# CHEMICAL COMPOSITION, OIL CONTENT, AND AMINO ACID CONTENT OF CASTOR BEAN (RICINUS COMMUNIS L.) SEEDS CULTIVATED IN THE KHOREZM REGION

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***https://doi.org/10.5281/zenodo.20809374***

***Abstract.*** *Castor bean (Ricinus communis L.) varieties are considered medicinal plants and represent a relatively new crop for the Khorezm region. Their cultivation technology, physiological characteristics, biochemical composition, and potential for cultivation under the soil and climatic conditions of the Khorezm region have not yet been sufficiently studied. Therefore, this article presents data on the content of macro- and microelements, oil content, as well as the composition and quantity of essential and non-essential amino acids in the seeds of four castor bean varieties-Zanzibarskaya, Gibsona, Impala, and the control variety Khersonskaya-10-grown on alluvial meadow soils of the Khorezm region.*

*The results of the study demonstrated that the Impala variety showed a clear advantage in terms of the total content of macro- and microelements. The lowest values were generally observed in the Khersonskaya-10 variety, with the exception of calcium. However, higher concentrations of sodium and sulfur were recorded in the Gibsona variety, while the Zanzibarskaya variety contained relatively higher amounts of boron, iron, and chromium compared to the other studied varieties.*

*The highest oil content and oil yield were determined in the Impala and Gibsona varieties, reaching 46.3% and 56.4 kg/ha, and 45.5% and 55.1 kg/ha, respectively. The lowest values were recorded in the control variety Khersonskaya-10 (43.8% and 51.8 kg/ha). The acid value of the oil extracted from the seeds of the studied castor bean varieties complied with the standards specified in the National Pharmacopoeia of Uzbekistan and ranged from 0.79 to 1.85 mg KOH/g.*

*Laboratory analyses further revealed that the Impala variety significantly exceeded the other varieties in both essential and non-essential amino acid contents. In particular, the concentrations of several amino acids, including threonine, arginine, histidine, and tryptophan, were substantially higher than those in the control variety Khersonskaya-10, differing by several-fold. Nevertheless, the Khersonskaya-10 variety was distinguished by its considerably higher glutamine content compared with the other varieties studied.*

***Keywords:*** *medicinal plants, varietal differences, macroelements, microelements, oil content, acid value, oil yield, essential and non-essential amino acids.*

**Introduction.** Macroelements and microelements are essential nutrients required at all stages of plant growth and development. These include nitrogen, phosphorus, potassium, sulfur, magnesium, and iron, which are present in relatively large amounts in plants and play a crucial role in ensuring their normal growth and physiological functioning. Deficiency or insufficiency of these nutrients can negatively affect plant growth and development, resulting in reduced productivity and increased fruit or seed shedding [1]. The oil content and oil yield of medicinal

plant seeds are among the most important indicators of their biological and economic value. Seed oils serve not only as energy reserves for seed germination and early plant growth but are also widely utilized in the pharmaceutical, cosmetic, and food industries. Modern scientific studies have demonstrated that seed oil content is a variable trait influenced by genetic, biotic, and abiotic factors, including environmental stress conditions, cultivation practices, soil characteristics, climatic conditions, and applied agronomic techniques [5]. Amino acids are organic compounds that function as the fundamental building blocks of proteins. They participate in numerous metabolic processes within the human body and are indispensable for maintaining physiological functions. Contemporary biochemical research has established that amino acids perform not only structural (plastic) functions but also regulatory, energetic, and signaling roles in living organisms [18]. Under the conditions of Uzbekistan, castor bean (*Ricinus communis* L.) remains insufficiently studied from both medical and pharmacological perspectives. Consequently, scientific literature contains very limited information regarding its chemical composition, seed oil content, and particularly the quantitative characteristics of essential and non-essential amino acids under the environmental conditions of the Khorezm region.

Macro-and microelements act as important catalysts in numerous biochemical and metabolic processes. They contribute significantly to the maintenance of vital physiological functions in the human body, enhance disease resistance, and support the immune system [3]. Recent scientific investigations have emphasized that the oil content of medicinal plant seeds is one of the principal morphophysiological indicators determining both their biological value and commercial potential. Seed oils mainly consist of triglycerides, fatty acids, vitamins, and various biologically active compounds, which collectively contribute to the high value of seeds as industrial and pharmaceutical raw materials [13]. In recent years, interest in amino acids within the fields of nutrition science and clinical medicine has increased considerably due to their significant effects on immunity, metabolism, and overall human health [15]. Essential amino acids cannot be synthesized by the human body and therefore must be obtained through dietary sources. These include valine, leucine, isoleucine, lysine, methionine, threonine, tryptophan, phenylalanine, and histidine [4].

**Literature review.** Chemical elements can be classified into three groups according to their participation in physiological and biochemical processes in living organisms. The first group includes structural elements (macroelements), which constitute the major components of all organs and tissues of plants. The second group consists of essential elements (microelements) that are physiologically necessary for the vital activity of living organisms and perform numerous functions within cells. The third group comprises toxic elements, which may exert harmful effects even at very low concentrations and can cause toxicity. These include elements such as aluminum, lead, cadmium, chromium, silver, and beryllium [24]. The human body is unable to synthesize the macro- and microelements required for its normal functioning; therefore, these elements must be obtained through food or biologically active supplements [23]. Although microelements are required by plants only in very small quantities (fractions of milligrams), their role in physiological processes is indispensable. They are components of numerous enzymes and contribute significantly to photosynthesis and metabolic activities [11].

