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RESEARCH OF SORGHUM QUALITY INDICATORS FROM VARIOUS REGIONS OF UKRAINE

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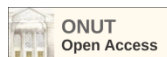
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Abstract. This article investigates the qualitative indicators of sorghum grain grown in different regions of Ukraine, in order to substantiate its effective use in food, feed and technical areas. The article analyzes the relevance of expanding the species composition of grain crops in Ukraine in view of climate change, limited resources, highlighting sorghum as a promising drought-resistant and high-yielding crop. A comparative analysis of the qualitative indicators of sorghum grain (moisture content, litter content, protein, starch, fat content) was conducted from samples obtained from Odessa, Kyiv, Mykolaiv, Cherkasy and Kirovohrad regions of Ukraine. The study revealed regional differences in qualitative characteristics, in particular regarding moisture and impurities, which often exceed international standards (EU, USA). At the same time, the protein and starch content in all samples meets or exceeds the regulatory values, which confirms the high feed and energy value of Ukrainian sorghum. A comparison of the main quality indicators of sorghum grain, which are regulated in the standards of the European Union (EU), the United States of America (USA) (according to Codex Alimentarius) and Ukraine (DSTU 4523:2006), was conducted. They cover such criteria as maximum moisture content, permissible percentage of waste and grain impurities, pest infestation, content of sprouted grains, smell and color of grain. In addition, a comparison was made of requirements for the content of mycotoxins, starch, protein, fat and tannins, which are key to determining the suitability of sorghum for various purposes (food, feed, technical purposes). The analysis shows that EU and US standards usually set more stringent requirements for purity, moisture and grain safety, and also provide for mandatory control over the content of biochemical components, while Ukrainian standards are more flexible and do not always directly regulate these indicators. This discrepancy may create challenges when exporting Ukrainian sorghum to international markets. The need to harmonize Ukrainian sorghum quality standards with international ones is emphasized to increase competitiveness in the world market and expand its use in the food and bioenergy industries.

Keywords: sorghum grain, quality indicators, international standards, grain moisture, grain contamination, chemical composition of sorghum.

Introduction. Formulation of the problem

In the current conditions of agricultural development in Ukraine, it is important to expand the species composition of grain crops that can provide stable yields under conditions of climate change, limited resources and soil degradation. One of the promising crops in this aspect is sorghum (*Sorghum* spp.) - a drought-resistant, undemanding to soils and environmentally plastic crop, characterized by high productivity of green mass and grain [1-4].

Sorghum is actively cultivated in the southern and central regions of Ukraine, where climatic conditions complicate the cultivation of traditional cereal crops, such as corn or wheat. However, for the effective use of sorghum in food, feed or technical areas, it is important not only to assess its yield, but also to conduct a comprehensive study of grain quality indicators - protein content, starch, fiber, mass fraction of impurities, moisture, etc.

Despite the growing popularity of sorghum in agricultural production in Ukraine, the qualitative characteristics of this crop grain from different regions have not been studied sufficiently. There is a shortage of systematic data on the influence of soil and climatic conditions, agrotechnical approaches and varietal characteristics on the formation of the qualitative composition of products. This limits the possibilities of rational use of sorghum in the processing industry and requires a comparative analysis of the indicators of samples grown in different natural zonal conditions of Ukraine [1, 5-8].

The relevance of the topic is due to the need to create a scientifically sound database on the qualitative composition of sorghum, which will become the basis for further selection work, optimization of growing technologies and expansion of areas of crop use.

Over the past decades, more and more attention has been paid to the search for alternative energy sources in the world, in particular those based on the use of renewable resources, among which plant raw materials occupy a special place. Such interest is due, first of all, to the instability of prices for fossil energy carriers and the threat of their complete depletion. It is predicted that in the near future the share of biofuels in world fuel consumption will reach 7–10% with further growth. At the same time, Ukraine's energy sector largely depends on imported resources – oil, gas, gasoline, the cost of which is constantly increasing. In this regard, the production of biofuels – bioethanol, biodiesel, biogas, etc. is a priority area for development [1, 5-8].

