

IMPROVING THE PROCESS OF HYDROTHERMAL TREATMENT AND DEHULLING OF DIFFERENT TRITICALE GRAIN FRACTIONS IN THE PRODUCTION OF GROATS

V. Liubych

Doctor of Agricultural Sciences, Professor*

V. Novikov

PhD*

E-mail: 1990vovanovikov1990@gmail.com

V. Zheliezna

PhD, Senior Lecturer*

V. Prykhodko

Teacher

Department of Plant Growing**

V. Petrenko

PhD

Laboratory of Grain Milling and Bakery Technology

Institute of Food Resources of National Academy of Agrarian Sciences

Sverstyuka str., 4A, Kyiv, Ukraine, 02002

S. Khomenko

Doctor of Agricultural Sciences, Senior Researcher, Head of Laboratory

Laboratory of Spring Wheat Breeding

The V.M. Remeslo Myronivka Institute of Wheat of National Academy

of Agrarian Sciences of Ukraine

Tsentralna str., 68, vil. Tsentralne, Kyivska reg., Ukraine, 08853

V. Zorunko

PhD, Associate Professor

Department of Plant Protection, Genetics and Breeding

Odessa State Agricultural Experimental Station

of the National Academy of Agrarian Sciences of Ukraine

Maiatska doroha str., 24, smt. Khlebodar,

Belyaevsky dist., Odessa reg., 67667

O. Balabak

PhD, Senior Researcher

Department of Genetics, Selection and Reproductive Biology of Plants

The National Dendrological Park "Sofiyivka"

of the National Academy of Sciences of Ukraine

Kyivska str., 12a, Uman, Ukraine, 20300

V. Moskalets

Doctor of Agricultural Sciences, Senior Researcher***

T. Moskalets

Doctor of Biological Sciences, Associate Professor***

*Department of Technology of Storage and Processing of Grain**

**Uman National University of Horticulture

Instyutska str., 1, Uman, Ukraine, 20305

***Department of Selection and Technological

Institute of Horticulture of the National Academy of Agrarian Sciences

Sadova str., 23, vill. Novosilky, Ukraine, 03027

Досліджено вплив водотеплового оброблення (зволожування зерна) та тривалості луцення на вихід і якість крупи із зерна різних фракцій тритикале. Проведено порівняльний аналіз виходу крупи і кулінарну її якість за різної вологості зерна залежно від його фракцій. Встановлено ступінь впливу досліджених чинників на вихід і якість крупи тритикалевої. Достовірним є вплив тривалості луцення, розміру зернівок тритикале та вологості зерна. Ці чинники істотно впливали на вихід і якість крупи. При цьому вплив тривалості луцення зерна був найбільшим. Найвищий вихід крупи отримано за тривалості луцення впродовж 20 с, найнижчі – за луцення 180 с.

Проведено соціальні дослідження та встановлено основні пріоритети для покупок круп'яних продуктів. Доведено, що найбільше значення під час вибору продуктів харчування споживачами приділяється кулінарним характеристиками готового продукту.

Встановлено, що оптимально луцити зерно тритикале впродовж 100 с. Застосування таких параметрів оброблення дозволяє отримати вихід крупи цілої 88,8% з кулінарною якістю 6,7 бала. Якість крупи відповідає вимогам ДСТУ 76992015. «Крупи пшеничні. Технічні умови».

На основі досліджень встановлено, що ефективним є розділення зерна тритикале на фракції, що відрізняються за геометричними властивостями, зокрема товщиною. Визначено особливості виходу крупи залежно від фракції зерна тритикале. Застосування водотеплового оброблення зерна тритикале (зволожування до 14,0%) дозволяє підвищити вихід крупи до 88,7%. Оброблення фракцій, що мають товщину зерна меншу 2,4 мм забезпечує вихід крупи до 87,8%. Вихід крупи під час луцення зерна, що має товщину більше 2,4 мм, становить від 88,8 до 89,1%.

Для виробництва крупи із зерна тритикале доцільно використовувати зерно, що має товщину 2,8 мм і більше. Оптимальна тривалість луцення становить 100 с. Для підвищення загальної кулінарної оцінки на 1 бал рекомендовано збільшувати тривалість луцення крупного зерна до 140 с. Відмінність від класичного способу полягає у використанні крупної фракції зерна з нижчою його вологістю.

Розроблені рекомендації можуть бути використані зернопереробними підприємствами під час перероблення тритикале для інтенсифікації виробництва

Ключові слова: водотеплове оброблення, луцення, фракції зерна, тритикале, вихід крупи, кулінарне оцінювання

Received date 06.04.2020

Accepted date 19.05.2020

Published date 30.06.2020

Copyright © 2020, V. Liubych, V. Novikov, V. Zheliezna, V. Prykhodko,

V. Petrenko, S. Khomenko, V. Zorunko, O. Balabak, V. Moskalets, T. Moskalets

This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0>)

1. Introduction

According to the Eurostat data [1], grain crops are one of the world's major sources of food, which makes up

about 300 million tons annually. Gross grain production in Ukraine, according to the State Statistics Service (2019), amounted to 75.1 million tons [2]. Products of grain processing are consumed worldwide [3, 4].

Triticale (*X Triticosecale* Wittmack) is a kind of grain culture of technogenic origin, obtained through the hybridization of wheat and rye. It was created for the combination of industrially valuable properties of parental forms. It has high growth energy, resistance to cold, and a high content of rye protein and medium bakery characteristics of wheat gluten. This crop has a series of technological advantages compared to wheat and rye. Triticale usually develops well under conditions of abiotic stress compared with wheat [5]. In addition, triticale is characterized by high resistance to fungal diseases [6]. However, plants do not have resistance against the damage by *Claviceps purpurea* [5]. Biochemical indicators of triticale grain vary in a wide range (Table 1). However, by the content of dietary fibers (pentoses, β -glucan), it is inferior to the grain of wheat, rye, and barley.

Table 1

Biochemical composition of grain, % per dry substance [7–9]

Indicator	Crop			
	Wheat	Rye	Triticale	Barley
Starch	52.1–64.5	46.5–59.7	52.7–63.9	42.3–58.1
Protein	7.6–15.8	5.6–11.3	6.8–16.0	6.7–14.3
Pentoses	3.5–7.0	5.9–10.2	9.1–14.0	5.8–7.5
Fat	1.7–2.2	1.3–2.7	1.5–2.4	1.9–3.5
β -glucan	0.3–1.2	1.3–1.7	0.8–3.0	3.1–5.5

The grain contains more lysine compared with wheat [10, 11]. The content of gluten in the triticale grain is by 20–30 % lower compared with wheat [12]. The grain contains more dietary fibers. The products of triticale grain processing are of high culinary quality [13].

World production of triticale is more than 20 million tons per year, half of which falls on Germany and Poland. Despite the high technological properties of grains, triticale flour is not widely used in the food industry. A significant part of the triticale grain is used for feeding farm animals [5].

Triticale grain has high dietary properties [14]. The constituents of the grain positively influence the intestines, reduce the release and absorption of glucose, control cholesterol content in the blood. It is obvious that triticale grain products will have a similar effect on the human body. Therefore, in order to take advantage of the beneficial nutritional properties, it is necessary to conduct research into the quality of grain products from triticale.

In addition, groats production is attractive for investing due to a low risk of capital investment. Taking into consideration large volumes [2, 5] of triticale grain production and its high technological properties, there arises the need to search for some rational ways of its processing. Insufficient information on cereal properties of the triticale grain leads to a decrease in the efficiency of processing productions [15].

