Analysis of protein and oil content in seeds of soybean collection varieties

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Abstract. The global need for food and protein is increasing as an expected consequence of the growth of the human population in the world, which by 2050 will reach 9 billion people. Already, about 1 billion people in the world are chronically malnourished. Field research was carried out in 2017-2021 on the experimental field of the Research Institute of Selection, Seed Production and Agricultural Technology of Cotton Growing. In the mid-early ripe variety sample CH3(-008), the protein content was medium protein (38.16%), and the oil content was medium oil (18.66%); in variety US-25 (-622), the protein content (40.00%) was above the average level, and the oil was medium oil and amounted to 19.05%. Intervarietal variation of protein was 1.0%, oil 1.56%. The minimum total indicator of protein and oil in soybean grain was 57.44±0.40 (Arletta variety), the maximum was 60.00±32.0% (Sparta variety).

1. Introduction

Currently, in the countries of the world that cultivate soybeans, it is of great importance to increase and maintain soil fertility, provide the population with protein and environmentally friendly food, and export soybeans. Countries such as the USA, Brazil, Argentina are leading in the production and export of the main part of soybeans [1-7]. This year the US grain harvest was 120.5 million tons, Brazil 107.0 million tons, Argentina 57.0 million tons, and worldwide 347.8 million tons [8-11]. Protein-containing crops (including legumes and soybeans) occupy only 3% of the cultivated area in the European Union. The global need for food and protein is increasing as an expected consequence of the growth of the human population in the world, which by 2050 will reach 9 billion people. Already, about 1 billion people in the world are chronically malnourished. Clearly, if action is not taken, the increase in protein demand will cause food prices to rise and increase pressure on livestock farms, as well as affect food security, both in the world and in the Russian Federation [12-17]. However, there are protein-rich alternatives to soy products that have been summarized in a number of reviews. Soy is the world's most widely cultivated oilseed and an important source of protein for both humans and farm animals [18-21].

In Uzbekistan, close attention is paid to testing and adapting to certain soil and climatic conditions, the production of a large number of high-quality environmentally friendly products of legumes, in particular new varieties of soybeans, as well as the development of agricultural technology, increasing and maintaining soil fertility [22-24]. Interestingly, soybean seeds contain a large amount of oil (17...25%) and protein (35...55%), which by its value ranks first among the most important agricultural crops, has high nutritional qualities [25].

It is known that abiotic stresses during the reproductive phases of soybean (R2-R6) can reduce the number, viability and energy of seed germination and change their chemical composition [26]. At the same time, drought is the most significant limiting factor that reduces the protein content in soybean seeds [27]. The study of the influence of agro-climatic factors showed that, depending on weather conditions and the region of cultivation, the level of protein content in soybean seeds can vary within 10-15%. According to this study and other authors, the protein content increases with increasing temperatures [28]. Studies show that high oil content is observed with increased moisture and relatively low temperature, and protein content is observed with dry weather and elevated temperature [29].

It is noted in the scientific literature that the protein content in soybeans can be up to 24.0-60.0%. The amount of

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protein and amino acid content varies depending on the type or variety of soybeans. It is known that not a single crop cultivated by man can be compared with soybeans in terms of the chemical composition of seeds and its quality. The content of protein and fat in the seeds of some varieties reaches up to 40-70% [30]. Attracting introduced varieties to breeding processes, creating varieties with a high content of protein and oil in seeds, providing the population with protein and vegetable oil, the development of animal husbandry and poultry farming is currently considered relevant [31].

2. Methods

Varieties from the collection of South Korea served as research material were used: early ripening - K09 (339), CH27 (-266), CH28 (-268), medium early ripening - CH3 (-008), CH7 (-014), CH30 (-969), US-25 (-622), KO18, mid-season - CH11 (-018), US-14 (-382), US-44 (-641), US-80 (-699), US-82 (-701), KO20, KO3 (-214), KO21(RR-1) and from the collection of the Russian Federation: early ripening-Arletta, Avanta, Sparta, Selecta 201, mid-ripening-Selecta 302 were used in the experiment. The mid-season variety Uzbekskaya-2 was used as a standard.