Microelements serve as important catalysts that regulate not only plant growth and development but also their internal biological activity. Despite their low concentrations in plant tissues, they directly participate in metabolic pathways, enzymatic reactions, and respiration processes. In particular, elements such as manganese and copper accelerate electron transport

during photosynthesis, thereby enhancing the plant's energy reserves [16]. Adequate levels of microelements improve cell membrane permeability and promote the efficient uptake of nutrients through the root system [9]. In crop production, plant resistance to environmental stresses—including drought, salinity, and extreme temperature fluctuations—is closely associated with elements such as zinc and boron. Zinc regulates the synthesis of natural plant growth hormones (auxins), while boron stimulates flowering and pollination processes and plays a crucial role in fruit and seed formation. Deficiency of any of these microelements weakens plant immunity, increases susceptibility to fungal and viral diseases, and consequently may lead to substantial reductions in crop productivity [14].

Furthermore, microelements significantly influence crop quality, particularly the protein and amino acid contents of seeds. For example, molybdenum regulates nitrogen metabolism and facilitates the conversion of nitrates into amino acids beneficial for plant growth. Therefore, proper mineral nutrition not only determines crop yield but also enhances its biological and nutritional value [17]. In summary, deficiencies of microelements in plants adversely affect productivity and reduce resistance to diseases and unfavorable environmental conditions. Consequently, the application of micronutrient fertilizers in modern crop production is considered an essential approach for obtaining high yields and producing environmentally safe, high-quality seeds and fruits [6]. The investigation of oil content and lipid composition in medicinal plant seeds contributes to improving the effectiveness of pharmacological products, optimizing cultivation technologies, and developing high-yielding varieties of medicinal plants. Modern analytical techniques allow accurate and reliable determination of both oil quantity and quality, which is of considerable scientific importance for their efficient utilization in industry, medicine, and pharmaceutical applications [21].

**Research methodology.** The oil content of medicinal plant seeds is directly associated with the quality of raw materials and their pharmacological value. Consequently, seed oils have broad applications in traditional medicine, modern healthcare, pharmaceutical manufacturing, and medicinal plant cultivation [26]. According to X. Wang, L. Chen [22] and other researchers, plant species and varietal differences significantly influence oil content and oil yield. For example, the oil content of fennel (*Foeniculum vulgare*) seeds ranges from 15–30%, whereas flax (*Linum usitatissimum*) seeds contain approximately 30–45% oil. Climatic conditions, soil characteristics, and agronomic practices such as fertilization and irrigation also substantially affect lipid biosynthesis. Dry climates and nutrient deficiencies can considerably reduce oil accumulation in seeds, thereby negatively affecting the quality and pharmacological properties of medicinal plant raw materials.

The quality of seed oils depends not only on their quantity but also on the composition of fatty acids, antioxidants, and biologically active compounds. From a pharmaceutical perspective, both the lipid content and the biochemical composition of seeds are of great importance. The highest oil accumulation generally occurs during the later stages of physiological maturation, particularly during fruit and seed ripening [19]. The acid value is a fundamental indicator reflecting the concentration of free fatty acids in oils and determining the extent of lipid hydrolysis. Its value is directly related to the quality, stability, and safety of oils used in pharmaceutical and medical applications [10]. International scientific and regulatory documents, including the **United States Pharmacopeia (USP)**, **European Pharmacopoeia (Ph. Eur.)**, **British Pharmacopoeia (BP)** and **Codex Alimentarius** recognize acid value as a mandatory parameter for quality control, standardization, and suitability assessment of oils. Therefore, this indicator is critically important

for ensuring the safety, efficacy, and stability of pharmaceutical products throughout all stages, from raw material processing to the production of finished medicinal preparations [2,7,8].

Recent studies indicate that branched-chain amino acids (BCAAs)-namely valine, leucine, and isoleucine-play a crucial role in muscle metabolism and energy homeostasis. Deficiency of essential amino acids in the human body may lead to negative nitrogen balance, impaired immune function, and dysfunction of various organs [20].

Non-essential amino acids are synthesized within the human body and include compounds such as alanine, asparagine, glutamate, and serine. Their synthesis primarily occurs in the liver and is closely associated with transamination processes [25].

Under certain physiological conditions, including stress, disease, injury, infection, and periods of rapid growth, the body's demand for specific amino acids increases significantly. Under such circumstances, amino acids such as arginine, glutamine, tyrosine, and cysteine are considered conditionally essential amino acids [12].

