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CURRENT AND PROSPECTIVE DIRECTIONS IN THE USE OF THE GRAIN CROPS TRITICALE

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Abstract. Triticale is a young crop that combines the main qualities of its ancestors - rye and wheat. This grain crop has a higher quality amino acid composition, which allows its use as raw material not only for special-purpose food products, but also for the feed industry. It is also less demanding of weather conditions and is resistant to various diseases, which allows increasing the grain harvest per hectare of crops. Breeding triticale varieties that combine high protein content with good biological quality is an important task for researchers. First of all, triticale is a grain crop, which allows expanding the range of foods and improving their nutritional value, since these products are in demand among consumers. Deficiency of protein and dietary fiber in the population's diet is still a pressing problem today. Triticale, in turn, can solve a number of problems associated with malnutrition, which makes research in this area promising and worthy of attention.

Keywords: *triticale, wheat, rye, chemical composition, protein, food, quality.*

Rezumat. Triticale este o cultură tânără care combină principalele calități ale strămoșilor săi - secara și grâul. Această cultură de cereale are o compoziție de aminoacizi de calitate superioară, ceea ce permite utilizarea sa ca materie primă nu numai pentru produsele alimentare de specialitate, ci și pentru industria furajelor. De asemenea, este mai puțin pretențios față de condițiile meteorologice și este rezistent la diferite boli, ceea ce permite creșterea recoltei de cereale la hectar de cultură. Creșterea soiurilor de triticale care combină conținutul ridicat de proteine cu o bună calitate biologică este o provocare importantă pentru cercetători. Studiul realizat a demonstrat o posibilă extindere a gamei de produse alimentare și îmbunătățirea valorii lor nutritive, deoarece aceste produse sunt solicitate în rândul consumatorilor. Deficitul de proteine și fibre alimentare din alimentația populației rămâne încă o problemă actuală a zilelor noastre. Triticale, la rândul său, poate rezolva o serie de probleme asociate malnutriției, ceea ce face ca cercetările în această direcție să fie promițătoare și să merite atenție.

Cuvinte cheie: *triticale, grâu, secară, compoziția chimică, proteine, alimente, calitate.*

1. Introduction

Particular interest in triticale as a valuable crop is caused by its hybrid features, combining the qualitative characteristics of rye and wheat. Despite the well-known successes of wheat breeding in developing new varieties that combine high productivity, good nutritional qualities, resistance to lodging, responsiveness to fertilizers and other valuable characteristics, it still has a weak expression of a number of important characteristics, first of all, this is insufficient resistance to the action of some unfavorable soil, climatic and environmental factors [1]. Practitioners note that the beneficial qualities of rye are poorly expressed in wheat. Wheat is very sensitive to temperature drops, excess salt, does not tolerate increased soil acidity, is more susceptible to fungi, needs organic and mineral fertilizers to a greater extent, etc. In addition, due to the ability to form a large number of spikelets in an ear (up to 50-60, with 20-25 in wheat), rye has higher potential and grain productivity [2]. The triticale ear is a combinatorial coalescence of morphological features of rye and wheat plants on which the yield depends: multi-spikelet ear (in rye), and multi-flowered ear (in wheat).

It should also be noted that protein deficiency and undernourishment in the world are increasing every year and can reach 30% in Central Africa and South Asia [3]. The data presented allow us to conclude that a fairly large part of the world's population suffers from protein deficiency - a disease that is a consequence of the imbalance between the formation and breakdown of protein. The alimentary cause of its occurrence is protein deficiency in the diet [4]. The European Union (EU) is mainly self-sustaining in agricultural area, due to its conventional policy of agriculture. Nevertheless, the EU livestock farming is severely relying on imports of proteins that are plant-based for cattle fodder. The connection between import of protein and clearcutting, if we look at it one way, and the major greenhouse gases from cattle raising, if we look at it another way, are also providing significant importance to the use of plant proteins in human nourishment. For a large number of adults living in Europe, the main source of protein is animal products such as meat and eggs, although plant sources are becoming increasingly popular [5].

