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Chemical composition of seeds and green beans of common bean varieties, breeded in Omsk State Agrarian University under conditions of southern forest-steppe zone of Western Siberia

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Abstract. The article considers the biochemical composition of green beans and seeds of common beans varieties, breeded in Omsk State Agrarian University named after P.A. Stolypin (OmSAU). The research was conducted in 2014–2016. Varieties of locally breeded beans, in comparison with the standards, have advantages in the content of protein, zinc, iodine, calcium, iron, sugar; green bean technological properties and tenderizing of seeds during cooking, which becomes an indispensable component of the diet.

Key words: Legume breeding, microelements contain, kidney beans, green beans.

INTRODUCTION

Beans originated and domesticated in Latin America in two geographically differentiable geographic origins (Mesoamerica and the Andes) derived from a common 100,000-year-old ancestor. In Mexico and South America, the bean were domesticated independently about 8,000 years ago. There are records of cultivated seeds of Phaseolus vulgaris 3,000 years old (Lara Flores, 2015).

Common bean (*Phaseolus vulgaris L.*) is the grain legume with the highest volume of direct human consumption in the world. Among food leguminous crops, common beans are distinguished by nutritional value and a variety of uses for food purposes. It has excellent taste qualities and medicinal properties. There is all the essential amino acids necessary for the human body in the protein of bean seeds, so beans are often called the 'concentrate of essential amino acids'. The bean protein is highly digestible (Beebe et al., 2014).

For Russia, green beans are a relatively young crop compared to cereals. In Western Siberia, on an industrial scale, it is not cultivated, mainly grown as garden crops. The main reasons for the weak introduction of beans into production are the absence of varieties adapted to a specific soil and climate zone, a small amount of seed production,

a high labor intensity of harvesting, and insufficient propaganda of valuable cultural qualities (Kazydub & Marakayeva, 2015).

Due to the features of the climate in Western Siberia, the bean varieties of foreign breeding can not realize the productive potential inherent in them, the production of such varieties is unprofitable (Kazydub et al., 2012).

In modern conditions, breeding work with beans should be aimed at satisfying of processing requests, as well as expanding the range of cultivation of the crop and the scope of its use (Kazydub & Marakayeva, 2015; Javaloyes, 2016).

Common bean is a valuable source of protein, minerals and vitamins. In terms of biofortification, improvement of mineral content is advantageous precisely because the baseline grain iron content is high at 55 ppm (mg kg^{-1}) and variability for the trait is great, ranging up to 110 ppm, allowing initial breeding attempts to be much more successful than in the cereals in overall iron and zinc content increases (Beebe et al., 2000). In addition, unlike many cereals that are polished before eating, resulting in significant loss of nutrients, common beans are consumed whole, thus conserving all their nutritional content. Estimates for the Harvest Plus challenge program on biofortification are that an addition of approximately 40 ppm to baseline iron levels in common bean can meet a large proportion of the recommended daily intake of iron (Blair, 2009).

Bean varieties must have good product quality (green beans and seeds). Seeds should have a good tenderizing (during cooking) and high taste qualities. Frozen vegetable mixtures, in which green beans are added, must fit the technological requirements. These indicators are closely related to the chemical composition of seeds and beans (Kazydub et al., 2016).

The bean varieties, existing in Russia, are not always satisfy the quality requirements and are inferior to the foreign varieties (Kazydub et al., 2012).

Breeders of Department of Agronomy, Breeding and Seed Production of Omsk State Agrarian University created new high-yield varieties of common beans: for green beans use – Pamjati Ryzhkovoj, Zoloto Sibiri, Marusja and Sibirjachka; for grain use – Lukerja, Olivkovaja, Omskaja Jubilejnaja, Sizaja, Sibskovskaja 100, Omichka.

The results of the scientific researches testify to the prospects of cultivation of this legume crop in the conditions of Western Siberia, since valuable protein products in our zone can be obtained fairly early. The use of beans in the diet of the population will increase the assortment of vegetables and leguminous crops of the Siberian region and increase their role in the system of 'health, nutrition, resources'. Need to note that local varieties of leguminous crops are the basis of 'healthy food', due to their high content of vitamins, essential organic acids and other biologically valuable substances.

