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СРАВНИТЕЛЬНАЯ ОЦЕНКА СОДЕРЖАНИЯ ОБЩЕГО БЕЛКА В СЕМЕНАХ СОРТОВ КИНОА (*Chenopodium quinoa* Willd.), ВЫРАЩЕННЫХ В ХОРЕЗМСКОЙ ОБЛАСТИ

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COMPARATIVE ASSESSMENT OF TOTAL PROTEIN CONTENT IN SEEDS OF QUINOA (*Chenopodium quinoa* Willd.) VARIETIES GROWN IN THE KHOREZM REGION

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Abstract. Quinoa (*Chenopodium quinoa* Willd.) is a pseudocereal crop valued for its nutritional composition, particularly its relatively high protein content. The present study aimed to compare the total protein content in seeds of five quinoa varieties grown under the agroecological conditions of the Khorezm Region. Seeds of the Check-2, New-14, New-36, New-42, and New-170 varieties were used as the study material. Total nitrogen content was determined by the Kjeldahl method, including sample mineralization, distillation, and subsequent titrimetric determination. The total protein content was calculated from the obtained nitrogen values using a conversion factor of 6.25. Each sample was analyzed at least in triplicate, and the mean values were calculated. The results showed differences in protein accumulation among the studied varieties. Nitrogen content ranged from 1.967 to 2.457%, while total protein content varied from 12.29 to 15.36%. The highest protein content was recorded in the seeds of New-170, followed by New-14, whereas the lowest value was found in Check-2. New-36 showed an intermediate protein level, while New-42 was characterized by a comparatively lower value. The observed variation indicates differences among quinoa varieties in seed protein accumulation under the growing conditions of the Khorezm Region. The obtained results can be used for comparative assessment of the nutritional value of quinoa varieties and for identifying high-protein genotypes suitable for further cultivation and selection under local agroecological conditions.

Аннотация. Киноа (*Chenopodium quinoa* Willd.) — псевдозлаковая культура, ценимая за свой питательный состав, особенно за относительно высокое содержание белка. Целью настоящего исследования было сравнение общего содержания белка в семенах пяти сортов киноа, выращенных в агроэкологических условиях Хорезмской области. В качестве материала для исследования использовались семена сортов Check-2, New-14, New-36, New-42 и New-170. Общее содержание азота определяли методом Кьельдаля, включающим минерализацию образца, дистилляцию и последующее титриметрическое определение. Общее содержание белка рассчитывали из полученных значений азота с использованием коэффициента пересчета 6,25. Каждый образец анализировали не менее чем в трех повторениях, и рассчитывали средние значения. Результаты показали различия в накоплении белка среди изученных сортов. Содержание азота варьировалось от 1,967 до 2,457%, а общее содержание белка — от 12,29 до

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15,36%. Наибольшее содержание белка было зафиксировано в семенах сорта New-170, за которым следует New-14, тогда как наименьшее значение было обнаружено в контрольном образце Check-2. В сорте New-36 наблюдался промежуточный уровень белка, а для сорта New-42 он был сравнительно ниже. Наблюдаемая вариация указывает на различия между сортами киноа в накоплении белка в семенах в условиях выращивания в Хорезмской области. Полученные результаты могут быть использованы для сравнительной оценки питательной ценности сортов киноа и для выявления высокобелковых генотипов, пригодных для дальнейшего выращивания и селекции в местных агроэкологических условиях.

Keywords: quinoa, *Chenopodium quinoa* Willd., seeds, total protein, nitrogen content, Kjeldahl method, Khorezm Region.

Ключевые слова: киноа, *Chenopodium quinoa* Willd., семена, общий белок, содержание азота, метод Кьельдаля, Хорезмская область.

Pseudocereal crops such as amaranth, buckwheat, and quinoa have attracted increasing attention as nutrient-dense raw materials for food production. Their seeds contain substantial amounts of starch, proteins, dietary fibre, minerals, vitamins, and other bioactive compounds. In particular, pseudocereal proteins are valued for their favourable amino acid composition and relatively high proportions of essential amino acids [7].

Growing demand for sustainable and nutritionally balanced protein sources has increased interest in plant-based alternatives. Quinoa (*Chenopodium quinoa* Willd.) is considered a promising crop in this context because of its relatively high protein and mineral contents, balanced amino acid profile, and gluten-free characteristics [2].

Its nutritional properties, together with its adaptability to different environmental conditions, have contributed to growing interest in quinoa as a crop with potential importance for food and nutritional security [10, 11].

