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MILLET AS A PROMISING RAW MATERIAL FOR MODERN GROAT PRODUCTION

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Abstract. The study emphasizes regional variation in the chemical composition of the varieties «Bila Altanka» and «Poltavske Zolotyste» cultivated in different regions of Ukraine during 2020–2022. Protein content was found to range between 9.36% and 15.07 %, depending on cultivation region and climatic conditions. Starch content in the analyzed samples ranged from 62.1 % to 66.5 %, which is consistent with average literature values for millet; however, its combination with elevated protein levels in certain cases resulted in an optimal nutrient balance for dietary applications. Variation in fiber (5.99–10.01%) and ash (2.24–3.45%). Kernel size distribution analysis showed that grain from the Cherkasy region demonstrated the most favorable characteristics for processing, with large kernels exceeding 89%. By contrast, samples from the Odesa region contained a higher proportion of medium-sized kernels, facilitating more uniform polishing and reducing the generation of fine particles. Samples from the Mykolaiv region were dominated by large kernels, which necessitates the optimization of dehulling regimes. These findings suggest that groat quality is strongly dependent on grain uniformity and kernel size distribution. The lowest husk percentage (15.0%) was recorded for the «Bila Altanka» variety from the Odesa region. Samples from Khmelnytskyi and Cherkasy regions, by contrast, exhibited thicker hulls (husk content above 18%). Test weight of the grain ranged between 713 and 771 g/L, while 1000-kernel weight varied from 5.53 to 7.91 g, reflecting morphological diversity and highlighting the need for adjustment of processing parameters depending on variety and cultivation region. The article also substantiates a technological scheme for the production of instant millet groats, which incorporates water-heat treatment of grain prior to dehulling, two-stage dehulling, separation of dehulled kernels using groat sieves, single-stage polishing, pneumatic separation of polished kernels, and an additional water-heat treatment of the polished product. This approach is intended to enhance processing efficiency while maintaining the nutritional and functional properties of millet groats.

Keywords: millet, groats, chemical composition, technological properties, instant groats production technology, water-heat treatment, «Bila Altanka» variety, «Poltavske Zolotyste» variety.

Introduction. Formulation of the problem

Millet (Panicum miliaceum L.) is one of the most ancient crops, which for many centuries formed the basis of human nutrition in various regions of the world and still retains its importance as a valuable raw material for food production. Archaeobotanical evidence indicates that the earliest centers of millet cultivation existed in northern China about 5000–6000 years ago, where it was, alongside sorghum and rice, one of the main components of the human diet. From China, millet spread westward, covering the territories of Central Asia and the Near East, where it became highly significant in the diet of nomadic tribes and agricultural civilizations. In Mesopotamia and the Middle East, millet was already known in the 2nd millennium BC, where it was primarily consumed as porridge and flatbreads, as well as used in the preparation of fermented beverages. Millet reached Europe around the first millennium BC, where it quickly gained wide distribution. Archaeological finds in present-day Hungary, Germany, Poland, and Ukraine testify to its use as early as the Bronze Age. In antiquity it was known in Ancient Greece and Rome, where it was consumed in the form of porridges and flat cakes. In medieval Europe millet played an important role in the diet of peasants, as it was affordable, relatively easy to store, and simple to prepare. Millet porridge remained a staple dish in Central and Eastern Europe for centuries, particularly in the Ukrainian and Polish territories, where it became an integral part of traditional cuisine. In Germany and the Czech lands, millet flour was commonly used for baking various products. In Africa, millet has been known since ancient times and continues to serve as a dietary staple in many countries of the continent. It is highly valued as a crop capable of producing nutritious food in arid regions where the cultivation of other cereals is limited. Millet is used for preparing thick porridges, flatbreads, and fermented beverages, which play an important role in local food culture. In the countries of West and Central Africa millet remains a strategic crop that ensures food security for millions of people. In South Asia millet was traditionally used as a base for porridges and flatbreads, and later became widely applied in flour production for a variety of national dishes. In India millet is still a popular dietary component, especially in regions with characteristically dry climates. In combination with legumes, it is used to prepare protein-rich meals that are essential in local diets. In North America and Western Europe, interest in millet intensified during the 19th–20th centuries, but its real development occurred in the second half of the 20th century, when attention to dietary and gluten-free products increased. In these regions, millet became a raw material for the production of flakes, puffed grains, blended gluten-free flour mixes, as well as products for children and dietary nutrition. Contemporary trends in healthy eating, particularly the demand for organic and gluten-free products, are contributing to the revival of millet's role as a food grain [1-4].

The range of millet-based products in different countries includes millet groats, flakes, puffed grains, flour for bakery and confectionery production, as well as ingredients for children and dietary-preventive nutrition. In Asian and African countries, millet is traditionally used for preparing national dishes and beverages, while in Europe and America it is gaining popularity as a component of healthy and gluten-free foods. The most common and traditional product is millet groats, which form the basis of many national cuisines. In Central and Eastern Europe, particularly in Ukraine and Poland, millet porridge remains an important part of the diet, consumed both as a standalone dish and as a side dish. In China and India, millet is widely used for preparing various porridge-like meals, as well as flatbreads and cakes made from millet flour. Millet is also processed into flour, which is used in the production of bakery and confectionery goods. Due to its gluten-free nature, millet flour serves as an important ingredient in the formulation of gluten-free products. In Europe and North America, millet flour is incorporated into baking mixes for bread, cookies, waffles, and is also applied in the confectionery industry for the production of dietary products with enhanced nutritional value. In India, traditional millet flour dishes include various types of flatbreads and desserts. Millet flakes, produced in a manner similar to oat flakes, hold a significant place among processed products. These are used in ready-to-eat breakfasts, muesli, as well as children and dietary nutrition. In the United States and Western Europe, millet flakes are included in the assortment of organic products. In China and Korea, flattened or extruded millet grains are commonly used in the production of light snacks. Another category is puffed millet grains, obtained by subjecting the grain to high pressure and temperature. Such products are popular in Asia and Europe as light snacks, and are also used as ingredients in bars and healthy food mixes. In Japan and China, sweet snacks based on millet, often combined with caramel or honey, are widely produced. In Africa, millet is used to prepare a wide variety of national dishes. In Nigeria and Ghana, millet serves as a raw material for local beer-like beverages, which hold significant cultural and social importance. In East African countries, millet is used in the preparation of fermented milk-grain dishes, where it is combined with dairy products to create high-protein foods [5-8].