The most popular source of vegetable protein for the population of the Republic of Moldova (RM) is bread and other bakery products and groceries. Bread consumption per person per year in Europe is about 58 kg. Although consumption of baked products varies greatly across the continent, in most countries the average consumption is 50 kg per capita. Examples of great bread consumers are Germany and Austria, with an average of 80 kg but in the RM the figure reaches 107 kg in 2023, while the United Kingdom and Ireland are at the bottom of the list with an annual consumption lower than 50 kg [6]. However, the nutritional value of traditional bread varieties does not fully meet the requirements of nutritionology, since the necessary balance of proteins and carbohydrates is not observed. As is known, without protein, a product cannot be considered complete, since it is what supplies our body with the necessary amino acids. The World Health Organization (WHO) sets the Safe Level of Protein intake at 0.83 g/kg/day [7].

The relevance of this work is that proteins of plant origin are currently the main resources of food and fodder protein and will not lose their importance in the near future.

Many scientists point to the primary importance of the amino acid composition of grain proteins as the most important factor in their food and feed value [8]. As is known, bread made from wheat flour is poor in the most important essential amino acid – lysine. Therefore, it is necessary to search for ways to increase the nutritional value of bread by expanding the raw material base of bakery production. In recent years, the grain crop triticale – an artificial hybrid of rye and wheat – has been increasingly recognized [9,10]. The new cereal crop has high potential yields and a number of valuable nutritional properties. Its amino acid composition is characterized by a significant content of glutamic acid, proline and a higher level of lysine, compared to wheat. All this contributes to the rapid spread of triticale culture across countries and continents and its gradual introduction into the flour-milling, baking, feed and even alcohol industries. However, despite the ongoing research on the creation, improvement and perfection of triticale crop selection, the technological features of triticale grain have still not been sufficiently studied, which does not allow for the expansion of mass production of flour and other products from this grain variety.

2. Features of triticale grain crop

Triticale is a young crop in evolutionary terms, synthesized by crossing chromosome complexes - wheat and rye. And only a little more than 30 years ago the first varieties were introduced into production. Today, its sown areas in the world amount to more than 3 Mha. The largest areas of triticale are in Poland (840 kha), Germany (537 kha), China (550 kha), Australia (400 kha), Ukraine (130 kha), in Russia they amount to 220 - 250 kha [11,12]. The interest of agricultural producers and processors in the new crop is steadily growing, the areas of its cultivation are expanding. The special interest in the crop is explained by the high potential of more complete protein content, better digestibility compared to wheat, high yield, resistance to unfavorable soil and climatic conditions, fungal and viral diseases, high winter hardiness, and reduced demands on soil fertility [13-15].

Figure 1. Triticale varieties obtained at the Institute of Genetics, Physiology and Environmental Protection, Moldova State University [22].

The term triticale arose from a combination of the generic names of the parent species of wheat - *Triticum* and rye - *Secale*. At first, this constant-intermediate hybrid was called *Triticosecale rimpau*, but the most widely used name was *Triticale*, which was proposed in his work by E. Oehler [16]. Modern varieties have been created by breeders using complex methods and genetic tools, although there are known cases of spontaneous emergence of triticale under the influence of unusual conditions during vegetation [17-20].

Today, the triticale grain crop has ceased to be a botanical curiosity and, in modern conditions, successfully competes with traditional cereals, since the nutritional value of the grain has significant advantages over other crops [21]. For several decades, it has been used in production mainly for grain fodder and green fodder. However, in recent years, breeders have been working hard to create and introduce grain varieties suitable for obtaining flour for the purpose of baking bread and flour confectionery products, Figure 1 [22].