Quinoa protein is characterized by a diverse composition of storage proteins. Mature quinoa seeds contain 11S-type globulin, commonly referred to as chenopodin, which accounts for approximately 37% of the total seed protein, while 2S albumins constitute about 35%. Prolamins occur at considerably lower concentrations, generally representing approximately 0.5–7% of the total protein fraction [3].

Quinoa also contains all nine essential amino acids, including phenylalanine, methionine, histidine, isoleucine, valine, leucine, lysine, threonine, and tryptophan. Its low content of prolamin-type fractions associated with gluten is another important nutritional characteristic [5].

The total protein content of quinoa seeds varies considerably depending on genotype and growing conditions. Published values generally fall within a broad range of approximately 12–23% [1].

Other studies have reported narrower ranges, commonly around 13.8–16.5%, indicating that varietal characteristics and environmental conditions can substantially influence protein accumulation in quinoa seeds [12].

Compared with several conventional cereals, quinoa generally contains a higher proportion of protein, although its protein concentration remains lower than that of many leguminous and oilseed crops [1, 13].

Considerable variation has also been reported among individual quinoa varieties. In Serbia, seeds of the Puno and Titicaca cultivars contained 14.1% and 14.0% protein, respectively, when analysed using the Kjeldahl method [14].

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Pochitskaya reported protein contents of 14.2%, 17.3%, and 16.1% in white, red, and black quinoa samples, respectively. Analysis of several quinoa varieties using near-infrared spectroscopy also revealed substantial variability: protein content reached 18.39% in the American variety, 17.16% in Egyptian, 16.27% in Rainbow, and 12.83% in Black quinoa [4, 12].

These findings demonstrate that seed protein concentration is strongly genotype-dependent.

Studies conducted under arid and saline conditions are particularly relevant to the cultivation of quinoa in Central Asia. In the marginal environments of the Aral Sea basin, protein contents of different quinoa genotypes ranged from approximately 10.85% to 15.43%, with considerable differences among the evaluated accessions [9].

Similarly, Yuldasheva et al. reported variation in seed protein content among six quinoa genotypes grown under the conditions of Tashkent and Chimbay [14].

In Tashkent, the protein content ranged from 10.85% to 15.43%, whereas under Chimbay conditions it varied from 10.4% to 14.9%. These results indicate that both genotype and growing environment may influence protein accumulation in quinoa seeds. Despite the available information on the nutritional composition of quinoa cultivated in different regions, comparative data on the protein content of quinoa varieties grown under the specific agroecological conditions of the Khorezm Region remain limited. Evaluation of locally cultivated genotypes is therefore necessary to identify varieties with comparatively high seed protein content and to assess their nutritional potential under regional conditions.

Accordingly, the aim of this study was to determine and comparatively assess the total protein content in seeds of five quinoa varieties — Check-2, New-14, New-36, New-42, and New-170 — grown under the agroecological conditions of the Khorezm Region using the Kjeldahl method.

Materials and Methods

Seeds of five quinoa (*Chenopodium quinoa* Willd.) varieties — Check-2, New-14, New-36, New-42, and New-170 — grown under the agroecological conditions of the Khorezm Region were used as the experimental material. Mature and visually intact seeds were selected, dried, and ground to a fine homogeneous powder prior to chemical analysis. Total nitrogen content was determined using the Kjeldahl method in accordance with the general procedure described in GOST 13496.4-2019 [8].

The prepared seed samples were subjected to acid digestion with concentrated sulfuric acid (H_2SO_4) to convert organically bound nitrogen into ammonium compounds. After completion of digestion, the samples were cooled and diluted with distilled water. Sodium hydroxide (NaOH) solution was then added to create an alkaline medium and release ammonia.

The liberated ammonia was separated by distillation and absorbed in a 4% boric acid (H_3BO_3) solution. The resulting solution was titrated with 0.1 N hydrochloric acid (HCl) using a mixed methyl red–bromocresol green indicator to determine the titration endpoint.

The nitrogen content was calculated from the volume of hydrochloric acid consumed during titration, taking into account the corresponding blank value. Total protein content was subsequently calculated from the nitrogen content using a conversion factor of 6.25:

$$\text{Proteincontent}(\%)=\frac{(V_1\text{-}V_0)\times N\times 14.01\times 6.25}{m}\times 100$$

where V1 is the volume of HCl used for titration of the sample (mL), V0 is the volume of HCl used for the blank determination (mL), NN is the normality of the HCl solution, 14.01 is the atomic mass of nitrogen, and mm is the mass of the sample (g).

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Each sample was analysed at least three times, and the results were expressed as mean values. Total nitrogen and total protein contents were reported as percentages.