The dynamics of global millet production over the past 10–15 years demonstrate relative stability at the global level. In 2008–2010, production volumes fluctuated around 28–29 million tons, with India and African countries playing the leading role, maintaining their leadership to this day. Gradually, between 2012 and 2016, global production increased to 30–31 million tons, primarily driven by the expansion of cultivated areas in West Africa. India remains the undisputed leader, producing more than 11–12 million tons annually. In 2010, Niger and Nigeria together produced about 4.5–5 million tons, while in the 2020s their combined output exceeded 6 million tons, reflecting the growing role of Africa in global millet cultivation. China, in the 2000s, held a significant position with production levels of about 3.5–4 million tons, but over the past 15 years its output has declined to around 2.5–2.7 million tons. In Europe and North America, production remained relatively low during the period under review. In 2008–2010, millet was primarily cultivated as a fodder crop, but since 2015 the focus has gradually shifted toward food use, especially in connection with the increasing demand for gluten-free products. The United States and several European countries have started expanding millet cultivation on a small scale to meet domestic demand from the food industry, as well as for export as niche products.In Ukraine, millet production in the 2010s averaged 150–200 thousand tons per year. After 2015, a tendency toward reduced cultivation areas was observed, leading in some years to a decline in harvest volumes to 80–90 thousand tons [9-12].

Analysis of recent research and publications

Based on grain color, common millet (Panicum miliaceum L.) is divided into several main groups, differing in the pigmentation of the hull and, partially, the inner endosperm. The most widespread forms are those with white and yellow grains, which are considered the most suitable for groat production due to their superior technological properties, including higher vitreousness and an attractive appearance of the finished product. White and yellow grains yield light-colored groats with pleasant organoleptic characteristics after polishing, which explains their popularity in food applications. A separate group consists of millet with red and brown hulls. Such grains contain higher levels of pigments and phenolic compounds. Although millet with these colors is less commonly used for traditional groat production, these forms possess greater nutritional value due to their higher content of bioactive compounds and enhanced resistance to oxidative processes, making them suitable for specialized food products, including functional groats and dietary mixes [13-16].

The chemical composition of millet grain is characterized by significant nutritional value, which is determined by a high carbohydrate content, moderate protein levels, and a considerable proportion of lipids enriched with essential fatty acids. Indirectly, millet grain contains 10–12% protein, 65–70% carbohydrates, 3.5–5.0% fat, 1.5–2.0% fiber, and 2.5–3.0% minerals. The protein fraction in millet grain averages 11.0–12.5%. The protein complex exhibits a specific distribution of fractions. The main fraction is prolamin, accounting for 40–50% of total protein. Glutelins occupy the second position (25–30%), soluble in dilute acid and alkali solutions. Albumins constitute approximately 8–12%, and globulins 10–15%. This fractional distribution indicates that millet's protein complex is predominantly storage in nature, with metabolic proteins (albumins and globulins) forming a smaller portion. The typical fraction ratio is: prolamins – 45%, glutelins – 27%, globulins – 15%, albumins – 10–12%. The amino acid composition of millet protein reflects its high nutritional value, although limitations exist due to deficiencies in lysine and threonine. The average concentration of essential amino acids (mg per 1 g of protein) is as follows: lysine – 19–22, methionine – 33–35, threonine – 35–38, valine – 47–50, isoleucine – 36–38, leucine – 80–85, phenylalanine + tyrosine – 95–100, tryptophan – 12–14. The total content of essential amino acids in millet protein reaches approximately 340–360 mg/g, corresponding to 34–36% of the total amino acid content. Among non-essential amino acids, the highest amounts are glutamic acid (approximately 180–200 mg/g), aspartic acid (90–95 mg/g), and serine (40–45 mg/g). The fat content in millet grain ranges from 3.5–5.0%, although some varieties may reach 5.5–6.0%. Lipids are mainly localized in the germ and aleurone layer, explaining their reduction during millet processing. Chemically, millet lipids are distinguished by a high content of unsaturated fatty acids. The average proportion of major fatty acids (% of total fatty acids) is as follows: linoleic (C18:2) – 42–50%, oleic (C18:1) – 30–37%, palmitic (C16:0) – 12–15%, stearic (C18:0) – 2.5–3.5%, linolenic (C18:3) – 1–2%. The proportion of polyunsaturated fatty acids reaches approximately 44–52%, making millet lipids biologically valuable. The ratio of unsaturated to saturated acids is about 3:1, corresponding to current concepts of an optimal fatty acid profile for human nutrition [17-20].