MATERIALS AND METHODS

The research was conducted in 2014–2016 on the fields of the Educational Experimental Farm of the Omsk State Agrarian University, located in the southern forest-steppe zone of the Omsk Region.

The southern forest-steppe zone is characterized by a warm, moderately humid climate. The sum of average daily temperatures over a period with a temperature above 10° is 100–130 days average. The frost-free period in this region averages 110–120 days, the period with a temperature above 0 °C – 185, above 5 °C – 157, above 10 °C – 123

days. Night frosts in the air in spring time are stop on May 21–22, and appear in the autumn of September 10–22. The abundance of sun and heat largely compensates the short duration of the frost-free period and ensures vegetation of plants. The southern forest-steppe of the Omsk region belongs to the zone of unstable hydration. The average long-term annual precipitation is 300–350 mm, for a period with a stable average daily air temperature above 10° precipitation, 190–220 mm falls out. Provision of plants with moisture in the area is characterized by a hydrothermal coefficient of 1.0–1.2, which indicates a satisfactory average moisture supply in the period of active vegetation. By the time of sowing, moisture reserves in the soil are usually sufficient. The soil of the field is ordinary black chernozem, medium humus.

The years of research varied according to meteorological conditions in 2014 was very dry (hydrothermal coefficient = 0.60), 2015 and 2016 were moisture-insulated (the hydrothermal coefficient was 1.02 and 1.1 respectively).

The object of research were common bean varieties of local breeding: of vegetable (green bean) use – Zoloto Sibiri, Pamjati Ryzhkovoj, Marusja and Sibirjachka; grain use – Lukerja, Olivkovaja, Omskaja Jubilejnaja, Sizaja, Sibskovskaja 100, Omichka. As a standard (control variety) for the evaluation of vegetable (green) beans used zoned variety Zolushka (breeding of the All-Russian Research Institute of Breeding and Seed Production Of Vegetable Crops, Moscow), grain beans - Nerussa (breeding of All-Russian Research Institute of leguminous crops, Orel).

Samples in the nursery were sown manually on single-row plots in fourfold repetition according to the scheme of 60 x 10 cm to a depth of 4–5 cm. The size of the plot is 5.2 m^2. Rows were arranged from north to south. The extreme rows were sown as protective bands.

The chemical analysis of green beans and seeds was carried out in the laboratory of the Omsk Agrochemical Center according to the following normative documents: state standard 13496.2-91 (crude fiber), state standard 26570-95 (calcium), state standard 26657-97 (phosphorus), state standard 13496.4-93 (raw protein), state standard 30692-00 (copper, zinc), state standard 27998-88 (iron), state standard 27997-88 (manganese).

Evaluation of seeds for tenderness was carried out in the Omsk laboratory of the State Inspectorate in accordance with the guidelines 'Technological evaluation of grains of peas, lentils, beans' (Komarov, 1992).

The plants were manually harvested during the full ripeness phase of the beans. The number of beans on the plant, the number of seeds in the bean, and the height of the attachment of the lower bean were taken into account. The weight method was used to determine the mass of seeds from one plant and the mass of 1,000 seeds.

Observations, surveys and analyzes in the field were carried out according to the methodological guidelines for studying the collection of grain legumes (All-Russian Institute of Plant Production, 1975) and studying samples of the world bean collection (All-Russian Institute of Plant Production, 1987).

Biochemical analysis of green beans was carried out in the testing laboratory of the Omsk branch of the federal state budget institution 'Federal Center for Evaluation of Safety and Quality of Grain and Products of Its Processing'. The content of sucrose in green beans is determined by the refractometer 'Refracto 30P'. The statistical processing of the experimental data (mean, standard deviation, variance analysis, etc.) was carried out according to the method described in the manual of B.A. Dospekhov (1985).

RESULTS AND DISCUSSION

Legumes are an affordable source of food and feed protein, balanced by amino acid composition. Synthesis of proteins from simple nitrogen compounds carried out through the root system of plants from the soil, and the role of assimilating factor are playing nitrogen fixing bacteria used only by legumes (Pivovarov, 2006).