Fig. 1. Modern autonomous infrared analyzer Infrascan-3150

In this research, field research was carried out in 2017-2021 on the experimental field of the Research Institute of Selection, Seed Production and Agricultural Technology of Cotton Growing. In early May, after preparing the field for sowing, the collection samples were sown in four repetitions, wide-row sowing, with a row spacing of 60 cm, a depth of 4–5 cm. The area of the plot was 63 m^2, the accounting area was 31.5 m^2, the placement of the plots was randomized. Analysis of the protein and oil content in the seeds of collection soybean varieties was carried out using a modern autonomous infrared analyzer Infrascan-3150 (Figure 1).

In this research work, field experiments were carried out in accordance with the methods of "Methodology of State Variety Testing of Agricultural Crops", "Methodology of Field Experience" [7]. Statistical processing of experimental data was carried out according to the method proposed by B.D. Dospekhov using the computer program Microsoft Excel. The correlation relationship of traits was determined by the following formula [7]:

$$r = \frac{\sum XY - (\sum X \bullet \sum Y)/n}{\sqrt{(\sum X^2 - (\sum X)^2/n) \bullet (\sum Y^2 - (\sum Y)^2/n)}}; \qquad m = \sqrt{\frac{1-r^2}{n-2}}; \qquad tr = \frac{r}{Sr}$$

where: r – correlation coefficient;
X, Y – indicators of quantitative traits;
m – correlation coefficient error;
n – sample size;
tr – correlation coefficient criterion.

3. Results and Discussions

According to the results of biochemical analysis of the composition of soybean grains from the collection of South Korean selection, the protein content in early ripening (K09 (339), CH_{27} (-266), CH_{28} (-268)) varieties was 38.41%, 38.52%, 40.00 % respectively. Oil content was 18.97%, 18.61%, 20.19%, respectively, in mid-early ripe varieties (CH_3 (-008), CH_7 (-014), CH_{30} (-969), US-25 (-622), KO18) the protein content was 38.16%, 40.00%, 39.17%, 39.76%, 41.00% respectively, and the oil content was 18.66%, 20.76%, 19.18%, 19, 05%, 17.64% respectively. Furthermore, oil content 18.97%, 18.61%, 20.19%, respectively, in mid-early ripe varieties (CH_3(-008), CH_7(-014), CH_{30} (-969), US-25 (-622), KO18) the protein content was 38.16%, 40.00%, 39.17%, 39.76%, 41.00% correspondingly. And the oil content was 18.66%, 20.76%, 19.18%, 19.05%, 17.64%, respectively, in mid-season varieties (CH_{11} (-018), US-14 (-382), US-44 (-641), US-80 (-699), US-82 (-701), KO20, KO3(-214), KO21(RR-1)). Whereas protein content was 39.00%, 39.53%, 39 .04%, 37.59%, 40.00%, 40.00%, 40.00%, 42.00% respectively, and the oil content was 18.95%, 19.14%, 20.27%, 18, 54%, 18.99%, 18.89%, 19.69%, 17.66%, respectively (Figure 2).