The currently known way [18] of intensification of the technologies of grain processing due to its fractionation for triticale is not used, and the level of research into this issue is insufficient. Therefore, priorities include:

- description of the mechanism of multiple rubbing out of the triticale grain of various fractions in hulling machines of periodic action, depending on the hydrothermal treatment;
- establishment of dependences through a comprehensive analysis;

- application of reliable organoleptic evaluation to reduce a subjective factor.

Improvement of parameters of hydrothermal treatment and dehulling of different fractions of triticale grain will make it possible to predict more accurately the indicators of groat production. In addition, it is necessary to optimize the groats yield at high quality indicators. Therefore, it is relevant to conduct appropriate scientific research.

2. Literature review and problem statement

Triticale, the crop that is currently known in the world, is used for food and fodder purposes (green fodder, silage, and hay). In addition, it is also an energy culture [12].

Triticale flour is used to replace rye in the formulation of wheat and rye bread. The resulting bakery products have a rye flavor of sorts of the soft-grain type of hardness, triticale is used to make waffles. Technologically, there are no specific properties and recommendations, which differ from wheat flour [13].

Triticale is suitable for producing a range of products: cakes, biscuits, muffins, waffle products, noodles, and spaghetti [14]. However, these studies do not deal with the use of triticale grain for the production of groats. Obtaining groats and cereal products is an important direction of processing. Groats are the raw material to produce independent products or as a component of products that are in great demand among the population of many countries [15]. There are the known studies, in which triticale is used separately or in mixtures with other grain groats for the production of high-quality snacks, prepared by means of extrusion or grain rupture [16]. However, the whole groats contain more biologically active substances compared to the crushed groats [17].

It was established that the grain quality varies depending on the growing conditions [18, 19] and varieties [20]. This determines the quality of products of its processing. In addition, the quality of the finished product depends on the elements of grain processing technology [21]. The groats yield and quality are significantly influenced by moisture content and grain dehulling duration. Hydrothermal treatment is one of the technological operations, which has a significant impact on the changes in the physical properties of the grain. Its application significantly affects the range and nature of changes in the internal structure of the processed raw materials. Improvement of the modes of hydration and tempering of the grain of hard varieties of wheat makes it possible to decrease the energy consumption of the technological process by 40–50 % [23]. The effectiveness of it greatly depends on the grain shape and its other geometric parameters [22]. The analyzed studies [18–22] refer to the wheat grain. In addition, the formation of culinary quality, depending on the elements of processing technology, has not been studied sufficiently. In Ukraine, the yield of whole groats from wheat grain in the production is about 60–70 % of the grain weight [24]. In paper [25], the moistening of triticale grain from 9.0 to 17.0 % increased the groats yield by 9.7 %. An increase in the groats yield contributed to a lower content of feed middling and broken endosperm. However, the total groats yield changed from 57.4 to 66.3 %, depending on the moisture content of grain. A low groat yield was caused by a long grain dehulling, which adversely affects the biological value of the finished product.

The use of the hydrothermal treatment of grain can affect an increase in the absorption of separate microelements [27]. The grain dehulling reduces the biological value of the finished product less due to incomplete removal of shells. Application of the longest grain dehulling does not completely ensure the removal of shells, aleurone layer, and the germ [28]. They are known to contain more microelements, polyphenols, fiber, and phytochemical compounds.

The technical indicators of groat production and the quality of finished products from soft wheat grain were studied partially. In papers [29, 30], the authors developed the scheme and parameters of the hydrothermal treatment of rolled groats, which does not require cooking by means of infrared radiation of the radiation flow power of 50–60 kW/m². In this case, it is established that the optimum index of grain dehulling was 4–5%. Culinary quality of rolled groats increased in comparison with the grain. However, the developed parameters of hydrothermal treatment are related to the rolled grain, the technological scheme of which is significantly different from that of the whole one.

It was established that it is optimal to dehull the spelt wheat grain for 120 s. The dehulling index at the same time is 10.9%. The consistency of cereal during boiling and overall organoleptic assessment is high (7.0–8.6 points). That is why the optimum dehulling index for spelt wheat grain is 11–13%. Grain moistening up to 15–16% and tempering for 30 min increases the groats yield by 1.5–3.0% [31]. However, studies [29–31] used the grains of wheat and barley, the technological properties of which differ significantly from those of triticale. In addition, specific features of processing the grains of various fractions were not studied.

The grain sorting into fractions by dimensions is an important element of groat production. Fractionation is carried out to intensify the operation of hulling machines, in particular, to increase the efficiency of grain dehulling. Grain fractionation is economically feasible at high-performance enterprises [30]. The studies revealed that the dehulling of the triticale grain of some fractions can increase the groats yield by 0.4–2.1% [26].

Under conditions of market relations, inherent to modern manufacturers of cereal products, the important place belongs to their competitiveness, which depends significantly on the quality of the finished product and its availability for consumers. The competitiveness of cereal products depends on their appearance, nutritional and biological value, and safety level.

Determining the quality level of the finished product is subjective. Subjectivity is caused by the disadvantages of expert methods of assessing the culinary characteristics and appearance of the finished product. That is why the significance coefficients obtained by the expert method should be verified under conditions close to the market conditions, in particular, by conducting social surveys.

Papers [23–25, 32] prove the reliable influence of dehulling modes on the yield and culinary quality of the groats from triticale grain. The yield of whole groats, in this case, was 77–95% and increased by 0.7–1.2% depending on the parameters of hydrothermal treatment. However, the influence of the parameters of hydrothermal treatment on the specified indicators of the grain of different fractions was not established. In addition, the research into the dehulling process was carried out using the simplest methods of correla-

tion and variance analysis, which does not make it possible to create mathematical models of the process.

It is possible to significantly enhance the quality and technological properties of food grain due to using the fractionation process [33, 34].

Grain separation into parts, which are similar in geometric or aerodynamic properties, make it possible to separate a large fraction of enhanced quality without significant deterioration in the quality of a medium-size fraction. In addition, the grain mixture leveled by the geometrical features makes it possible to intensify the dehulling process and hydrothermal treatment of grains.

Nowadays, the practical application of the fractionation stage exists in the technology of processing buckwheat grain into groats, which is characterized by the formation of six grain fractions and their separate treatment [35]. A substantial increase in material consumption of process and energy consumption for the production of the finished product during the implementation of the fractionation process is negative. However, during processing the buckwheat grain into the groats, energy consumption, associated with fractionation, are reasonable. It is possible to minimize the yield of cracked grain and increase the efficiency of grain dehulling only in this way.

In the technologies of wheat, rye, and triticale processing, fractionation can be used at the stage of grain peeling, but, subsequently, the fractions are not processed. However, they differ significantly in their properties. Thus, in paper [36], it was proved that the biochemical composition (protein and gluten content) of grains of different fractions differs significantly. Technological properties of the grain of different fractions (weight of 1000 grains and the grain nature) are also different. The main recommendations of the research include the use of the fractionation process for a controlled change in the grain mass.

The relevance of using fractionation at the stage of peeling the barley and rye grain was substantiated in papers [37, 38]. However, the technological properties of different fractions of grain were studied insufficiently. The corresponding issue was partly resolved in article [39]. It was proved that fractionation of wheat grains results in significant improvement of its flour milling properties. The quality of bread, made of flour, obtained from a large fraction of wheat grains, was significantly higher compared to the bread made of small-fraction flour. The problem of processing the grain of various triticale fractions was partially tackled in papers [9, 26], in particular, the technological properties of different fractions of triticale grains were studied.