The carbohydrate complex of millet grain is formed primarily by starch, simple sugars, and dietary fibers, which together determine its technological properties and nutritional value. On average, millet grain contains 65–70% carbohydrates. The main portion of carbohydrates is represented by starch, which accounts for 55–60% of the grain mass. Within the starch complex of millet, polymers of amylopectin and amylose predominate, and their ratio is crucial for the culinary properties of the groats. Typically, millet contains more amylopectin than amylose: the share of amylopectin reaches 70–75%, while amylose accounts for 25–30%. This ratio provides millet porridge with a loose texture and reduces stickiness compared to rice or corn. Millet starch granules are relatively small, ranging from 2 to 10 μm in diameter, which contributes to a faster swelling rate. In addition to starch, millet grain contains 1.5–2.0% simple sugars, mainly glucose, fructose, and sucrose. Sugar content depends on the grain's development stage and drying conditions: freshly harvested grain contains more sugars than post-harvest dried grain. Maltose, formed through amylase activity upon grain hydration, is also important. Simple sugars impart a sweet taste to millet and participate in browning reactions during heat treatment. The carbohydrate complex also includes dietary fibers, which constitute 2–3% of whole grain, while in polished grain their content is significantly lower due to the removal of the husks. Millet fiber consists mainly of cellulose and hemicelluloses located in the pericarp and aleurone layer. Pentosans, particularly arabinoxylans, are also present and exhibit pronounced water-binding capacity. The total fiber content in millet ranges from 1.5–2.0%, while in bran it can exceed 8–10%. Compared to other cereals, millet's carbohydrate complex is characterized by a high starch content and relatively low amylose levels. This makes millet groats less prone to forming sticky structures but ensures better digestibility and culinary versatility. The vitamin complex of millet is diverse and contributes significantly to its biological value in the human diet. The grain contains both B-group vitamins and fat-soluble vitamins, with tocopherols being the most characteristic. Vitamin concentrations strongly depend on their localization within the kernel: they are most abundant in the germ and aleurone layer, so significant losses occur during the production of polished groats. The core of millet's vitamin complex consists of B vitamins, which are involved in carbohydrate, protein, and lipid metabolism. Thiamine (B1) is predominant, with an average concentration of 0.35–0.45 mg per 100 g of grain, essential for nervous system function and enzymes involved in oxidative decarboxylation. Riboflavin (B2) is present at 0.18–0.25 mg/100 g and participates in tissue respiration as part of flavin cofactors. Niacin (PP or B3) is one of the most abundant vitamins in millet, reaching 1.2–1.6 mg/100 g, and plays a role in redox reactions and energy synthesis. Pyridoxine (B6) is present at 0.35–0.45 mg/100 g and is associated with amino acid metabolism and neurotransmitter synthesis. Folate (B9) is found at 40–45 μg/100 g and is essential for nucleic acid synthesis and hematopoiesis. Millet also has a relatively high content of pantothenic acid (B5), ranging from 0.6–0.8 mg/100 g, a component of coenzyme A directly involved in energy metabolism. Trace amounts of biotin (B7), around 2–3 μg/100 g, are also present and contribute to metabolic regulation. Among fat-soluble vitamins, vitamin E, mainly in the form of α- and γ-tocopherols, is most significant, with concentrations of 0.6–0.9 mg/100 g, performing antioxidant functions and stabilizing membrane lipids. Carotenoids, which act as provitamin A, are also present, with higher levels in yellow and red millet than in white, where the average β-carotene content is 0.05–0.08 mg/100 g. Carotenoids provide the yellowish hue of millet groats. The mineral composition of millet is a key factor in its nutritional and biological value, as the grain accumulates a wide range of macro- and microelements, primarily in the germ and husks. Processing results in significant losses, yet even polished grain retains substantial mineral content. The total ash content averages 2.5–3.5%. Dominant macronutrients include potassium, at 200–250 mg/100 g, which is the main intracellular cation essential for osmotic pressure and water-salt balance. Phosphorus ranks second at 280–300 mg/100 g, with about 80% in phytic form localized in the aleurone layer and germ. Calcium is present at 8–12 mg/100 g, but its bioavailability is limited due to interaction with phytates. Magnesium is significant at 110–130 mg/100 g, playing a key role in enzymatic reactions related to energy metabolism. Sodium occurs in trace amounts, up to 10 mg/100 g. Among microelements, iron is notable, averaging 2.5–4.0 mg/100 g, primarily in the husk and germ, thus much lower in polished grain. Zinc is 1.5–2.0 mg/100 g, copper 0.6–0.8 mg/100 g, and manganese 0.7–0.9 mg/100 g, all essential as enzymatic cofactors supporting antioxidant protection and metabolism. Selenium content is 3–5 μg/100 g, contributing to antioxidant defense. A unique feature of millet is its high silicon content, which may exceed 40–60 mg/100 g, considerably higher than in wheat or rice, playing a role in connective tissue formation and bone mineralization. Small amounts of iodine (2–4 μg/100 g) and cobalt (1–2 μg/100 g) are also present, contributing to thyroid function regulation and hematopoiesis [21-24].

The State Register of Plant Varieties Suitable for Distribution in Ukraine [25] lists 35 varieties of common millet (Panicum miliaceum L.) used as groat grain. Among them, the most widespread is the variety Myronivske 51, which was entered into the Register in 1978. Later, the varieties Kyivske 87 (1991) and Kyivske 96 (1999) were registered. During the first two decades of the 21st century, new breeding developments appeared almost every year, with 2006 being a record year for the number of registered varieties: that year, «Denvikske», «Zolushka», «Konstantynivske», «Lana», and «Tavriyske» were included in the Register. In the last four years, six more varieties have been registered: «Dyvovyzhne», «Kazkove Dzherelo», and «Kornberger Mittelfrue» (all in 2020), «Yardush» (2021), «Kesha» (2022), and «Peremozhne» (2023). These data indicate that millet breeding in Ukraine continues continuously, and modern varieties create real prospects for expanding the raw material base of the groat industry.

According to DSTU 5026:2008 “Millet. Technical Specifications” [26], millet grain is divided into three classes based on quality. The main criteria for classification are moisture content, the proportion of impurities and grain admixtures, and the overall quality of the grain. Class I includes grain with the highest quality. Its moisture must not exceed 14.0%, impurities are limited to 2%, and grain admixtures to 3%. The grain should have a typical color, smell, and be healthy, free from pest damage or mold. First class is primarily intended for food use and export. Second class allows slightly lower quality. Its moisture can reach up to 14.5%, impurities up to 3%, and grain admixtures up to 5%. This grain may show minor reductions in glassiness or partially damaged kernels, but it should not contain a significant number of sprouted grains. Third class has even lower quality standards. Moisture may reach 15.0%, impurities up to 5%, and grain admixtures up to 8%. Kernels may have a higher proportion of damaged, shriveled, or discolored grains. This grain is generally used for fodder or technical purposes and less often for groat production.

For groat production under DSTU 5026:2008, grains of first and second classes are suitable. First class is considered optimal, as it has the lowest levels of impurities and grain admixtures and guarantees healthy kernels with typical color and aroma, ensuring high-quality polished millet. Second class is also allowed for processing, but this grain often contains more impurities and shriveled kernels, requiring more thorough cleaning and sorting before processing, resulting in a lower groat yield compared to first class. Third class is mainly suitable for fodder and technical purposes and is not used for food production, as it exceeds allowable impurity limits and has lower kernel quality.

The demand for millet products in Ukraine remains low due to several interconnected reasons. Primarily, this is due to changes in dietary habits: traditional consumption of millet porridge, which was common in the past, has significantly declined because it has been replaced by more popular products such as rice, buckwheat, wheat, and pasta. These products are considered more familiar in the daily diet and have a wider range of ready-to-eat options in the market. An additional factor is the specific taste and aroma of millet, which is formed due to the presence of lipids in the germ and their tendency to oxidize during storage. As a result, millet quickly loses quality and becomes bitter, reducing its appeal to consumers.

Another important factor is the underdeveloped culture of millet consumption. Unlike in Asia or Africa, where millet occupies a significant place in the diet and is used in many traditional dishes, in Ukraine it is mostly perceived as raw material for porridge, and modern technologies for producing ready-to-eat foods based on millet are limited. This narrows the product range and does not stimulate consumer interest.

Other cereal crops have higher profitability, better taste characteristics, and wider application possibilities, so producers focus their efforts on promoting them. Consequently, millet is rarely advertised, and consumers do not associate it with a modern or convenient product.

Research materials and methods

The aim of the study is to analyze the chemical composition and technological properties of millet grain grown in Ukraine, specifically in the Odesa, Mykolaiv, Cherkasy, Khmelnytskyi, and Chernihiv regions, of the varieties «Bila Altanka» and «Poltavske Zolotyste», for the harvests of 2020–2022.

