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Varietal features of the formation of quality indicators and amino acid composition of soybean grain under the conditions of the left-bank forest-steppe of Ukraine

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ABSTRACT

The study aims to identify varieties with better grain quality indicators for cultivation under the conditions of the northeastern forest-steppe of Ukraine. The study aims to optimize the formation of soybean quality indicators according to varietal characteristics and weather conditions. The survey subject is 26 soybean varieties of domestic and foreign selection, the weight of 1000 seeds, the quality of seeds, and weather conditions. During the experiment, among the studied varieties, the highest weight indicators of 1,000 seeds (190.4–202.4 g) were formed by varieties such as Asuka, Diadema Podillya, Tenor, and Millennium, significantly higher than the weighted average value for the group of studied varieties (Duncan test = 15.3 g). The largest seed was formed under the conditions of 2020 (180.7 g). During the 2019–2021 study period, varieties such as Titan, Paradis, Tenor, and Kyoto (40.5–41.0%) had the highest protein content on average. In terms of the years studied, 2020 was marked as the most favorable; under its weather conditions, the varieties formed an average of 40.1% of the protein in the grain. The Vinni, Navigator, Alaska, Knyazhna, Amadea, Oriana, Triada, Merlin, and Arisa varieties showed significantly higher fat content than the average (19.8–20.7%). Seeds harvested in 2019 had the maximum oil content on average (20.0%). The study of the amino acid profile of different soybean varieties revealed significant variations in essential and non-essential amino acids. The Tytan variety is characterized by the highest levels of lysine (2.99 g/100 g), leucine (3.42 g/100 g) and alanine (1.83 g/100 g). In contrast, the Tenor and Cordoba varieties show the lowest levels of these amino acids (1.70–1.71 g/100 g lysine, 2.26–2.43 g/100 g leucine, and 1.33–1.40 g/100 g alanine, respectively). High levels of threonine are also observed in the Vinni and Tytan varieties (1.80–1.88 g/100 g). The maximum concentration of methionine was noted in the varieties of Favor and Tenor (0.08–0.09 g/100 g), while in most other varieties, the content of this amino acid did not exceed 0.03–0.04 g/100 g. Tenor, Arisa, Tytan, Vezha, and Vinni are the leaders in the content of valine, isoleucine, phenylalanine, proline, glutamic, and aspartic acids, respectively. In contrast, the varieties of Alaska, Diadema Podillya, and Cordoba are characterized by the lowest content of these amino acids. The highest histidine content (1.90 g/100 g) was recorded in the variety of Samorodok, and the lowest (1.21–1.27 g/100 g) was recorded in the varieties of Tenor and Cordoba.

Keywords: soybean, varietal characteristics, weight of 1000 seeds, protein, oil, amino acid.

INTRODUCTION

Ensuring the country's food security is correlated with the level of development of the country's food industry. The ability to meet the needs of the domestic market and increase the level of competitiveness of enterprises depends on a clear understanding of the challenges facing the strategically important branch of domestic industry [Rymar and Mazurkevych, 2021; Anghinoni et al., 2021]. In today's world, with a constantly growing population, there is a need to provide humanity

with high-quality food products. The issue of protein scarcity and replenishment of fat resources is particularly acute. The cultivation of soybeans can contribute to solving these problems.

Soy is a leading protein and oil crop with many uses in the food, feed, and technical industries. It is also of special agricultural importance. The crop is profitable, which makes it popular among agricultural producers. The chemical composition of soy protein is like animal protein, allowing it to manufacture various food products [Zhuykov et al., 2020; Szpunar-Krok & Wondołowska-Grabowska, 2022]. The protein of leguminous crops has historically been identified in the Asian region. It is considered an essential food source for meeting the need for protein in the human body because it is a suitable substitute for animal-origin food and is widely used in vegetarian diets [Rizzo and Baroni, 2018]. Their consumption in appropriate combinations can complement each other [Ahnen et al., 2019]. Moreover, soy contains about 20% fats, which are among the most used in the world and are a source of saturated and unsaturated fatty acids that help maintain the proper level of cholesterol in the human and animal body [Thrane et al., 2017; Benbouriche et al., 2022].