Back in the early 1980s, Ukrainian scientists substantiated the feasibility of increasing the sown areas in the southern regions of Ukraine and the North Caucasus. A significant contribution to this research was made by Doctor of Agricultural Sciences, Professor M.A. Shepel. He proved that in the southern regions of Ukraine there is a potential for expanding grain sorghum crops to 1.8 million hectares. In the late 1980s and early 1990s, the area under this crop in Ukraine was 20–25 thousand hectares. The creation of early-ripening varieties and hybrids made it possible to grow grain sorghum up to 50–52° north latitude, and sugar sorghum and sorghum-sudanka hybrids for fodder – up to 55°, that is, almost throughout the country. However, due to the extensive model of agriculture in the 1990s and the shortage of quality seeds, agricultural producers did not show interest in expanding sorghum crops [1, 2, 9-11].

However, further expansion of areas was hampered by the problem of sales: the domestic market was not ready for the full use of the harvested grain, so the main prospects lay in exports. To make sorghum cultivation economically profitable, it is necessary to coordinate the actions of all market participants – suppliers, agricultural producers and traders.

Currently, the interest of traders and fodder producers in sorghum has significantly increased, which stimulates the demand for this crop. In the context of globalization, agricultural enterprises of Ukraine are forced to look for new methods of management. Many farms that do not engage in livestock breeding and do not have their own processing are switching to commercial crop production, focused exclusively on the sale of products.

Analysis of recent research and publications

A number of researchers [1-3, 11-16] emphasize the need for adaptive sorghum breeding, which should take into account the regional specifics of the formation of grain quality indicators. In their works, they identify varieties and hybrids that are better adapted to the conditions of the Steppe, Forest-Steppe and Polissya, indicating the features of protein, ash and fiber composition. In general, most studies focus either on the agrotechnical aspects of sorghum cultivation or on its chemical composition obtained from a specific region, while there is a lack of a comprehensive comparative analysis of the quality indicators of sorghum grain grown in different natural and climatic zones of Ukraine.

The ARVALIS Institute of Plant Production, together with the National Agency for Agricultural and Marine Products FranceAgriMer, conduct analyses of grain sorghum every year. They show that its chemical composition is similar to the chemical composition of other cereals, such as wheat and corn (Table 1). In sorghum, the starch content, which is a source of energy, is 74% of dry matter. This indicator is higher than in wheat and equal to the starch content in corn. The protein content of sorghum is on average 11%. This figure can vary from 10% to 12% in the best cases and is also very attractive. [22-27]. Very high energy value for poultry. Sorghum not only has a favorable chemical composition, but, in addition, it is the most energy-intensive crop for poultry. Sorghum can make up up to 40% in diets. Care must be taken to adapt the proportion of sorghum addition, depending on the growth stage of the animals or the stage of production. For example, in the early stages of development, it is better to limit the proportion of sorghum inclusion to, at most, 30%.

Compared to corn, sorghum contains less xanthophyll, the pigment that gives the final product its yellow color. Poultry fed a diet rich in sorghum will produce less yellow meat than poultry fed on corn. However, some markets prefer white meat, and although the color of the meat changes when sorghum is used in the diet, this does not affect its taste [16, 17]. Sorghum has a reputation for being a high-tannin crop. This is damaging to its image, as the presence of tannins in animal feed is a serious negative factor for digestibility in monogastric animals.

Table 1 – Comparative chemical composition of sorghum, maize and wheat grains (on dry matter, approximate values) [1-4]