**Analysis and results.** Based on the objectives of the study, a comparative analysis of the macro- and microelement contents in the seeds of different castor bean (*Ricinus communis* L.) varieties revealed several notable differences. In the seeds of the Zanzibarskaya variety, the concentrations of macroelements were as follows: calcium – 2.712 mg/g, phosphorus – 53.463 mg/g, magnesium – 23.652 mg/g, sodium – 7.142 mg/g, sulfur – 6.716 mg/g, potassium – 146.712 mg/g, and boron – 0.252 mg/g. In the Gibsona variety, the corresponding values were calcium – 3. 222 mg/g, phosphorus – 62.836 mg/g, magnesium – 26.117 mg/g, sodium – 9.150 mg/g, sulfur – 8.127 mg/g, potassium – 150.224 mg/g, and boron – 0.182 mg/g.

The Impala variety exhibited the highest concentrations of several macroelements, including calcium (4.443 mg/g), phosphorus (64.392 mg/g), magnesium (27.305 mg/g), and potassium (175.112 mg/g). The contents of sodium, sulfur, and boron in this variety were 8.300 mg/g, 6.254 mg/g, and 0.318 mg/g, respectively. In the control variety, Khersonskaya-10, the macroelement contents were comparatively lower and amounted to calcium – 3.155 mg/g, phosphorus – 52.196 mg/g, magnesium – 19.382 mg/g, sodium – 6.150 mg/g, sulfur – 5.646 mg/g , potassium – 135.112 mg/g, and boron – 0.164 mg/g (Table 1). A comparative analysis of the macroelement contents in the seeds of the studied castor bean (*Ricinus communis* L.) varieties revealed that the Impala variety showed a clear superiority in terms of overall macroelement accumulation. In contrast, the Khersonskaya-10 variety exhibited the lowest values for most macroelements, with the exception of calcium. However, the Gibsona variety was distinguished by its relatively higher concentrations of sodium and sulfur, while the Zanzibarskaya variety contained a comparatively higher amount of boron than the other varieties examined. These findings indicate significant varietal differences in mineral composition and nutrient accumulation capacity.

***Table 1.***

***Comparative Macroelement Composition of Seeds of Different Castor Bean (*Ricinus communis *L.) Varieties (mg/10 g)***

| **Ca 317.933 (mg/10g)** | **P 213.617 (mg/10g)** | **Mg 285.213 (mg/10g)** | **Na 589.592 (mg/10g)** | **S 181.975 (mg/10g)** | **K 766.490 (mg/10g)** | **B 249.677 (mg/10g)** |
|---|---|---|---|---|---|---|
| **Zanzibarskaya variety** | | | | | | |
| 2,712 | 53,463 | 23,652 | 7,142 | 6,716 | 146,712 | 0,252 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Gibsona variety** | | | | | | |
| 3,222 | 62,836 | 26,117 | 9,150 | 8,127 | 150,224 | 0,182 |
| **Impala variety** | | | | | | |
| 4,443 | 64,392 | 27,305 | 8,300 | 6,254 | 175,112 | 0,318 |
| **Khersonskaya-10 variety** | | | | | | |
| 3,155 | 52,196 | 19,382 | 6,150 | 5,646 | 135,112 | 0,164 |

When the microelement contents of castor bean (*Ricinus communis* L.) seeds were analyzed, the seeds of the Zanzibarskaya variety contained copper – 0.143 mg/g, manganese – 0.124 mg/g, selenium – 0.209 mg/g, iron – 0.922 mg/g, zinc – 0.246 mg/g, cobalt – 0.007 mg/g, molybdenum – 0.383 mg/g, and chromium – 0.040 mg/g. In the Gibsona variety, the corresponding values were copper – 0.139 mg/g, manganese – 0.152 mg/g, selenium – 0.259 mg/g, iron – 0.761 mg/g, zinc – 0.441 mg/g, cobalt – 0.007 mg/g, molybdenum – 0.323 mg/g, and chromium – 0.020 mg/g. The seeds of the Impala variety contained copper – 0.171 mg/g, manganese – 0.216 mg/g, selenium – 0.319 mg/g, iron – 0.609 mg/g, zinc – 0.482 mg/g, cobalt – 0.006 mg/g, molybdenum – 0.646 mg/g, and chromium – 0.037 mg/g. In the control variety, Khersonskaya-10, the contents of these microelements were determined as follows: copper – 0.122 mg/g, manganese – 0.116 mg/g, selenium – 0.185 mg/g, iron – 0.561 mg/g, zinc – 0.231 mg/g, cobalt – 0.003 mg/g, molybdenum – 0.323 mg/g, and chromium – 0.022 mg/g (Table 2).

***Table 2.***

***Comparative Microelement Composition of Seeds of Different Castor Bean (*Ricinus communis *L.) Varieties (mg/10 g)***

| **Cu 327.393 (mg/10g)** | **Mn 257.610 (mg/10g)** | **Se 196.026 (mg/10g)** | **Fe 238.204 (mg/10g)** | **Zn 206.200 (mg/10g)** | **Co 228.616 (mg/10g)** | **Mo 202.031 (mg/10g)** | **Cr 267.716 (mg/10g)** |
|---|---|---|---|---|---|---|---|
| **Zanzibarskaya variety** | | | | | | | |
| 0,143 | 0,124 | 0,209 | 0,922 | 0,246 | 0,007 | 0,383 | 0,040 |
| **Gibsona variety** | | | | | | | |
| 0,139 | 0,152 | 0,259 | 0,761 | 0,441 | 0,007 | 0,323 | 0,020 |
| **Impala variety** | | | | | | | |
| 0,171 | 0,216 | 0,319 | 0,609 | 0,482 | 0,006 | 0,646 | 0,037 |
| **Xersonskaya variety** | | | | | | | |
| 0,122 | 0,116 | 0,185 | 0,561 | 0,231 | 0,003 | 0,323 | 0,022 |