Soy proteins are primarily globulins, which comprise about 70% of all proteins and have auxiliary functions. Other proteins belong to the albumin group, which performs enzymatic and structural functions. Most of them can form low-activity complexes that affect raw materials' biological value and technological suitability for food production. They also regulate proteolytic activity [Modgil & Kumar, 2021]. It has long been believed that the quality of soy protein depends on the content of essential amino acids. However, for many reasons, the animal feed and human food markets have only recently begun to evaluate it accordingly [Monte et al., 2020].

The quality of soy protein can be compared to meat, milk, and egg proteins. Among plant sources of protein, soy protein is considered to have the highest biological value, in particular in terms of the content of exogenous amino acids – phenylalanine, methionine, threonine, valine, isoleucine, leucine, tryptophan, lysine. The reference literature provides the following percentages of their content in soybeans: leucine about 8 g/100 g of protein; lysine – 6.5 g/100 g of protein; valine – 5 g/100 g of protein; isoleucine – 5 g/100 g of protein; phenylalanine – 4 g/100 g of protein. Compared to animal proteins, soy protein is characterized by a lower content of sulfur amino acids [Kudełka et al., 2021]. For soybeans, the total sulfur content of the amino acids cysteine and methionine is less than 1.5% of the total protein, below the level that meets the daily dietary recommendations for humans [Assefa et al., 2018]. It is also estimated that together the essential amino acids (isoleucine, histidine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine) and the conditionally essential amino acids (arginine, cysteine, glutamine, glycine, ornithine, proline, and serine) constitute about 20% of the protein in soybean seeds [Tessari et al., 2016].

The biochemical composition of seeds, such as protein, oil, and fatty acid content, can be influenced by genotype, environment, growing technological elements, and their interactions [Dhungana et al., 2017; Phansak et al., 2016]. A large part of the impact on the protein and fat content falls on the features of the variety [Kalenska et al., 2022]. To achieve this, breeders put much effort into choosing the source material, which is decisive in this matter [Melnyk et al., 2022]. The protein content of the hybrid offspring is closely correlated with the protein content of the parental forms [Liu et al., 2016].

MATERIAL AND METHODS

The article aims to identify varieties with the best quality indicators of soybean seeds for cultivation under the conditions of the left bank forest-steppe of Ukraine. The study aims to optimize the formation of soybean quality indicators according to varietal characteristics and weather conditions.

The subject of the study is 26 soybean varieties of domestic and foreign selection, the weight of 1000 seeds, the quality of seeds, and weather conditions. The research was conducted regarding the educational-scientific-production complex (ESPC) of the Sumy National Agrarian University (latitude: 49.6; longitude: 34.9; height above sea level – 113 m) during 2019–2021.

The primary meteorological data were obtained from the laboratory of the Institute of Agriculture of the Northeast of the National Academy of Sciences of Ukraine (the village of Sad – 5 km from the experimental field). Selyaninov's hydrothermal coefficient (HTC) was used to provide comprehensive characteristics of the area's moisture. Based on the analysis of the weather conditions of the growing season in

2019, it was found that the year had insufficient precipitation (Fig. 1). Precipitation was deficient throughout the growing season, particularly in June (16.8 mm) and August (only 4.5 mm), which led to a decrease in overall soybean productivity that year compared to 2020. The air temperature exceeded the long-term indicators by 2.1–4.3 °C in all months of the soybean vegetation period (Fig. 2). In general, during the vegetation period (May–September), the average monthly temperature varied from 15.5 to 23.0 °C and the amount of precipitation ranged from 4.5 to 53.4 mm.

We found out that the growing season 2020 differed from the annual average of 0.9 mm rainfall in August to 57.0 mm. At the same time, a larger amount fell in May (93.2 mm) compared to the annual average (54.0 mm), which made it possible to form good seedlings and, subsequently, highly productive soybean plants. It should also be noted that the temperature regime in May (13.5 °C) was lower than the long-term average parameters (15.6 °C). In summer, an increase in average monthly temperatures compared to long-term data by 1.7–4.5 °C was recorded. Generally, the average monthly temperature of the growth season varied from 13.5 °C to 23.3 °C, and the amount of precipitation from 0.9 mm to 93.2 mm.

Enough precipitation in all months characterized the vegetation period 2021 except for July and September. It should be noted that the amount of precipitation in May (168.3 mm) and June (101.9 mm) exceeded the average long-term data (54.0 and 67.0 mm), respectively. Therefore, excessive moisture and low-temperature conditions in the specified year caused a slowdown in plant development and a delay in the calendar onset of the main phases. As mentioned, the air temperature in April and May was lower than the average long-term data. There was a gradual increase in the temperature regime starting in June and ending in August. Average monthly temperatures of the growth season ranged from 12.8 °C to 25.0 °C, and the amount of precipitation ranged from 7 to 168.3 mm.