Component	Sorghum	Maize	Wheat
Protein (%)	8 - 12	8 - 11	10 - 18
Fat (%)	2,1 – 7,6	3,5 - 6	1,5 – 2,5
Carbohydrates (%)	65 - 76	72 - 75	60 - 75
Starch	56 - 75	72 - 73	60 - 75
Sugars	0,7 – 4,2	1 - 3	< 5
Fiber (%)	1,0 – 3,4	2 - 7	2 - 3.5
Ash (%)	1,3 – 3,3	1,2 – 2,9	0,5 – 1,5
Minerals	Phosphorus, Potassium, Magnesium, Iron, Calcium, Zinc	Phosphorus, Potassium, Magnesium, Iron, Zinc	Phosphorus, Potassium, Magnesium, Iron, Zinc, Copper, Selenium
Vitamins	Group B (Thiamine, Niacin, Riboflavin), Vitamins A, D, E	Group B, Vitamins A, E	Group B (Thiamine, Niacin, Riboflavin, B5, B6, B8, B12), Vitamins E, K, A, Ascorbic acid
Other compounds	Tannins (especially in dark varieties), phenolic compounds	Carotenoids (especially in yellow corn), anthocyanins	Gluten (gluten), phenolic compounds, bioflavonoids

Thanks to the efforts of European breeders, European sorghum has been tannin-free for 30 years. And this does not depend on the color of the sorghum. In order to register a variety in the European catalog, the tannin level must not exceed 0.3%. However, this threshold can be equated to the "absence of tannins", because it is so insignificant that it has no effect on the quality of livestock feed [1, 28].

In terms of the volume of cultivation of sorghum, it ranks fourth in the world after wheat, rice and corn. The homeland of sorghum is considered to be Africa. The crop belongs to the genus of annual and perennial herbaceous plants of the cereal family. Taking into account that the crop is thermophilic and resistant to drought and heat, it can be successfully grown in all climatic regions of the planet. The plant adapts well to soil growing conditions. A huge number of natural and cultivated varieties of sorghum can be found in Northeast Africa, in particular in Ethiopia and Sudan. Sorghum is rightfully considered the oldest crop of world agriculture, because humanity grew it as early as 3,000 BC in India and Ancient China. Currently, the USA is the largest producer of sorghum in the world. The leaders in crops here are the states of Kansas and Texas. Given the extreme weather conditions that are a consequence of global warming, the plant is grown primarily in arid regions [1-5].

The main reasons for the increase in sorghum imports include a decrease in the production of grain crops in the EU, a sharp increase in the cost of grain on the European market, as well as a decrease in the level of final stocks of major grain crops. Sorghum is practically not grown in Europe, although this crop has all the properties to adapt to climatic conditions.

Ukrainian agriculture is increasingly feeling the consequences of global warming, as quite serious climate changes have occurred over the past 20 years. Ukrainian agriculture, which is accustomed to a temperate climate, will have to take extreme weather conditions into account more often in the future. Therefore, agricultural producers have to reorient themselves to new crops. And more and more often, Ukrainian farmers are betting on such drought-resistant cereals as sorghum. Growing this crop in our country will allow to increase the yield from the lands of the southern regions of the country.

Among the many crops that are given for the production of ethanol, one of the most promising is sorghum. It has high photosynthetic efficiency and can form a powerful biomass rich in energy in a short time. In addition, the plant contains a huge part of the energy contained in substances that are easily converted into ethanol. Sugar sorghum contains a whole complex of sugars, and grain sorghum contains starch. Grain sorghum has a much higher starch yield - 74% than, for example, corn - 67%. And sugar sorghum has a much higher alcohol yield. This crop is the future of bioethanol production. If, in addition to stalks, grain is also used for the production of bioethanol, you can get up to 7000 liters per hectare per year. In addition, the plant can successfully grow in the steppe and forest-steppe zones [1, 11-18, 22-23].

Goal: To conduct a comprehensive study of the quality indicators of sorghum grain from various growing regions and compare them with national (DSTU) and international standards (Codex Alimentarius, USDA, ISO, EN).

Tasks:

1. To assess the relevance and prospects of sorghum cultivation in modern conditions of Ukrainian agriculture.

2. To conduct a comprehensive study of the quality indicators of sorghum grain (protein, starch, fiber, mass fraction of impurities, moisture) from samples grown in different regions of Ukraine.

3. To compare the obtained quality indicators of sorghum grain with national (DSTU) and international standards (Codex Alimentarius, USDA, ISO, EN).

Research materials and methods

The determination of the quality of sorghum grain was carried out according to the following main indicators: moisture, contamination, protein content, starch content, fat content.