2.2. Morphology of grain crops and their selection

There are two main types of plants according to the vegetation period: winter and spring triticale. Winter triticale can differ greatly in morphological features depending on the origin of the parental forms. The morphology of triticale grain is intermediate [23]. There are 30 to 40 spikelets in an ear. The best grain-forage varieties of triticale exceed both rye and wheat in spikelet length and the number of spikelets in an ear. Ripening triticale ears often exceed 15 cm in length and are usually awned. Triticale grains are yellowish-brown, exceeding wheat grains in length, reaching 10-12 mm in length and up to 3 mm in width [24].

An important task in breeding any grain crop is to create varieties that have ecological plasticity, high productivity and grain quality, and resistance to abiotic and biotic stress. Currently, triticale breeding has achieved significant success in the field of creating highly productive varieties.

Breeding triticale for quality is associated with a number of difficulties, such as the large phenotypic variability of quantitative traits characterizing grain quality [25]. One of the main and difficult tasks is selection for a high level of protein, with high quality. To solve such a problem, biochemical technological assessment and genetic analysis of the selection material are necessary [26-29]. One of the real and promising ways of creating high-protein forms is to search for genomes that have factors of high protein content with good quality. For this purpose, it was proposed to involve the rye genome and the A genome of wheat [30,31]. Such data allow us to assume that one of the reserves for increasing the protein content is to increase the dose of the A genome in triticale.

3. Biochemical composition of triticale

The general chemical composition of triticale grain is typical for cereal grains, a characteristic feature of which is a high content of carbohydrates and protein. It should be noted that the chemical composition of triticale grain varies widely depending on the variety, production zone, agroecological and meteorological conditions [32,33].

Protein is an important building material for our body. Every cell of the body consists of it, it is part of all tissues and organs. In addition, a special type of protein plays the role of enzymes and hormones in a living organism.

3.1. Protein-proteinase complex of triticale grain

The special interest in wheat-rye amphidiploids observed recently is explained by the ability of the crop to accumulate a significant amount of protein of high biological value in the grain [34]. The amount of protein in any grain is the ratio of the endosperm to the pericarp and aleurone layer, however, in the newest varieties of triticale, which have well-formed grain, the amount of protein is equal to or slightly higher than in soft wheat varieties.

The special value of triticale grain protein is its high lysine content, which is 15-30% higher than that of wheat, a nearly ideal amino acid balance, and a lower content of antinutrients than that of other crops. The use of triticale protein to increase biological value is preferable to the use of other sources [35,36].

Triticale grain contains: 12.1 - 14.0% water, 12.8 - 15.1% proteins, 68.8 - 71.44% carbohydrates, 1.07 - 1.7% fat, 13.1 – 16.0% dietary fiber, and 1.5 - 2.0% ash [3,22,37,38]. The grain endosperm consists of 26-28% water-soluble proteins, 7-8% salt-soluble proteins, 25-20% alcohol-soluble proteins, and 18-20% acetic acid-soluble proteins. Most authors note that the total protein content in the grain of wheat-rye amphidiploids is higher than that of rye and wheat [39,40].

The nutritional value of protein depends on its content of essential amino acids. Studies conducted in the commonwealth of independent states (CIS) countries and abroad have shown that triticale protein is characterized by a well-balanced amino acid composition, as convincingly demonstrated by the following data, presented in Table 1 [41].

Table 1

Content of some amino acids in wheat, rye and triticale grains, % of total protein content

Name	Wheat	Rye	Triticale
Lysine	3.00	4.09	3.50
Histidine	2.25	2.25	2.35
Arginine	4.36	4.79	5.22
Glutamic acid	31.18	24.95	29.93
Proline	9.46	11.00	12.01

In terms of the content of amino acids lysine, aspartic, glutamic acids, threonine, alanine, valine, tyrosine, triticale grain proteins occupy an intermediate position between the proteins of wheat and rye. According to Bugstaller, triticale contains 14% more protein, 35% more methionine and 15 % more cysteine than wheat [42].