The soil of the experimental site is a typical deep-medium-humus coarse-grained medium-loam black soil on loess rocks. According to

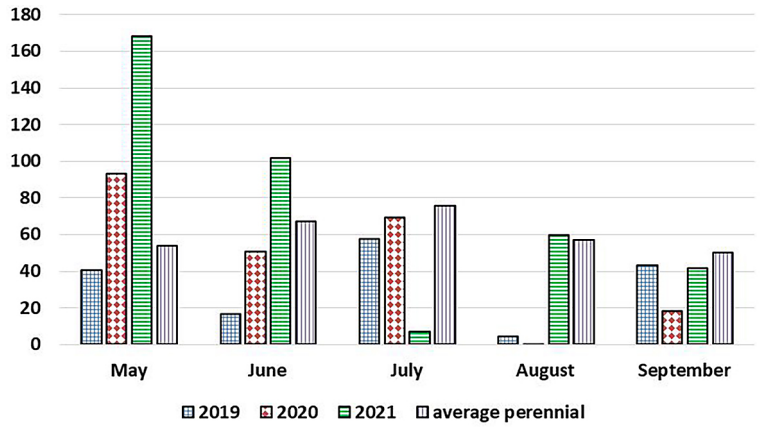

Figure 1. Amount of precipitation by month for the 2019–2021 research years, mm

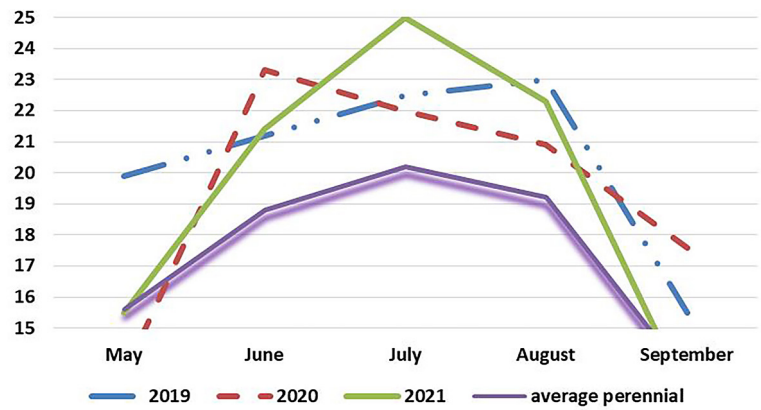

Figure 2. Average monthly air temperature for the 2019–2021 research years, °C

Tyurin, Humus content is 3.8–4.1%; saline pH – 6.0–6.2. According to Kornfield, the content of easily hydrolyzed nitrogen is 120 per kg of soil, mobile compounds P_2O_5 and K_2O, according to Chyrykov – 195.1 mg per kg of soil and 72.4 mg per kg of soil, respectively. The method of sowing is the usual row (15 cm). The sowing rate was 650.000 units. ha^{-1}. The weight of 1000 pcs. was determined according to DSTU 4138-2002. Harvest accounting was carried out continuously from each accounting plot. The "Methodology of State Varietal Testing of Crops" determined the crop structure elements. The protein, oil, and amino acid composition of soybean protein content was determined using an infrared analyzer SupNir 2750 – according to DSTU 4117:2007 of "Grain and its processing products". Technology was generally accepted for the research area at the time of the research, except for the elements under study. The predecessor was grain ears.

Statistical and correlation-regression analysis of research results was carried out on a personal computer using modern packages of mathematical processing applications Excel, Statistica 10 and relevant methods of field experiments [Rozhkov et al., 2016].