The moisture content was determined according to DSTU ISO 712:2015 «Cereals and cereal products. Determination of moisture content. Reference method (ISO 712:2009, IDT)». The protein content on a dry matter basis (N*6.25) was determined according to DSTU ISO 20483:2016 «Cereals and pulses. Determination of the nitrogen content and crude protein content – Kjeldahl method (ISO 20483:2013, IDT)». Fat content at actual moisture was determined according to DSTU ISO 659:2007 «Oilseeds. Determination of oil content (reference method) (ISO 659:1998, IDT)». Starch content at actual moisture was determined according to GOST 10845-98 «Grain and its processed products. Method for the determination of starch». Crude fiber content at actual moisture was determined according to DSTU ISO 6585:2004 «Fruits, vegetables and derived products. Determination of cadmium content. Flame-less atomic absorption spectrometric method (ISO 6561:1983, IDT)». Ash content at actual moisture was determined according to DSTU ISO 2171:2009 «Cereals, pulses and their milled products. Determination of total ash by ashing method (ISO 2171:2007, IDT)».

The methodology for determining the grain size and granulometric composition of millet involves sieving a sample of the grain for a specific time at a defined frequency of the sieve frame oscillations (Table 1). Sieves for sieving are selected depending on the type of product. Manual sieving is allowed provided that sieving conditions are properly maintained.

Grain size indirectly characterizes the endosperm content of the grain, thereby influencing the yield of the final product. The sample is sieved through an appropriate set of sieves.

Table 1 – Sieving conditions for millet on a mechanical sieve shaker

Product	Weight, g	Sieving duration, min	Oscillation frequency, min^{-1}
Millet grain	25	5	110-120

The residues on each sieve and the material passing through the bottom sieve are weighed, and the content of each i-th fraction (X_i) is calculated using the formula and expressed as a percentage.

$$Xi = \frac{m_i}{m} 100\%,$$

Ie, m – sample weight (100 g – for grain;), g;

m_i – mass of the i-th fraction, g

Method for determining the hull content of millet: from the composite sample, a 25 g portion is taken. The selected portion is cleaned of grain impurities. The remaining grain is mixed, and two portions of whole grains are taken to determine the content of hulled grains, and two portions for determining hull content, each weighing 2.5 ± 0.01 g. Hulled grains are separated manually and their content is expressed as a percentage. The portion of grain for hull determination is placed in a porcelain mortar, and by gently pressing and rotating it with a pestle, the hulls are separated, avoiding crushing the grains. To facilitate hull separation, the product obtained after hulling is sieved through sieves with openings of the following sizes: for millet –1.4×20 or 1.2×20 mm. Unhulled grains that remain are separated from the hulled grains, placed in the mortar, and hulled completely. The same procedure is applied to other portions. The hulls obtained from hulling are weighed to hundredths of a gram.

The content of hulled grains $\omega_{об}$ is expressed as a percentage relative to the mass of the portion taken, using the formula:

$$\omega_{об} = \frac{m_2}{m_1} 100$$

де, m_1 – mass of the initial grain sample, g;

m_2 – mass of hulled grains, g.

The hull content $\omega_{пл.}$ expressed as a percentage of the mass of the sample taken by the formula:

$$\omega_{пл} = \frac{m_2}{m_1}100$$

де, m_1 – mass of the initial grain sample, g;
m_2 – mass of hulls obtained as a result of dehulling, g.

The determination of test weight (hectoliter mass) was carried out according to DSTU 4233:2003/ISO 7971:1986 "CEREAL CROPS. Determination of bulk density, so-called 'hectoliter mass' (Reference method)" and DSTU 4234:2003/ISO 7971-2:1995 "CEREAL CROPS. Determination of bulk density, so-called 'hectoliter mass'. Part 2. Working method."

The determination of the thousand-kernel weight was performed according to DSTU ISO 520:2015 (ISO 520:2010, IDT) "CEREALS AND LEGUMES.

Determination of the mass of 1000 grains."All obtained digital data were processed using Excel software from the Microsoft Office 2007 service package. Data were presented as arithmetic mean and standard error (M ± m).

Results of the research and their discussion

The results of the chemical composition analysis of millet grains obtained from different regions of Ukraine and from different varieties allow tracing both varietal characteristics and the influence of soil-climatic conditions on the accumulation of major constituents. All samples are characterized by a relatively similar moisture content, ranging from 11,1 to 11,3 %, which corresponds to optimal conditions for storage and further processing. This stability is explained by the natural conditions during harvesting and the uniform requirements for grain moisture at collection, but it does not significantly affect other chemical composition parameters, which show much wider variation.

Particular attention is drawn to the protein content, which was highest in the «Bila Altanka» variety from the Odesa region (15,07 %), an excellent indicator exceeding average literature values for millet (approximately 10–12 %). This may result from a combination of the variety and the agro-technical conditions of the region, in particular a more arid climate, which promotes protein concentration in the grain.

The lowest protein level was recorded in a sample from the Khmelnytskyi region (9,36 %), indicating a significant influence of soil-climatic factors, as the variety in this case was the same. For other samples of this variety, the values were intermediate: 11,57 % in the Mykolaiv region and 13,20 % in the Cherkasy region. The «Poltavske Zolotyste» variety from Chernihiv region is characterized by a high protein content (14,03 %), close to the Odesa «Bila Altanka» sample, confirming the good adaptability of the variety to the conditions of the northern Forest-Steppe.

The fat content in the studied samples varied between 2.89 and 3.35%. The lowest value was observed in the «Bila Altanka» variety from the Odesa region (2.89%), while the highest was recorded in the Cherkasy region (3.35%). These differences may be related to regional climatic conditions that influence fat accumulation. Overall, the fat content corresponds to the typical range for millet, which is 2.5–40%.

The starch content, as the main carbohydrate component of the grain, ranged from 62.1 to 66.5%. The highest value was recorded for «Bila Altanka» from Odesa (66.5%), which correlates well with its high protein content, since the combination of these two components largely determines the nutritional value of the grain. In contrast, samples from Cherkasy and Mykolaiv regions had lower starch content (62.1–62.2%), explained by the higher levels of fiber and ash in these samples. Samples from Khmelnytskyi and Chernihiv regions were intermediate (64.0%), reflecting balanced growing conditions in these regions.

Fiber content proved to be the most variable parameter, ranging from 5.99 to 10.01%. The lowest content was found in «Bila Altanka» from Odesa (5.99%), while the highest was in the same variety from Khmelnytskyi (10.01%). This is important in terms of the technological properties of the grain, as excessive fiber complicates processing and reduces the yield of finished groats, and also affects sensory characteristics. The Mykolaiv and Cherkasy samples of «Bila Altanka» had increased fiber content (8.75 and 8.27%, respectively), which, together with higher ash levels, indicates a greater proportion of bran structures in the grain. «Poltavske Zolotyste» from Chernihiv held an intermediate position (8.37%), combining relatively high protein with a moderate fiber level.