The combination of high protein content with the productivity of the best triticale varieties provides a high protein yield per hectare, 25-45% higher than that of wheat and rye. Two hectares of crops of the best triticale varieties are equivalent in protein yield to three hectares of wheat [43]. Significant variability in the protein and lysine content of triticale grain compared to wheat indicates the possibility of further improvement of quality in this indicator in parallel with selection for increased productivity and improved grain density [44].

3.2. Carbohydrate-amylase complex of triticale grain

The most important component of triticale grain is starch. Unlike its ancestors, triticale has a lower starch content in the grain. However, in terms of nitrogen, ash, fat and phosphorus content, triticale starch is practically no different from the starch of the parent forms. Only a lower amylose content is noted.

In terms of the shape of starch grains, triticale occupies an intermediate position between the parent forms, rye starch is characterized by the smallest size of starch grains with a content of fine fraction, and wheat - the largest. Triticale grain accumulates up to 5% of sugars, only an insignificant amount is accounted for by monosaccharides, and mainly fructosides predominate, the amount of which is close to rye. The amount of alcohol-soluble carbohydrates in triticale significantly exceeds that of wheat and is comparable to rye. Alcohol-soluble sugars accumulate up to 3%, of which oligosaccharides make up about 70%, fructose 0.1-7.0%, glucose - 1.9-5.0%, sucrose – 2.0-3.0%, maltose - 4-8% [45].

It should be remembered that immature triticale grain has a low starch content. This phenomenon is associated with high activity of α-amylase, which is of great importance for the technology of processing grain into flour for baking purposes. The presence of such a factor leads to defective bread. As is known, α-amylase is active in wheat only at the time of germination, unlike rye, where it is active even in a state of full ripeness [46].

3.3. Lipids of triticale grain

Many biochemical processes occurring during storage and processing, as well as the nutritional value of grain, largely depend on the characteristics of the lipid complex. As is known, along with the energy role, lipids perform functional and structural roles. It should be noted that the composition of triticale lipids is very complex and is not an intermediate form between wheat and rye. Free lipids contain 83-89% of non-polar components, mainly triglycerides. Bound lipids contain 61-73% of polar and 27-39% of non-polar components. The main components of polar groups are fatty acids - palmitic, stearic, linoleic and linolenic [47]. Their content in grain is affected by the growing region.

The synthesis of polyunsaturated fatty acids in the human body is limited, and since the lipids of triticale contain an increased content of linoleic acid, we can talk about the increased biological value of the crop. Native lipids of grain crops contain tocopherols (vitamin E), which are in an active form in vegetable oils. They are represented by the α-form, which indicates a low antioxidant activity of their lipids. Studies have revealed a high content of phospholipids in the fraction of bound lipids of triticale, which brings this crop closer to rye [47].

3.4. Micronutrients of grain

The question of the role of mineral substances and vitamins in cereal grains in supplying the human body with these substances, as well as the question of protein composition, is of particular relevance given the relatively large share of grain products in human nutrition.

Triticale grain and its milled products are a good source of such minerals as potassium, phosphorus, magnesium, sodium, copper, zinc and iron [48]. It is noted that triticale flour has an increased content of phosphorus, magnesium and iron compared to whole-grain wheat flour.

The vitamin composition of triticale (thiamine, riboflavin, biotin, folic acid, pantothenic acid) is at the same level as wheat. However, in general, its composition is better than that of rye, with the exception of nicotinic acid [49,50].

When grinding grain, mineral substances are distributed unevenly among the milled products. The greatest amount of phosphorus, iron, and manganese is contained in the bran of torn systems, which are characterized by the highest ash content (5.03-5.38%). A positive relationship was noted between the content of protein, phosphorus and manganese. It was found that the content of mineral substances in triticale flour is usually lower than in bran. Thus, it can be said that the mineral composition of triticale is at the same level as wheat, but in general the composition is better than that of rye [51].

4. Usage of triticale in bakery

The daily human diet includes grain products: bread, bakery and pasta, of particular interest is the use of whole grain flour, which contains a significant amount of fiber, all essential amino acids, vitamins, as well as micro- and macroelements such as magnesium, calcium, potassium, sodium, iron, phosphorus, copper, zinc and selenium while having a low-cost price [52].