RESULTS AND DISCUSSION

One of the important indicators of soybean seed quality is its size, which is determined by the weight of 1.000 seeds (Table 1). The research results in 2019–2021 show that the average weight

Table 1. Weight of 1,000 pcs of seeds of modern soybean varieties in the conditions of the northeastern forest-steppe of Ukraine (2019–2021)

The name of the variety	Years of research				Ratio to the average by varieties
	2019	2020	2021	Average	
Amadea	172.4	186.5	168.9	175.9	4.1
Asuka	187.4	197.7	186.3	190.4	18.6
Alaska	153.3	165.7	151.2	156.7	-15.1
Arisa	184.0	194.9	180.8	186.6	14.8
Tundra	139.2	176.5	190.2	168.6	-3.2
Kofu	182.5	195.2	179.6	185.8	14.0
Merlin	145.1	154.5	141.7	147.1	-24.7
Padua	142.9	153.5	141.1	145.8	-26.0
Kent	180.8	192.3	179.4	184.2	12.4
Vezha	169.8	183.8	165.3	173.0	1.2
Knyazhna	147.5	158.3	146.9	150.9	-20.9
Vinni	157.5	168.2	155.1	160.3	-11.5
Oriana	143.4	151.8	141.1	145.4	-26.4
Samorodok	141.9	153.4	139.3	144.9	-26.9
Triada	157.2	172.2	154.1	161.2	-10.6
Millenium	199.3	212.6	195.3	202.4	30.6
Tytan	179.2	189.2	176.2	181.5	9.7
Paradis	166.2	178.2	165.3	169.9	-1.9
Navigator	168.2	182.3	165.3	171.9	0.1
Mentor	175.2	188.2	170.5	178.0	6.2
Favor	178.7	190.2	175.8	181.6	9.8
Lissabon	171.3	184.9	167.1	174.4	2.6
Kioto	157.2	172.2	154.2	161.2	-10.6
Diadema Podillya	189.4	200.3	187.8	192.5	20.7
Cordoba	172.6	184.5	169.9	175.7	3.9
Tenor	198.5	210.8	196.0	201.8	30.0
Average	167.7	180.7	167.1	171.8	
Duncan test					15.3

of 1000 seeds of the studied soybean varieties was 171.8 g. Among the studied varieties, the maximum coarseness (190.4–202.4 g) was formed by such varieties as Asuka, Diadema Podillya, Tenor, and Millennium, which is significantly higher than the weighted average value for the group of studied varieties (Duncan test = 15.3 g). The grain of such varieties as Samorodok, Oriana, Padua, and Merlin was significantly smaller (144.9–147.1 g). The rest of the varieties' weight of 1,000 pcs. was formed at the average value level. It was also found that the largest grain was formed under the conditions of 2020 (180.7 g), and smaller – under the conditions of 2019 (167.7 g). The minimum mass indicators of 1.000 pcs. were characteristic of seeds collected in 2021 (167.1 g). Soy is a high-quality source of vegetable protein that can be compared with other protein products. Soy protein has a similar amino acid composition to milk and whey proteins, making it a valuable source of nutrients. The PDCAAS (Protein Digestibility Corrected Amino Acid Score) and soy protein digestibility coefficient are comparable to milk and whey proteins [Hertzler et al., 2020; Sui et al., 2021]. In addition, the quality of soy protein meets the standards set for egg white [Rizzo et al., 2018]. The protein content of soybeans is an important indicator of their quality (Table 2). During the 2019–2021 study period, varieties such as Titan, Paradis, Tenor, and Kyoto (40.5–41.0%) had the highest protein content on average. At the level of the average value (39.3%), the protein content was formed by such varieties as Oriana, Knyazhna, Navigator, Vinni, Kent, Alaska, Vezha,

Table 2. Protein content in the grain of different soybean varieties under the conditions of the left bank forest-steppe of Ukraine (2019–2021)

The name of the variety	Years of research				Ratio to the average by varieties
	2019	2020	2021	Average	
Amadea	35.0	39.7	38.8	37.8	-1.5
Asuka	40.9	39.1	39.7	39.9	0.6
Alaska	37.6	38.9	40.9	39.1	-0.2
Arisa	34.7	36.0	37.7	36.2	-3.1
Tundra	38.9	40.3	39.7	39.7	0.4
Kofu	38.7	41.3	40.3	40.1	0.8
Merlin	37.6	36.6	38.1	37.5	-1.9
Padua	38.3	39.6	41.4	39.8	0.5
Kent	37.4	40.9	39.2	39.1	-0.2
Vezha	37.0	41.2	39.5	39.2	-0.1
Knyazhna	36.8	40.0	38.8	38.5	-0.8
Vinni	37.4	40.5	39.2	39.0	-0.3
Oriana	36.5	39.9	38.3	38.2	-1.1
Samorodok	40.9	39.5	38.5	39.6	0.3
Triada	36.0	37.7	40.0	37.9	-1.4
Millenium	37.9	40.0	40.4	39.4	0.1
Tytan	39.7	40.5	41.3	40.5	1.2
Paradis	40.3	42.3	39.3	40.6	1.3
Navigator	37.5	39.2	40.1	38.9	-0.4
Mentor	38.5	42.3	39.1	40.0	0.7
Favor	38.4	39.2	40.0	39.2	-0.1
Lissabon	39.0	40.8	39.9	39.9	0.6
Kioto	39.4	43.1	40.5	41.0	1.7
Diadema Podillya	38.2	42.2	39.2	39.9	0.6
Cordoba	37.9	41.4	39.2	39.5	0.2
Tenor	40.3	41.7	40.7	40.9	1.6
Average	38.1	40.1	39.6	39.3	
Duncan test					2.5