Ash content, reflecting the mineral composition of the grain, ranged from 2.24 to 3.45%. The lowest value was recorded in «Bila Altanka» from Odesa (2.24%), associated with lower bran content. The highest ash content was found in «Poltavske Zolotyste» from Chernihiv (3.45%), highlighting the richer mineral composition of this variety. «Bila Altanka» samples from Mykolaiv and Khmelnytskyi also showed high ash levels (3.23 and 3.19%, respectively), confirming the denser structure and higher mineral content of their grains. The Cherkasy sample demonstrated an intermediate level (2.70%), combining relatively high fat and fiber content with moderate ash.

Analysis of the data indicates that the best chemical balance is observed in «Bila Altanka» from Odesa, which combines high protein and starch content with low fiber and ash, making the grain particularly suitable for groat production with high yield and good quality.

The «Poltavske Zolotyste» sample from Chernihiv is notable for high protein and ash, although its elevated fiber content may slightly reduce technological efficiency during processing. «Bila Altanka» samples from Mykolaiv, Cherkasy, and Khmelnytskyi regions have higher fiber and ash content, making them less advantageous for processing, although they may be of interest as raw material with increased dietary fiber and mineral content.

Table 2 – Results of the chemical composition determination of the studied millet samples

Variety	Moisture content, %	Protein content, %	Fat content, %	Starch content, %	Fiber content, %	Ash content, %
«Bila Altanka» (Odesa region)	11.15	15.07	2.89	66.50	5.99	2.24
«Bila Altanka» (Mykolaiv region)	11.12	11.57	3.07	62.20	8.75	3.23
«Bila Altanka» (Cherkasy region)	11.27	13.20	3.35	62.10	8.27	2.70
«Bila Altanka» (Khmelnytskyi region)	11.32	9.36	3.03	64.00	10.01	3.19
«Poltavske Zolotyste» (Chernihiv region)	11.30	14.03	3.25	6.00	8.37	3.45

These results highlight significant regional differences in the chemical composition of millet grains of the same variety, which are explained by climatic conditions, soil type, and agricultural practices. This emphasizes the importance of considering grain origin for food use, as the combination of protein, starch, fiber, and ash content determines not only the nutritional value but also the technological suitability of the grain for groat production.

At the next stage, the technological properties of the studied millet grain samples were determined. Analysis of the particle size distribution allows for the assessment of grain uniformity and the prediction of its behavior during dehulling, polishing, and groat production. These parameters directly affect the yield of the final product, the uniformity of water-heat treatment, and the quality of the finished product, as large and medium grains are processed differently from smaller grains, which are more prone to damage and generate powdery fractions

For the «Bila Altanka» variety from Odesa, a significant proportion of medium-sized grains (Ø 2.2–2.0 mm) was observed at 57.4%, while large grains (Ø ≥2.2 mm) accounted for only 40.2%, and small grains (Ø ≤2.0 mm) – 2.1%. This indicates a relatively homogeneous material with a low content of small grains, ensuring a high groat yield during polishing and a minimal amount of powdery by-products. The high proportion of medium grains allows for uniform processing in polishing machines and reduces the risk of mechanical damage to the kernels.

The Mykolaiv sample is characterized by a predominance of large grains (Ø ≥2.2 mm – 87.1 %), with the medium fraction constituting only 12.2% and small grains 0.9%. This grain composition indicates high uniformity and significant individual grain mass, which positively affects mechanical resistance during transport and processing. However, the high proportion of large grains may require optimization of polishing regimes, as the thicker hulls of large grains can reduce groat yield under standard processing parameters.

The Cherkasy sample demonstrates the most favorable structure for technological processing: large grains make up 89.8 %, medium grains 8.0 %, and small grains 2.2 %. This high percentage of large grains with a small share of medium and small fractions enables a high groat yield with minimal losses during mechanical processing. Grain uniformity ensures even treatment throughout the technological process, improving product quality and reducing the formation of powdery particles.

The Khmelnytskyi sample has a more balanced distribution: large grains – 80.0 %, medium – 18.3 %, small – 1.7 %. This indicates a greater proportion of medium-sized grains compared to previous samples, which may slightly reduce groat yield under standard dehulling and polishing regimes due to uneven hull thickness. However, this composition provides better resistance to fragmentation of small grains.

The «Poltavske Zolotyste» variety from Chernihiv has 82.7 % large grains, 16.1 % medium, and 0.9 % small grains. This grain structure offers good technological suitability for groat production: the high proportion of large grains promotes a high groat yield, the medium fraction provides flexibility in dehulling and polishing conditions, and the low content of small grains minimizes losses in the form of dust.

Analysis of the granulometric composition shows that the «Bila Altanka» samples from Odesa and Cherkasy regions best meet the technological requirements for groat production due to the high proportion of large grains and the low content of small grains. The samples from Khmelnytskyi and Poltava regions have a higher share of medium grains, which requires optimization of dehulling and polishing regimes to ensure maximum product yield. The Mykolaiv sample, predominantly composed of large grains, demonstrates high uniformity and mechanical resistance but requires precise adjustment of processing to minimize losses during dehulling and polishing.

Analysis of the technological properties of millet grain based on hull content, hectoliter weight, and thousand-kernel weight allows evaluation of its suitability for processing, prediction of groat yield, and determination of optimal polishing and dehulling conditions. Hull content, which characterizes the proportion of the outer layer relative to the grain mass, in the studied samples ranges from 15.0 % to 20.3 %. The lowest hull content (15.0%) is observed in the «Bila Altanka» sample from Odesa, indicating a thin husk and high potential groat yield during polishing. High hull content values (19.4–20.3%) were recorded for samples from Khmelnytskyi and Cherkasy regions, reflecting thicker and stronger husks. Such grains require more thorough thermal treatment or extended polishing time to achieve high groat purity, but this may result in a greater amount of processing waste.