A comparative analysis of the microelement contents in the seeds of the studied castor bean (*Ricinus communis* L.) varieties revealed that the Impala variety showed a clear superiority in terms of total microelement accumulation. The lowest concentrations were generally observed in the control variety, Khersonskaya-10. The Zanzibarskaya variety was distinguished by relatively higher contents of iron and chromium compared with the other varieties examined, whereas cobalt was found to be present at nearly the same level in all three experimental varieties. Based on the results obtained, it can be concluded that the observed varietal differences are associated with the genetic characteristics and geographical origin of the varieties, as well as with the soil and climatic conditions and agromeliorative practices applied during castor bean cultivation. In addition, the oil-related characteristics of the Zanzibarskaya, Gibsona, Impala, and control (Khersonskaya-10) varieties were comparatively evaluated, including oil content, oil yield, and acid value. The

experiments were conducted at the Applied Research Laboratory of the Institute of Bioorganic Chemistry of the Academy of Sciences of the Republic of Uzbekistan.

The seeds of the Zanzibarskaya variety contained 44.7% oil, with an oil yield of 53.3 kg/ha. In the Gibsona variety, these values were 45.5% and 55.1 kg/ha, respectively. The Impala variety exhibited the highest oil characteristics, with an average oil content of 46.3% and an oil yield of 56.4 kg/ha. In contrast, the control variety, Khersonskaya-10, showed the lowest values, with an oil content of 43.8% and an oil yield of 51.8 kg/ha (Figure 1, Appendix 1).

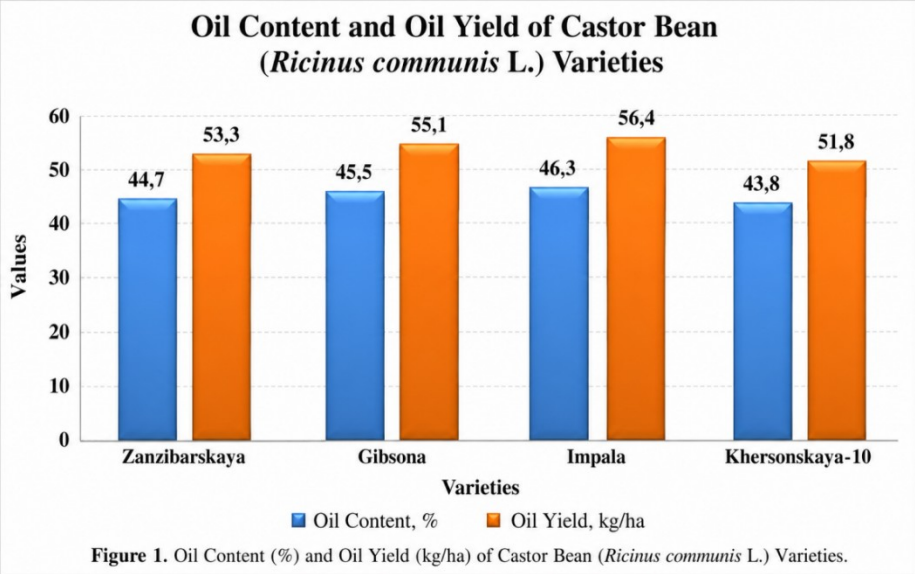



**Figure 1.** Oil Content (%) and Oil Yield (kg/ha) of Castor Bean (*Ricinus communis* L.) Varieties.

***Figure 1. Oil Content of Castor Bean (Ricinus communis L.) Varieties***

The results of our long-term experiments demonstrated that the acid value of oil extracted from castor bean (*Ricinus communis* L.) seeds was generally consistent with the standards specified in the National Pharmacopoeia of Uzbekistan, ranging from 0.79 to 1.85 mg KOH/g. According to pharmacopoeial requirements, the acid value should not exceed 0.65–1.50 mg KOH/g, as this parameter serves as an important indicator of oil quality and ensures the suitability of products intended for medical and cosmetic applications. The obtained results indicate that the seed oils of certain castor bean varieties can be classified as high-quality oils with favorable physicochemical characteristics (Figure 2).