Grain moisture is one of the most important indicators of its quality, which determines its safety, energy value, suitability for processing and possible DSTU ISO 712:2015 Cereals and products thereof. Determination of moisture content. Control method (ISO 712:2009, IDT)

According to DSTU 4117:2007 "Grain and products thereof. Determination of quality indicators by infrared spectroscopy", the determination of grain quality, in particular moisture, protein, gluten, starch, fat content, is carried out using infrared analyzers (IR analyzers), which operate on the principle of near infrared spectroscopy (NIR – Near Infrared Reflectance).

DSTU EN 16378:2022 (EN 16378:2013, IDT) "Cereal crops. Determination of impurities in corn (*Zea mays*, L.) and sorghum (*Sorghum bicolor*, L.)"

Results of the research and their discussion

Sorghum, as a technical and fodder crop, is subject to standardization according to quality indicators that regulate the suitability of grain for use in the food, feed and bioenergy industries. Requirements for sorghum in Ukraine are regulated by relevant national standards (DSTU), while the Codex Alimentarius, USDA (USA), ISO and European regulations are used worldwide.

Key differences:

Grain classification. In Ukraine, sorghum grain is rarely classified by class (like, for example, wheat). The main focus is on the purpose: technical, fodder or food.

In the USA, there is a classification by classes (Grade 1, Grade 2, etc.), which regulates in detail the physical properties of the grain and the permissible levels of impurities and damage.

Tannin. Domestic standards do not establish clear norms for tannin content, although in practice it is taken into account, especially when used in the food industry. In the USA and Codex, clear restrictions on tannin

content are established, especially for food sorghum, which must be low-tannin.

Quality requirements for different purposes. In Ukraine, the standard is mainly one - for general use. In the USA and the EU, standards are differentiated depending on the end use (food, feed, technical, ethanol).

Biochemical composition. In the domestic system, quality assessment often does not include regular laboratory analysis for the content of starch, protein, fat, etc. International standards - especially ISO and USDA - include such indicators as part of the requirements or as recommended for inspection during export.

Harmonization of domestic standards with international ones is a necessary condition for expanding sorghum exports, increasing its added value and expanding its use in the food industry. The transition to multi-component quality assessment and the introduction of differentiated requirements for grain by purpose will allow Ukraine to fully compete on the world market.

An important aspect in ensuring the competitiveness of Ukrainian sorghum grain on the world market is compliance with international quality requirements. Contrary to popular belief, there is no single system of EU grain standards, and not all EU members even have their own grain quality standards. The characteristics of grain quality assessment in the EU can be judged by the requirements imposed on grain purchased by the EU Commission into intervention stocks (so-called "standard quality" grain), as well as by the requirements of EU export exchanges. In Europe, the protein or gluten content of wheat is not a decisive factor in determining quality. This does not apply to high-quality milling wheat, the protein content of which determines the quality of products made from it. The main data on which the quality assessment methodology is based are nature, purity and external consumer characteristics: color, smell, commercial appearance, etc. Grain moisture is usually limited to 15%. Grain exports from the European Community go through two official export exchanges — LIFFE (Great Britain) and MATIF (France). Although both the USA and the EU have their own quality standards, they are developed by different regulatory bodies and have differences in approaches to regulation and certification.

In this context, a comparison of the EN 16378:2013 standard, which regulates the quality of sorghum in the EU countries, the USDA United States Grain Standards Act; ISO 6322, Codex Alimentarius CXS 172-1989, a US regulatory document, with the Ukrainian DSTU 4962:2008 "Sorghum. Technical conditions" allows us to outline the differences and identify areas for improving national quality control (Table 2).