Favor, Millennium, Cordoba, Samorodok, Tundra, Padua, Asuka, Diadema Podillya, Lissabon, Commander, and Kofu (38.2–40.1%). Significantly lower protein content in a seed (36.2–37.9%) was obtained using seeds of such varieties as Arisa, Merlin Amadea, and Triada (Duncan test = 2.5%). In terms of the years studied, 2020 was marked as the most favorable; under weather conditions, the varieties formed an average of 40.1% of the protein in the seed. A little less protein was formed in the seed under the weather conditions of 2021, namely 39.6%. The minimum protein content (38.1%) was formed by seed collected in 2019.

The value of soybeans depends on their oil content and fatty acid composition because soybean oil is widely used in the food industry [Carrera et al., 2017; Anwar et al., 2016]. Soybean oil is often used in food and food products such as pastry fillings, salad oil, cooking, mayonnaise, and food dressings [Zhang et al., 2023; Srikanth et al., 2023]. Thus, we found that the maximum oiliness on average (20.0%) was obtained from seeds collected in 2019 (Table 3). A slightly lower fat content (19.5%) was obtained in 2021. The minimum fat content on average (19.2%) was calculated in 2020. Vinnie, Navigator, Alaska, Knyazhna, Amadea, Oriana, Triada, Merlin, and Arisa varieties showed significantly higher than average fat content (19.8–20.7%). On the contrary, the fat content was lower (18.4–19.3%) in such varieties as Kyoto, Tenor, Padua, Paradis, Diadema Podillya, Tundra, Kofu, Titan, and Samorodok (Duncan test = 1%). In the rest of the

Table 3. Fat content in the grain of different soybean varieties under the conditions of the left bank forest-steppe of Ukraine (2019–2021)

The name of the variety	Years of research				Ratio to the average by varieties
	2019	2020	2021	Average	
Amadea	20.6	19.2	19.8	19.9	0.3
Asuka	19.1	19.4	19.6	19.3	-0,3
Alaska	20.1	19.8	19.4	19.8	0.2
Arisa	20.9	20.7	20.6	20.7	1.1
Tundra	19.4	18.6	19.6	19.2	-0.4
Kofu	19.8	18.6	19.7	19.3	-0.3
Merlin	20.6	20.1	20.3	20.3	0.7
Padua	20.3	18.4	18.6	19.1	-0.5
Kent	20.0	19.3	19.8	19.7	0.1
Vezha	20.8	18.9	19.4	19.7	0.1
Knyazhna	20.4	19.2	20.2	19.9	0.3
Vinni	20.3	19.0	20.1	19.8	0.2
Oriana	20.2	19.6	20.2	20.0	0.4
Samorodok	18.9	19.3	19.7	19.3	-0.3
Triada	21.0	20.1	19.5	20.2	0.6
Millenium	19.8	19.6	18.9	19.4	-0.2
Tytan	18.2	19.6	20.1	19.3	-0.3
Paradis	19.1	19.5	18.8	19.1	-0.5
Navigator	20.5	19.7	19.2	19.8	0.2
Mentor	20.4	18.8	19.4	19.5	-0.1
Favor	20.0	19.5	19.3	19.6	0.0
Lissabon	19.9	19.1	19.3	19.4	-0.2
Kioto	19.3	17.5	18.4	18.4	-1.2
Diadema Podillya	19.5	18.8	19.1	19.1	-0.5
Cordoba	20.2	19.2	19.2	19.5	-0.1
Tenor	20.4	18.1	18.7	19.1	-0.5
Average	20.0	19.2	19.5	19.6	
Duncan test					1.0

varieties, the fat content was formed at the average value level (19.6%).