Results and Discussion

The analysis revealed clear differences in total protein content among the studied quinoa varieties. Total nitrogen content ranged from 1.967 to 2.457%, corresponding to total protein values of 12.29–15.36%. The results for the five varieties are presented in Figure.

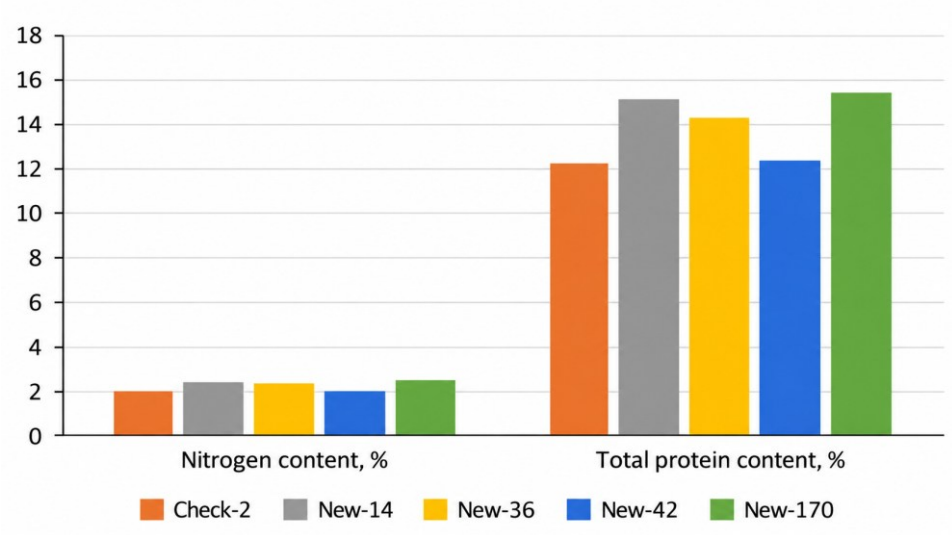


Figure. Nitrogen and total protein contents in quinoa varieties, %

Among the investigated varieties, New-170 had the highest total protein content, followed by New-14. These two varieties therefore showed the greatest potential in terms of seed protein concentration under the agroecological conditions of the Khorezm Region. New-36 showed an intermediate protein level, whereas comparatively lower values were recorded for New-42 and Check-2. The lowest protein content was observed in Check-2.

The difference between the maximum and minimum protein contents was 3.07 percentage points, indicating appreciable varietal variability within the studied material. Since total protein was calculated from the measured nitrogen content using a conversion factor of 6.25, the observed proportional relationship between nitrogen and protein values is inherent to the Kjeldahl calculation procedure rather than an independent biological correlation.

The obtained protein range is generally consistent with values reported for quinoa in previous studies. Savic et al. [10] reported protein contents of 14.1% and 14.0% for the Puno and Titicaca varieties, respectively. Pochitskaya [12] found values ranging from 14.2% to 17.3% depending on quinoa type, while other varietal assessments reported a broader range of approximately 12.83–18.39% [4].

Under the marginal conditions of the Aral Sea basin, protein concentrations of different quinoa genotypes ranged from about 10.85% to 15.43% [7]. Similarly, Yuldasheva et al. [14] observed substantial variation among quinoa genotypes cultivated under the conditions of Tashkent and Chimbay.

The present results therefore fall within the range previously reported for quinoa, while also demonstrating differences among the varieties cultivated in Khorezm. The relatively high protein content observed in New-170 and New-14 suggests that these varieties may be of particular interest for further evaluation as high-protein quinoa genotypes. However, protein concentration alone does

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not provide a complete assessment of nutritional quality; additional characteristics such as amino acid composition, mineral content, and other seed-quality parameters should be considered in further studies.

Conclusion

The study demonstrated clear varietal differences in the protein content of quinoa seeds grown under the agroecological conditions of the Khorezm Region. Total nitrogen content ranged from 1.967 to 2.457%, corresponding to total protein values of 12.29–15.36%. The highest protein content was recorded in New-170, followed by New-14, whereas the lowest value was observed in Check-2. The difference between the maximum and minimum protein contents was 3.07 percentage points. These results indicate that varietal characteristics may play an important role in protein accumulation under local growing conditions. Among the studied materials, New-170 and New-14 showed the highest seed protein concentrations and may therefore be considered promising genotypes for further cultivation and selection aimed at improving the protein value of quinoa. Further studies including amino acid composition and other nutritional quality parameters would allow a more comprehensive assessment of these varieties.

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