Nutritional and technological parameters of common bean varieties bred at Omsk State Agrarian University

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Abstract. In the southern forest-steppe of Western Siberia the shortage of proteins can be overcome cultivating legumes such as beans, peas, broad beans and chickpeas. The varieties of dry and green beans bred at Omsk State Agrarian University are adapted to the conditions of the southern forest-steppe; they are characterized by high and stable productivity and possess high compensatory abilities as regards unfavourable environmental factors (drought, waterlogging, ground frost and others). The aim of the research was to determine the technological and nutritional parameters of the grains of common bean varieties bred at the University (protein and sucrose content, seed cooking rate). 6 varieties of common beans bred at the University served as research materials. As a results, the following varieties were identified as possessing valuable technological and nutritional properties: high protein content – Fizkulturnitsa (23.75 %), Lukerya (23.6 %), Omskaya yubileinaya (24.6 %) and Olivkovaya (25.5 %); high zinc content – Fizkulturnitsa (36.86 mg/kg), Lukerya (40.93 mg/kg) and Olivkovaya (40.35 mg/kg); high iron content – Olivkovaya (108.00 mg/kg); high iodine content – Lukerya (0.23 mg/kg) and Olivkovaya (0.21 mg/kg); high calcium content – Fizkulturnitsa (1.86 %); fast seed cooking rate – Fizkulturnitsa, Omichka and Lukerya (57-59 min); high sucrose content in the leaves – Omichka, Olivkovaya, Lukerya and Fizkulturnitsa (0.10-0.15 %).

1 Introduction

Legumes are an excellent alternative to more expensive animal proteins, so they are ideal for improving the diet of all social groups. If compared to other crop families, legumes produce per each land unit a larger amount of high-quality, digestible, cheap proteins, involving in the biological cycle atmospheric nitrogen, which is inaccessible for other plants [1, 2, 3, 4]. Among legumes, common beans are the most requested food crops in the world, ranking second in world farming after soybeans [5, 6, 7]. Increasing the cultivation area of common beans has an important nutritional, economic, agrotechnical and agrochemical value for the Siberian region [8, 9].

The grains of common beans are used to prepare many different dishes; they contain more than 30 different amino acids, proteins, sucrose, organic fatty acids, flavonoids as well as micronutrients (copper, zinc, iron, iodine and others) and vitamins C, E, B2, B6 and PP. The consumption of beans can help solve the problem of the shortage of easily accessible vegetable proteins for human and animal nutrition [10, 11, 12]. Therefore, the cultivation area of beans should be systematically increased in the Russian Federation.

As of December 12th 2020, the State Register of Breeding Achievements of the Russian Federation contains 26 varieties for use in agricultural production, 5 of which have been bred at Omsk State Agrarian University [13, 14].

For this reason, the present research aimed at evaluating the quality of the grains of new common bean varieties bred at Omsk State Agrarian University. The main parameters of consumer properties must include the commercial qualities of seeds – colouring, dimensions, shape, cooking rate and biochemical composition of grains.

The results of the research have confirmed the promising outlooks of cultivating this specific leguminous crop in Western Siberia, as it provides a means for obtaining valuable protein-containing products within relatively early time limits for the region. The introduction of beans in the diet can increase the range of legumes in the Siberian region and improve their role in the "health – nutrition – resource" system.

Nutritionists agree that legumes must be included in the list of the 10 most useful food products for human health and should account for 8-10 % of people's diet [15].

2 Research Methods

The experimental part of the work was carried out in the educational and experimental farm of the Omsk State Agrarian University together with the Center for Collective Use "Selection and seed production of field crops" in the southern forest-steppe of the Omsk region (2015-2018). The Nerussa variety (bred at the All-Russian Science and Research Centre of Leguminous

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and Cereal Crops in the city of Oryol) was used as a control sample.

The chemical analysis of grains was executed at the certified laboratory of the Omsk branch of the Federal State Budgetary Institution "Federal Centre for the Evaluation of the Security and Quality of Grains and Processed Products" according to the following normative documents: National Standard 10846 – 91 (proteins), National Standard 30178 – 96 (zinc), National Standard 28458 – 90 (iodine), National Standard 26928 – 86 (iron) and National Standard 26570 – 95 (calcium). Data were mathematically elaborated following the method by B.A. Dospekhov (1985).