When combined appropriately, plant proteins can complement each other in their amino acid profile. A typical example is lysine, which is abundant in beans but often deficient in cereals. On the other hand, methionine is abundant in cereals but rarely found in legumes [Ahnen et al., 2019]. The highest lysine content (Table 4) is observed in the varieties of Tytan (2.99 g/100 g) and Oriana (2.84 g/100 g). In contrast, the lowest lysine content is observed in the varieties Tenor (1.70 g/100 g) and Cordoba (1.71 g/100 g). The maximum content of threonine was recorded in the varieties of Vinni (1.80 g/100 g) and Tytan (1.88 g/100 g), and the minimum content in the varieties of Alaska, Diadema Podillia, and Kyoto (132–1.35 g/100 g). The content of methionine varies slightly among the varieties, with the highest values in Favor and Tenor (0.08–0.09 g/100 g) and the lowest in most other varieties (0.03–0.04 g/100 g). The highest valine content is found in the varieties of Tenor (2.18 g/100 g) and Amadea (2.14 g/100 g), the lowest in the varieties of Alaska and Arisa (1.72–1.73 g/100 g). The highest isoleucine content is observed in the Tenor (1.86 g/100 g) and Arisa (1.80 g/100 g) varieties, the lowest in the Alaska and Arisa varieties (1.48–1.49 g/100 g). The highest leucine content is observed in the Titan, Amadea, and Vinni varieties (3.26–3.42 g/100 g), the lowest in the Kyoto, Diadema Podillya, and Cordoba varieties (2.26–2.43 g/100 g). The highest phenylalanine content is observed in the Tytan (2.36 g/100 g) and Kyoto (2.52 g/100 g) varieties, the lowest in the Diadema Podillya (1.75 g/100 g) and Cordoba varieties (1.72 g/100 g). Despite the potential deficiency of one or more essential amino acids, plant proteins often contain significant

Table 4. The content of essential amino acids in grains of different soybean varieties under the conditions of the northeastern forest-steppe of Ukraine (average for 2019–2021), g/100 g

The name of the variety	Essential amino acids, g/100 g						
	Lysine	Threonine	Methionine	Valine	Isoleucine	Leucine	Phenylalanine
Amadea	2.67	1.73	0.04	2.14	1.74	3.28	2.30
Asuka	2.46	1.51	0.04	1.78	1.55	2.75	2.03
Alaska	2.17	1.35	0.05	1.72	1.48	2.58	1.78
Arisa	2.38	1.42	0.04	1.73	1.49	2.76	1.87
Tundra	2.31	1.65	0.07	2.12	1.80	2.86	2.10
Kofu	2.38	1.59	0.05	1.91	1.64	2.70	2.00
Merlin	2.49	1.55	0.04	1.91	1.62	2.87	2.01
Padua	2.36	1.51	0.05	1.85	1.59	2.72	1.93
Kent	2.43	1.60	0.04	1.98	1.70	2.67	1.99
Vezha	2.74	1.77	0.05	2.06	1.78	3.05	2.30
Knyazhna	2.58	1.63	0.05	2.02	1.72	3.01	2.14
Vinni	2.73	1.80	0.04	2.10	1.73	3.26	2.24
Oriana	2.84	1.63	0.04	1.83	1.60	2.99	2.10
Samorodok	2.81	1.63	0.03	1.81	1.58	2.82	2.03
Triada	2.40	1.55	0.06	1.93	1.67	2.81	1.99
Millenium	2.45	1.59	0.05	1.89	1.62	2.82	2.06
Tytan	2.99	1.88	0.05	2.13	1.76	3.42	2.36
Paradis	2.36	1.47	0.04	1.78	1.56	2.59	1.92
Navigator	2.77	1.66	0.03	1.91	1.65	2.92	2.07
Mentor	2.56	1.60	0.05	1.96	1.69	2.93	2.06
Favor	2.09	1.48	0.08	2.01	1.77	2.55	1.96
Lissabon	2.11	1.41	0.05	1.92	1.65	2.56	1.90
Kioto	2.20	1.32	0.05	2.01	1.51	2.43	2.52
Diadema Podillya	1.80	1.33	0.07	1.92	1.68	2.26	1.75
Cordoba	1.71	1.43	0.07	2.04	1.70	2.43	1.72
Tenor	1.70	1.39	0.09	2.18	1.86	2.50	1.81

