
3	–//–	5 % water extract from amaranth malt on calcium chloride solution (Ca^{2+}=0.5 g/l)	0.05	17.12±0.38
4	–//–	5 % water extract from amaranth malt on calcium chloride solution (Ca^{2+}=0.01 g/l)	0.0025	17.22±0.36
5	Starch grains	dry amaranth malt (flour)	–	3.24±0.18
6	–//–	5 % water extract from amaranth malt without the preparation	–	4.98±0.36
7	Wheat flour	without preparation	–	3.94±0.37
8	–//–	dry barley malt (flour)	–	9.81±0.35
9	–//–	dry amaranth malt (flour)	–	9.03±0.34
10	–//–	5 % water extract from amaranth malt (distilled water)	–	9.52±0.21
11	–//–	5 % water extract from amaranth malt (tap water)	–	10.53±0.38

All the above results with full reliability indicate quite high amylolytic activity of APA, due to which they increase sugar forming capability of wheat flour, and thus, its gas forming capability.

However, for obtaining high quality products, semi-finished product must also possess good capability to detain carbon dioxide, emitted during fermentation, stretching under its pressure and increasing in volume. Many data in literature [11–13] show that it not the firmest dough that has maximum gas-retaining capability. If the gluten basis of dough is too firm, dough will not stretch under pressure. At some point, the pressure inside the gas bubbles in dough will reach such value, that the shell of a bubble will be broken and gas will evaporate outside. To enhance gas-retaining capability of such a semi-finished product, it is necessary to weaken the dough structure, to make the gluten base more stretchable.

It is in this respect that an increase in proteolytic activity of flour, allowing us to somewhat weaken dough and enhance its stretchability, will be very effective. But in addition to the impact on dough rheological properties, the additives, increasing proteolytic activity of flour, will contribute to accumulation of free amino acids in dough and thus will create conditions for a more intensive process of melanoidin formation.

That is why when using the APA, which showed high amylolytic activity, it is also necessary to take into consideration proteolytic capability. However, at that it should be noted, however, that the existing methods of determining proteolytic activity of enzymes (accounting for hemoglobin [20], dry casein hydrolysis [21]) are not express-methods.

The method for determining proteolytic activity of enzyme preparations or enzyme raw materials, based on the change of viscosity of gelatin solutions as a result of influencing them, was proposed. This method is quick, preparative, does not require any bulky equipment and can be an express-method for establishing activity of one or another proteolytic preparation. The method has one drawback – it does not give direct data on the quantitative activity of a preparation. The method is suitable only for comparing activity of the studied preparations with the known standard, selected in advance. However, it seems suitable for solving the problems, set in the study. Using this method, we determined relative proteolytic activity of flour from dry purple amaranth foliage, amaranth malt and barley malt as a comparator, expressed with the help of relative viscosity (η_{rel}) of the studied gelatin solutions. The data of the experiment are given in Table 8.

Table 8

Determining proteolytic activity of enzyme preparations

No. of entry	Enzyme preparation	Relative viscosity, (η_{rel})
1	–	1.54
2	Barley malt (flour)	1.07
3	Amaranth malt (flour)	1.13
4	Dry PA foliage (flour)	1.09

According to the obtained data, APA demonstrate considerable proteolytic activity, splitting peptide bonds of gelatin. The flour from dry amaranth foliage has higher activity, comparable with the activity of barley malt, while amaranth malt is less active, albeit slightly. Thus, the detected proteolytic activity of APA must affect the quality of wheat flour gluten and, as a result, the bakery merits of the latter.

With a view to establishing the regularities of the influence of proteolytic enzymes of additives on bakery merits of wheat flour, we conducted the experiments on determining the yield of crude and dry gluten at kneading dough of top grade wheat flour with addition of 1 % of APA immediately after kneading and after one-hour binning. The data of the experiments are shown in Table 9. Stretchability of crude gluten, which characterizes its quality and influences greatly the crumb structure, was additionally determined by the method of Kozmina-Kranz [20].