Table 2 - Main grain quality indicators regulated in the EU, USA and Ukrainian standards

Indicator	Ukraine requirements (DSTU 4962:2008)	USA requirements (Codex Alimentarius)	EU requirements (LIFFE, Matif)
Maximum moisture, %	≤15.0 (food), ≤14.0 (for storage)	≤14.0% (sometimes allowed up to 14.5%)	≤14.5
Foreign matter, %	≤2.0 (for premium and 1st class)	≤1.5% – 2.0% depending on class	≤1.0
Grain admixture, %	≤5.0	≤2.0–5.0%	≤2.0
Pest infestation, %	≤2.0 (dead pests); live pests not allowed	Not allowed	≤1.0
Sprouted grains, %	≤3.0	≤3.0	Not allowed (or by contract)
Grain odor	Typical, without musty or rotten smell	Typical for sorghum, free from mold or foreign odors	Typical for sorghum, free from mold or foreign odors
Color	Depending on color and huskiness, sorghum grain is divided into types and subtypes	Classified by color (white, red, yellow)	Classified by color (white, red, yellow)
Mycotoxin content	May be regulated upon consumer request	Mandatory control	Mandatory control according to EU regulations
Starch content, % d.m.	Not directly regulated	≥68/72% (food/technical use)	68/75 (food/technical use)
Protein content, % d.m.	Not directly regulated	≥7.0	≥9.0
Fat content, % d.m.	Not directly regulated	≤4.0	≤4.0
Tannin in grain, % d.m.	Not strictly regulated, but considered	≤0.25% for food use, higher allowed for feed	≤0.3%

As can be seen from the table, EU standards set stricter requirements for purity, moisture, impurities and safety indicators, such as mycotoxins and pesticide residues. Particular attention is paid to the use of modern quality control methods, in particular infrared spectroscopy (IRS).

In contrast, the Ukrainian standard DSTU 4962:2008 "Sorghum. Technical conditions" is more flexible, which allows the circulation of grain for both food and feed purposes. However, this flexibility can become a barrier when exporting sorghum to the EU, since compliance with European technical regulations and certification (for example, ISO 22000, HACCP or GMP+) is required.

The need to harmonize regulatory documents (DSTU) for sorghum grain in Ukraine and other EU countries and the USA is due to several key factors that affect the competitiveness of Ukrainian products on the world market and the expansion of their areas of use.

The main reasons for the need for harmonization:

Disparities in quality standards: Ukrainian standards (DSTU 4523:2006) differ from international standards, such as the EU (EN 16378:2013), the US (USDA United States Grain Standards Act) and Codex Alimentarius. This creates difficulties when exporting

Ukrainian sorghum, as the domestic accounting system does not always provide for the provision of detailed grain characteristics required by foreign importers.

Stricter requirements of international standards: EU standards, in particular, set stricter requirements for purity, moisture, impurities and safety indicators, such as mycotoxins and pesticide residues. They also require mandatory control of mycotoxin content, unlike Ukrainian standards, where this can be regulated at the request of the consumer.

Absence of standards for biochemical composition in DSTU 4962:2008. Ukrainian standards do not directly regulate the content of starch, protein and fat in sorghum grain, while international standards, especially ISO and USDA, include such indicators as part of the requirements or as recommended for inspection during export. For example, EU and US standards regulate the content of starch (≥68/72-75%), protein (≥7.0-9.0%) and fat (≤4.0%).

Grain classification: In Ukraine, sorghum grain is rarely classified by class, the main attention is focused on its purpose (technical, feed, food). In the USA, there is a detailed classification by class (Grade 1, Grade 2, etc.) with regulation of physical properties and permissible levels of impurities.

Regulation of tannin content: Domestic standards do not establish clear norms for tannin content, although it is taken into account in practice. However, in the USA and Codex, clear restrictions on tannin content are established, especially for food sorghum ($\leq 0.25\%$).

Harmonization of Ukrainian standards with European ones or parallel implementation of a two-stage control system (domestic + export) is a relevant direction of modernization of the agricultural industry.

The next stage was the determination of sorghum grain quality indicators. Sorghum samples that underwent primary processing and were stored in granaries. Samples of the 2023/2024 harvest were taken from different growing regions: Kyiv, Odessa, Kirovohrad, Mykolaiv, Cherkasy regions

The study was conducted on the following indicators: moisture, litter, starch content, protein content, fat content.

