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# Physicochemical Properties and Elemental Composition of Various Kurdish Rice (*Oryza sativa* L.) Landraces in Iraqi Kurdistan

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## Abstract

Rice is a staple food crop that provides a primary source of energy and essential nutrients worldwide. This study aimed to assess the physicochemical characteristics and seven elemental compositions of fourteen locally cultivated rice varieties. Fourteen rice samples were collected from various locations throughout Iraqi Kurdistan. Physiochemical properties, such as grain size and shape, thousand-grain weight (TGW), percentage of chalky rice grain, bulk density, moisture content, ash content, gel consistency, and amylose content were quantified according to established protocols. The elemental composition (Al, Ba, Ca, K, Mg, Na, Se) was analysed using inductively coupled plasma mass spectrometry (ICP-OES). The findings demonstrated significant variability among rice samples, with grain sizes varying from medium to short and shapes primarily categorised as bold or medium. Thousand grain weight (TGW) showed significant variation, with Shex Tawil and Kani Krmanj reaching the highest values. The gel consistency (41–54%) and amylose content (16.2–19.1%) revealed variations in cooking quality, with Akre Tahalwf demonstrating the softest texture and Shex Tawil the firmest. Calcium concentrations fluctuated between 333.5 and 535.6 mg/kg, magnesium ranged from 319.2 to 660.8 mg/kg, and potassium varied from 500.8 to 1148.4 mg/kg, indicating significant variations among locations. Sodium levels were comparatively low across samples, with Batas (115.8 mg/kg) exhibiting the highest concentration, while selenium levels were generally minimal, with Bazian presenting the highest value (0.319 mg/kg). Barium concentrations, while lower, demonstrated considerable variation among samples. Comparisons with contemporary literature reveal that the elemental concentrations of Kurdish rice align generally with global findings, although certain landraces displayed increased levels of potassium and calcium, indicating enhanced nutritional potential. In conclusion, the studied Kurdish rice grown in Iraqi Kurdistan revealed significant diversity in grain morphology and elemental composition, highlighting their value as a local genetic resource for nutrition, breeding, and enhancement of food security.

***Keywords: Rice, Physicochemical properties, Elemental composition, Rice grain quality***

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# I. INTRODUCTION

Rice (*Oryza sativa* L.) is an essential staple food worldwide, nourishing more than half of the global population. The rising demand requires enhanced research aimed at improving the quality and nutritional value of rice to ensure global food security (Kshash & Oda, 2024). The food quality of rice is a complex attribute, influenced by both its physicochemical properties and its essential mineral profile. Key physicochemical characteristics, such as grain size, shape, amylose content, and gelatinization temperature, directly affect cooking and eating quality, which are crucial aspects of food quality (Gao et al., 2024). Simultaneously, the presence of essential elements determines its nutritional value, a fundamental component of quality and a factor with direct implications for human health.

The Kurdistan region of Iraq possesses a rich agricultural heritage, with indigenous rice cultivars forming an integral part of the local economy and culture (Mustafa, 2023). These traditional landraces have adapted to specific local environmental conditions, potentially developing unique properties that contribute to their regional food quality. Despite their cultural and economic importance, a comprehensive scientific analysis of the food quality characteristics and nutritional composition of these specific Kurdish rice grains is currently lacking. A detailed understanding of these properties is therefore essential for both promoting the cultivation of superior local varieties and ensuring their long-term sustainability as a high-quality food source (Qadir, 2023). Existing scientific literature on rice often overlooks the unique varieties cultivated in the Kurdistan region, creating a significant knowledge gap. There is an urgent need for a detailed scientific assessment that specifically examines the physicochemical properties and essential element profiles of these local rice cultivars to determine their overall food quality (Liang et al., 2024). Addressing this gap will provide valuable, currently undocumented information about their potential as a high-quality, nutritious food source.

This study's primary objective is to comprehensively assess the food quality parameters of several Kurdish grown rice grains. The investigation will focus on physicochemical properties, including grain morphology (the size and shape of the grains), amylose content and gel consistency, which is a major determinant of cooking and eating quality, as well as, the mineral content in rice, specifically, Calcium (Ca), Potassium (K), Magnesium (Mg), Sodium (Na), and Selenium (Se) are vital for the proper functioning of the human body. Deficiencies can lead to health issues, while excessive intake may also be harmful; the presence of Aluminum (Al) and Barium (Ba) typically relates to food safety and toxicological concerns (WHO, 1996). The generated data will provide a scientific basis for evaluating the quality of these grown rice grains and for developing strategies to better integrate high-quality local rice into food systems.