amounts of non-essential amino acids. In particular, amino acids such as asparagine, glutamine, glutamine, glutamic acid, alanine, serine, cysteine, tyrosine, glycine, arginine, proline, and aspartic acid are characterized by high content in plant proteins. Their functional role is critical for ensuring normal human metabolism [Hertzler et al., 2020]. For example, soy protein is a valuable source of arginine and glycine. These amino acids are important in the urea cycle and collagen synthesis [Sa et al., 2020]. The highest alanine content (Table 5) is observed in the varieties Titan (1.83 g/100 g) and Amadea (1.82 g/100 g). In contrast, the lowest alanine content is observed in the varieties of Alaska (1.38 g/100 g) and Diadema Podillya (1.33 g/100 g). The highest proline content is observed in Tytan (1.81 g/100 g) and Vezha (1.78 g/100 g). The lowest proline content is observed in the varieties of Tenor (1.33 g/100 g), Diadema Podillya (1.27 g/100 g), and Cordoba (1.23 g/100 g). The highest glutamic acid content was observed in Tytan (7.24 g/100 g) and Amadea (7.12 g/100 g). The Tenor (5.30 g/100 g) and Alaska (5.32 g/100 g) had the lowest glutamic acid content. The maximum content of aspartic acid was recorded in the Vinni (4.64 g/100 g) and Amadea (4.63 g/100 g) varieties; the minimum content was in the Alaska (3.48 g/100 g) and Diadema Podillya (3.47 g/100 g) varieties. The Tenor (2.18 g/100 g) and Titan (2.22 g/100 g) varieties had the highest serine content. In contrast, the lowest serine content was observed in the Alaska (1.71 g/100 g) and Paradis (1.74 g/100 g) varieties. Vezha (3.36 g/100 g) and Tundra (3.15 g/100 g) are characterized by a high arginine content. Varieties of Triada, Cordoba, and Diadema Podillya had the lowest content of this amino acid

Table 5. The content of replaceable amino acids in the grain of different soybean varieties in the conditions of the northeastern forest-steppe of Ukraine (average for 2019–2021), g/100 g

The name of the variety	Non-essential amino acids, g/100 g						
	Alanine	Proline	Glutamic acid	Aspartic acid	Serine	Arginine	Histidine
Amadea	1.82	1.74	7.12	4.63	2.12	3.06	1.63
Asuka	1.54	1.67	5.68	3.88	1.76	2.68	1.61
Alaska	1.38	1.47	5.32	3.48	1.71	2.29	1.41
Arisa	1.53	1.58	5.95	3.64	1.76	2.24	1.57
Tundra	1.64	1.57	5.97	4.19	2.10	3.15	1.45
Kofu	1.51	1.49	5.54	3.73	1.86	2.86	1.58
Merlin	1.58	1.61	6.23	3.96	1.92	2.43	1.73
Padua	1.53	1.56	5.91	3.83	1.85	2.34	1.58
Kent	1.51	1.43	5.51	3.66	1.93	2.88	1.68
Vezha	1.69	1.78	6.32	4.25	2.10	3.36	1.61
Knyazhna	1.67	1.70	6.10	4.16	2.01	2.98	1.56
Vinni	1.72	1.71	7.05	4.64	2.14	2.85	1.70
Oriana	1.63	1.64	5.94	3.93	1.82	2.75	1.69
Samorodok	1.60	1.59	6.10	3.71	1.81	2.62	1.90
Triada	1.60	1.65	6.25	3.91	1.98	2.32	1.60
Millenium	1.53	1.65	5.69	3.84	1.90	2.96	1.60
Tytan	1.83	1.81	7.24	4.57	2.22	3.01	1.70
Paradis	1.48	1.50	5.29	3.57	1.74	2.80	1.65
Navigator	1.65	1.59	6.21	3.92	1.90	2.61	1.86
Mentor	1.64	1.60	6.07	4.01	1.96	2.71	1.65
Favor	1.53	1.53	4.82	3.76	1.98	2.80	1.25
Lissabon	1.51	1.37	5.45	3.52	1.79	2.51	1.39
Kioto	1.52	1.45	5.88	3.69	2.04	2.63	1.31
Diadema Podillya	1.33	1.27	5.44	3.47	1.80	2.23	1.39
Cordoba	1.40	1.23	5.59	3.82	2.03	2.32	1.27
Tenor	1.51	1.33	5.30	3.95	2.18	2.58	1.21

(2.23–2.32 g/100 g). The highest concentration of histidine was observed in the Samorodok variety (1.90 g/100 g). At the same time, the lowest amount of this amino acid was found in the Tenor and Cordoba varieties (1.21–1.27 g/100 g).