3 Findings

Breeders at Omsk State Agrarian University have create new high-yielding varieties of dry beans, viz. Lukerya, Olivkovaya, Omskaya yubileinaya, Omichka, Fizkulturnitsa.

The dry bean varieties bred at Omsk State Agrarian University are characterized by high yield levels. Over the years of the research, the yield varied between 1.5 and 5.7 t/ha, as shown in Table 1. The highest yield from the varieties at study was obtained in 2017 with an average of 4.1 t/ha; the lowest one was obtained in 2016 with an average of 2.3 t/ha. The Fizkulturnitsa, Lukerya, Sizaya, Omskaya yubileinaya and Olivkovaya varieties significantly surpassed the control sample as regards their yielding capacity.

Table 1. Yield of the seeds of dry bean varieties bred at Omsk State Agrarian University, 2015-2018

Variety	2015	2016	2017	2018	Average
Nerussa, control sample	2.6	1.5	2.8	2.5	2.3
Fizkulturnitsa	3.5	2.1	3.7	3.2	3.1
Lukerya	4.8	3.1	3.8	3.4	3.9
Omskaya yubileinaya	4.3	2.6	3.1	3.0	3.3
Olivkovaya	5.7	2.2	3.2	3.3	3.7
Omichka	3.0	1.5	2.6	3.0	2.4
Average	4.1	2.3	3.2	3.0	3.2
LSD_{05}	0.6	0.3	0.5	0.4	0.5

*accurate if $p > 05$

As a result, the varieties bred at Omsk State Agrarian University distinguished themselves as regards yield on top of having high manufacturability, which is important for commercial crop cultivation.

The yield of common bean varieties depended not only on the varietal peculiarities of the plants, but also on weather conditions. The highest seed yield was obtained in 2015 with the most favorable hydrothermal parameters. In case of excessive or insufficient humidity the yield was significant inferior than in case of optimal growth conditions ($r = – 0.14 \pm 0.57$).

Several other parameters influence the yield of dry beans as well. A correlation between the yielding capacity and productivity features has been established, as well as a strong dependence on the thousand kernel weight and the mass per seed.

The varieties bred at Omsk State Agrarian University show high manufacturability, which is a key factor for commercial crop cultivation. Varieties with a compact bush, height between 40 and 60 cm and lower bean attachment from 15 cm or more are of particular interest for mechanized cultivation. The varieties bred at Omsk State Agrarian University show high manufacturability which is a key factor for commercial crop cultivation. Varieties with a compact bush, height between 40 and 60 cm and lower bean attachment from 15 cm or more are of particular interest for mechanized cultivation, Figure 1.

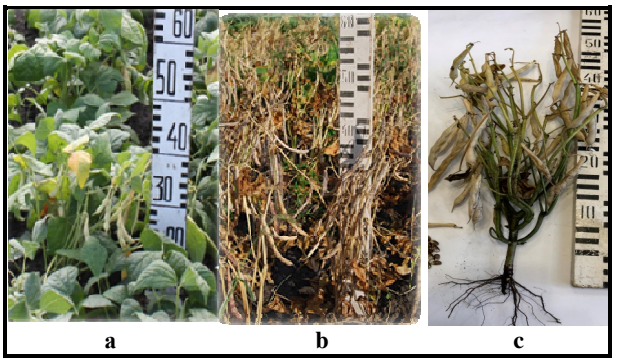

Fig. 1. Appearance of bean plants, demonstrating their manufacturability (a - Olivkovaya, b - Omichka, c - Fizkulturnitsa).

The parameter of plant height characterizes the length of its main stalk and is determined by its genotype as well as by the growth and development conditions. The varieties of beans under trial were bush-shaped, their determinant feature of plant growth and height ranged over the years between 38.2 and 69.0 cm (CV – 9.0 %). The bean varieties bred at Omsk State Agrarian University are highly technological varieties which can significantly decrease the yield loss while harvesting, allowing an increase in the total grain yield. The obtained varieties are consistent with the specific model that has been elaborated for the conditions of the southern forest-steppe of Western Siberia and are commercially viable if compared to their analogues.

The value of these dry bean varieties, when compared to their analogues, is represented by their high protein content (24-27 % against 19-22 % in the control sample), grain-cooking rate, excellent taste properties and non-dehiscence of pulses. They also possess high compensatory abilities as regards unfavourable environmental factors (drought, waterlogging, ground frost and others). The varieties currently available in Russia do not always meet the requirements regarding

production quality and are inferior to the ones bred in other countries.