The chemical composition of sorghum is important, since the components of protein, starch and oil are of significant interest to end users. These attributes provide additional information related to nutritional value for feeding livestock and poultry, as well as other types of processing.

Chemical analyses of sorghum grain were performed using an Infratec 1241 FOSS infrared grain analyzer. Results are given on a dry matter basis (percentage of anhydrous matter).

Protein is very important for poultry and livestock nutrition because it supplies essential sulfur-containing amino acids and improves feed conversion efficiency. Protein is usually inversely proportional to starch concentration.

Starch is associated with metabolizable energy for livestock and poultry. High starch concentrations often indicate good grain ripening conditions and fairly moderate grain density.

Oil is an important component of poultry and livestock diets. It serves as a source of energy, allows the use of fat-soluble vitamins, and provides certain essential fatty acids. Oil can also be an important by-product of sorghum processing.

The results of the qualitative analyses of sorghum are given in Table 3. Results are given on a percent dry

matter basis. Standard deviation: 0.39... 1.19%. The maximum (minimum) permissible value from the EU, USA and Ukrainian standards is taken as the normative value. (Fig. 1)

According to the standards, the maximum permissible moisture content of sorghum grain for storage is no more than 14.0%. The analysis shows that sorghum grain grown in Odessa and Cherkasy regions has limit or exceeded values (14.0% and 14.2%, respectively), which requires additional processing before storage. Grain from other regions (Kyiv, Mykolaiv, Kirovohrad) has a moisture content within the permissible norms of 13.5–13.8%, which indicates proper harvesting conditions or agroclimatic factors.

According to the requirements of the standard, the trash admixture should not exceed 1.0%, and the grain admixture - 2.0%. Sorghum grain from none of the regions fully meets both of these requirements.

The worst indicators of trash admixture are observed in the Odessa (2.2%) and Kyiv (1.8%) regions. Grain impurities exceed the norm in grain from Kyiv (3.0%), Odessa (2.7%) and Kirovohrad (2.2%) regions. Only sorghum from Mykolaiv (1.8%) and Cherkasy (1.4%) regions meet the norm. Therefore, in most cases, additional grain cleaning is necessary, which may affect the cost and speed of sale.

The protein content in all regions exceeds the norm of 9.0%, which indicates the high feed value of sorghum. The highest protein values were recorded in sorghum grain samples from Mykolaiv (12.4%) and Cherkasy (11.2%) regions. The starch content also meets or exceeds the norm of 68% in all samples, which indicates the high energy value of the grain. The maximum value is in sorghum grown in Kyiv region (75.5%).

The fat content in samples from Odessa (4.3%) and Kyiv (4.1%) regions exceeds the permissible limit of 4.0%, which may be undesirable for long-term storage due to the increased risk of rancidity. The lowest fat content is observed in sorghum grain from Kirovohrad region (2.9%).

Table 3 Qualitative indicators of sorghum from different growing regions (n=3; P \geq 0.95)

Indicator	Normative value	Sample 1 Odesa region	Sample 2 Kyiv region	Sample 3 Mykolaiv region	Sample 4 Cherkasy region	Sample 5 Kirovohra d region
Moisture, %	≤ 14.0	14.0	13.8	13.5	14.2	13.6
Foreign matter, %	≤ 1.0	2.2	1.8	1.2	1.0	1.8
Grain admixture, %	≤ 2.0	2.7	3.0	1.8	1.4	2.2
Protein content, % d.m.	≥ 9.0	11.0	9.1	12.4	11.2	10.1
Starch content, % d.m.	≥ 68	72.2	75.5	71.2	69.1	72.6
Fat content, % d.m.	≤ 4.0	4.3	4.1	3.2	3.9	2.9