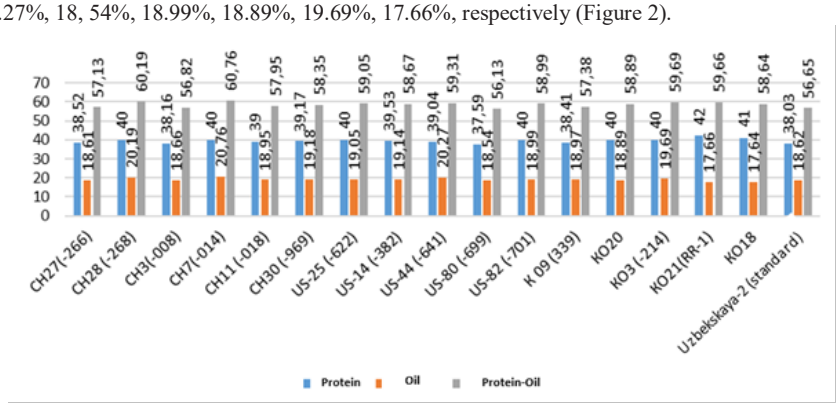


Fig. 2. Biochemical composition of seeds of collection varieties of South Korea

Soy is one of the highest protein crops (31, 24, 16). To effectively address many practical and fundamental issues of vegetable-type soybean introduction, along with the traditional mandatory morphological characteristics, it is necessary to use the analysis of its biochemical composition [18, 17, 32]. The protein content of early ripe accessions K 09 (339), CH_{27} (-266) was medium protein, medium oil and amounted to 38.41%, 38.52% and 18.97%, 18.61%, respectively. It was noted that in variety accession CH_{28} (-268), the content of protein (40.00%) and oil (20.19%) was above the average level. In the mid-early ripe variety sample CH_3(-008), the protein content was medium protein (38.16%), and the oil content was medium oil (18.66%); in variety US-25 (-622), the protein content (40.00%) was above the average level, and the oil was medium oil and amounted to 19.05%. The protein content of variety KO18 was above the average level and amounted to 41.00%, and the oil content was below the average level and amounted to 17.64%. It was noted that in the accession CH_7(-014) the content of protein and oil was above the average level and the indicators were 40.0% and 20.76%, in the accession CH_{30} (-969) the content of protein and oil was below the average level and amounted to 39, 17% and 19.18% respectively.

Analysis of the content of protein and oil in the seeds of mid-season soybean varieties CH11 (-018), US-80 (-699) showed that these indicators were 39.00%, 37.59% and 18.95%, 18.54%, respectively, and were medium protein, medium oil content. Protein and oil content in varieties US-14(-382), US-82(-701), KO20, KO3(-214) were 39.53%, 40.00%, 40.00%, 40.00% and 19 , 14%, 18.99%, 18.89%, 19.69%, respectively, and according to the “International classifier of the CMEA of the genus Glycine Willd”, the protein content was above the average level, and the oil content was medium oil (33). The variety accession KO21(RR-1) has a higher protein content than the other studied accessions and amounted to 42%, which was higher than the average protein level, but the oil content was lower than the average oil content and amounted to 17.66%. It was noted that among the studied variety samples, the variety sample US-44(-641) in terms of protein content (39.04%) is medium protein, and in terms of oil content it is above the average level and amounted to 20.27%.

Based on the above data, it should be noted that according to the content of protein and oil in the seeds of Korean collection varieties, early ripening K09(339), CH_{27}(-266), mid-early ripening CH_3(-008), mid-ripening CH_{11}(-018), US-80(-699) they are medium protein and medium oil, in which the indicators were close to those of the standard variety Uzbekskaya-2 (protein content 38.03%, oil content 18.62%). It was noted that early-ripening SN28 (-268), medium-early SN7(-014), SN30 (-969), mid-season US-44(-641) accessions in terms of protein and oil content exceed

the average protein and average oil level and, compared with the standard variety Uzbekskaya- 2, these figures were higher by 1.01-1.97% (protein content) and 0.56-2.14% (oil content). It was found that in mid-early ripening US-25 (-622) and mid-seasoning US-14 (-382), US-82 (-701), KO20, KO3 (-214) variety samples, the protein content is higher than the average protein level, in terms of oil content - medium oil, and also compared with the standard variety Uzbekskaya-2 (38.03% and 18.62%), the protein content was higher by 1.5-1.97% and oil by 0.27-1.07%.