Soybeans, whose seeds are one of the best sources of high-quality vegetable proteins and oils, have recently received much attention [Huang et al., 2020]. Both environmental and genetic factors generally influence the nutrients contained in soybeans [Melnyk et al., 2022]. Major external environmental factors, such as temperature, location of cultivation, year of cultivation, farming conditions, and solar radiation, are significant in determining the composition of soybean metabolites [Didur, 2023]. Many studies have been conducted to establish the correlation between these factors and protein and oil accumulation in soybeans [Assefa et al., 2018]. Thus, according to the results of research by Ukrainian scientists, it was established that the factors of the growing area – 31% and the variety – 25% had the largest share of influence on the content of crude protein in the seeds of the studied varieties. It was also determined that the factor of the growing zone affected the oil content in soybeans by 25% and the variety by 21% [Topchiy et al., 2020]. The literature also contains evidence of the positive effect of mineral fertilizer application on seed quality indicators. According to research by Furman and other scientists in the right-bank forest-steppe of Ukraine, it was found that the application of mineral fertilizers increased the crude protein content in soybean grain by an average of 0.74–2.06% [Furman et al., 2022].

According to research by foreign scientists, the protein concentration also affects the amino acid composition of soybeans. The relative content of amino acids, such as lysine, methionine, cysteine, tryptophan, and threonine, decreased with increasing protein concentration in seeds, while arginine and glutamic acid increased [Pfarr et al., 2018]. Our previous studies saw a tendency to increase the content of most amino acids in the mid-early Tenor variety. An increase in the content of essential and non-essential amino acids in soybeans was recorded due to the application of mineral fertilizers. The only exception was essential methionine, which content decreased by 0.04–0.09 g/100 g compared to the control when mineral fertilizers were applied [Bruniov and Dudka, 2023].

CONCLUSIONS

According to the results of the conducted research, it was established that under the conditions of the left bank forest-steppe of Ukraine, the maximum mass index of 1.000 pcs. seeds (190.4–202.4 g) were formed in Asuka, Diadema Podillya, Tenor, and Millennium varieties. Notably, such varieties as Titan, Paradis, Tenor, and Kyoto had the maximum protein content (40.5–41.0%). Vinnie, Navigator, Alaska, Knyazhna, Amadea, Oriana, Triada, Merlin, and Arisa varieties showed a significantly higher than average fat content (19.8–20.7%). The most favorable conditions for the realization of the genetic potential of soybean varieties for seed size and protein content are 2019 and for oil content – also 2019, which is determined by the distribution of the temperature regime and precipitation during the growth season of the crop. The study of the amino acid composition of different soybean varieties revealed significant variations in the content of essential and non-essential amino acids. The highest content of lysine (2.99 g/100 g), leucine (3.42 g/100 g), and alanine (1.83 g/100 g) were observed in the Tytan variety. In contrast, the lowest content of these amino acids was recorded in the Tenor and Cordoba varieties (1.70–1.71 g/100 g lysine, 2.26–2.43 g/100 g leucine and 1.33–1.40 g/100 g alanine, respectively). The Vinni and Tytan varieties were also characterized by a high threonine content (1.80–1.88 g/100 g). The highest concentration of methionine was found in the varieties of Favor and Tenor (0.08–0.09 g/100 g), while the content of this amino acid in most other varieties ranged from 0.03–0.04 g/100 g. The leaders in the content of valine, isoleucine, phenylalanine, proline, glutamic, and aspartic acids were the varieties Tenor, Arisa, Tytan, Vezha, and Vinni, respectively. The lowest amount of these amino acids was observed in Alaska, Diadema Podillya, and Cordoba varieties. The variety of Samorodok was distinguished by the highest histidine content (1.90 g/100 g). In contrast, the lowest content of this amino acid was recorded in the varieties of Tenor and Cordoba (1.21–1.27 g/100 g).

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