The findings of this research are expected to be highly valuable to various stakeholders. For farmers and agricultural scientists, the results will facilitate the selection and promotion of cultivars with superior food quality attributes. For consumers and nutritionists, the detailed data on elemental compositions will provide clear information on the nutritional benefits and overall food quality of these specific rice varieties (Ilia, et al., 2023). This research will ultimately contribute to the preservation of local crop biodiversity and support initiatives to improve food security and public health in the Kurdistan region of Iraq.

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## II. MATERIALS AND METHODS

### *Study Area and Sample Collection*

This study was conducted in the Iraqi Kurdistan region, focusing on predominant rice production areas to ensure representative sampling of local cultivars. A total of fourteen Kurdish rice (Oryza sativa) cultivars were collected from these districts: Akre three months (3M), Akre six months (6M), Akre Tahalwf, Bani Khellan, Bansnduq, Baqubara, Batas, Bazian, Belula, Daradoen, Kani Krmanj, Niska Jo, Salah Agha, and Shex Tawil. To ensure reproducibility and traceability of the samples, the exact collection locations were documented using geographical coordinates (latitude and longitude) (Figure 1).


Figure 1. Map of the sampling site of Kurdish-grown rice grain in the Iraqi Kurdistan Region

### *Sample Handling*

Upon collection, all rice samples were immediately placed in individual, sealed plastic bags to prevent contamination. The bags were carefully labeled with the cultivar name and location of origin. The samples were then transported to the laboratory and stored under controlled conditions to preserve their integrity prior to further physicochemical and elemental analysis.

### *Physiochemical Properties*

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***Grain Size and Shape***

The physical properties of rice grains were determined by measuring the length (L), width (W), and thickness (T) of 100 randomly selected grains using an electronic Vernier caliper with a precision of 0.01 mm. The measurements were repeated three times on each grain to obtain a reliable average value for each dimension (Bai et al., 2023). IRRI uses the subsequent scale for size classification: extra-long, >7.50 mm; long, 6.61 to 7.50 mm; medium, 5.51 to 6.60 mm; and short, <5.50 mm. Grain shape is defined by the length-to-width ratio. Slender: >3.0; Medium: 2.1 to 3.0; Bold: 1.1 to 2.0; Round: <1.0.

***Thousand Grain Weight Measurement (TGW)***

The thousand grain weight was determined using a standard gravimetric method. For each replicate, 1,000 randomly selected grains were counted either manually. The weight of these 1,000 grains was then measured to the nearest 0.01 g using a precision digital balance. (Okamura et al., 2023).

***Bulk Density***

The bulk density of rice grains was determined by measuring the mass of a known volume of the sample. A graduated measuring cylinder was filled with the rice grains up to a specific volume. The mass of the rice sample was then measured using a digital balance (Varnamkhasti et al., 2008).

***Percentage of Chalky Rice Grains***

A representative 100 g sample of milled rice was manually sorted on a light table into translucent and chalky categories. Grains with any opaque, white areas were classified as chalky. The chalky grains were weighed, and the chalkiness percentage was calculated as the ratio of their weight to the total sample weight. This procedure was repeated three times, and the average was reported following the Standard Evaluation System (SES) of the International Rice Research Institute (IRRI, 1996).

***Moisture Content Determination***

The initial moisture content of the rice was determined using a standard oven drying method at 105°C for 24 hours (AOAC, 2010).

***Ash Content Determination***

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The total ash content of the rice samples was determined using the dry ashing method according to AOAC Official Method 923.03 (AOAC, 2010).

### *Gel Consistency*

The gel consistency of rice is determined by measuring the length of a cold, alkali-treated rice flour gel. The method involves mixing 100 mg of rice flour with ethanol 95% that contained 0.025 % thymol blue followed by a second mixing of 0.2 N (KOH), heating it in a boiling water bath for 8 minutes to gelatinize the starch, and then cooling it for 15 minutes. The gel length is recorded in millimeters after 30–60 minutes. The length of the resulting gel is measured in millimeters, and the rice is classified as hard (26–40 mm), medium (41–60 mm), or soft (61–100 mm) based on this length (Huang et al., 2022).