According to statistics, in RM the population actively consumes bakery and other flour products, in particular those made from premium and first grade wheat flour, due to their affordability, wide range and high energy value, Table 2.

Table 2

Average food consumption in the Republic of Moldova by categories [53]

Category	2021	2022	2023
Bread and flour products, kg/person	116.7	112.1	107.3
Meat products, kg/person	54.2	54.0	54.5
Dairy products, L/person	232.3	230.3	225.0
Vegetables, pumpkin and their processed products, kg/person	124.1	116.3	117.1
Fruits, berries and their processed products, kg/person	69.8	71.0	70.3

Insufficient balance of the chemical composition of such products is a problem of both quantitatively and qualitatively insufficiency of vitamins A, B, E, H, PP, dietary fiber, micro- and macronutrients in the diet [54].

One of the possible solutions is to use new raw material sources of plant origin. Triticale grain has an increased content of amino acids, including lysine, valine, leucine, etc. Therefore, triticale is the most promising for expanding the range of everyday food products. Triticale flour can be used to produce unfermented products such as waffles, muffins, gingerbread, cookies. There is sufficient data on the technology of their preparation in this area [55,56].

4.1. Flour and flour mixes

Traditional wheat and rye-wheat bread, which is the most popular among the population, has insufficient nutritional value and an imbalance of essential nutrients. The chemical composition of bread is not entirely complete in biological terms. Bread does not have a high enough protein content, and bread proteins are poor in essential amino acids, primarily lysine, tryptophan and methionine, and bread also lacks calcium salts and a number of vitamins [57].

Triticale grain has unique properties that are due to the predecessors of this crop. The whiteness of the flour and the presence of gluten proteins conventionally classify the grain as a wheat crop, and the high activity of amylolytic enzymes and the balance of proteins - as a rye crop. Due to its high frost resistance, as well as resistance to many diseases, triticale does not require treatment with additional plant protection products and the use of fertilizers. Despite the advantages of the crop in terms of nutritional value and the presence of gluten proteins, triticale grain is not in demand by the flour-milling industry as a raw material. The explanation for this is the difficulty of milling such grain according to the wheat type [58].

Today, triticale flour is mainly used as an improver and substitute for enzyme preparations, due to the high autolytic activity of flour. Methods have been developed to improve the quality and increase the nutritional value of rye and wheat bread with low amylase activity, gas and sugar-forming capacity. Various technological solutions are proposed for the possibility of using triticale flour as the main raw material for bakery production [57,58]. Flour is produced in three grades: sifted, peeled and wholemeal, in accordance with the rules for organizing and conducting technological processes at flour mills and in compliance with approved sanitary norms and rules.

The researchers also proposed a method for obtaining triticale-rye-flax flour, according to which the initial raw material is first purified, then a grinding mixture is made from prepared triticale grain, rye grain and flax seeds in a ratio of 5.0:4.3:0.7. The need to enrich bakery flour with polyunsaturated fatty acids is justified by the fact that the human body cannot synthesize ω-3 and ω-6 fatty acids due to the lack of an enzyme system [59]. The invention will make it possible to obtain food flour with a rich content of mineral elements, water-soluble and fat-soluble vitamins, tocopherols and polyunsaturated fatty acids.

Table 3

Chemical composition of the control sample and triticale-rye-flaxseed flour with increased fat and protein content [59]

Name	Moisture content, %	Fat content, %	Protein content, %	Ash content, %
Original wheat flour	14.9	1.12	11.9	0.74
Triticale-rye-flaxseed flour	13.4	4.37	13.9	3.27

Analysis of the data in Table 3 shows that the resulting products are characterized by a high content of protein and fat, which allows them to be located as a high-lipid flour mixture in the production of a wide range of bakery and flour confectionery products, including functional products.

