The indices of sorghum seed quality in dependence on ecological and geographical origin

V V Kovtunov, N A Kovtunova and A S Popov

Agricultural Research Center “Donskoy”, 3 Nauchny Gorodok Street, Zernograd, Rostov region, 347740, Russia

E-mail: Kovtunow85@mail.ru

Abstract. The current paper presents the study results of protein percentage, content of lysine and starch in the collection samples of grain sorghum of various ecological and geographical origin. It was determined that the seed protein percentage in the grain sorghum samples varied from 9.0 to 13.5%. The highest values were identified in the samples from Russia (KiM, Krymbel, Krusta, Ros’), Ukraine (Pioneer 412/Milovskoe 6, No. 13-13, Pioneer 878/Genicheskoe brown 129) and China (KX 8, No. 26-13, Pioner 878/Genicheskoe brown 129) with 13.0-13.5%. The lysine content in protein of the studied samples was 2.5-4.3%, while the value of the standard variety Zernogradskoe 88 was 3.17% with the standard deviation of 0.24%. The maximum content (3.8-4.3%) was identified in the samples Early Hegari (Peru), Line ExF3 IS12606 (Australia), DN-35f (Ukraine), CS-175 (Philippines), H.S.-21 (Romania), Sorghum k-9553 (Korea). The starch content in seed of the collection samples varied within 70.2-77.5%. The highest intragroup values were showed by the samples from Peru (73.9%), Australia (73.8%), France (73.0%), Senegal (73.4%).

1. Introduction
Sorghum is one of the world major grain crops. It ranks fifth after maize, rice, wheat and barley. Sorghum is currently cultivated in 86 countries, and the sown area is 45 million hectares. India, Ethiopia, China, Sudan, Niger, Mali, Nigeria, Burkina Faso, the Central African Republic, Mexico and the United States account for 75% of the total sorghum sown area [1]. In the developed countries, sorghum is mainly used as animal feed, but it is becoming more and more popular as a raw material for food [2].

The study used to focus on biotic and abiotic factors such as pests, diseases, environmental stresses (lack of moisture, high and low temperatures), but insufficient attention was paid to nutritional aspects. Currently, the breeding of various agricultural crops, including sorghum, aims at their improvement [3].

In the breeding work, the initial material was used in hybridization, taking into account their ecological and geographical origin [4]. It was noted that the varieties were adapted precisely to those soil and climatic conditions in which the breeding work was carried out, and the introduction could have a various effect on severity of the trait [5]. The protein percentage, starch content, amino acid composition and other quality indices can differently vary depending on the genotype and environmental conditions during plant growth and development [3]. Therefore, the evaluation of
collection samples according to the main quality traits is an important stage in the development of grain sorghum varieties and hybrids for feed and food use.

2. Materials and methods
The current study was carried out on the experimental plots of the Federal State Budgetary Scientific Institution “Agricultural Research Center “Donskoy” in 2018-2020. The soil of the experimental plots was ordinary carbonate blackearth (chestnut soils), with 3.6% of humus in the arable layer.

The objects of the study were 146 grain sorghum samples of various ecological and geographical origin. The seed protein percentage, content of lysine and starch in sorghum seed were the subject of the study.

The field trials were conducted according to the Methodology of the State Variety Testing [6] and Methodology of a field trial [7]. The sowing was carried out at the optimum time (I-II decade of May), by using a wide-row method (70 cm of row spacing) and the seeding rate of 280 thousand seeds per hectare. The collection samples were sown without sequences in the single-row plots with the area of 7 m². The standard variety Zernogradskoe 88 was sown in each 10 rows.

The seed protein percentage and starch content were determined on the infrared analyzer SpectraStar 2200, and for the control, protein was determined by the Kjeldahl method (State Standard 10846-91), starch was determined by the Evers polarimetric method (State Standard 10845-98). The lysine content was valued by the “Acid Orange dye-binding method” [8].