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Table 3 – Results of the particle size distribution analysis of the studied millet samples

Sample	Content, %		
	–/Ø2,2	Ø2,2/Ø2,0	Ø2,0 / –
«Bila Altanka» (Odesa region)	40.2	57.4	2.1
«Bila Altanka» (Mykolaiv region)	87.1	12.2	0.9
«Bila Altanka» (Cherkasy region)	89.8	8.0	2.2
«Bila Altanka» (Khmelnytskyi region)	80.0	18.3	1.7
«Poltavske Zolotyste» (Chernihiv region)	82.7	16.1	0.9

Table 4 – Results of hull content, hectoliter weight, and thousand-kernel weight determination for the studied millet samples

Sample	Hull content, %	Grain hectoliter weight, g/L	Thousand-kernel weight, g
«Bila Altanka» (Odesa region)	15.0	713	5.53
«Bila Altanka» (Mykolaiv region)	19.4	717	6.79
«Bila Altanka» (Cherkasy region)	18.2	757	7.91
«Bila Altanka» (Khmelnytskyi region)	20.3	771	7.71
«Poltavske Zolotyste» (Chernihiv region)	17.9	756	7.12

Grain hectoliter weight, which determines its bulk density and compactness, varies between 713 and 771 g/L. The lowest hectoliter weight (713 g/L) is observed in the «Bila Altanka» sample from Odesa, which, in combination with its low hull content, indicates a light yet dense kernel that is well-suited for polishing. The highest hectoliter weight (771 g/L) is recorded for the sample from Khmelnytskyi region, correlating with its increased hull content and grain mass, reflecting greater structural density of both the husk and endosperm

Thousand-kernel weight ranges from 5.53 g to 7.91 g, indicating significant interregional and varietal differences in grain size. The lowest thousand-kernel weight (5.53 g) in the «Bila Altanka» sample from Odesa is explained by its thin husk and smaller kernel size, which contributes to producing more uniform groats during processing. The samples from Cherkasy (7.91 g) and Khmelnytskyi (7.71 g) regions have larger grains with thicker husks, which increases overall grain strength but reduces the yield of polished groats under standard processing conditions. Intermediate thousand-kernel weights (6.79–7.12 g) in the Mykolaiv and Chernihiv samples indicate a balanced grain structure, providing a reasonable combination of product yield and mechanical resilience during handling and processing.

The «Bila Altanka» sample from Odesa exhibits optimal technological properties for groat production: low hull content and smaller kernel mass allow for high groat yield with minimal losses, while moderate hectoliter weight ensures sufficient mechanical stability during processing. Samples from Khmelnytskyi and Cherkasy regions, despite higher hectoliter weight and grain mass, require enhanced pre-treatment and optimized dehulling and polishing regimes, as thicker husks increase energy consumption and reduce final product yield. Samples from Mykolaiv and Chernihiv regions show intermediate properties, making them versatile for different processing schemes and providing a compromise between groat yield and quality.

At the next stage of the study, a technological scheme for processing millet grain into polished groats was developed. Cleaned millet grains with moisture not exceeding 14 % are directed in a single stream to water-heat treatment, carried out using hot conditioning in batch-type steamers, such as the «A9-BPB» (manufactured by OLIS LLC, Odesa) [27].

Millet is characterized by relatively low natural moisture during storage (typically 11–13 %) and limited water absorption capacity, ranging from 14 to 16 % depending on the variety and growing conditions. This means that achieving the optimal kernel moisture for effective dehulling (around 15–16 %) requires a controlled steaming regime, since excessive moisture can promote microbial growth and reduce free-flowing properties, whereas insufficient moisture maintains high kernel brittleness.

In batch-type steamers «A9-BPB» [27], working steam pressures of 0.10–0.35 MPa and adjustable steaming times (usually 8–15 minutes) create conditions for gradual moisture penetration into the grain surface layers while simultaneously exerting thermal effects on cellular structures. This increases endosperm plasticity, while the bonds between the husk and the kernel weaken due to denaturation of aleurone layer proteins and partial degradation of hemicelluloses. Under properly selected conditions, the husk softens, facilitating its subsequent separation.

Steaming millet at 100–120 °C for 10–12 minutes preserves kernel structural integrity while reducing husk adhesion by nearly one-third. After drying, the grain reaches an optimal moisture content of 14.5–15.5 %, increasing polished millet yield by 2–3 % compared to conventional processing without water-heat treatment. In addition, the proportion of broken grains decreases by 20–25 %, and the kernel extraction coefficient rises to 80–82 % versus 75–77 % in traditional dehulling.

The action of steam causes partial swelling and partial gelatinization of the outer layers of starch granules, and subsequent drying densifies these layers, enhancing kernel mechanical strength. This reduces losses in the form of flour during polishing. Conducting water-heat treatment in batch-type «A9-BPB» steamers [27] not only facilitates dehulling but also improves process energy efficiency, as less mechanical effort is required to achieve the same degree of husk separation.

A steaming regime of 0.12–0.15 MPa and 10–12 minutes reduces the total microbial count three- to fourfold, inactivates lipase complex enzymes that inhibit rancidity, and increases the storage stability of the final groats. Using the «A9-BPB» batch steamer (manufactured by OLIS LLC, Odesa) [27] for water-heat treatment of millet before dehulling provides a range of technological and quality advantages with scientifically validated justification. The steamer enables a stable steaming regime at pressures up to 0,35 MPa, with a steam consumption of approximately 150–200 kg/t and a productivity of about 2.8 t/h per cycle lasting around 12 minutes. This regime ensures uniform grain moisture and heating without mechanical destruction, enhancing endosperm plasticity and weakening husk–kernel adhesion. As a result, the proportion of damaged grains during dehulling is significantly reduced, and the kernel extraction coefficient is increased. Steaming contributes to the reduction of microbial contamination, inactivation of enzymatic systems that catalyze oxidative processes, and inhibition of insect pest development in stored grain. As a result, the microbiological stability of the raw material is improved, the risk of rancidity and loss of organoleptic properties is reduced, and the shelf life of the finished groats and flakes is extended.

Equally important is the technological feasibility of integrating the «A9-BPB» apparatus [27] into production schemes. Its compact size, moderate energy requirements, and adjustable steaming regimes make it suitable for use in small- and medium-scale enterprises. The batch operation of the apparatus provides high flexibility in the technological process, allowing adaptation of the regimes to the specific characteristics of the millet varieties being processed. This, in turn, stabilizes technological parameters, enhances raw material utilization efficiency, and optimizes the balance of finished product yield.

The steamed millet is dried in vertical steam dryers, such as the «VPS-O» (manufactured by OLIS LLC, Odesa) [27], to a moisture content not exceeding 14 %. Drying millet after preliminary steaming in vertical steam dryers of the «VPS-O» type [27] offers several advantages that justify its use in polished millet production schemes. One key feature is the uniformity of the dehydration process, achieved through the vertical design of the equipment. An important element of this technological equipment is the cooling section, equipped with a device for distributing and regulating cooling air, which ensures uniform cooling of the product. Grain movement occurs under the force of gravity, enabling laminar flow through multiple drying zones with controlled heat distribution. This organization minimizes moisture and temperature gradients within the kernel, reducing the likelihood of microcrack formation and preserving the plasticity and structural integrity of the endosperm.