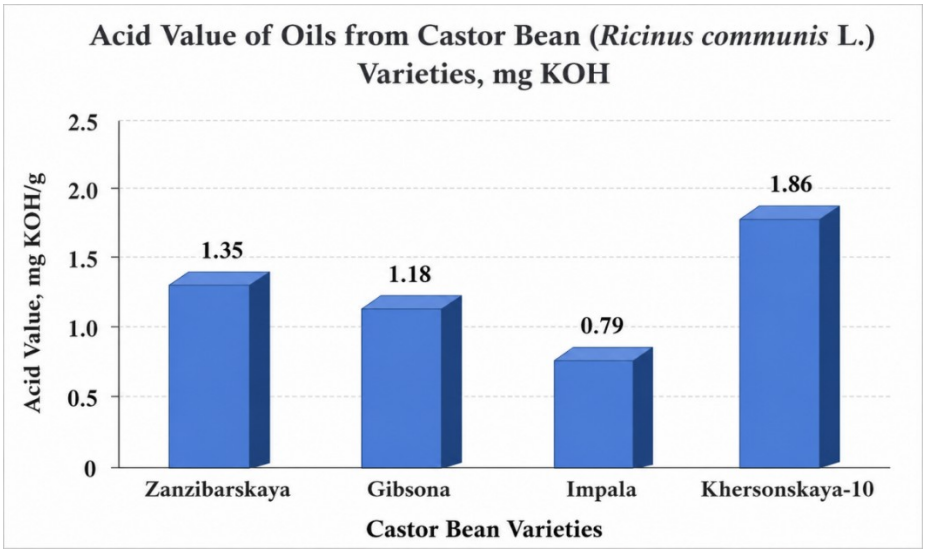



***Figure 2. Comparative Analysis of the Acid Value of Oils from Different Castor Bean (Ricinus communis L.) Varieties (mg KOH/g)***

***Appendix 1.***

***Comparative Oil Content (%) and Oil Yield (kg/ha) of Castor Bean (*Ricinus communis *L.) Varieties, Average Data for 2026***

| Navlar | M±m | V | L | S |
|---|---|---|---|---|
| **Oil Content, %** | | | | |
| Zanzibarskaya | 44,7±0,28 | 0,51 | 41,3-45,8 | 0,32 |
| Gibsona | 45,5±0,03 | 0,40 | 25,1-25,4 | 0,10 |
| Impala | 46,3±0,03 | 0,48 | 22,0-22,3 | 0,10 |
| Khersonskaya-10 | 43,8±0,03 | 0,48 | 22,0-22,3 | 0,10 |
| **Oil Yield, kg/ha** | | | | |
| Zanzibarskaya | 53,3±0,03 | 0,04 | 265,8-266,1 | 0,10 |
| Gibsona | 55,1±0,05 | 0,05 | 312,8-313,4 | 0,17 |
| Impala | 56,4±0,06 | 0,07 | 267,6-268,2 | 0,19 |
| Khersonskaya-10 | 51,8±0,06 | 0,07 | 267,6-268,2 | 0,19 |
| **Acid Value, mg KOH/g** | | | | |
| Zanzibarskay | 1,35±0,03 | 0,50 | 0,31-0,32 | 0,01 |
| Gibsona | 1,18±0,05 | 0,23 | 0,26-0,27 | 0,06 |
| Impala | 0,79±0,06 | 0,18 | 0,29-0,30 | 0,06 |
| Khersonskaya-10 | 1,86±0,06 | 0,18 | 0,29-0,30 | 0,06 |

***V – Coefficient of Variation (%);*L – Range (Minimum–Maximum); *S – Standard Deviation**

Based on the experimental results, significant varietal differences were observed in the oil-related characteristics of castor bean (***Ricinus communis*** L.) seeds. The highest oil content and oil yield were recorded in the Impala and Gibsona varieties, reaching 46.3% and 56.4 kg/ha, and 45.5% and 55.1 kg/ha, respectively. The lowest values for both parameters were observed in the control variety, Khersonskaya-10, with an oil content of 43.8% and an oil yield of 51.8 kg/ha. The Zanzibarskaya variety occupied an intermediate position, with corresponding values of 44.7% and 53.3 kg/ha. Furthermore, a comparative investigation of essential and non-essential amino acids was conducted in the seeds of the Zanzibarskaya, Gibsona, Impala, and Khersonskaya-10 varieties. Laboratory analyses revealed the presence of a total of 20 amino acids in castor bean seeds, including 10 essential and 10 non-essential amino acids, indicating that the seeds are a rich source of biologically active compounds. According to the results obtained for essential amino acids, the seeds of the Zanzibarskaya variety contained threonine – 0.60 mg/g, arginine – 0.12 mg/g, valine – 0.76 mg/g, methionine – 0.34 mg/g, histidine – 3.27 mg/g, isoleucine – 1.00 mg/g, leucine – 1.49 mg/g, tryptophan – 4.04 mg/g, phenylalanine – 0.58 mg/g, and lysine – 0.10 mg/g, with a total essential amino acid content of 12.3 mg/g. In the Gibsona variety, the corresponding values were threonine – 2.28 mg/g, arginine – 0.30 mg/g, valine – 1.01 mg/g, methionine – 0.58 mg/g, histidine – 3.48 mg/g, isoleucine – 1.07 mg/g, leucine – 1.73 mg/g, tryptophan – 4.70 mg/g, phenylalanine – 1.11 mg/g, and lysine – 0.14 mg/g, with a total essential amino acid content of 16.4 mg/g.