The experiments have established that the protein content in dry bean varieties bred at Omsk State Agrarian University varied between 22.18 to 26.55 %. Four dry bean varieties significantly surpassed the Nerussa control sample (21.50 %): Fizkulturnitsa (23.75 %), Lukerya (23.6 %), Omskaya yubileinaya (24.6 %) and Olivkovaya (25.5 %). The protein content in the seeds of the varieties at study varied from year to year: in 2015 from 22.06 % to 24.88 %, in 2016 from 19.07 % to 24.06 %, in 2017 from 21.81 % to 29.28 %, in 2018 from 21.26 % to 26.83 %. It can be stated that the protein content in the grains is mainly correlated to different weather conditions in the period of grain formation and filling depending on the year of cultivation.

As regards the micronutrient content, zinc in the grains of the common bean varieties under study varied from 11.37 mg/kg to 40.93 mg/kg. The following varieties distinguished themselves by the zinc content: Fizkulturnitsa with 26.86 mg/kg, Lukerya with 40.93 mg/kg, Olivkovaya with 40.35 mg/kg, which is twice as high as in the Nerussa control sample. As regards the iron content, the Olivkovaya variety distinguished itself with 108.00 mg/kg in 2017 against an average among all sorts varying from 7.0 to 80.00 mg/kg. The iron content ranged between 8.72 and 18.11 mg/kg in 2014, between 7.22 and 68.80 mg/kg in 2015, between 10.00 and 80.00 mg/kg in 2016, between 24.00 and 108.00 mg/kg in 2017 and between 7.00 and 26.00 mg/kg in 2018. The iodine content varied from 0.10 to 1.7 mg/kg depending on the variety. The highest iodine content was observed in Lukerya (0.23 mg/kg) and Olivkovaya (0.21 mg/kg) samples in 2016. This can be related to the specific characteristics of the varieties and to the year of cultivation.

As far as macronutrients are concerned, the calcium content in the grains varied from 0.29 to 1.86 %. The highest calcium content was observed in the Fizkulturnitsa variety with 1.86 % in 2015 and 2016, the lowest one – in the Nerussa control sample with 0.10 % in 2016.

The following varieties were identified for their stable content of proteins and micro-macronutrients: Lukerya, Olivkovaya, Fizkulturnitsa and Omskaya yubileinaya. They are worth using in breeding practices as sources of the aforementioned substances.

The analysis of the correlation between the protein content and the seed mass per plant has shown an average correlation between these parameters ($r = 0.40 \pm 0.29$). Favourable hydrothermal conditions facilitate the formation of well-developed seeds, the accumulation of nitrogen in the plants and its further reutilization, which causes a growth in the protein content. The study on the correlation between the protein content in the grains and the hydrothermal index has shown a negative correlation between these parameters ($r = -0.87 \pm 0.28$). As a consequence, a negative correlation has been established between the protein content in grains and the atmospheric temperature. The research has shown a positive correlation between the volume of precipitation in August and the protein content in the grains. According to the results obtained, a lower volume of precipitation in August than in July (2015-2018) had a positive effect on the accumulation of proteins in the grains.

An important parameter for dry beans is represented by the cooking rate of grains, which depends on the water absorbing capacity and shape of seeds, the thickness of the seed coat, the conditions of mineral nutrition, the environmental conditions under which seeds have been forming and maturing. In order to evaluate the consumer advantages of the beans, the cooking rate of the sample seeds was evaluated following the method of the laboratory for the technological evaluation of agricultural crops of the All-Russian Institute of Plant Industry. According to the cooking evaluation, the varieties of dry been bred at Omsk State Agrarian University have shown an excellent cooking rate (from 57 to 67 min) and can be classified as belonging to the I category. The shorter cooking time was observed in the Fizkulturnitsa (57 min) and Lukerya (58 min) varieties. The analysis of the obtained data has shown that the common bean grains harvested in 2018 are cooked by 2 min quicker than grains harvested in 2014-2017. This can be due to varietal features as well as weather conditions. The classification of the varieties according to their cooking rate has shown a good evaluation for all the samples at study, which can be considered promising breeding sources for this specific parameter.