A critical structural component of this dryer is its own steam-generation unit, which reduces energy consumption and increases equipment efficiency. The use of saturated steam as a heat carrier ensures gentle drying. Thermal exposure within the range of 55–70 °C in the working zone facilitates gradual removal of excess moisture without abrupt thermal fluctuations typical of drum or shaft dryers. This prevents deep denaturation of protein fractions and degradation of starch granules that are common in intensive convective heating. Consequently, the kernel retains high vitreousness and enhanced mechanical strength, directly improving the efficiency of subsequent dehulling and polishing stages, yielding a higher proportion of whole kernels and reducing the fraction of broken grains.

From the perspective of energy efficiency, vertical steam dryers also have advantages. Their operation is based on the principle of partial recirculation of the heat carrier, which allows optimizing steam consumption and reducing specific energy costs per unit of finished product. The compact design combined with high productivity ensures rational use of production space, making these units suitable for both large and medium-sized enterprises. The high-temperature environment, combined with moisture removal, provides significant reduction of microbial contamination and inactivation of enzyme systems, particularly the lipase complex, which catalyzes rancidity processes. This contributes to the stabilization of the grain during storage and ensures a longer shelf life for the finished groats with minimal loss of organoleptic properties.

A notable advantage of «VPS-O» type units [27] is their technological flexibility. The ability to adjust drying parameters – such as heat carrier temperature, grain movement speed, and residence time in the working zone – allows adapting the process to specific millet varieties and varying initial moisture content after steaming. This ensures an optimal final grain moisture level (14.5–15.5 %), which is critical for the stability of dehulling and the energy efficiency of subsequent operations.

At the next stage, millet is directed to dehulling, which is carried out on two sequential systems using roller-deck machines, such as the «VDSO» (manufactured by OLIS LLC, Odesa) [27]. Dehulling millet on «VDSO» roller-deck machines [27] has significant technological and qualitative advantages, which increase the efficiency of the processing operation. The main benefit of this equipment is the combination of intensive mechanical action with controlled impact on the grain, achieved through an optimal combination of the abrasive deck surface and adjustable roller pressure. A key feature of this roller-deck machine is the use of a rubberized deck made of special food-grade rubber, ensuring reliable operation and gentle handling of the product. This allows uniform removal of husks without excessive kernel damage, maintaining a high yield of whole polished grains.

The use of roller-deck machines significantly reduces the amount of by-products in the form of broken kernels and floury particles, enhancing the economic efficiency of production. Thanks to the design features of the «VDSO» [27], technological parameters remain stable, and their precise adjustment is possible depending on the moisture content and physical-mechanical properties of the grain, which is especially important for millet. Dehulling products after each dehulling system are separated in air separators, such as the «ASO» (manufactured by OLIS LLC, Odesa) [27].

Separating millet dehulling products in «ASO» air separators [27] offers several significant advantages that directly affect the quality and yield of the finished groats. The main feature of this equipment is the use of a controlled airflow to separate particles of different mass and size, ensuring high precision in the separation process. During separation, husks, powdery fractions, and light particles are efficiently removed, while intact kernels remain in the working stream. This reduces the content of undesirable impurities in the final product, improving its sanitary-hygienic characteristics and organoleptic properties.

Compared to traditional sieve separators, which rely primarily on differences in particle size, «ASO» air separators [27] have a significant advantage in removing light organic impurities that are difficult to eliminate mechanically. This ensures higher purity of the grain mass and lowers the risk of husk particles or flour residues entering the finished groats, which could negatively affect appearance and taste.

The use of aerodynamic principles provides high throughput with relatively low energy consumption. Additionally, the design features of «ASO» separators [27] allow adjustment of airflow parameters according to the physical-mechanical properties of the processed mass, ensuring flexibility and stability of the process even with significant variability in grain characteristics.

Before the polishing system, the products are controlled in a groat sifter, such as the «RKO» (manufactured by OLIS LLC, Odesa) [27]. In the sifter, residual flour is removed from the dehulling products. Whole dehulled kernels are collected from the 1.4×20 mm sieve and directed to polishing, while the 1.4×20 mm sieve fraction contains broken kernel particles, remaining flour, and husk.

The use of the groat sifter «RKO» (manufactured by OLIS LLC, Odesa) [27] for controlling products prior to the polishing system is of fundamental importance for ensuring stability and quality in millet production. The main advantage of this equipment lies in its ability to accurately fractionate the products by size and structural characteristics before they enter the polishing stage. This preliminary separation optimizes the load on the polishing machines, prevents the entry of excessively large or small particles that could reduce processing efficiency, and minimizes product losses.

The «RKO» sifter [27] effectively removes incompletely dehulled kernels, fine particles, and excess husk fragments, ensuring that the mass entering the polishing stage is uniform and consistent in its physical properties. This significantly reduces the risk of uneven hull removal during polishing, stabilizes technological parameters, and allows a higher yield of finished groats of standard quality.

Another important advantage is increased resource efficiency. By performing preliminary product control, mechanical load on the polishing machines is reduced, which extends the service life of working elements, lowers energy consumption, and decreases maintenance costs. Additionally, precise fractionation minimizes flour formation and reduces losses of the valuable endosperm portion. Compared to technological schemes without a preliminary control stage, the use of the RKO [27] significantly improves the organoleptic properties of the finished product. Efficient removal of fine husk particles results in groats with a more uniform structure, better culinary properties, and a more attractive appearance.

Polishing of whole kernels is carried out on a single system. For this stage, «Kaskad» dehulling–polishing machines (manufactured by OLIS LLC, Odesa) [27] or their analogues, which operate on the same principle, are used. After polishing, the product mixture undergoes double sifting in closed-cycle air separators, such as the «ASO» (manufactured by OLIS LLC, Odesa) [27], to remove residual flour.

The use «Kaskad» dehulling–polishing machines (manufactured by OLIS LLC, Odesa) [27] at the stage of whole-kernel polishing provides a range of advantages that significantly enhance the efficiency of the technological process and the quality of the final product. The key feature of this equipment is the integration of dehulling and polishing actions in a single machine, which allows optimal treatment of the kernel surface while preserving its structural integrity.

The design features of the «Kaskad» machine ensure adjustable intensity of abrasive impact and precise control of pressure applied to the kernels. This allows the process to be adapted to different millet varieties, minimizing the formation of broken grains and flour. The uniform distribution of working elements throughout the polishing chamber ensures consistent processing of each kernel, which positively affects the appearance and organoleptic properties of the final product.

Compared to other types of polishing machines, the «Kaskad» dehulling–polishing machines [27] demonstrate significant advantages, supported by both experimental research and practical application in groat production. Traditional polishing machines, including abrasive and disk types, often perform only superficial hull removal and partially process the kernel, leading to uneven treatment, increased formation of broken grains, and floury waste. In the «Kaskad» machine, the combination of dehulling and polishing actions ensures complete yet gentle removal of the hull while maintaining the structural integrity of the kernel, increasing the yield of finished millet by 4–6 % compared to separate machines.