The statistical analysis of the data obtained was carried out according to B.A. Dospekhov’s method [7] by using computer programs Statistica 10 and Ms. Excel.

3. Results and discussion
Cultivated sorghum has a large phenotypic and genotypic diversity. The studied collection of grain sorghum was represented by the samples from 17 world countries. The most part of the samples (57 pcs (39%)) were the samples from Russia; there were 27 samples from the Southern Federal District (SFD) (Rostov Region, Agricultural Research Center “Donskoy”), Krasnodar Area (Kuban Experimental Station VIR), Republic of Crimea (Crimean Federal University named after V.I. Vernadsky). There were 24 samples from Volga Federal District (VFD) (Saratov Region, Research Institute of Agriculture of the South-East “Rossorgo”), Samara Region (Volga Region Research Institute Breeding and Seed Production named after P.N. Konstantinov)) and the North Caucasian Federal District (NCFD) (Stavropol Area, North Caucasus Federal Agricultural Research Center). In addition, the collection was represented by the samples from Africa, Asia, Europe, Australia, South America, and the USA (Figure 1).

Protein is one of the main indices characterizing quality of sorghum seed intended for feeding farm animals and is the basis of all vital processes. No other substance is capable of fulfilling this specific role in a living organism. Protein deficiency does not only reduce animal productivity and quality of products, but also results in an unproductive consumption of feed, cost increase of livestock products.

Throughout the three-year study the seed protein percentage in grain sorghum averaged 9.0-13.5%, while the value of the standard variety Zernogradskoe 88 was 12.2% with the standard deviation of 0.7%. The highest values (13.0-13.5%) were identified in the samples KX 8 (China), KiM (Russia, Stavropol Area), Krymbel (Russia, Republic of Crimea), Krusta (Russia, Saratov Region), Pioneer 412/Milovskoe 6 (Ukraine), No. 26-14 (China), No.13-13 (Ukraine), Ros (Russia, Samara region), Pioneer 878/Genicheskoe brown 129 (Ukraine).
Figure 1. Origin of the grain sorghum collection samples.

According to the samples ecological and geographical origin (through the world countries), the analysis of intraspecific variation in the seed protein percentage was carried out. The highest intraspecific average values (median) were identified in the samples from the USA (11.9%), Russia (11.9%), China (12.2%), and Moldova (12.4%). Among the samples from Russia the highest seed protein percentage was identified in the samples from the North Caucasian Federal District (12.1%). The lowest median values were identified in the samples from the Philippines (10.1%), Brazil (10.2%), and Korea (10.5%) (Figure 2).
In general, the variation of the trait from year to year showed average variability among the samples. There was a weak variation in the samples from Sudan (V = 8.2%), Moldova (V = 9.5%), France (V = 9.5%) and Russia (V = 9.9%). In Russia the lowest variation coefficient was identified in the group of the samples from the Southern Federal District (V = 8.9%).

Protein quality depended significantly on the amino acid composition and, first of all, on essential amino acids. Sorghum seed had a low protein percentage of the essential amino acid lysine, which largely affected its nutritional value. The feed with a high lysine content is of significant advantage over the conventional feed. Therefore, it was advisable not only to increase the amount of final products, but also to improve its quality. One way to achieve this goal was to select the appropriate initial material.

The lysine content in protein of the grain sorghum collection samples varied from 2.5 to 4.3%, while that of the standard variety Zernogradskoe 88 was 3.17% with the standard deviation of 0.24%. The highest values (3.8-4.3%) were identified in the samples Early Hegari (Peru), Line E × F3 IS12606 (Australia), DN-35f (Ukraine), CS-175 (Philippines), HS-21 (Romania), Sorghum k-9553 (Korea). The maximum values of the median were identified in the samples from Korea, Romania, and the Philippines. Among all samples from Russia, there was identified a low lysine content in protein.
(3.2%) at the highest seed protein percentage in the samples from the North Caucasus Federal District (Figure 3).