Moreover, in the mid-early ripe variety accession KO18 and the mid-season variety accession KO21(RR-1), the protein content was 41.0%, 42.0%, respectively, which indicates an advantage in these traits over other variety accessions and the standard variety Uzbekskaya-2. In the mid-early ripe variety accession KO18 and the mid-season variety accession KO21(RR-1), the protein content was 41.0%, 42.0%, respectively, which indicates an advantage in these traits over other variety accessions and the standard variety Uzbekskaya-2. When comparing the results with data obtained by other researchers, it was revealed that in the data of the US testing system, the earliest maturing groups had a protein content almost comparable to that recorded by us - 40.4-40.9%, but a smaller amount of oil - 19.8-20.5 % (22).

It was observed that mid-early KO18 and mid-season KO21(RR-1) variety samples were higher in protein content, and lower in oil content than the average level. In terms of protein content, the indicators were higher by 2.97-3.97%, compared with the standard variety Uzbekskaya-2, and in terms of oil content, they were lower by 0.96-0.98%. The protein content above the average level was noted in the grain of the variety KO21 (RR-1) - 42.00 ± 0.39, and below the average level in US-80 (-699) - 37.59 ± 0.30, the oil content in the grain of the variety CH7(-014) was above the average level and amounted to 20.76±0.12. The oil content of grain sample KO18 was below the average level and amounted to 17.64±0.23%. The intervarietal variation of oil was 3.12%, protein - 4.41%.

Analysis of research results Litvinenko O.V. and others showed that new soybean varieties are medium protein (35.61±0.22...38.68±0.14%) and medium oil (17.79±0.25...19.78±0.19 %) (33). The authors noted the protein content above the average level in the grain of the Nevesta (40.70±0.49%) and Kruzhnitsa (41.58±0.42%) varieties, oils - in the grain of the Pepelina varieties (19.80±0.41%), Enchantress (20.34±0.25%) and Topaz (20.74±0.05%). The oil content of the soybean variety Bride was below the average level and amounted to 17.77±0.20%. The intervarietal variation of the oil was 2.97; protein - 5.97% (20).

The minimum total indicator of protein and oil in soybean grains was 56.13±0.51% (varietal accession US-80 (-699)), the maximum was 60.76±0.38% (varietal accession CH_7(-014)), which was less than the minimum indicator by 0.52%, and more than the maximum indicator by 4.11% than the standard variety Uzbekskaya-2. It was reported that the minimum total indicator of soybean grain protein and oil was 55.57±0.78% (Pepelina variety), the maximum was 59.36±0.74% (Kruzhnitsa variety) (20). Thus, it should be noted that among the studied soybean varieties, to increase the protein content, it is possible to use varieties KO21(RR-1) (42%) and KO18 (41%), to increase the oil content - US-44 (-641) (20.27%), as well as for their simultaneous increase, varieties CH_{28} (-268) and CH_7 (-014) (protein content 40.0-40.0% and oil content 20.19-20.76%, respectively). A comparative analysis of the protein content in the seeds of the collection soybean varieties from the Russian Federation showed that the protein content ranges from 39.00% (Arletta, Avanta) to 40.00% (Sparta, Selecta 201, Selecta 302). In most variety samples, the protein content ranged from 39.00-40.0%. The Russian varieties in terms of protein content (39.00-40.00%) exceeded the standard variety Uzbekskaya-2 (38.03%) (Figure 3).