The protein content in seeds (dry weight) of grain beans breeded in Omsk SAU varied from 21.22 to 24.06%. The four varieties of grain beans were significantly higher than the standard: Sizaja (24.06%), Lukerja (23.38%), Omskaja Jubilejnaja (22.60%), Olivkovaja (23.13%), Table 1.

Table 1. Chemical composition of seeds (dry weight) of grains bean varieties breeded in Omsk SAU (2014–2016)

Variety	Content				
	Protein, %	Zinc, mg kg^{-1}	Iodine, mg kg^{-1}	Calcium, mg kg^{-1}	Iron, mg kg^{-1}
Nerussa, control	19.0	20.7	0.1	0.1	21.1
Sibakovskaja 100	21.2	25.5*	0.2*	0.2*	10.0
Sizaja	24.0*	24.3	0.2*	1.4*	54.0*
Lukerja	23.4*	20.9	0.2*	0.3*	80.0*
Omskaja Jubilejnaja	22.6*	27.8*	0.2*	0.2*	12.0
Olivkovaja	23.1*	28.1*	0.2*	0.9*	17.0
Omichka	21.8	26.9*	0.2*	0.6*	10.0
Average	22.2	24.9	0.2	0.5	26.4
LSD_{05}	3.3	3.7	-	0.1	4.0

* significantly at $P > 0.05$.

In the research work of Gorbataya (2010–2013), which was performed on the basis of the Training and Experimental Farm of Omsk State Agrarian University, it was noted that lysine, methionine, tryptophan, cysteine are considered the most valuable for human nutrition. Her studies showed that the seeds of the common bean varieties under conditions of southern forest-steppe of Western Siberia contained on average 2.46 g 100 g^{-1} of lysine, 1.20 g 100 g^{-1} of methionine, 1.11 g 100 g^{-1} of tryptophan, 0.43 g 100 g^{-1} of cysteine.

The mass fraction of amino acids, including essentials, in the seeds of beans characterizes its high biological value. Our researches have shown that in the conditions of southern forest-steppe zone of Omsk region, the seeds of grain beans contain around 27.7 g 100 g^{-1} of amino acids, of which 12.7 g are essential. The highest content of amino acids was observed in varieties: Lukerja (29.89 g 100 g^{-1}, of which 14.0 g are essential) and Olivkovaja (28.96 g 100 g^{-1}, of which 13.40 g 100 g^{-1} are essential).

The zinc content in the seeds of the studied grain bean samples varied from 20.9 to 28.1 mg kg^{-1}. High contain of zinc in the seeds, significantly higher than the standard, have had varieties of Omsk breeding: Sibakovskaja 100 (25.5 mg kg^{-1}), Omskaja Jubilejnaja (27.8 mg kg^{-1}), Olivkovaja (28.1 mg kg^{-1}), Omichka (26.9 mg kg^{-1}).

The average iron content in grain bean varieties ranged from 10.0 to 80.0 mg kg^{-1}. With its maximum content was characterized varieties Lukerya (80.0 mg kg^{-1}) and Sizaja (54.0 mg kg^{-1}).

The iodine content in beans of Omsk varieties was more than 2 times higher than the standard, and ranged from 0.15 to 0.23 mg kg^{-1}. The highest iodine content was found in the varieties Lukerja (0.23 mg kg^{-1}) and Olivkovaja (0.21 mg kg^{-1}).

The average content of calcium in new varieties of grain beans varied from 0.24 to 0.85 mg kg^{-1}. The maximum content had varieties Olivkovaja (0.85 mg kg^{-1}) and Omichka (0.60 mg kg^{-1}).

All varieties created in Omsk SAU for iodine and calcium content significantly surpassed the control variety Nerussa.

For grain beans an important feature is the rate of seed tenderizing during cooking, which depends on water-absorbing capacity and shape of the seeds, the percentage and thickness of the seed coat, the conditions of mineral nutrition, and on the conditions under which seed formation and maturation took place. In order to assess the consumer benefits of beans, was made the evaluation of bean sample's tenderizing by the method developed in the laboratory of technological evaluation of crops of the All-Russia Institute of Plant Growing.