The Impala variety exhibited the highest concentration of essential amino acids, containing threonine – 5.47 mg/g, arginine – 0.63 mg/g, valine – 1.20 mg/g, methionine – 0.70 mg/g, histidine – 6.96 mg/g, isoleucine – 1.07 mg/g, leucine – 1.91 mg/g, tryptophan – 5.50 mg/g, phenylalanine – 1.33 mg/g, and lysine – 0.20 mg/g, with a total content of 25.0 mg/g. In contrast, the control variety, Khersonskaya-10, contained considerably lower amounts of essential amino acids:

threonine – 0.16 mg/g, arginine – 0.06 mg/g, valine – 0.43 mg/g, methionine – 0.30 mg/g, histidine – 1.40 mg/g, isoleucine – 0.66 mg/g, leucine – 1.02 mg/g, tryptophan – 1.36 mg/g, phenylalanine – 0.27 mg/g, and lysine – 0.09 mg/g, with a total essential amino acid content of only 5.75 mg/g (Figure 3).

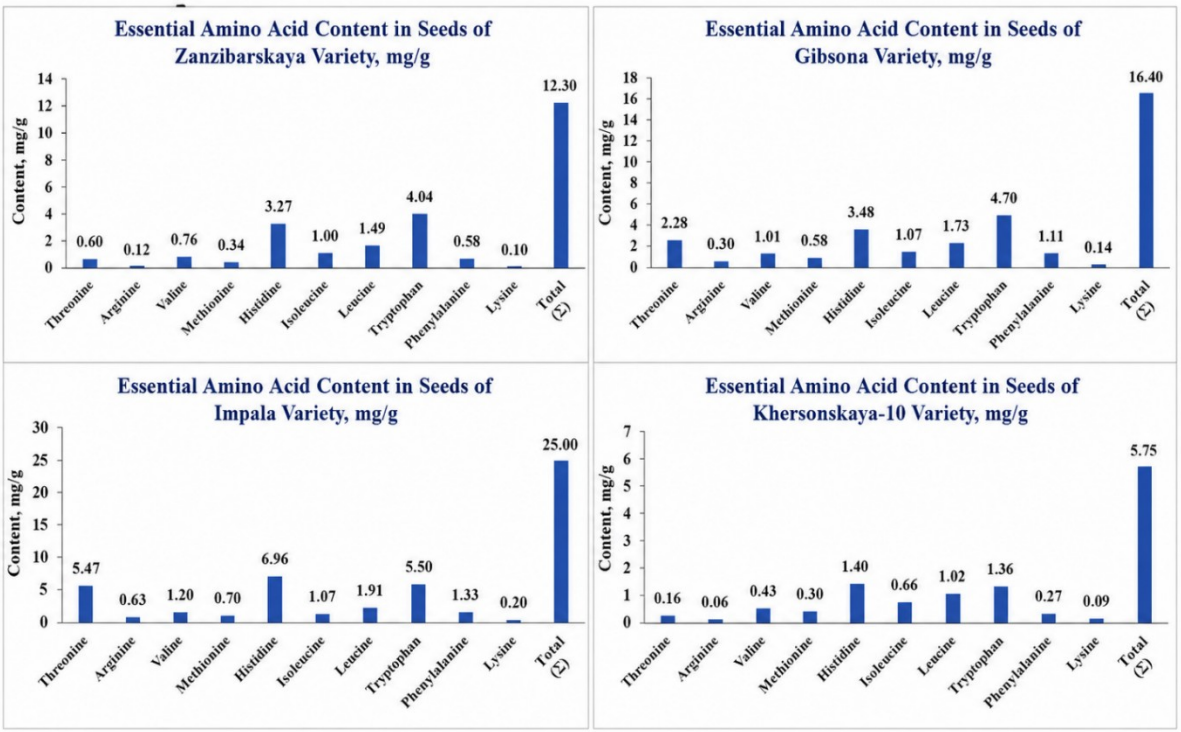



***Figure 3. Comparative Analysis of Essential Amino Acid Contents in Seeds of Different Castor Bean (Ricinus communis L.) Varieties (mg/g)***

***Appendix 2.***

***Comparative Essential Amino Acid Composition of Seeds of Different Castor Bean (Ricinus communis L.) Varieties (mg/g)***

| Amino Acid Name | Zanzibarskaya, mg/g | Gibsona, mg/g | Impala, mg/g | Khersonskaya-10, mg/g |
|---|---|---|---|---|
| Threonine | 0,60 | 2,28 | 5,47 | 0,16 |
| Arginine | 0,12 | 0,30 | 0,63 | 0,06 |
| Valine | 0,76 | 1,01 | 1,20 | 0,43 |
| Methionine | 0,34 | 0,58 | 0,70 | 0,30 |
| Histidine | 3,27 | 3,48 | 6,96 | 1,40 |
| Isoleucine | 1,00 | 1,07 | 1,07 | 0,66 |
| Leucine | 1,49 | 1,73 | 1,91 | 1,02 |
| Tryptophan | 4,04 | 4,70 | 5,50 | 1,36 |
| Phenylalanine | 0,58 | 1,11 | 1,33 | 0,27 |
| Lysine | 0,10 | 0,14 | 0,20 | 0,09 |
| **Total (Σ)** | **12,3** | **16,4** | **25,0** | **5,75** |

According to the laboratory analyses, the highest concentrations of all essential amino acids were generally recorded in the Impala variety. The only exception was isoleucine, whose content in the Impala variety was identical to that of the Gibsona variety, reaching 1.07 mg/g.