4.2. Bread

Attempts have been made over time to use triticale in the production of bread, biscuits and various pastas, but the prevalence of its use in food production remains low. The main reasons for this are the weak gluten system, high amylolytic activity and low stability of the technological properties of triticale grain [60]. Although triticale is characterized by high α-amylase activity and weak dough rheological properties, some varieties can produce bread of acceptable quality [61].

Studies have shown that the addition of 20-25% triticale flour improved wheat bread, especially from ordinary flour with low gluten quality due to the higher activity of amylases and proteases and high gluten extensibility. More recently, researchers have shown that a mixture of up to 50% triticale flour with wheat flour produced bread with a quality similar to that of wheat flour [62]. Baking bread from triticale flour in Hungary under industrial conditions has shown that sifted flour, but with a lower ash content, and rye type with an ash content of 0.9% give a high-quality bread, intermediate in its properties between wheat and rye. It was observed that mixing wheat and triticale flour in a ratio of 1:1 has a positive effect on the rheological properties. It is recommended to add triticale flour up to 30% to bake wheat bread. Bread with triticale flour is similar to wheat bread in appearance and crumb color and has good taste and aromatic properties [62].

A number of studies were conducted by Kharkov researchers to develop a technology for producing bakery products from triticale flour. When making bread from hulled and wholemeal triticale flour, the products were of unsatisfactory quality, with a sharp sour taste, dense crumb, and cracks in the upper crust. It was also shown that the method of producing bread from triticale flour cannot fully correspond to the methods used for making bread from rye and wheat flour. Therefore, a concentrated lactic acid leaven with low acidity was added to the dough kneading. In addition, intensive kneading of the dough was excluded. Thus, new types of bakery products with increased biological and nutritional value using triticale flour are currently being actively developed [63]. Triticale bread had a specific taste and pleasant aroma, retained freshness for a long time. Systematic consumption of even 100 g of bread per day will allow the body to receive a significant share of the recommended average daily intake of essential amino acids, vitamins B, PP [64].

Ghendov-Mosanu et al. investigated the quality of different triticale varieties (Ingen 35, Ingen 33, Ingen 93, Ingen 54, Ingen 40, Fanica and Costel) grown in the RM from the point of view of the flour, dough, and bread quality characteristics. Triticale flours were analyzed for physicochemical quality and CIELab color parameters. It was demonstrated that triticale flours were suitable for bakery. According to the sensory data, all bread samples except those obtained from the Costel variety were of very good quality [22].

4.3. Biscuit and shortbread semi-finished products

One of the stable segments of the world market remains the confectionery market, which in recent years has been characterized by a constant increase in production and consumption volumes. The trend in recent years is an increase in consumer demand for healthy food products. These include functional confectionery products, including fortified ones [65].

Since triticale flour has a low gluten quality, but a high nutritional value, the possibility of its use in the production of flour confectionery products has been investigated. The effect of triticale flour on the quality of biscuit and shortbread semi-finished products has been studied [66]. In the recipes of these products, premium wheat flour was replaced by triticale flour in amounts of 20, 40, 60, 80 and 100%. Samples of finished products were analyzed in terms of sensory and physicochemical quality. As the dose of triticale flour increased, the color of the crumb of the finished product acquired a grayish hue, and the samples were characterized by uneven porosity and light compaction. The moisture content of the finished product in all experimental variants fluctuated insignificantly and remained within the limits provided by the standard (25±3%). The height of the semi-finished product slightly decreased with the increase in the dose of triticale flour from 2.6 cm to 2.2 cm [66].

4.4. Pasta

Triticale grain is a raw material for the flour and cereal industry. In addition, there is an increase in demand for products with increased biological value and functional food products, which include products with a high content of protein, vitamins, minerals [67]. To solve this problem, it is possible to use flour from modern varieties of triticale grain, which will increase the nutritional value of pasta and expand the range. Flour for the production of pasta is produced mainly in special flour mills from hard and soft high-vitreous wheat [68,69]. As a result of comprehensive studies of the physicochemical characteristics of triticale grain and the determination of the technological properties of its processed products, taking into account their quality indicators, a technology for the production of pasta flour from triticale grain has been developed, and the main technological parameters of the production process have been determined [69].