It follows from the research results [37, 38] that it is effective to separate the grain mass by the parameter of caryopsis thickness. The separation of grain by thickness is made by using metal-stamped punching sieves with rectangular openings. The corresponding sieves have a standard length of openings (20 mm), but their width varies in a wide range.

The efficiency of fractionation, proved in papers [37–39], requires an additional study for the 4-type triticale grain due to the differences of its properties from the crops considered in these studies. The papers dealing with the issues of triticale fractionation [9, 26] did not propose an efficient way of using its separation into fractions and their separate processing into dehulled groats of the maximum culinary

quality and attractive appearance. Currently, there are no recommendations for processing the 4-type triticale grain of different sizes with respect to the opinions of end consumers of similar products. It is necessary to establish the mechanisms for changing the yield and culinary quality of groats, depending on geometric sizes of grain and the modes of its processing, which is an interesting issue from the theoretical point of view. Elimination of the identified shortcomings will make it possible to improve the typical technological processes of triticale grain dehulling and moistening during the groats production. This makes the prerequisites for the transfer of the obtained technological solutions and their use under conditions of existing cereal factories of different productivity.

3. The aim and objectives of the study

The aim of this study was to improve the modes of moistening and dehulling of different fractions of triticale grain according to the yield and culinary quality of the finished product. This will make it possible to produce the groats from triticale No. 1, which has a high culinary quality. The quality indicators of groats will meet the requirements of DSTU 76992015 “Wheat Groats. Technical specifications”. The obtained research results will be valuable for low-productivity enterprises.

To achieve the aim, the following tasks were set:

- to determine the parameters of optimization of the process of hydrothermal treatment taking into consideration social surveys of potential consumers of dehulled groats;
- to establish the influence of moistening and dehulling of triticale grain of different fractions on the groats yield;
- to substantiate the rational modes of processing the triticale grain into groats;
- to study the culinary quality of groats, depending on the parameters of groats production.

4. Materials and methods to study the influence of production parameters on the yield and quality of groats

4.1. Raw material to study the fractionation efficiency in the groats production technology

The grain of four-type triticale of the Strategist variety, which had the highest protein content, the amino acid composition of which was better balanced compared to the other samples, was used for the research. The raw material was cultivated under Pravoberezhny forest-steppe conditions (at the Educational and Production Department

of Uman National University of Horticulture (the city of Uman, Ukraine)).

4.2. Program, procedure, and equipment to study cereal properties of different fractions of triticale grain

The research was conducted in a laboratory at the Department of Grain Storage and Processing, the Uman National University of Horticulture (the city of Uman, Ukraine).

The process of making dehulled groats from triticale grain, including the fractionation stage, was simulated under laboratory conditions (Fig. 1).

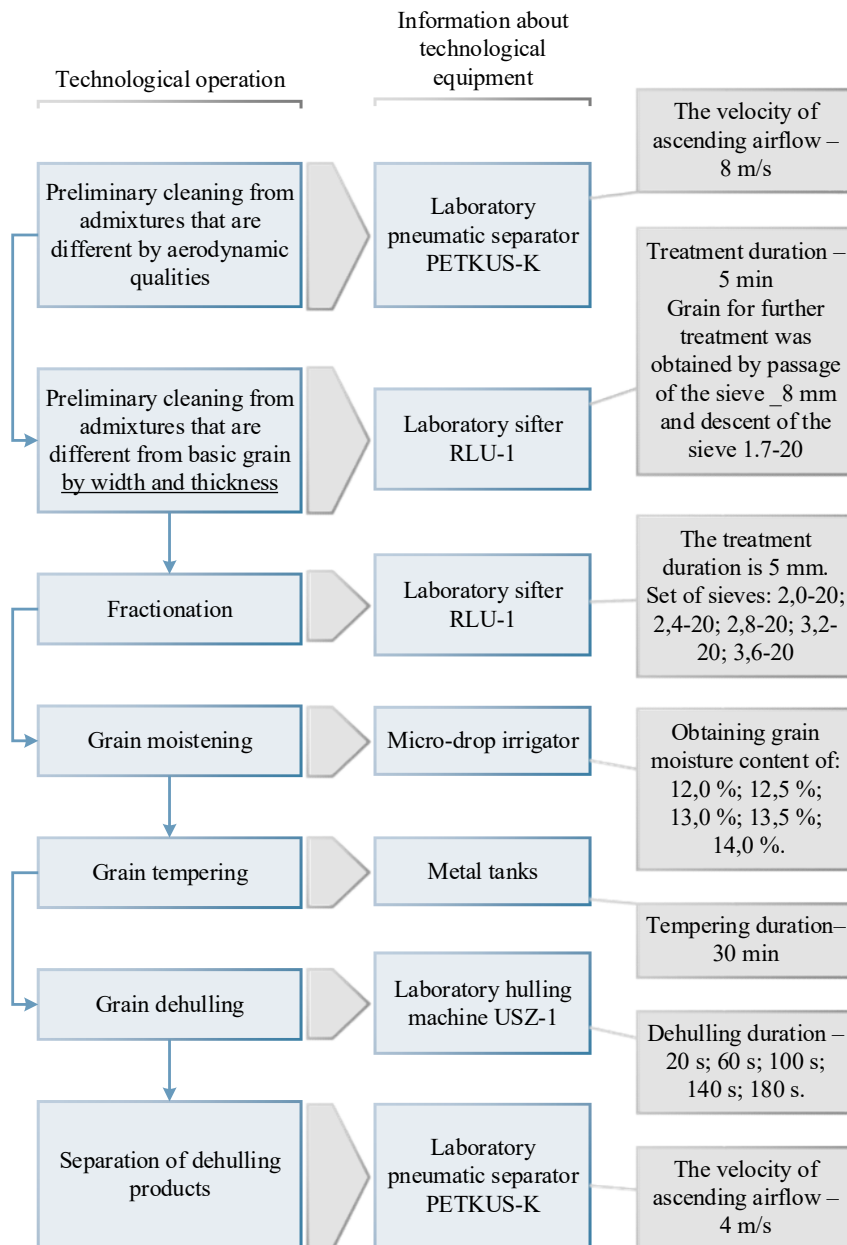


Fig. 1. A principal diagram of the production of dehulled groats under laboratory conditions

During the studies, the grain was divided into 5 fractions using the sieves with rectangular openings. Given the peculiarity of the separation of grain mass by geometric dimensions, the fractions, obtained by the passage and descent

of certain sieves, had in their composition the grain of the thickness that varied between the working dimensions of the corresponding sieves. For example, the thickness of the grain obtained by passage of the sieve 3.2×20 and descent of the sieve 2.8×20 ranged from 2.8 to 3.2 mm. The detailed characteristics of the fractions are shown in Table 2.

Table 2
Characteristics of the thickness of different fractions of triticale grain

Fraction No.	Conditions of obtaining	Grain thickness, mm
1	passage of sieve 2.0×20	<2.0
2	passage of sieve 2.4×20 descent of sieve 2.0×20	2.0–2.4
3	passage of sieve 2.8×20 descent of sieve 2.4×20	2.4–2.8
4	passing the sieve 3.2×20 descent of sieve 2.8×20	2.8–3.2
5	descent of sieve 3.2×20	>3.2

The resulting factions were treated according to the plan of a full factor experiment (Table 3)

Table 3
Pitches and variation levels of the experiment for establishing the influence of production parameters on its effectiveness

Level	Dehulling duration, s	Moisture content, %
minimal	20	12.0
0	100	13.0
Maximal	180	14.0
Pitch	80	1.0

The factor of tempering duration was not studied. According to the recommendations for processing the wheat grain, we chose the mode for all variants, which included the tempering duration of 30 minutes.