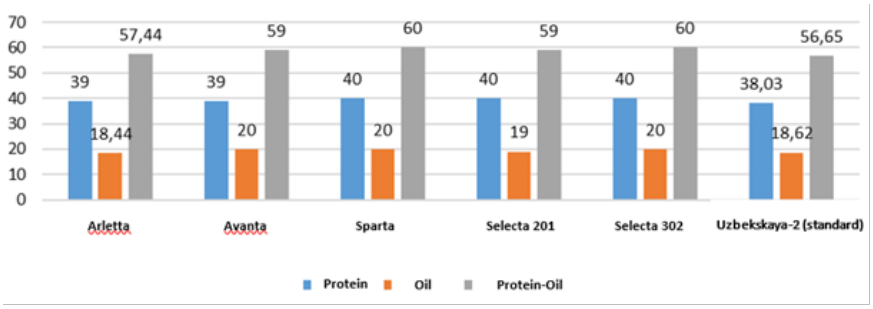
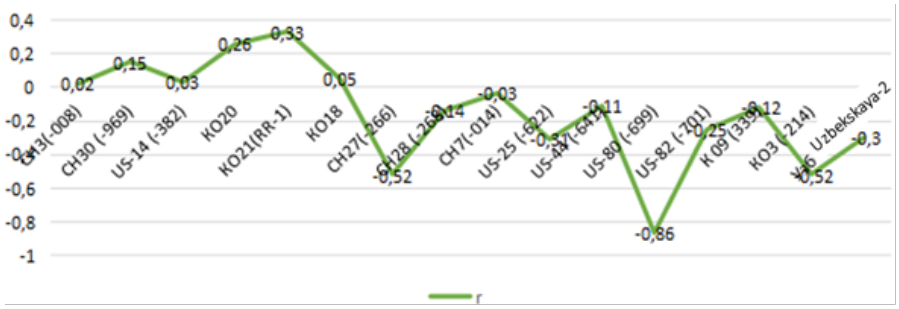


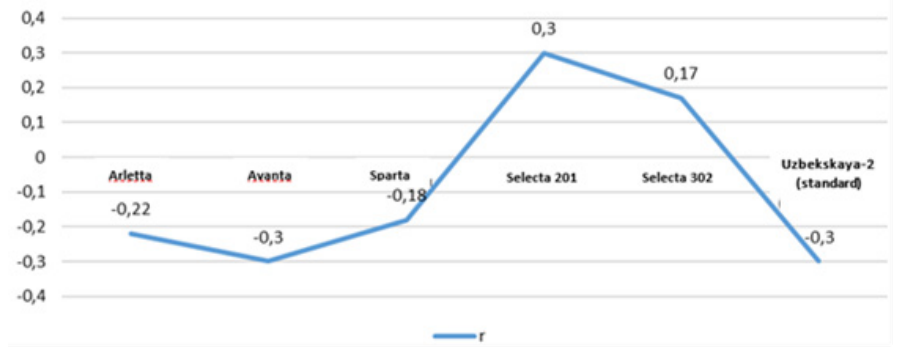
Fig. 3. Biochemical composition of seeds of collection variety samples of the Russian Federation

In the early ripe variety Arletta, the content of protein and oil was medium protein (38.70%) and medium oil (18.44%), and in the early ripe variety Avanta, in terms of protein content (39.00%), medium protein, oil in grain (20.00%) above average. The protein content of the variety sample Selecta 201 (40.00%) is above the average level, and the oil content (19.0%) is medium oil content. It was noted that the content of protein (40%) and oil (20.0%) in the early ripe variety Sparta and mid-season variety Selecta 302 were above the average level.In the studies of Novikova L.Yu. and other

early varieties had protein at the level of 40.0 ± 3.6% and relatively high oil - 21.6 ± 1.5% (22).
In different regions of the world, the influence of climate on the protein content in seeds is much more pronounced than on the oil content (10, 27), and both of these traits vary significantly under different growing conditions (4; 26, 25). In different regions of the world, the influence of climate on the protein content in seeds is much more pronounced than on the oil content (10, 27), and both of these traits vary significantly under different growing conditions (4; 26, 25). It should be noted that the early ripe varieties Arletta and Avanta are medium in protein. The protein content above the average level was noted in the grain of the early-ripening varieties Sparta, Selecta 201 and the mid-ripening variety Selecta 302, the indicators for this trait in which were higher by 0.97-1.97% than in the standard variety Uzbekskaya-2.
In terms of oil content in grain, the early-ripening varieties Arletta and Selecta 201 are medium oil-bearing and they were close in terms of indications to the standard variety Uzbekskaya-2. The oil content of early-ripening soybean varieties Avanta, Sparta and mid-season Select 302 was higher than the average level and 1.38% more than that of the standard variety Uzbekskaya-2. Essential linoleic acid is the most important in soybean oil, the share of which is 50-60%. Its content is closely correlated with the amount of α-linolenic acid (up to 8%), which gives the oil a peculiar taste and aroma and contributes to its rapid oxidation (15). In breeding work, it is required to investigate correlations not only between quantitative traits, but also between the physiological and biochemical parameters of samples (5). As a result of comprehensive studies of the chemical composition of grain, it was found that soybean is the richest crop in terms of protein content (from 20 to 45% or more), which contains a number of essential amino acids (23) (Figure 4).