![Graph showing lysine content in protein of grain sorghum collection samples in dependence on ecological and geographical origin.](image)

**Figure 3.** Lysine content in protein of the grain sorghum collection samples in dependence on ecological and geographical origin.

This indicator was stable over the years. The variation coefficient did not exceed 4.5% in any group of grain sorghum samples.

Endosperm occupied 80-85% of the seed size and determined its quality. Due to the biological characteristics of the grain crop, most of the sorghum seed endosperm is starch, which is the main source of energy stored in the seed.

The starch content in the seed varied within 70.2-77.5%, and the maximum range of variation was identified in the samples from Ukraine. The highest intragroup values were identified in the samples from Peru (73.9%), Australia (73.8%), France (73.0%), Senegal (73.4%) (Figure 4). Among the Russian samples, the highest starch content was recorded in the samples from the North Caucasus Federal District (72.5% of median). In general, among the collection samples the samples Kamyshinskoe 31 (Russia) with 74.4%, Genicheskoe 130 (Ukraine) with 74.4%, K-10989 (Ukraine) with 74.5%, No. 26-14 (China) with 76.3%, No. 13-13 (Ukraine) with 76.9%, Milovskoe 84 (Ukraine) with 77.5% were identified, they showed the highest values of starch content in the seed.
It should be noted that the trait “starch content” in sorghum seed was characterized by medium and significant variability. The lowest values of the variation coefficient were identified in the samples from China (18.6%) and Russia (20%).

4. Conclusions
The seed protein percentage in the grain sorghum samples varied from 9.0 to 13.5%. The highest values (13.0-13.5%) were identified in the samples from Russia (KiM, Krymbel, Krusta, Ros’), Ukraine (Pioner 412/Milovskoe 6, No. 13-13, Pioner 878/Genicheskoe brown 129) and China (KX 8, No. 26-14). Among the samples from Russia the highest seed protein percentage was identified in the samples developed under the conditions of the North-Caucasus Federal District (12.1%).

The lysine content in seed protein of the grain sorghum samples varied from 2.5 to 4.3%. The maximum content was identified in the samples from Korea, Romania, Philippines, namely CS-175 (Philippines) with 3.66%, H.S.-21 (Romania) with 3.74%, Sorghum k-9553 (Korea) with 4.11%. Among the samples from Russia, there were samples from the North-Caucasus Federal District with the highest seed protein percentage and the lowest lysine content.
The starch content in the seeds varied within 70.2-77.5%, the maximum variation was identified in the samples from Ukraine. The highest intragroup values were shown by the samples from Peru, Australia, France and Senegal. Among them there were the samples Kamyshestskoe 31 (Russia), Genicheskoe 130 (Ukraine), k-10989 (Ukraine), No. 26-14 (China), No. 13-13 (Ukraine), Milovskoe 84 (Ukraine).

References

[1] Fano D 2017 Breeding of sorghum for high lysine in the seed *Int. J. of Agriculture Sciences* (9) 4702-4707.

[2] Taylor J R N, Schober T J and Bean S R 2006 Novel food and non-food uses for sorghum and millets. *J Cer Sci.* 44 252-271

[3] Mofokeng A M, Shimelis H and Laing M 2017 Breeding strategies to improve sorghum quality *AJCS* 11(02)142-148

[4] Min’kach T V and Selikhova O A 2010 Inheritance of economically valuable traits in interspecific hybrids of soybean F1 *Achievements of Science and Technology of the Agro-Industrial Complex* 7 11-13

[5] Shanina E P 2008 Study of potato varieties of Belarusian breeding in the conditions of the Middle Urals *Potato Growing* 14 317-323

[6] *Methodology of the State Variety Testing of Agricultural Crops Cereals, groats, legumes, maize and forage crops* 1989 (Moscow) 194

[7] Dospekhov B A 2014 *Methodology of a Field Trial with the Basics of Studied Results Statistical Processing* (Moscow: Alliance) p 351

[8] Ryadchikov V G 1978 *Improvement of Grain Proteins and Estimation* (Moscow: Kolos) pp 110-114