200 respondents were questioned during conducting social surveys. The overall characteristics of the respondents are shown in Table 4.

Table 4
Age characteristic and level of income of respondents

Parameter	Number of respondents	Percentage of respondents
Age characteristic		
below 20	38	19
20–30	56	28
30–50	66	33
above 50	40	20
Level of income		
Low	32	16
Medium	118	59
High	42	21
Very high	8	4

The survey was conducted randomly in leading retail chains and small grocery stores. They were conducted in Uman, Ukraine.

The culinary quality was determined according to the improved procedure [43]. The assessment was conducted by the Commission, whose competence was very high (82 points). The procedure for determining competence is shown in [44]. Overall culinary assessment (OCA) was determined from the following formula:

$$OCA = \frac{S + T + C_1 + C_2 + C_3}{5}, \text{ points}, \tag{1}$$

where *S* – smell, points; *T* – taste, points; *C*₁ – consistency, points, *C*₂ – consistency of cereal during chewing, points, *C*₃ – color, points.

4. 3. Statistical treatment of experimental data

The study was conducted in four repetitions, which were randomized in time. The results were processed using the Microsoft Excel 2010 and Statistica 12 software according to the guidelines given in [40, 41].

5. Results of studying the influence of parameters of hydrothermal treatment, dehulling of different fractions of triticale grain on the yield and quality of groats

5. 1. Priority criteria for the optimization of triticale processing into cereal products

In order to identify the actual criteria for optimization of production of groats, dehulled from the four-type triticale grain, the social survey using the questionnaire method was conducted. The survey results were generalized and the respondents’ opinions were distributed by priorities from a very low to a very high. A very high priority regarding the set problem meant its paramount importance when choosing a product. A very low testified to its insignificant or unprincipled value.

The appearance of dehulled groats was important for the respondents (Fig. 2). Thus, 10 % of the respondents gave advantages only to the products that had an attractive appearance (packaging, the physical appearance of cereal products, the color of products, etc.). However, most of the respondents (46 %) did not pay attention to the appearance of dehulled groats.

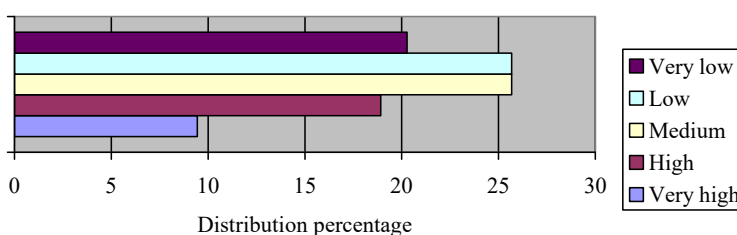


Fig. 2. Distribution of consumers’ opinions regarding the priority of product physical appearance when they make a purchase

Quite a small number of respondents (3 %) paid attention to the chemical composition of dehulled groats before purchasing them. Most respondents did not pay significant attention to this factor, and 19 % of the consumers have never paid attention to the chemical composition of the products before purchasing them (Fig. 3).

Compared to the appearance of food products, their organoleptic characteristics were the most significant when consumers were choosing them. The survey found no respon-

dents who had a very low priority of the culinary quality of the finished product. The low value of the organoleptic parameters of foodstuffs was found in 4% of the respondents (Fig. 4).

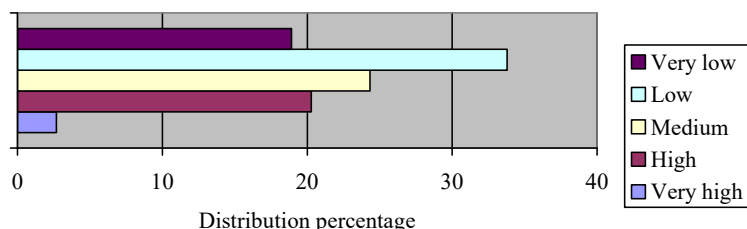


Fig. 3. Distribution of consumers' opinions regarding the priority of the chemical composition of products

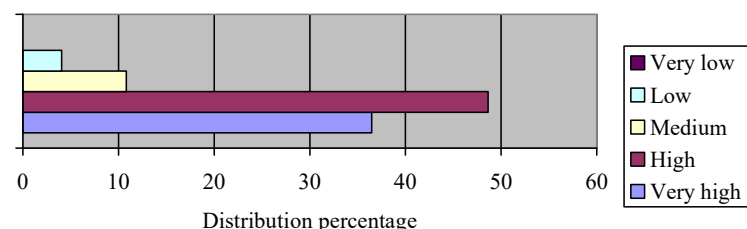


Fig. 4. Distribution of consumers' opinions regarding the priority of organoleptic properties of products

Thus, out of the main factors that form the quality of the finished product, only its culinary characteristic has significant importance for its final consumer. Therefore, studying the dependence between different geometric dimensions of triticale grains, the yield of the finished product and its culinary characteristics is relevant.

5. 2. The influence of parameters of the hydrothermal treatment and dehulling the grain of different fractions of triticale grain on groats yield

The methods of variance analysis revealed the reliable dependences between the groats yield and grain dehulling duration, its humidity before dehulling, and thickness of the processed grain (Fig. 5).

Moistening of grain has a step-like character due to its anisotropy. The moisture penetration to the internal layers of caryopsis depends on many factors, in particular, moistening gradient, tempering duration, the temperature of water and the environment. In addition, the flow of the moistening process is significantly influenced by the characteristics of surface layers of caryopsis (shells and the aleurone layer). The grain that was larger in size was characterized by larger content of endosperm (Fig. 6).

On the contrary, the content of shells was less compared to small grains. The thickness of the surface layers was similar in all the studied fractions, and the endosperm content was different. That is why a decrease in endosperm content resulted in a proportional increase in the percentage of shell content. The effectiveness of the application of moistening of large grain was higher compared to the effectiveness of the moistening of small grain because the thickness of their surface layers did not differ significantly, but the large grain had a larger area of the outer surface.

The greatest influence on the groats yield was made by grain dehulling duration (Fig. 7).

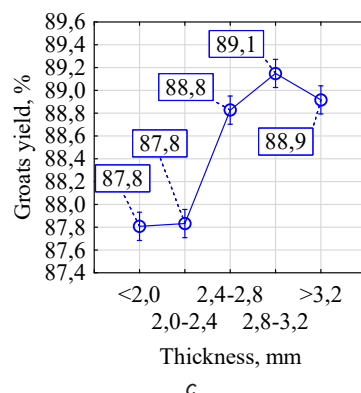
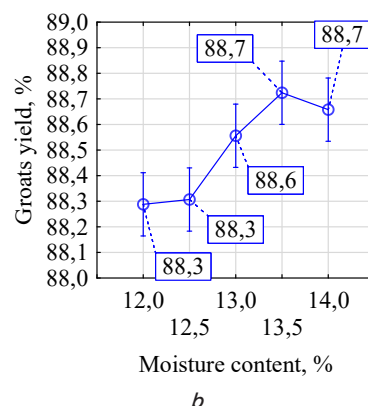
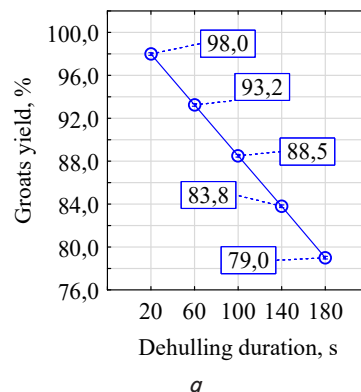