tr>=1.01 significant correlation
Fig. 4. Correlation of Korean soybean



collection varieties by analysis of protein and oil content
tr>=1.01 significant correlation
Fig. 5. Correlation of Russian collection variety samples according to the analysis of protein and oil content

It was found that intervarietal variation of protein was 1.0%, oil 1.56%. The minimum total indicator of protein and oil in soybean grain was 57.44±0.40 (Arletta variety), the maximum was 60.00±32.0% (Sparta variety). It is noted in the scientific literature that the content of protein and oil in soybean grain is in a negative correlation and varies significantly - from r = -0.25 to r = -0.93 (29). The ratio of protein and fat in soybean seeds is in a negative correlation (r=0.50-0.62) (16). According to Novikova L. Yu. et al., the average content of protein in the seeds of samples in the

studied sample (hereinafter referred to as the collection) varied from 27.2 to 50.0%, oil - from 15.2 to 26.6%. The extreme limits of variability were 23.8–51.1% for protein and 13.8–27.2% for oil. The content of oil and protein in the samples are inversely correlated, the correlation coefficient is r = –0.53. With an average increase in oil of 1%, the protein decreased by 1.1% (22) (Figure 5).

As the results of the study showed, among Korean varieties, KO21(RR-1) (r=0.33), KO20 (r=0.26), CH30 (-969) (r=0.15), KO18 (r=0 .05), CH11 (-018) (r=0.04), US-14 (-382) (r=0.03) and CH3(-008) (r=0.02), as well as among Russian varieties Select 201 and Select 302 (r=0.30 and r=0.17, respectively) showed a weak positive relationship (Figure 4, 5). The presence, albeit to a weak degree, of a positive correlation relationship between the traits indicates that these varieties can be used as starting material in genetic breeding studies to increase the content of protein and oil. It should be noted that according to the analysis of protein and oil content in the studied Russian varieties Sparta (40%, 20%, respectively) and Selecta 302 (40.0%, 20.0%, respectively) showed direct average correlations between these traits compared with other samples. A high content of protein and oil in soybean grain was noted in varieties Sparta (40% and 20%) and Selecta 302 (40% and 20%), and a high protein content of Select 201 (40%), Avanta varieties were also high in oil (20.0 %), Sparta (20.0%) and Selecta-302 (20.0%). The rest of the variety samples showed a negative correlation relationship from a weak to a strong degree.

4. Conclusions

It was found that intervarietal variation of protein was 1.0%, oil 1.56%. The minimum total indicator of protein and oil in soybean grain was 57.44±0.40 (Arletta variety), the maximum was 60.00±32.0% (Sparta variety). Based on the results of field experiments, to increase the protein and oil in the grain of future soybean varieties, the following collection varieties of South Korea: KO21(RR-1), KO18, US-44(-641), CH_7(-014), CH_{28}(-268) and the Russian Federation: Selecta-201, Sparta, Selecta 302 should be used in further genetic breeding studies.

To increase the protein content, it is recommended to include varieties KO21(RR-1) and KO18 from the collection of South Korean selection in the genetic selection process; grain accessions CH_7(-014) and CH_{28}(-268), as well as from the collection of Russian breeding selecta-201 to increase protein in soybean grain, to increase oil, Avanta accession, to simultaneously increase protein and oil, accessions Sparta, Selecta 302.

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