Table 9

Impact of APA on the quality of wheat flour gluten

No. of entry	Enzyme preparation	Yield of crude gluten, %		Yield of dry gluten, %		Stretchability, cm	
		immediately	in an hour	immediately	in an hour	immediately	in an hour
1	–	32.3±1.9	36.5±2.1	14.0±0.8	13.2±0.8	3.5±0.2	5.0±0.2
2	Barley malt (flour)	40.4±2.5	40.2±2.3	14.0±0.9	12.9±0.7	5.3±0.2	4.4±0.2
3	Dry foliage of PA (flour)	35.9±2.3	39.9±2.2	14.0±0.6	12.7±0.6	5.6±0.2	5.6±0.2
4	Amaranth malt (flour)	40.2±2.4	40.2±2.4	14.0±0.7	12.8±0.6	5.7±0.2	5.2±0.2

According to data from Table 9, the additive to wheat flour significantly increases the yield of crude gluten. Elasticity of gluten is also enhanced at the use of additives. Data on the yield of dry gluten coincide with the data on determining proteolytic activity of preparations.

6. Discussion of results of research into the impact of additives of purple amaranth on the baking properties of wheat flour

Results of determining the activity of α- and β-amylases of flour from dry PA foliage (Table 1) show that while exploring the impact of the studied enzyme preparation on various substrates, α-amylase can be neglected without any harm during total determining of activity of the amylase complex (Table 2).

High (Table 2) amylolytic activity of the preparation from dry PA foliage was detected, which puts it almost at the same level with barley malt.

The impact (Table 3) of APA concentration on the content of basic biologically active substances in wheat flour was established. Introduction of the additive in the amount of less than 1 % seems inappropriate. On the other hand, the concentration of APA of 1 % or higher can worsen baking merits of wheat flour and negate a positive result, obtained from its fortification. Studying the impact of APA concentration on gluten quality (Table 4) proves that APA concentration, which is equal to 1 %, is optimal. It is sufficient to fortify wheat flour with major biologically active compounds and not high enough to worsen the gluten quality. Experimental data on the influence of APA on the indicators of whiteness and a color shade of wheat flour (Table 5) make it possible to decide on the concentration of the additive of 1 % as the most optimal for the fortification of top grade wheat flour.

It was determined (Table 6) that sugar forming capability of flour increases dramatically with the addition of a small amount of flour from dry PA foliage. When carrying out the reaction using not distilled water, but tap water, the activity of amylases increases even more. Water hardness is conditioned mainly by the content of Ca^2 and Mg^{2+} ions in it, which turns it into an electrolyte and increases reactivity. These data seem quite encouraging and allow considering flour from dry PA foliage as a fully-fledged preparation of active amylases, specifically, β-amylase.

It was found (Table 7) that the amylase complex of amaranth malt is somewhat less active compared to barley malt both in the dry form and in the form of the extract. The conducted experiment on assessment of amylase activity of non-germinated amaranth grains proved the well-known fact of an increase in enzyme activity in a germinating grain [13]. But inconsiderable adding calcium chloride solution with the concentration of ions Ca^{2+}=0.5 g/l increases the amylase activity of the preparation and puts it on the same level with barley malt. The same holds when cooking an enzyme extract not on distilled water, but on calcium chloride solution with the concentration of the ions of Ca^{2+}=0.01 g/l. In this case, the concentration of calcium ions in the sugared solution is the value that is smaller by an order of magnitude than in the previous case and sugaring activity of the preparation even slightly increases. The explanation is most likely to be found in the method of preparation of the enzyme extract. When using an electrolyte solution, complete extraction of the enzyme from raw materials occurs, which is typical of many proteins, and its concentration in the sugared solution increases [22]. As the data from Table 7 show, sugar forming capability of flour increases dramatically at addition of dry amaranth malt. When carrying out the reaction with the use of not distilled, but tap water, amylase activity increases even more, which is not unexpected in the light of the above experiments.