Fig. 5. Influence of the initial moisture content of grain, its dehulling duration and thickness on groats yield: a – influence of dehulling duration; b – the influence of moisture content; c – the influence of grain thickness

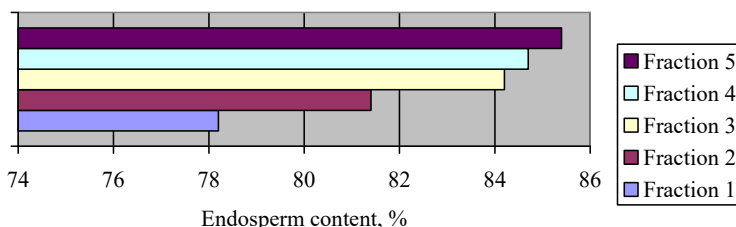


Fig. 6. Endosperm content in different fractions of triticale grains

The level of influence of grain thickness was 5 times as high compared with the influence of its moisture content before dehulling. The significance of moistening increased as a result of fractionation.

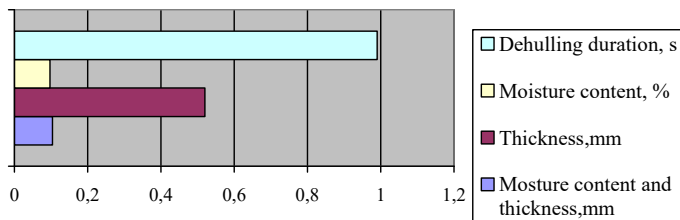


Fig. 7. The degree of influence of parameters of hydrothermal treatment, dehulling and geometric dimensions of grain on groats yield

5. 3. The influence of parameters of hydrothermal treatment and dehulling of triticale grain of different fractions on the overall culinary assessment of groats

The conducted social research revealed significant importance of culinary characteristics of the finished product for the finished consumer. Additional costs for fractionation of triticale grain in the production of cereal products can be leveled by the cost of the finished product of enhanced culinary quality and steady demand for it.

The influence of parameters of dehulling, hydrothermal treatment of grain, and its geometric sizes on the overall culinary assessment of groats was similar to the influence of corresponding factors on the groats yield (Fig. 8).

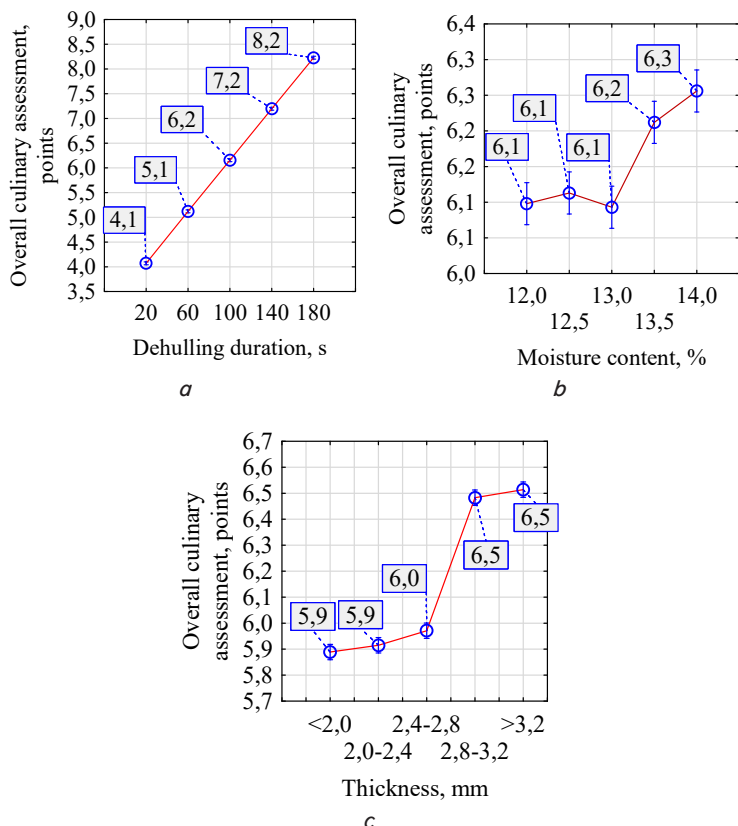


Fig. 8. Influence of initial moisture content of grain, its dehulling duration and thickness on the overall culinary assessment of groats: *a* – influence of dehulling duration; *b* – the influence of moisture content; *c* – the influence of grain thickness

The overall culinary assessment of groats significantly increased as a result of the increasing duration of grain dehulling (Fig. 8, *a*). For the culinary quality of the whole dehulled grains (such as Poltavska No. 1), the content of

shells is significant, but the specified indicator is not regulated by current DSTU 7699:2015 “Wheat groats. Technical specifications”. A significant number of shells significantly increase the duration of cooking the cereal. It decreases the culinary quality of the finished product by the indicators of consistency, consistency during chewing, color, and smell. That is why the variants with the highest degree of removal of surface layers (maximum dehulling duration) had the largest overall culinary assessment. An increase in grain moisture content before its dehulling had a positive influence on the culinary quality of groats. The best groat quality was found during the processing of large grains (thickness over 2.8 mm).

The degree of influence of the factors on the culinary assessment of groats is shown in Fig. 9.

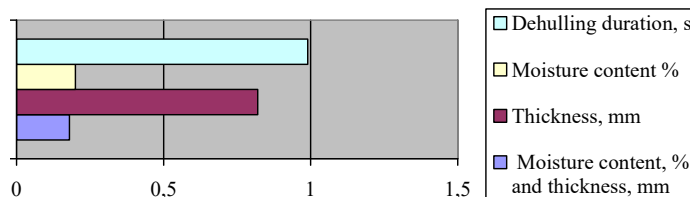


Fig. 9. Degree of influence of parameters of hydrothermal treatment, dehulling and geometric dimensions of grain on the overall culinary assessment of groats

Grain thickness, its moisture content before dehulling and dehulling duration had a stronger connection with the culinary assessment of groats compared to their influence on the groats yield (Fig. 6, 8). The common effect of a change in the geometric dimensions of the grain and its humidity before dehulling on the culinary assessment of groats was twice as strong in comparison with the effect of these factors on the groats yield.

5. 4. Rational modes for processing different fractions of triticale grain into dehulled groats

The optimum modes of processing the triticale grain were selected according to the results of the construction of generalized desirability function. Generalized desirability function included the influence of all weight factors on the yield and culinary assessment of the finished product. The optimization conditions were to find the modes for obtaining the highest groats yield at its best culinary quality. The limitation was the minimum number of points of the overall culinary assessment. We accepted for consideration only the option, the culinary assessment of which was more than 5 points, which corresponds to the satisfactory groat quality.

According to the results of statistical treatment, it was determined that dehulling the large grain (the thickness of 2.8 mm) for 100 s satisfies the set requirements by 55 % (Fig. 10). Grain moistening before dehulling up to 14.0 %

had a positive effect. Given a low degree of influence of the factor of moistening of triticale grain before dehulling, it is possible to perform dehulling at its actual humidity from 13.0 to 14.0 %. It is appropriate to exclude hydrothermal

treatment from the technology of processing the triticale grain into groats for new enterprises of low productivity since it will significantly reduce capital investment and associated risks.

on of respondents' opinions indicate low consumer awareness of the issues of nutrition, which requires intensive work in the corresponding direction.