For the classification of seed tenderness is proposed the scale: I group – excellent (up to 90 minutes); Group II – good (91–124 min); Group III – satisfactory (125–161 min); IV group – unsatisfactory (162–299 min).

All new Omsk varieties of beans had excellent tenderness (57 to 67 min.), and were assigned to group I. The shortest cooking time had varieties Sizaja (57 min.) and Lukerja (58 min), Table 2.

Table 2. Tenderness time of bean varieties of OmSAU breeding (2014–2016)

Variety	Seed coloring	Tenderness, min			
		2014	2015	2016	Average
Nerussa, control	White	58	60	59	59
Sibakovskaja 100	White, dark cherry pattern at the rib	60	61	60	60
Sizaja	Blue-grey	57	58	57	57
Lukerja	Black	57	59	58	58
Omskaja Jubilejnaja	Beige with brown pattern	65	67	66	66
Olivkovaja	Olive	60	63	61	61
Omichka	White, blue strokes	58	60	59	59
LSD_{05}	-	8.9	9.2	9.0	9.0

Varieties of grain beans of Omsk SAU breeding are distinguished by a high level of yield. During the years of testing, the yields of varieties ranged from 1.5 to 5.7 t ha^{-1}, Table 3. The maximum yield of varieties was 4.1 t ha^{-1} in 2014, the minimum in 2015 – 2.3 t ha^{-1}. Varieties Sibakovskaja 100, Lukerja, Sizaja, Omskaja Jubilejnaja and Olivkovaja were significantly exceeded the control variety for the yield.

Green beans are valuable food product, in which there are almost all substances necessary for normal human nutrition. Vegetable beans are rich in organic and mineral substances, as well as potassium, iron, calcium, zinc, iodine, etc. (Javaloyes, 2016). When choosing varieties for processing, account should be taken of the roundness and fleshiness of the bean, the absence of the parchment layer and fibers in the pod of the bean.

Most of the production of green beans available on the Russian market is imported from countries with a more favorable climate for their cultivation, for example, from Poland. Therefore, it is important to study the chemical composition and technological qualities of green beans breeded in Omsk SAU for various types of processing (Kazydub et al., 2012).

Table 3. Yield of grain beans varieties breeded in Omsk SAU (2014–2016)

Variety	Seed yield, t ha^{-1}			Average
	2014	2015	2016	
Nerussa, control	2.6	1.5	2.8	2.3
Sibakovskaja 100	4.5	2.8	3.4	3.6
Sizaja	3.5	2.1	3.7	3.1
Lukerja	4.8	3.1	3.8	3.9
Omskaja Jubilejnaja	4.3	2.6	3.1	3.3
Olivkovaja	5.7	2.2	3.2	3.7
Omichka	3.0	1.5	2.6	2.4
LSD_{05}	0.6	0.3	0.5	0.5

* Significant at $P > 0.05$.

In the phase of technical maturity we evaluated the green beans varieties according to their processability. The results of the studies are presented in Table 4.

Table 4. Indicators of processability of green beans varieties breeded in Omsk SAU (average for 2014–2016)

Variety	Cross-sectional shape	Fleshiness, point	The parchment layer, +, - *	Bean thickness, cm
Zolushka, control	round	2	-	0.5
Zoloto Sibiri	round	3	-	0.8
Pamjati Ryzhkovoj	round	3	-	1.0
Marusja	round	3	-	0.8
Sibirjachka	round	3	-	1.0
LSD_{05}	-	-	-	0.2

* + *presence, - absence.*

The green beans of Omsk breeding varieties in the stage of technical maturity were differed from the control variety by the higher fleshiness and the cross-sectional thickness of the bean (from 0.8 to 1.0 cm), had long straight thick beans of round shape, without a parchment layer, yellow and green. These parameters characterize the suitability of bean varieties for freezing and canning.

The nutritional value of grain and green beans is high and depends on the content of organic and mineral substances, vitamins, micro- and macro-elements (Gamzikova, 1979). Research had shown that the chemical composition of common beans is unstable and subject to variability depending on the species, variety, and also varies due to growing conditions (Kazydub, 2013).

The protein content, as well as micro- and macro-elements in green beans of Omsk varieties are presented in Table 5.