All the aforementioned reliably proves a rather high amylolytic activity of APA.

It was determined (Table 8), that APA demonstrate considerable proteolytic activity, splitting peptide bonds of gelatin. Flour from dry foliage of PA (η_{rel}=1.09) demonstrates higher activity, comparable with the activity of barley malt, while amaranth malt is less active (η_{rel}=1.13), albeit only slightly.

The established (Table 9) positive impact of proteolytic enzyme of the additives on baking qualities of wheat flour shows a significant increase in the yield of crude gluten. It seems logical, since enzyme preparations stimulate gluten proteins hydration. Moreover, the use of the enzyme preparation accelerates the process of hydration itself and an-hour lying of dough is not needed. Gluten elasticity also is enhanced. The data on the yield of crude gluten entirely coincide with those on determining proteolytic activity of the preparation. While the yield of crude gluten immediately after kneading is the same for all four experiments, after lying, when gluten proteins were affected by proteolytic enzymes, the lowest yield of crude gluten is observed in the case of using flour from dry amaranth foliage as an additive. This indicates the highest activity of its enzymes.

Thus, it was established as a result of the carried-out research that APA improve baking merits of top grade wheat flour. The gas forming capability of flour increases, structural-mechanical properties of semi-finished products are enhanced, the dough process accelerates. This makes it possible to assume the possibility and expedience of using these additives in creation of new kinds of products of yeast dough with enhanced consumer characteristics and improved nutritional value.

APA, in comparison with analogues, not only alter baking properties of flour and structurally-mechanical properties of flour semi-finished products, but also allow fortification of the latter with the complex of biologically active substances.

However, it can be assumed that existence of the proposed additives to the formulation mixture of pastry will lead to a change in some parameters of technological stages. From the position of a systemic approach to development of the technology of bakery foods with APA, a parametric technology model should be constructed.

The found high enzyme activity of the additives, increasing the amount of reducing sugars, enhancing rheological properties of dough, makes it possible to predict changes in the ratio of certain formulation components, first of all, a decrease in the amount of yeast. But above all, it is necessary to determine to what extent biologically active compounds, especially vitamins, found in amaranth, are retained in the finished product. Only 15 % of vitamin C is known to be retained in the process of baking, while vitamin E is retained by 85 %. For this purpose, it is planned to conduct a series of test baking with APA and to study the chemical composition of finished products.

7. Conclusions

1. It was experimentally found that APA have high enzyme activity, which is proved by the high activity of the amylase complex: maltose number of 5 % water extract from dry PA foliage is 12.31±0.36 %, with addition of $CaCl_2$ (Ca^{2+}=0.01 g/l), it is 16.0±0.35 %. The obtained results indicate the prospects of using APA for enhancing baking properties of wheat flour.

2. We determined the required concentration of the additive of flour from dry PA foliage to wheat flour (1 %) for the fortification with biologically active substances, enhancement of baking properties of flour and retaining organoleptic parameters. The influence of different concentrations of APA on the content of basic biologically active substances in wheat flour, gluten running, and indicators of whiteness and color shade of wheat flour were explored.

3. It was experimentally found that APA enhance baking properties of wheat flour. High amylolytic activity of flour with APA was established: maltose number of 5 % water extract (tap water) from dry PA foliage PA is 9.42±0.34 %, from amaranth malt, it is 10.53±0.38 %. There is an increase of sugar forming, and as a consequence, gas forming capability of wheat flour. The APA demonstrates considerable proteolytic activity: flour from dry PA foliage – (η_{rel}=1.09), from amaranth malt – (η_{rel}=1.13), comparable with activity of barley malt. Application of the enzyme preparation accelerates the process of hydration of gluten proteins of wheat flour (one-hour lying of dough is not required), gluten elasticity is also improved. Thus, the expedience of the use of APA in the technology of products from yeast dough was substantiated.

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