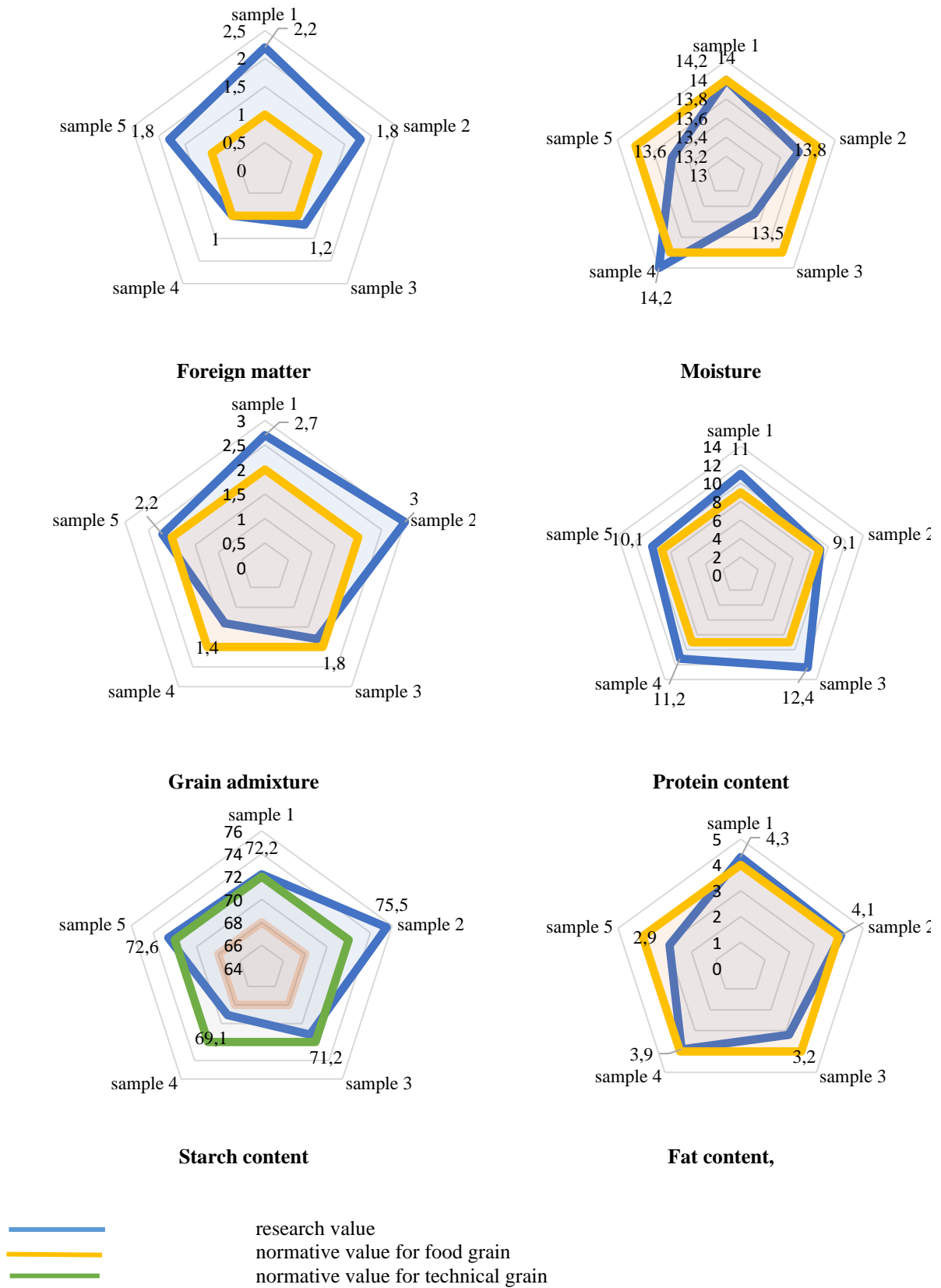


Fig. 1 – Compliance of sorghum quality indicators with international standards

A comparative analysis of the quality indicators of sorghum grain from different regions of Ukraine showed that:

sorghum grain grown in Mykolaiv and Cherkasy regions demonstrate the most balanced indicators, which indicates good quality of raw materials with minimal needs for additional processing.

sorghum grain grown in Odessa and Kyiv regions have the highest levels of impurities and moisture, which requires intervention before storage and sale.