Table 5. Chemical composition of green beans of Omsk State Agrarian University (2014–2016)

Variety	Mass fraction in absolutely dry matter			
	Protein,%	Zinc, mg kg^{-1}	Iodine, mg kg^{-1}	Iron, mg kg^{-1}
2014				
Zolushka, control	21.13	19.63	0.014	2.0
Zoloto Sibiri	18.31	21.23	0.010	2.0
Pamjati Ryzhkovoj	20.63	28.68	0.014	3.1
Marusja	23.60	23.74	0.014	3.2
Sibirjachka	22.16	26.21	0.016	3.2
Average	21.17	23.90	0.011	2.7
LSD_{05}	3.17	3.58	0.002	0.4
2015				
Zolushka, control	19.13	20.14	0.014	1.9
Zoloto Sibiri	17.75	20.95	0.017	1.6
Pamjati Ryzhkovoj	17.81	27.54	0.018	1.8
Marusja	20.94	22.14	0.017	1.8
Sibirjachka	19.38	24.84	0.018	1.8
Average	19.00	23.12	0.028	1.8
LSD_{05}	2.85	3.47	0.003	0.3
2016				
Zolushka, control	18.17	20.05	0.014	1.1
Zoloto Sibiri	19.79	25.30	0.014	1.1
Pamjati Ryzhkovoj	18.63	21.20	0.012	1.2
Marusja	18.79	22.10	0.013	1.4
Sibirjachka	18.19	27.30	0.014	1.8
Average	18.71	23.19	0.013	1.3
LSD_{05}	2.81	3.48	0.002	0.2

The protein content in green beans of studied bean varieties over the years of research ranged from 17.75 in wet and cool conditions to 23.60% in arid conditions. By highest content of protein was characterized variety Marusja – 23.60% (in 2014), 20.94% (in 2015) and Zoloto Sibiri – 19.79 (in 2016).

Iron plays a big role in immunobiological and oxidation-reduction reactions, with its lack is possible developing of anemia. The biggest amount of iron was found in green beans of varieties Pamjati Ryzhkovoj (1.2–3.1 mg kg^{-1}) and Marusja (1.4–3.2 mg kg^{-1}).

It should be emphasized the importance of zinc presence in the green beans, which is necessary for the normal operation of the pancreas and prostate gland. The high content of zinc was recorded in green beans of the following varieties: Pamjaty Ryzhkovoj – 28.68 mg kg^{-1} (in 2014), 27.54 mg kg^{-1} (in 2015) and Sibirjachka – 27.30 mg kg^{-1} (in 2016).

With a lack of iodine, nervous and irritability is noted in the body, memory and intellect are weakened. Over time, there is an arrhythmia, decreases the level of hemoglobin in the blood. This is especially important for iodine deficiency areas, including the Omsk Region. By the highest content of iodine in green beans were characterized varieties – Sibirjachka (0.014–0.018 mg kg^{-1}), Marusja (0.013–0.017 mg kg^{-1}) and Pamjaty Ryzhkovoj (0.012–0.018 mg kg^{-1}).

Green beans and seeds of common beans contain a significant amount of sugars (up to 6%). The main sugar contained in all kinds of legumes, including beans, is sucrose (from 0.66 to 1.23%). As the beans mature, the content of sucrose decreases. In 2016, we evaluated the green beans for the content of sucrose during the technical maturity during the second and third harvesting (July 18 and August 3, respectively), Table 6.

Table 6. The content of sucrose in green beans of Omsk SAU breeding (2016), %

Variety	Technical maturity		
	II harvest (18.07)	III harvest (03.08)	Average
Zolushka, control	3.5	0.6	2.1
Zoloto Sibiri	3.8*	1.8*	2.8*
Pamjati Ryzhkovoj	4.1*	2.1*	3.1*
Marusja	3.9*	1.1*	2.5*
Sibirjachka	3.9*	1.4*	2.7*
Average	3.8	1.4	2.6
LSD_{05}	*0.2*	*0.3*	*0.3*

* Significant at *P> 0.05.*

The research revealed that the content of sucrose in green beans at the second harvest (July 18) varied from 3.5 to 4.1%. In the subsequent harvest (August 3) the value of this indicator is less than 2.7 times (from 0.6 to 2.1%). Consequently, a high content of sucrose in green beans provides harvesting in the second half of July, with later harvesting times, the content of sucrose is significantly reduced.