Among the essential amino acids, the highest concentration of threonine was observed in the Impala variety (5.47 mg/g). This value was approximately two times higher than that of the

Gibsona variety (2.28 mg/g) and substantially greater than that of the Zanzibarskaya variety (0.60 mg/g). The lowest threonine content was recorded in the control variety, Khersonskaya-10 (0.16 mg/g). The highest levels of arginine and valine were also detected in the Impala variety, reaching 0.63 mg/g and 1.20 mg/g, respectively. In contrast, the lowest values were found in the Khersonskaya-10 variety, amounting to 0.06 mg/g and 0.43 mg/g, respectively.

Similarly, the highest concentrations of methionine, histidine, and leucine were observed in the Impala variety, with values of 0.70 mg/g, 6.96 mg/g, and 1.91 mg/g, respectively. The lowest concentrations of these amino acids were recorded in the Khersonskaya-10 variety (0.30 mg/g, 1.40 mg/g, and 1.02 mg/g, respectively), while relatively low values were also observed in the Zanzibarskaya variety (0.34 mg/g, 3.27 mg/g, and 1.49 mg/g, respectively). In the case of isoleucine, both the Impala and Gibsona varieties exhibited the same value of 1.07 mg/g, whereas the Zanzibarskaya variety showed a comparable concentration of 1.00 mg/g.

The Impala variety also demonstrated the highest levels of tryptophan, phenylalanine, and lysine, reaching 5.50 mg/g, 1.33 mg/g, and 0.20 mg/g, respectively. The Gibsona variety occupied an intermediate position, with corresponding values of 4.70 mg/g, 1.11 mg/g, and 0.14 mg/g. Lower tryptophan concentrations were observed in the Zanzibarskaya variety compared with the Impala and Gibsona varieties. Regarding lysine content, the Zanzibarskaya variety exhibited a value comparable to that of the control variety, Khersonskaya-10, amounting to 0.10 mg/g and 0.09 mg/g, respectively.

Overall, the Impala variety showed a pronounced superiority over the other varieties in terms of essential amino acid content. In particular, the concentrations of threonine, arginine, histidine, and tryptophan were several-fold higher than those recorded in the control variety, Khersonskaya-10. When compared with the Gibsona variety, however, the differences were less pronounced, indicating a relatively similar nutritional profile between these two varieties.

Based on the obtained results, it can be concluded that the Impala and Gibsona varieties possess the highest concentrations of essential amino acids and therefore exhibit superior nutritional value among the studied castor bean varieties. Considering these findings, the contents of non-essential amino acids in castor bean seeds were also investigated.

The results revealed significant varietal differences in the concentrations of non-essential amino acids. Among the studied varieties, the highest total content of non-essential amino acids was recorded in the Impala variety, reaching 21.6 mg/g. The Gibsona and Khersonskaya-10 varieties exhibited relatively similar values, amounting to 14.5 mg/g and 14.1 mg/g, respectively. The lowest total content was observed in the Zanzibarskaya variety, with a value of 10.3 mg/g (Appendix 3). The highest concentration of aspartic acid was also found in the Impala variety, reaching 5.29 mg/g. The corresponding values for the Gibsona, Zanzibarskaya, and Khersonskaya-10 varieties were 3.20 mg/g, 2.76 mg/g, and 1.61 mg/g, respectively.

***Appendix 3.***

***Comparative Non-Essential Amino Acid Composition of Seeds of Different Castor Bean (Ricinus communis L.) Varieties (mg/g)***

| Amino Acid Name | Castor Bean Varieties | | | |
|---|---|---|---|---|
| | Zanzibarskaya, mg/g | Gibsona, mg/g | Impala, mg/g | Khersonskaya-10, mg/g |
| Aspartic Acid | 2,76 | 3,20 | 5,29 | 1,61 |
| Glutamic Acid | 0,60 | 1,15 | 2,34 | 9,48 |

| | | | | |
|---|---|---|---|---|
| Serine | 1,22 | 2,07 | 3,23 | 0,28 |
| Glycine | 1,27 | 1,47 | 1,85 | 0,40 |
| Asparagine | 1,25 | 1,48 | 1,87 | 0,42 |
| Glutamine | 0,53 | 0,55 | 0,60 | 0,32 |
| Cysteine | 0,12 | 0,42 | 0,52 | 0,03 |
| Alanine | 0,96 | 2,43 | 2,65 | 0,68 |
| Proline | 1,00 | 1,20 | 2,25 | 0,54 |
| Tyrosine | 0,61 | 0,51 | 0,97 | 0,33 |
| Total (Σ) | 10,3 | 14,5 | 21,6 | 14,1 |

The control variety, Khersonskaya-10, exhibited a pronounced superiority over the other varieties in terms of glutamic acid content. The concentration of glutamic acid reached 9.48 mg/g, accounting for more than 67% of the total non-essential amino acid content. In contrast, the concentrations of glutamic acid in the Impala, Gibsona, and Zanzibarskaya varieties were considerably lower, amounting to 2.34 mg/g, 1.15 mg/g, and 0.60 mg/g, respectively.