### *Amylose Content*

Amylose content was determined using the iodine colorimetric method as described by Huang et al. (2022). A 20 mg starch sample was dissolved in 0.5 N KOH, with a 10 mL aliquot subsequently treated with HCl and iodine. Following overnight color development, the absorbance was measured at 625 nm to quantify the amylose content using UV Visible Spectrophotometer.

### *Sample Preparation and Digestion for Element Analysis by ICP-OES*

The collected rice samples were first finely powdered using a stainless-steel grinder (COF-3820). The resulting flour was then passed through a 355 µm sieve (prufsieb – ISO 3310-1) to reduce the particle size and obtain a fine fraction. The flour was stored at room temperature until analysis.

Prior to digestion, all samples were dried in an oven at 105°C for 2 hours. Approximately 0.5g of each dried sample was weighed directly into a PTFE-TFM vessel. An acid mixture consisting of 8mL of nitric acid ($HNO_3$) and 1mL of hydrogen peroxide ($H_2O_2$) was added to each vessel, and the vessels were immediately sealed. Sample digestion was performed using a microwave digestion system (Multiwave GO Plus – Anton Paar, Austria) with the following heating program: a ramp time of 20 minutes to reach 200°C, followed by a hold time of 20 minutes at 200°C.

After the digestion program was completed, the vessels were cooled to room temperature and vented. They were then filled with deionized water from a Barnstead Gen Pure - Thermofisher system, closed, and vigorously shaken to dislodge any remaining colloids from the vessel walls. The resulting solution was filtered through a Whatman filter paper 41 with a pore size of 20 µm, diluted to a final volume of 25mL with deionized water in a volumetric flask, and stored at 4°C until analysis. This protocol was certified by National Institute of Standards and Technology (NIST, 2021). The concentrations of elements in the digested samples were determined using Inductively Coupled Plasma Optical Emission Spectrometry (a Thermo Scientific iCAP 7600 ICP-OES Duo with Intelligent Scientific Data Solution™ (ISDS)).

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***Statistical analysis***

All the data were conducted in triplicate and analysed by an analysis of variance (one-way ANOVA) using XLSTAT-pro (version 2022.3.1.1320). Duncan's multiple range test was used to determine significant differences between parameters at P≤0.05. The statistical analysis was performed to identify and analyse the differences among the various parameters at the sampled locations for Kurdish rice grains.

## III. Results And Discussion

***Physiochemical Properties***

***Grain size and shape***

The grain lengths of the rice samples varied from 4.307 mm in Salah Agha to 5.843 mm in Akre Tahalwf, with the majority of varieties classified as medium grain size (5.5–6.6 mm) according to the IRRI classification system (IRRI, 2013). Only Salah Agha and Bansnduq were notably shorter (<5.5 mm) with a predominantly bold grain shape (L/W ratio < 2.0) classifying as short grains. The measured length of these shorter varieties aligns with previous research on short-grain rice, which typically occupies a comparable size range (Dou et al., 2024). The grain width ranged from 1.980 mm (Bansnduq) to 2.987 mm (Salah Agha). These differences indicate a synthesis of genetic and environmental factors affecting grain morphology, providing significant insights for agricultural and breeding initiatives (Liu et al., 2021). The thickness varied from 1.820 mm (Bansnduq) to 2.227 mm (Akre 3M). According to the L/W ratio, samples like NiskaJo (2.64) and Bansnduq (2.37) were designated as medium-shaped grains, whereas others, including Shex Tawil (1.64) and Baqubara (1.69), were classified as bold grains (TABLE 1). In comparison to global rice studies, these Kurdish varieties exhibit shorter and bolder grain characteristics than typical long-grain indica types documented in Asia (Feng et al., 2017), yet align with certain medium–short bold japonica-like grains identified in Mediterranean and Middle Eastern landraces (Custodio et al., 2019). The prevalence of medium and short bold grains may indicate adaptation to regional agricultural practices and consumer inclinations for softer-textured rice.