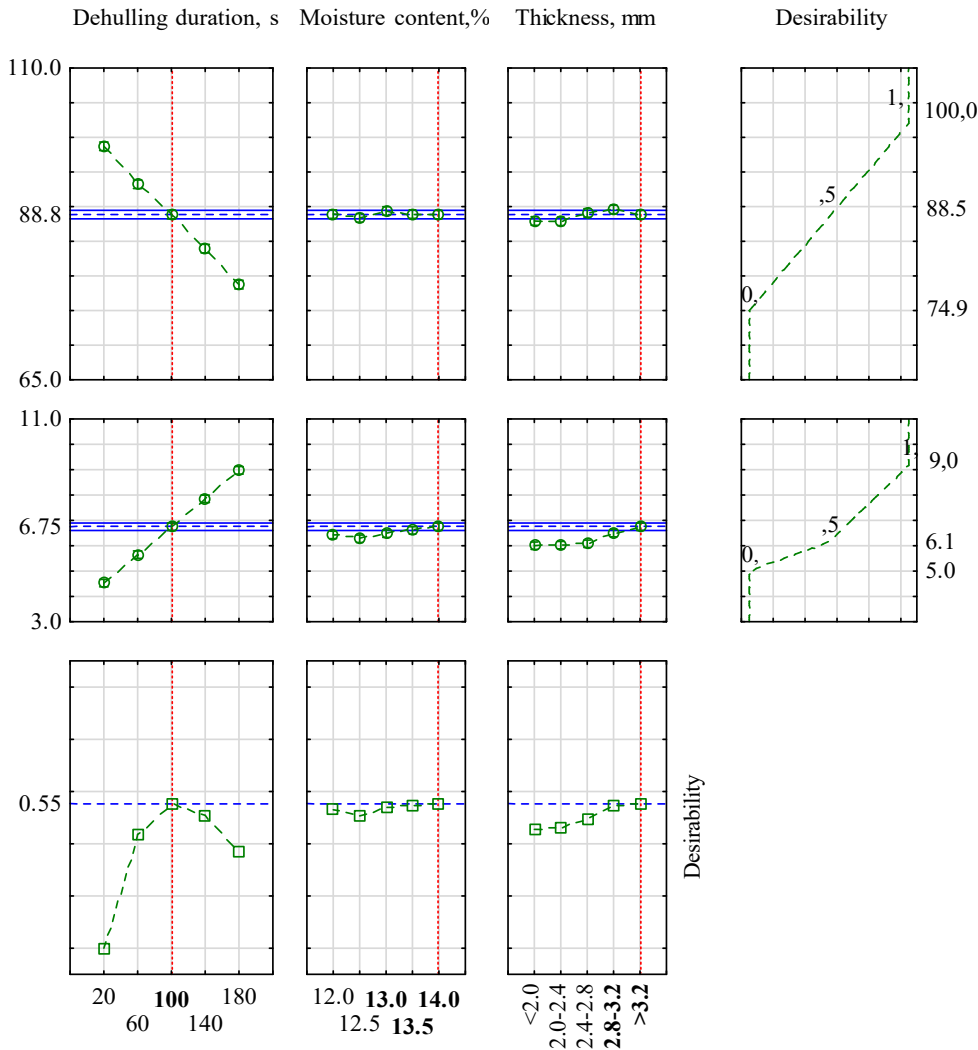


Fig. 10. Generalized desirability function of the process of groats production from different fractions of triticale grain

Given the significant value of culinary quality of products for consumers, it is advisable to increase the total duration of grain dehulling by 40 s (up to 140 s). This makes it possible to increase the overall culinary assessment of groats at a slight decrease in its yield (Fig. 10).

6. Discussion of results of studying the triticale grain processing into dehulled groats

A significant number of respondents (52.7 %) pay little attention to the chemical composition of the products they buy (Fig. 3). 18.9 % of them are not interested in this issue at all. The total number of respondents who purchase the finished product only after getting acquainted with its chemical composition and biological value is less than 2.6 %. In contrast to low attention to the biological value of foodstuffs, their appearance and culinary quality are the top priority. Such tendencies of the distributi-

Products of triticale grain processing can qualitatively expand the range of cereal products due to the high protein content, balanced by amino acid composition. In addition, triticale has natural protection against a significant number of diseases, and therefore requires simplified agricultural technology. Fewer protection means, compared to wheat, significantly increases its safety level. It creates preconditions for the production of whole grain products or products with high fiber content.

An increase in the duration of triticale dehulling at the different initial moisture content (from 12.0 % to 14.0 %) contributed to a significant decrease in the groats yield (Fig. 5, a). This is explained by the action of abrasive working bodies of the hulling machine and friction forces occurring in the grain mass during its treatment. The result is an intensive rubbing out of surface layers. The groats yield decreases and the yield of by-products (pinch, torment), on the contrary, increases.

The increase in moisture content from 12.0 to 13.5 % contributed to the increase in the groats yield by 0.4 % (Fig. 5, b). The reliable increase in the groats yield at the further increase in moisture content up to 14.0 % was not recorded. Surface layers of grain at the humidity approaching the equilibrium one (14.0 %) have more elasticity compared to dry grain. In addition, the properties of shells and endosperm as a result of moistening differ more. This causes a decrease in the amount of by-products during dehulling. Rubbing out of peripheral layers of grain is more evenly distributed.

When using the identical modes of triticale grain moistening and tempering before dehulling, the lowest groats yield was recorded during the dehulling of fraction No. 1 (thickness <2.0 mm) and No. 2 (thickness 2.0–2.4 mm) (Fig. 5, c). It can be assumed that a decrease in the grain size contributed to its denser laying. This increased the contact area between the grains and intensified their friction among themselves. The highest groat yield was recorded during processing the fraction with a grain thickness of 2.8–3.2 mm (Fig. 5, c). During processing the grain with the greatest

size (fraction No. 5), we obtained the groats yield that was by 0.2 % lower compared to fraction No. 4 (thickness of 2.8–3.2 mm) (Fig. 5, c). A decrease in groats yield during processing large triticale grain took place due to an increase in the number of fines (germ parts, beaten during dehulling, an aleurone layer, or endosperm). This may indicate the existing differences in the hardness indicator of the grain of different sizes. However, the corresponding statement requires additional studies.

The results of the studies indicate (Fig. 6) that the triticale grain fractionation has a positive effect on the groats yield. The fractionation process is continuous in time; for its implementation, the typical equipment that is common in the processing industry is used. With a greater influence on the yield of triticale grain groats (Fig. 6), fractionation can be an alternative to carrying out the hydrothermal treatment at low-capacity industrial enterprises. The traditional methods for hydrothermal treatment used in the production of dehulled groats have a range of drawbacks:

- periodicity;
- dependence on environmental conditions (a decrease in air temperature
- requires an increase in tempering time or additional heating of grain and water);
- the need to adjust the process for specific raw material.

The modes of hydrothermal grain treatment (cold conditioning) of triticale before dehulling could not significantly affect the physical-chemical properties of the grain (denaturation of proteins, gelatinization of starch, migration of vitamins from peripheral parts of grain to endosperm), since they were carried out without an additional supply of heat (water heating) and were characterized by the low tempering duration. That is why a change in culinary properties as a result of grain moistening and its fractionation can be explained by the intensification of removal of surface layers during dehulling, which significantly worsens the quality of the finished product.