During the period of the experiments, the yield of green beans varied on average from 3.9 to 5.6 t ha^{-1}. All studied varieties of Omsk SAU have surpassed the control variety for this parameter. The highest yield was registered for variety Pamjaty Ryzhkovoj – 5.3 t ha^{-1} (in 2014), 5.8 t ha^{-1} (in 2015 and 2016).

The formation of yields in green beans of vegetable beans was greatly influenced by meteorological conditions. Thus, under conditions of insufficient humidification in 2014 and 2015 (hydrothermal coefficient = 0.7), the yield was the lowest, Table 7. With the ensured wetting of 2016 (hydrothermal coefficient = 1.0), the yield of green beans was increased by an average of 7%. In conditions of sufficient heat and moisture availability in the studied varieties, this indicator varied from 3.0 to 5.8 t ha^{-1}.

Table 7. The yield of green beans varieties of Omsk SAU (2014–2016 years), t ha^{-1}

Variety	2014	2015	2016	Average
Zolushka, control	3.3	2.9	3.0	3.0
Zoloto Sibiri	4.0	3.8*	4.1	3.9*
PamjatiRyzhkovoj	5.3*	5.8*	5.8*	5.6*
Marusja	4.3*	4.4*	4.9*	4.5*
Sibirjachka	4.2*	4.4*	4.8*	4.5*
LSD_{05}				0.4

* Significant at *P> 0.05.*

CONCLUSIONS

1.The results of our studies indicate the possibility of growing beans with high potential yields of grain and green beans and excellent product quality in the southern forest-steppe of the Omsk region.

2.Varieties of Omsk beans are characterized by a complex of valuable features:

- high potential yield of: green beans – Pamjaty Ryzhkovoj (5.3–5.8 t ha^{-1}), and grains – Sibakovsaja 100 (3.6 t ha^{-1}), Sizaja (3.7 t ha^{-1}), Lukerja (3.9 t ha^{-1}), Olivkovaja (3.7 t ha^{-1});
- high content of protein: in grain – Sizaja (24.06%), Lukerja (23.38%), Omskaja Jubilejnaja (22.60%), Olivkovaja (23.13%), and green beans – Marusja (23.60–20.91%), the Zoloto Sibiri (19.79%);
- high content of zinc in: grain – Sibakovskaja 100 (25.5 mg kg^{-1}), Omskaja Jubilejnaja (27.8 mg kg^{-1}), Olivkovaja (28.1 mg kg^{-1}), Omichka (26.9 mg kg^{-1}), and in green beans – Pamjaty Ryzhkovoj (28.68–27.54 mg kg^{-1}) and Sibirjachka (27.30 mg kg^{-1});
- high iron content in: grain – Lukerja (80.0 mg kg^{-1}), Sizaja (54.0 mg kg^{-1}), and green beans – Pamjaty Ryzhkovoj (1.8–3.2 mg kg^{-1}) and Marusja (1, 8–3.3 mg kg^{-1});
- high content of iodine in: grain – Lukerja (0.23 mg kg^{-1}) and Olivkovaja (0.21 mg kg^{-1}), and in green beans – Sibirjachka (0.014–0.018 mg kg^{-1}), Marusja (0.014–0.018 mg kg^{-1}) and Pamjaty Ryzhkovoj (0.012–0.018 mg kg^{-1});
- high sugar content in green beans – Pamjaty Ryzhkovoj (2.1–4.1%).

3.Omsk beans varieties are characterized by a high content of amino acids in the grain: Lukerja (29.89 g 100 g^{-1}, of which 14.0 g are essential) and Olivkovaja (28.96 g 100 g^{-1}, of which 13.40 g 100 g^{-1} are essential).

4.Varieties of beans of Omsk SAU breeding have excellent technological indexes and can be recommended for processing: excellent grain tenderness (from 57 to 67 minutes), high fleshiness, greater cross-sectional thickness and length of green beans, without parchment layer, attractive yellow and green color of beans, and high sugar content.

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