Significant varietal differences were also observed in the content of serine. The highest concentration was recorded in the Impala variety (3.23 mg/g), followed by the Gibsona variety (2.07 mg/g) and the Zanzibarskaya variety (1.22 mg/g). The lowest serine content was found in the control variety, Khersonskaya-10, where it amounted to 0.28 mg/g.

The concentrations of glycine and asparagine varied considerably among the studied varieties. Glycine content ranged from 0.40 to 1.85 mg/g, while asparagine content ranged from 0.42 to 1.87 mg/g. The highest concentrations of both amino acids were observed in the Impala variety (1.85 mg/g and 1.87 mg/g, respectively). The lowest concentrations were recorded in the control variety, Khersonskaya-10, with values of 0.40 mg/g and 0.42 mg/g, respectively. The Gibsona (1.47 mg/g and 1.48 mg/g) and Zanzibarskaya (1.27 mg/g and 1.25 mg/g) varieties occupied intermediate positions.

The concentration of glutamine did not differ substantially among the varieties. The highest value was observed in the Impala variety (0.60 mg/g), which was comparable to those recorded in the Gibsona (0.55 mg/g) and Zanzibarskaya (0.53 mg/g) varieties. In the Khersonskaya-10 variety, the glutamine content was 0.32 mg/g.

Particular attention was drawn to the accumulation patterns of sulfur-containing and related amino acids, namely cysteine, proline, and tyrosine. Among these, cysteine was present in the lowest concentrations in all varieties. Nevertheless, its content in the Impala (0.52 mg/g) and Gibsona (0.42 mg/g) varieties was substantially higher than in the control variety (0.03 mg/g) and several times greater than that observed in the Zanzibarskaya variety (0.12 mg/g).

A similar trend was observed for proline and tyrosine. The Impala variety once again demonstrated superior biosynthetic performance, accumulating 2.25 mg/g of proline and 0.97 mg/g of tyrosine. In contrast, the lowest concentrations of these amino acids were recorded in the Khersonskaya-10 variety, amounting to 0.54 mg/g and 0.33 mg/g, respectively.

The concentration of alanine ranged from 0.68 to 2.65 mg/g among the studied varieties. The highest value was recorded in the Impala variety (2.65 mg/g), followed closely by the Gibsona variety (2.43 mg/g). The Zanzibarskaya variety contained 0.96 mg/g, whereas the control variety, Khersonskaya-10, contained 0.68 mg/g of alanine.

Overall, the results demonstrated that the Impala variety possessed the highest concentrations of most non-essential amino acids, indicating a rich amino acid composition and

superior nutritional quality. The Gibsona variety occupied an intermediate position for most parameters, while the Zanzibarskaya variety was characterized by relatively balanced amino acid levels. Although the control variety, Khersonskaya-10, exhibited lower concentrations of most amino acids, it was distinguished by its exceptionally high glutamic acid content compared with the other varieties investigated.

**Conclusion.** The results of the present study demonstrated that the Impala variety of castor bean (*Ricinus communis* L.) exhibited a clear superiority in terms of macroelement accumulation. In contrast, the lowest concentrations of most macroelements were recorded in the Khersonskaya-10 variety, with the exception of calcium. However, the Gibsona variety was characterized by relatively higher contents of sodium and sulfur, while the Zanzibarskaya variety contained a comparatively greater amount of boron than the other varieties investigated.

A comparative analysis of microelement composition revealed that the Impala variety also possessed the highest concentrations of most microelements. The lowest values were generally observed in the control variety, Khersonskaya-10. The Zanzibarskaya variety was distinguished by relatively high concentrations of iron and chromium, whereas cobalt was present at similar levels among the studied varieties.

The highest oil content and oil yield were recorded in the Impala and Gibsona varieties, reaching 46.3% and 56.4 kg/ha, and 45.5% and 55.1 kg/ha, respectively. The lowest values were observed in the control variety, Khersonskaya-10 (43.8% and 51.8 kg/ha). The Zanzibarskaya variety occupied an intermediate position, with an oil content of 44.7% and an oil yield of 53.3 kg/ha.

The acid value of oils extracted from castor bean seeds ranged from 0.79 to 1.85 mg KOH/g, which generally corresponded to the requirements established by the National Pharmacopoeia of Uzbekistan and confirmed the satisfactory quality of the obtained oils.

Laboratory analyses further demonstrated that the Impala variety possessed significantly higher concentrations of essential amino acids compared with the other varieties. In particular, the contents of threonine, arginine, histidine, and tryptophan were several times higher than those recorded in the control variety, Khersonskaya-10.

Similarly, the Impala variety exhibited the highest levels of most non-essential amino acids, indicating its superior nutritional and biochemical value. The Gibsona variety generally occupied an intermediate position, while the Zanzibarskaya variety was characterized by relatively balanced amino acid contents. Although the Khersonskaya-10 variety showed lower concentrations of most amino acids, it was distinguished by its markedly higher glutamic acid content compared with the other varieties studied.

Overall, the results indicate that the Impala and Gibsona varieties are the most promising castor bean varieties for cultivation under the soil and climatic conditions of the Khorezm region due to their favorable mineral composition, high oil content, and rich amino acid profile.

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