The studies of the influence of grain size on the culinary quality of the resulting product indicate the prospects of implementation of the relevant process in production. Selection and separate processing of large triticale grain will make it possible to obtain a product of high culinary quality. It will expand a range of products of triticale processing.

Improved modes of processing technology can be used for triticale grain of the Strategist variety or with the other that have similar technological properties. Processing the grain of triticale varieties with other technological properties needs particular improvement. In addition, the developed modes involve the use of triticale grain with high protein content. Processing the grain with low protein content will contribute to obtaining products of satisfactory quality.

The issue of triticale grain fractionation is relevant and has practical significance for the modern grain processing

industry. The revealed effect of grain fractionation before dehulling indicates the possibility of implementation of the proposed processing methods in production. However, the establishment of economic indicators of production modernization, which is associated with the integration fractionation process, requires further exploration. The noticeable effect of the grain fractionation process before dehulling, which was moistened to the moisture content level (14.0 %) allows assuming its similar effect during dehulling the triticale grain, which has a larger gradient of moistening. The influence of the tempering duration on the efficiency of cereal production in combination with the fractionation factor requires further studying since this factor was not given sufficient attention (the duration of tempering was the same for all the samples and made up 30 minutes). Further research into cereal properties of different fractions of the new triticale grain varieties is promising.

7. Conclusions

1. The parameters of the optimization of the hydrothermal treatment process were determined by taking into consideration the social surveys of the potential consumers of dehulled groats. The culinary quality of the grain has priority during the selection of dehulled groats. Much less attention is paid to its appearance and chemical composition.

2. At the moisture content of 12.0–14.0 % of the triticale grain of different fractions, the dehulling duration has the greatest impact on the groats yield. The impact of various grain fractions and moistening on groats yield was lower but still substantial. Application of moistening of triticale grain (by 2.0 %) of the fraction of 2.0–2.4 mm makes it possible to increase the groats yield from 82.3 to 83.4 %. Hydrothermal treatment of the grain fraction of 2.8–3.2 mm ensures the groats yield from 84.0 to 85.0 % at the dehulling duration of 140 s.

3. The culinary quality of groats significantly depends on the duration of dehulling. The parameters of hydrothermal treatment affect the culinary quality least of all. The culinary quality of the groats, obtained from the grain of the size of 2.0–2.4 mm is 6.9–7.0 points, and in the large fraction (2.8–3.3 mm) – 7.1–7.9 points.

4. In the technology of production of triticale groats, it is optimal to moisten the grain of the fraction of 2.8–3.2 mm up to the moisture content of 14.0 % with the dehulling duration of 100 s. The use of such parameters of treatment makes it possible to obtain 88.8 % of whole groats with the culinary rate of 6.7 points according to the 9-point scale, which corresponds to the satisfactory result. A significant improvement in the culinary assessment of groats (by 1 point) is achieved by an increase in the total duration of their dehulling up to 140 s. At the same time, the groats yield decreases on average by 4.7 % (up to 83.8 %).

References

1. Agriculture, Forestry and Fishery Statistics. 2016 Edition (2016). Luxembourg: Publications Office of the European Union. doi: <http://doi.org/10.2785/147560>
2. Ploshchi, valovi zbory ta urozhainist silskohospodarskykh kultur za yikh vydamy ta po rehionakh u 2019 rotsi. Available at: http://www.ukrstat.gov.ua/operativ/operativ2017/sg/pvzu/arch_pvzu.htm
3. Burdo, O., Bandura, V., Zykov, A., Zozulyak, I., Levtrinskaya, J., Marenchenko, E. (2017). Development of wave technologies to intensify heat and mass transfer processes. *Eastern-European Journal of Enterprise Technologies*, 4 (11 (88)), 34–42. doi: <https://doi.org/10.15587/1729-4061.2017.108843>

4. Iorgachova, K., Makarova, O., Khvostenko, K. (2018). Effect of flour made from waxy wheat on the structural–mechanical properties of dough for hardtacks without sugar. *Eastern-European Journal of Enterprise Technologies*, 5 (11 (95)), 63–70. doi: <https://doi.org/10.15587/1729-4061.2018.143053>
5. Furman, B. J. (2016). Triticale. Reference Module in Food Science. doi: <https://doi.org/10.1016/b978-0-08-100596-5.00019-6>
6. Kiseleva, M. I., Kolomiets, T. M., Paholkova, E. V., Zhemchuzhina, N. S., Lyubich, V. V. (2016). Differentsiatsiya sortov ozimoy myagkoy pshenitsy (triticum aestivum l.) po ustoychivosti k naibolee vredonosnym vzbuditelnyam gribnyh bolezney. *Agricultural Biology*, 51 (3), 299–309. doi: <https://doi.org/10.15389/agrobiol.2016.3.299rus>
7. Morales-Osorio, A., Gutierrez Martinez, M. de G., Osorio Avalos, J., Robles Jimenez, L. E., González Ronquillo, M., Castelan Ortega, O. A. (2018). Forage yield, chemical composition and in vitro gas production of triticale varieties (x Triticosecale Wittmack) preserved by silage or hay. *Acta Agronómica*, 67 (3), 431–437. doi: <https://doi.org/10.15446/acag.v67n3.68127>
8. Daribayeva, G., Magomedov, G. O., Iztaev, B., Zhexenbay, N., Tyussypova, B. (2019). Preparation of triticale flour by ion-ozone treatment for pasta quality improvement. *Eastern-European Journal of Enterprise Technologies*, 4 (11 (100)), 64–73. doi: <https://doi.org/10.15587/1729-4061.2019.174805>
9. Liubych, V. V., Polianetska, I. O., Novikov, V. V. (2014). Fizychni vlastyivosti zerna trytykale ozymoho zalezno vid yoho rozmiriv. *Naukovi pratsi ONAKhT*, 1 (46), 23–26. Available at: <http://journals.urau.ua/swonaft/article/view/40508/36683>
10. Mergoum, M., Singh, P. K., Peña, R. J., Lozano-del Río, A. J., Cooper, K. V., Salmon, D. F., Gómez Macpherson, H. (2009). Triticale: A “New” Crop with Old Challenges. *Cereals*, 267–287. doi: https://doi.org/10.1007/978-0-387-72297-9_9
11. Kaplan, M., Kökten, K., Akçura, M. (2014). Determination of silage characteristics and nutritional values of some triticale genotypes. *Turkish Journal of Agricultural and Natural Sciences*, 1 (2), 102–107. Available at: https://www.researchgate.net/publication/301549379_Determination_of_Silage_Characteristics_and_Nutritional_Values_of_Some_Triticale_Genotypes
12. Tiefenbacher, K. F. (2017). Technology of Main Ingredients – Water and Flours. *Wafer and Waffle*, 15–121. doi: <https://doi.org/10.1016/b978-0-12-809438-9.00002-8>
13. Wrigley, C., Bushuk, W. (2017). Triticale: Grain-Quality Characteristics and Management of Quality Requirements. *Cereal Grains*, 179–194. doi: <https://doi.org/10.1016/b978-0-08-100719-8.00008-5>
14. Salmon, D. F., Mergoum, M., Macpherson, H. (2004). Triticale production and management. *FAO Plant Production and Protection Paper*. No. 179, 27–36.
15. Laskowski, W., Górka-Warsewicz, H., Rejman, K., Czczotko, M., Zwolińska, J. (2019). How Important are Cereals and Cereal Products in the Average Polish Diet? *Nutrients*, 11 (3), 679. doi: <https://doi.org/10.3390/nu11030679>
16. Liubych, V., Novikov, V., Polianetska, I., Usyk, S., Petrenko, V., Khomenko, S. et. al. (2019). Improvement of the process of hydrothermal treatment and peeling of spelt wheat grain during cereal production. *Eastern-European Journal of Enterprise Technologies*, 3 (11 (99)), 40–51. doi: <https://doi.org/10.15587/1729-4061.2019.170297>
17. Lorenz, K., Lee, V. A., Jackel, S. S. (1977). The nutritional and physiological impact of cereal products in human nutrition. *C R C Critical Reviews in Food Science and Nutrition*, 8 (4), 383–456. doi: <https://doi.org/10.1080/10408397709527227>
18. Petrenko, V., Liubich, V., Bondar, V. (2017). Baking quality of wheat grain as influenced by agriculture systems, weather and storing conditions. *Romanian Agricultural Research*, 34, 69–76. Available at: <https://www.cabdirect.org/cabdirect/abstract/20183008263>
19. Hospodarenko, H., Prokopchuk, I., Nikitina, O., Liubych, V. (2019). Assessment of the Contamination Level of a Podzolized Chernozem with Nuclides in a Long-term Land Use. *Agriculture (Pol'nohospod rstvo)*, 65 (3), 128–135. doi: <https://doi.org/10.2478/agri-2019-0013>
20. Osokina, N., Liubych, V., Novak, L., Pushkarova-Bezdil, T., Priss, O., Verkhohantseva, V. et. al. (2018). Elucidation of the mechanism that forms breadbaking properties of the spelt grain. *Eastern-European Journal of Enterprise Technologies*, 2 (11 (92)), 39–47. doi: <https://doi.org/10.15587/1729-4061.2018.126372>
21. Panasiewicz, M. (2007). Influence of hydrothermal processes on final moisture content of barley grain. *Pol. J. Food Nutr. Sci.*, 57 (2A), 129–135.
22. Jones, D., Chinnaswamy, R., Tan, Y., Hanna, M. (2000). Physicochemical properties of ready to eat breakfast cereals. *Cereal Foods World*, 45 (4), 164–168.
23. Dmytruk, Ye. A., Liubych, V. V., Novikov, V. V. (2015). Vykhid krupy plushchenoi iz zerna trytykale zalezno vid stupenia yoho lushchinnia ta rezhymu vodno-teplovei obrobky. *Zernovi produkty i kombikormy*, 1 (59), 23–27. doi: <https://doi.org/10.15673/2313-478x.59/2015.51151>
24. Liubych, V. V., Novikov, V. V., Polianetska, I. O. (2015). Matematychni modeliuvannia vodno-teplovei obrobky zerna trytykale. *Visnyk Zhytomyrskoho natsionalnoho ahroekolohichnoho universytetu*, 1 (2), 385–391.
25. Dulaev, V. G. (1999). Scientific and technical aspects of creating a new generation of grain products with a given content of basic nutrient and biologically active substances. *Storage and processing of agricultural raw materials*, 1, 25–27.
26. Lyubych, V. V., Novikov, V. V. (2014). Fractional composition of triticale grain winter and its technical characteristics depending on variety. *Vestnik Prikaspiya*, 1 (4), 21–24.
27. Fredlund, K., Bergman, E.-L., Rossander-Hulthén, L., Isaksson, M., Almgren, A., Sandberg, A.-S. (2003). Hydrothermal treatment and malting of barley improved zinc absorption but not calcium absorption in humans. *European Journal of Clinical Nutrition*, 57 (12), 1507–1513. doi: <https://doi.org/10.1038/sj.ejcn.1601718>