The versatility of the developed method lies in the possibility of obtaining the final product with the intended use in the form of semolina for culinary purposes or flour for the production of pasta, depending on the milling properties (vitreosity, grain hardness) [70].

Comparison of the developed method with the method for producing pasta flour from durum wheat during triticale grain processing showed that the general structure of technological operations and the selected equipment modes allow increasing the yield of semolina with a more uniform structure by size; extracting the endosperm part of higher quality grain with high efficiency; conducting an effective enrichment process, and reducing energy costs for obtaining the final product by reducing the technological process.

The quality of gluten affects the elasticity, strength (fragility), and roughness of pasta products. When producing pasta, they focus on the quality of gluten corresponding to weak groups I and II (60 - 90 units of the device IDK). Too weak gluten produces raw products prone to crushing and sticking, and strong gluten can lead to an increase in breakage and roughness of the finished product [71]. The data on the quality of gluten obtained from triticale grain indicate their compliance with weak groups I and II and also indicate a possible "strengthening" effect on the produced pasta.

Ribbon pasta is pasta formed in the form of threads that have an oval shape in cross section. During the studies, the obtained samples of pasta have pleasant organoleptic properties and are able to hold the shape of the product, among the disadvantages it is possible to highlight the dark shade of the cooked pasta. There is an insignificant difference in the coefficient of cooking, in the sample produced from flour of triticale grain of the "Bereket" variety, which indicates better dimensional stability [67]. It is also necessary to study and select additional ingredients to improve the appearance of the finished product, by adding wheat or rice flour, which will also improve the physicochemical quality indicators of the finished product. Thus, it is possible to expand the range of pasta products attractive to the consumer and endowed with increased biological value.

5. Alternative uses of triticale

Many researchers have proven that the nutritional value of food products containing substances of only animal or plant origin is low [72-75]. The use of plant raw materials in the production of milk, in addition to enriching it with functional ingredients, increases digestibility and allows you to get food products that meet human physiological norms. In recent years, scientists have been improving the technology of dairy products of high nutritional and biological value, the range of which is constantly expanding. One of the prospects for expanding the range of functional fermented milk products is the use of sources of natural biologically active substances. Such enrichments include grain crops [72].

5.1. Adding triticale culture to yogurt

The effect of triticale grains on the sensory properties, nutritional and biological value of a new yogurt with the addition of triticale grains was studied. Crushed triticale grains were used as a filler [72]. It was shown that the presence of 1.5% triticale grains in yogurt influenced the taste and smell, being very pleasant. The taste was slightly specific to triticale grains, the consistency was uniform. The taste and smell of the sample with 2% triticale grains, unlike the previous sample, had a slightly floury taste. The mixture was evenly distributed in the product volume. The consistency was uniform. The specific taste and smell of triticale grains in the 5% yogurt sample was very clearly visible. The mixture of triticale grains was unevenly distributed in the product volume, the consistency was uneven. During the sensory analysis, yogurt with 1.5% and 2% triticale received 4.8 and 4.6 points out of 10 for taste and smell. Thus, the introduction of ground triticale grains into the yogurt production recipe enriches the product with vitamins, microelements and dietary fiber, increases its shelf life, improves sensory properties and does not require changes in the technological process of product production. Given the good taste properties and chemical composition of triticale grains, the production of yogurt with plant components allows improving its nutritional and biological properties and expanding the range of fermented milk products in the functional direction [72].