According to biochemical indicators, all samples are competitive for feed use, and some for technical or food processing.

Thus, regional differences in the quality of sorghum grain in Ukraine are due not only to varietal characteristics, but also to agrotechnical techniques and harvesting conditions.

Conclusion

Comparative analysis of quality indicators of sorghum grain from different regions of Ukraine revealed significant regional differences, due to both varietal characteristics and agrotechnical techniques and harvesting conditions. Sorghum samples were studied according to such criteria as maximum moisture content, percentage of waste and grain impurities, starch content, and protein.

In general, grain samples grown in Mykolaiv and Cherkasy regions demonstrated the most balanced quality indicators, indicating good quality of raw materials with minimal needs for additional processing. Sorghum grain grown in Odessa and Kyiv regions has the highest levels of impurities and moisture, which requires intervention before storage and sale.

All samples are competitive for feed use, and some are also suitable for technical or food processing. Further improvement of cleaning and drying technologies is key to achieving international quality standards and increasing the competitiveness of Ukrainian sorghum on the world market.

Exporting sorghum to the EU requires compliance with European technical regulations and certification (e.g. ISO 22000, HACCP or GMP+). Discrepancies in standards reduce the competitiveness of Ukrainian products on the world market, especially in the food and bioenergy sorghum segment. Harmonization of domestic standards with international ones is a necessary condition for expanding sorghum exports, increasing its added value and expanding its use in the food and bioenergy industry. The transition to multi-component quality assessment and the introduction of differentiated requirements for grain by purpose will allow Ukraine to fully compete on the world market.

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ДОСЛІДЖЕННЯ ЯКІСНИХ ПОКАЗНИКІВ СОРГО З РІЗНИХ РЕГІОНІВ УКРАЇНИ

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Анотація. Ця стаття досліджує якісні показники зерна сорго, вирощеного в різних регіонах України, з метою обґрунтування його ефективного використання в продовольчому, кормовому та технічному напрямках. У статті проаналізовано актуальність розширення видового складу зернових культур в Україні з огляду на кліматичні зміни, обмежені ресурси, висвітлюючи сорго як перспективну посухостійку та високоврожайну культуру. Проведено порівняльний аналіз якісних показників зерна сорго (вологість, засміченість, вміст білка, крохмалю, жиру) зі зразків, отриманих з Одеської, Київської, Миколаївської, Черкаської та Кіровоградської областей України. Дослідження виявило регіональні відмінності у якісних характеристиках, зокрема щодо вологості та домішок, які часто перевищують міжнародні норми (ЄС, США). Водночас, вміст білка та крохмалю у всіх зразках відповідає або перевищує нормативні значення, що підтверджує високу кормову та енергетичну цінність українського сорго. Проведено порівняння основних показників якості зерна сорго, які нормуються у стандартах Європейського Союзу (ЄС), Сполучених Штатів Америки (США) (згідно з Codex Alimentarius) та України (ДСТУ 4523:2006). Вони охоплює такі критерії, як максимальна вологість, допустимий відсоток сміттєвих та зернових домішок, ураження шкідниками, вміст пророслих зерен, запах та колір зерна. Крім того, проведено порівняння вимог щодо вмісту мікотоксинів, крохмалю, білка, жиру та танінів, що є ключовими для визначення придатності сорго для різних цілей (харчове, кормове, технічне призначення). Аналіз показує, що стандарти ЄС та США зазвичай встановлюють більш жорсткі вимоги до чистоти, вологості та безпеки зерна, а також передбачають обов'язковий контроль за вмістом біохімічних компонентів, тоді як українські стандарти є більш гнучкими і не завжди безпосередньо нормують ці показники. Це розбіжність може створювати виклики при експорті українського сорго на міжнародні ринки. Підкреслюється необхідність гармонізації українських стандартів якості сорго з міжнародними для підвищення конкурентоспроможності на світовому ринку та розширення його використання у харчовій та біоенергетичній промисловості.

Ключові слова: зерно сорго, показники якості, міжнародні стандарти, вологість зерна, засміченість зерна, хімічний склад сорго.