The Fizkulturnitsa and Lukerya varieties distinguished themselves for their shorter cooking rate depending on the year (57-58 min). According to their phenotypes, the bush of these varieties has an erect form, which is a valuable quality for mechanical harvesting. The vegetation period lasts 90 days. The Fizkulturnitsa and Lukerya varieties can be recommended as sources of short grain cooking rate for breeding.

While analyzing the technological parameters on the grain quality of the bean varieties bred at Omsk State Agrarian University, it should be noticed that their size varied from 4.0 + 5.1 to 8.1 + 7.1 mm. The biggest grains were observed in the Fizkulturnitsa variety (8.1 mm). The grain uniformity in the varieties at study was stable between 90 % and 95 %. The average content of seed coat amounted to 10 %, with lowest amount in the Olivkovaya variety (8 %). The colour of the seed coat of the new varieties is varied, one-colour (white, olive, black) or spotted (dark brown, ochre, gray spots), Figure 2.

An important role in the plant is played by sugars, which can be found in the plant cells as a reserve, in particular in the cell sap, or are directly consumed by the plant as nutritional and energetic material. It is well-known that the sucrose content increases along with the plant development.

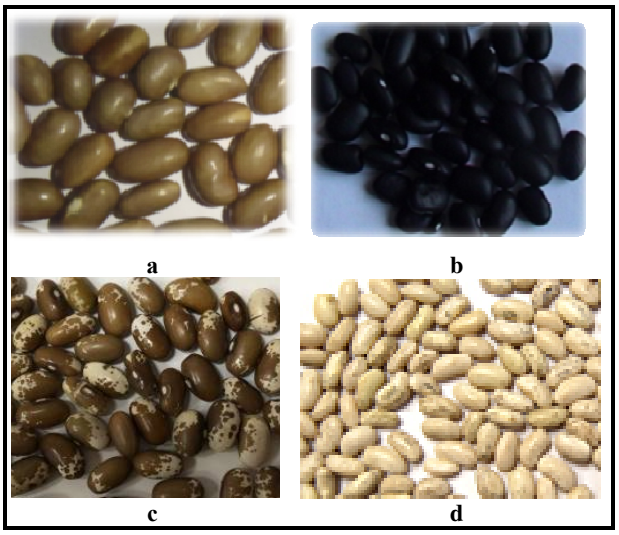

Fig. 2. Appearance of bean plants, demonstrating their manufacturability (a - Olivkovaya, b - Lukerya, c - Fizkulturnitsa, d - Omichka).

The Omichka, Olivkovaya, Lukerya and Fizkulturnitsa varieties distinguished themselves for the sucrose content in the leaves (0.10-0.15 %). The highest amount of sucrose in the bean leaves was observed in the phase of milky ripeness, while its content decreased along with ripening. By the last evaluation moment (July 27th) in the early-ripening samples of the Omskaya yubileinaya and Omichka varieties the sucrose content had decreased, since the sugar was converted to starch along with ripening, while in late-ripening ones it was continuing to increase. The obtained results should be kept in consideration when breeding crops as well as when compiling the varietal passport.

4 Conclusion

1. The following bean varieties have shown the highest protein content: Fizkulturnitsa (23.75 %), Lukerya (23.6 %), Omskaya yubileinaya (24.6 %) and Olivkovaya (25.5 %).

2. The following varieties were identified as having high content of micro- and macronutrients:

- zinc: Fizkulturnitsa (36.86 mg/kg), Lukerya (40.93 mg/kg), and Olivkovaya (40.35 mg/kg);
- iron: Olivkovaya (108.00 mg/kg);
- iodine: Lukerya (0.23 mg/kg) and Olivkovaya (0.21 mg/kg);
- calcium: Fizkulturnitsa (1.86 %).

4. The shortest cooking rate (from 57 to 59 min) has been observed in the Fizkulturnitsa, Omichka and Lukerya varieties.

5. The highest sucrose content (0.10-0.15 %) was observed in the Omichka, Olivkovaya, Lukerya and Fizkulturnitsa varieties.

6. The Lukerya, Omskaya yubileinaya and Fizkulturnitsa varieties distinguished themselves according to the overall evaluation of their technological parameters.

7. The common bean varieties under study can be recommended as sources for use in the breeding process aimed at creating new varieties with improved nutritional and technological parameters

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