28. Brouns, F., Hemery, Y., Price, R., Anson, N. M. (2012). Wheat Aleurone: Separation, Composition, Health Aspects, and Potential Food Use. *Critical Reviews in Food Science and Nutrition*, 52 (6), 553–568. doi: <https://doi.org/10.1080/10408398.2011.589540>
29. Filatov, V. V. (2010). Modern processes, apparatuses and technologies for processing grain and cereals with infrared energy supply. *Storage and processing of agricultural raw materials*, 10, 19–24.
30. Kuropatkina, O. V., Andreeva, A. A., Kirdyashkin, V. V. (2014). Tehnologiya proizvodstva gotovyh k upotrebleniyu pshenichnyh hlop'ev. *Hleboprodukty*, 3, 54–56.
31. Osokina, N., Lyubich, V., Vozian, V. (2016). Output and quality of cereals from wheat spelled depending on husk index. *Agrobiodiversity for improving nutrition, health and life quality*, 1, 341–345.
32. Dmytruk, Ye. A., Liubych, V. V., Novikov, V. V. (2014). Vplyv volohosti zerna trytykale ozymoho ta tryvalosti vidvolozhuvannia na vykhid yadra. *Naukovi pratsi ONAKhT*, 46 (1), 19–23.
33. Kandrov, R. et. al. (2011). Fraktsionirovanie tverdogo pshenitsy na fotoelektronnom separatore F 5.1. *Hlebobulochnye izdeliya*, 8 (1), 48–49.
34. Tarasenko, A. P. et. al. (2012). Fraktsionirovanie zernovogo voroha na reshetah. *Sel'skohozyaystvennye mashiny i tehnologii*, 5 (1), 26–29.
35. Mar'in, V. O., Vereshchagin, A. O. (2011). Povyshenie effektivnosti fraktsionirovaniya zerna grechihi. *Hleboprodukty*, 6 (1), 54–55.
36. Pasynkova, E. N. et. al. (2012). Izmenenie pokazateley kachestva zerna yarovoy pshenitsy pri ee fraktsyinirovanii. *Agrofizika*, 4 (1), 25–33.
37. Pasynkov, A. V., Andreev, V. L., Zavalin, A. A., Pasynkova, E. N. (2013). Changes in the parameters of winter rye quality after grain fractionation. *Dostideniya nauki i tehniki APK*, 9 (1), 36–40.
38. Pasynkov, A. V., Zavalin, A. A., Pasynkova, E. N., Skorobogatykh, N. A. (2017). Change of quality parameters of brewing barley grain at fractionation. *Rossiyskaya sel'skohozyaystvennaya nauka*, 4, 12–16.
39. Lichko, N. M., Lichko, A. K. (2007). Improvement of grain technological characteristics with the help of the fractioning by aerodynamical characteristics. *Izvestiya TSHA*, 4 (1), 82–92.
40. Litun, P. P., Kyrychenko, V. V., Petrenkova, V. P., Kolomatska, V. P. (2009). Systematychnyi analiz v selektsii polovykh kultur. *Kharkiv*, 351.
41. Tsarenko, O. M., Zlobin, Yu. A., Skliar, V. H., Panchenko, S. M. (2000). *Kompiuterni metody v silskomu hospodarstvi ta biolohii*. Sumy, 200.
42. Liubych, V., Polyanetska, I. (2015). Quality of cereals grain of spelt wheat depending on the index its unhusking and water-heat processing. *Bulletin of the Uman National Horticultural University*, 2, 34–38.
43. Liubych, V., Novikov, V., Polianetska, I., Usyk, S., Petrenko, V., Khomenko, S. et. al. (2019). Improvement of the process of hydrothermal treatment and peeling of spelt wheat grain during cereal production. *Eastern-European Journal of Enterprise Technologies*, 3 (11 (99)), 40–51. doi: <https://doi.org/10.15587/1729-4061.2019.170297>