5.2. Using infrared radiation (IR) to make ready-to-eat breakfast

Currently, one of the areas of development of grain processing technology is the production of new types of products that do not require long cooking. These are, for example, baby and dietary food, ready-to-eat breakfast cereals. The application of infrared (IR) rays is especially promising in the production of such products. Dry breakfast cereals from cereal raw materials obtained by IR processing are widely used in the population's nutrition [73]. At the same time, it is necessary to address the issue of expanding the raw material base for the production of ready-to-eat breakfast cereals, in particular, using triticale grains. Various rational ways of IR processing of triticale grains to obtain a new product with high nutritional value and high content of dietary fiber in the form of flakes have been investigated. IR-processed triticale cereal flakes can be used as a ready-to-eat product in the form of dry breakfast cereals [74].

Slow heating of the grain resulted in its gradual drying. The moisture contained inside the grain was removed from it without damaging the grain structure. Rapid heating of triticale grains resulted in the evaporation of moisture inside the grain, which led to an increase in the water vapor pressure inside the triticale grain [75]. The grain "explodes" from the inside, leading to the destruction of the structural framework of the grain. The use of short-wave IR radiation of 0.9–1.1 μm for treatment of triticale grains ensures uniform heating of the grain throughout its volume. Treatment of triticale grains with IR rays, which causes the grain to "explode" from the inside, significantly affects the state of all grain components, affecting protein, carbohydrate and lipid complexes. The nature and depth of changes depend on the IR treatment modes. The carbohydrate complex of triticale grains, and primarily starch, undergoes the greatest changes as a result of IR treatment. Since water vapor fills the entire intermolecular volume, all starch granules of triticale grains are destroyed. The peeling of grains is accompanied by additional destruction of starch and an increase in the amount of dextrins in the product. Intensification of IR treatment leads to an increase in the amount of crumbs when flattening the grains. Immediately after IR processing, triticale grains are flattened into flakes while hot. The technology of obtaining a new food product from whole triticale grains allows for the preservation of fiber, which is explained by the presence of triticale grain husks during IR processing [76]. Thus, a new product in the form of triticale grain flakes was obtained, which has a high nutritional value and a high content of dietary fiber. It has a good appearance, a pleasant smell and taste, practically does not require cooking and is made available by simply adding boiling water or milk and can be used as a dry breakfast.

6. Conclusion

Triticale is a grain crop that undoubtedly has a promising future. At the present stage, it is already rightfully considered a viable commercial grain crop used in the production of human food and feed. The growing interest in the crop is caused by its great potential, as it is adapted to the conditions of all regions where wheat and rye grow. Increasing aridity, the manifestation of other abnormal phenomena of climate and agriculture create conditions for greater preference for triticale in agricultural production compared to other cereals. In such situations, the advantage of new hexaploid triticale varieties becomes especially obvious. Being a hybrid, triticale embodied in its genome the highest ecological plasticity of winter rye.

Triticale combines the best features and properties of the parent species: it has large grain, contains a higher mass fraction of protein, and significantly exceeds other grain crops in terms of total protein yield per hectare. Breeding triticale varieties that combine high protein content with good biological quality is a difficult task due to the instability of the quantity and quality of protein in grain depending on the place of grain cultivation. In order to improve the biological quality of triticale protein, it is necessary to use wheat and rye varieties with high nutritional and feed value.

The above allows us to draw a conclusion about the advisability of further in-depth studies of the technological properties of triticale grain and flour in order to determine valuable and promising varieties for their effective use in the production and expansion of the range of bakery products. As well as continuing research in the field of developing technologies for dietary, therapeutic and prophylactic food products from triticale flour. When developing technologies and recipes for bakery products from triticale flour, it should be remembered that the production should be based on the principle of suppressing excess enzymatic hydrolysis of starch under the action of amylases during dough fermentation and bread baking, as well as increasing the initial acidity of the dough. The results of breeding, biochemical and technological studies presented in the monograph showed high efficiency of triticale production and its use for food and industrial purposes, which allows us to transfer this crop from the ranks of "scientific" to the category of industrial crops. And the scientific achievements obtained in this area of research should become the basis for further scientific forecasting in the work of breeders, agronomists and technologists.

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