After polishing, the obtained millet kernels are directed to a pneumatic sorting table, such as the «SPS» (manufactured by OLIS LLC, Odesa) [27], which ensures quality control of the polished kernels and removes any unhulled grains from the mixture, returning them to the second dehulling system.

The use of the «SPS» pneumatic sorting table [27] for controlling polished millet kernels is a technologically justified measure that enhances the quality and stability of the final product in accordance with modern groat production standards. A key scientific and technical advantage of this equipment is its use of aerodynamic sorting principles, which allow differentiation of the grain mass by density, volume, shape, and individual particle mass. This separation effectively removes under-polished kernels, damaged grains, fine husk particles, and powdery fractions, improving the uniformity of polished kernels and ensuring consistent organoleptic and technological properties of millet.

The «SPS» table [27] applies a gentle mechanical load on the grain, reducing the risk of cracks or kernel breakage during quality control. An additional advantage is the high degree of technological flexibility. Adjusting the air flow rate, the tilt angle of the working surface, and the speed of grain movement allows the process to be adapted to different millet varieties, varying moisture content, and degrees of polishing. This ensures stability of the final product characteristics regardless of variability in the incoming raw material.

The millet kernels obtained after processing on the pneumatic sorting table are directed to a second stage of water-heat treatment. The steamed kernels are dried in vertical steam dryers, such as the «VPS-O» (manufactured by OLIS LLC, Odesa) [27], to a moisture content of 12 %, after which they are subjected to inspection with magnetic separators and then sent for packaging or storage in finished product bins.

Instant products based on polished, steamed millet groats represent complex functional systems, formed under the influence of water-heat treatment, which ensures optimal physicochemical and structural-mechanical properties of the final product. The second stage of steaming polished groats at a steam pressure of 0.20–0.22 MPa for 5–10 minutes significantly alters the internal structure of the endosperm, promoting partial starch gelatinization and granule swelling. At the molecular level, hydrogen bonds in the starch macromolecules are disrupted, increasing their hydrophilicity and water absorption capacity. Simultaneously, the husk structures soften, internal stresses in the kernel decrease, and the kernel's plasticity improves.

These transformations create conditions for producing instant products with high uniformity and stable structure. The enhanced hydration capacity of the kernel allows for a significant reduction in cooking time, as water penetrates more quickly into the inner layers of the endosperm and initiates complete starch gelatinization. This ensures even cooking of the product and formation of a uniform texture without the excessive formation of broken kernel particles, which is a critical quality indicator for instant products.

The applied steam pressure and temperature over the defined time reduce the activity of amylases and other enzymatic systems, decrease microbial counts, and partially inhibit oxidative processes in the endosperm lipid complex. As a result, instant products achieve improved storage stability, reduced risk of rancidity, and a longer shelf life without loss of nutritional value.

Conclusion

Studies of the chemical composition and technological properties of millet grain cultivated in various regions of Ukraine confirm the significant influence of soil and climatic conditions on the accumulation of key nutrients and the formation of parameters critical for processing. It was established that protein content in the samples varies widely (9.36–15.07 %), largely depending on the cultivation region. The highest protein level was recorded in the «Bila Altanka» variety from the Odessa region, making this sample particularly promising for the production of high-protein groats. Samples from the Mykolaiv, Cherkasy, and Khmelnytsky regions are characterized by higher fiber and ash content, which may reduce groat yield but makes them valuable as sources of dietary fiber and minerals.

Granulometric analysis revealed differences in the structure of the grain mass depending on the region, directly affecting the uniformity of water-heat treatment and the purity of the resulting groats. In particular, the grain from Mykolaiv is dominated by larger fractions, whereas Odessa samples have a significant proportion of medium-sized grains, ensuring higher groat yield and reducing the formation of dust-like particles.

Research on husk proportion and test weight confirmed that the «Bila Altanka» grain from Odessa has the lowest fraction of husks, creating favorable conditions for obtaining groats with high yield. At the same time, samples from Khmelnytsky and Cherkasy regions exhibit higher husk content and density, requiring more thorough thermal preparation.

These results indicate the potential of using domestic millet varieties as raw material for groat production, taking into account regional characteristics of chemical composition and technological properties. This provides a foundation for optimizing processing regimes, expanding the range of groats, and developing functionally oriented products.

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ПРОСО ПЕРСПЕКТИВНА – СИРОВИНА ДЛЯ СУЧАСНОГО КРУП'ЯНОГО ВИРОБНИЦТВА

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Анотація. В роботі акцентовано увагу на регіональних відмінностях хімічного складу зерна сортів Біла альтанка та Полтавське Золотисте, вирощених у різних областях України протягом 2020–2022 років. Встановлено, що вміст протеїну коливається в межах від 9,36 % до 15,07 % залежно від регіону вирощування та кліматичних умов. Вміст крохмалю у досліджених зразках становив 62,1–66,5 %, що відповідає середнім літературним даним для проса, проте поєднання з підвищеним рівнем білка у деяких випадках створює оптимальне співвідношення основних речовин для харчових цілей. Виявлені відмінності за вмістом клітковини (5,99–10,01 %) і золи (2,24–3,45 %). Гранулометричний склад показав, що найбільш сприятливі характеристики для переробки має зерно з Черкаської області, де частка великих зерен перевищувала 89 %. У той же час зразки з Одеської області відзначалися значною часткою середніх зерен, що сприяє рівномірності шліфування та зниженню кількості пилоподібних частинок. Миколаївські зразки містили переважно великі зерна, що створює потребу в оптимізації режимів лущення. Таким чином, визначено, що якість крупи значною мірою залежить від однорідності зерна та співвідношення його фракцій.Найнижчий рівень плівчастості (15,0 %) зафіксовано у Білої альтанки з Одеської області. Зразки з Хмельниччини та Черкащини відзначалися більшою товщиною оболонок (плівчастість понад 18 %). Натура зерна змінювалася від 713 до 771 г/л, а маса 1000 зерен – від 5,53 до 7,91 г, що свідчить про морфологічну різноманітність і потребу в коригуванні режимів переробки залежно від конкретного сорту та регіону походження. В роботі обґрунтовано технологічну схему виробництва круп швидкого приготування з проса, що включає воднотеплову обробку зерна перед лущенням, лущення на двох системах, контроль лущеного ядра у крупяних розсійниках, шліфування на одній системі, контроль шліфованого ядра на пневматичному столі, воднотеплову обробку шліфованого ядра.

Ключові слова: просо, крупа, хімічний склад, технологічні властивості, технологія виробництва круп швидкого приготування, воднотеплова обробка, сорти Біла альтанка, Полтавське Золотисте.