**TABLE (1): LENGTH, WIDTH, THICKNESS, L/W RATIO, AND IRRI CLASSIFICATION FOR RICE GRAIN SIZE AND SHAPE**

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| Rice sample | Length (mm) | Width (mm) | Thickness (mm) | L/W ratio | Grain Shape | Grain size |
|---|---|---|---|---|---|---|
| **Akre 3M** | 5.280 bc | 2.963 ab | 2.227 a | 1.78 | Bold | Short |
| **Akre 6M** | 5.597 ab | 2.767 abc | 1.934 ab | 2.02 | Medium | Medium |
| **Akre Tahalwf** | 5.843 a | 2.767 abc | 1.860 b | 2.11 | Medium | Medium |
| **BaniXellan** | 5.078 cde | 2.963 ab | 1.989 ab | 1.71 | Bold | Short |
| **Bansnduq** | 4.697 f | 1.980 d | 1.820 b | 2.37 | Medium | Short |
| **Baqubara** | 4.936 def | 2.921 ab | 2.083 ab | 1.69 | Bold | Short |
| **Batas** | 5.330 bc | 2.660 c | 2.122 ab | 2 | Medium | Short |
| **Bazian** | 5.157 cd | 2.603 c | 1.933 ab | 1.98 | Bold | Short |
| **Belula** | 5.697 a | 2.938 ab | 2.225 a | 1.94 | Bold | Medium |
| **Daradoen** | 5.553 ab | 2.733 bc | 1.953 ab | 2.03 | Medium | Medium |
| **Kani Krmanj** | 4.757 ef | 2.743 bc | 1.933 ab | 1.73 | Bold | Short |
| **NiskaJo** | 5.520 ab | 2.090 d | 1.990 ab | 2.64 | Medium | Medium |
| **Salah Agha** | 4.307 g | 2.987 a | 1.988 ab | 1.44 | Bold | Short |
| **Shex Tawil** | 4.893 def | 2.986 a | 2.074 ab | 1.64 | Bold | Short |

*Different letters within the column indicate the presence of statistical differences at the level of $\rho \leq 0.05$.

***Thousand grain weight (TGW)***

The thousand rice grain weight data showed that 'Shex Tawil' and 'Kani Krmanj' had the highest weights and 'Belula' and 'Akre 6M' the lowest (Figure 2). This supports a large body of research showing that thousand grain weight is highly heritable, meaning it is mostly determined by the rice variety (Bharali et al., 2024). Other research has shown that high temperatures and other stressors during grain-filling can reduce 1000 grain weight (Zakaria et al., 2002). Our samples' differences possible reflect a combination of genetic potential and the specific environmental conditions under which each sample was grown.

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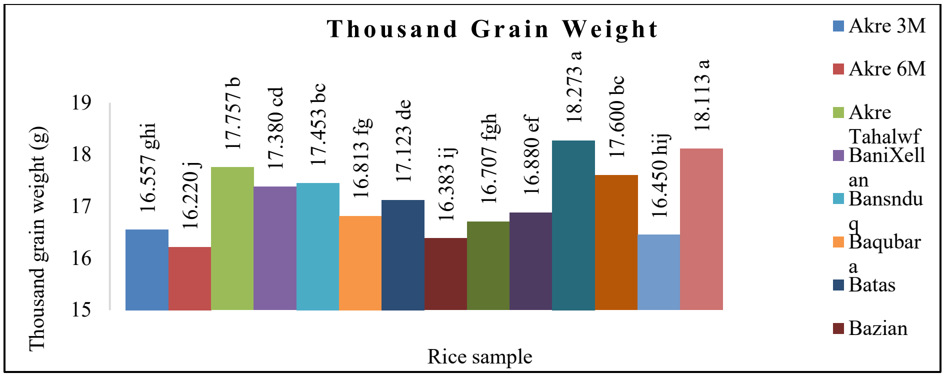


Figure 2. Thousand grain weight of rice samples

***Bulk Density***

The highest bulk density was 0.908 g/mL from the Bazian sample and the lowest was 0.841 g/mL from the NiskaJo sample in fourteen rice samples. Ten samples and the Batas, Bansnduq, and Salah Agha samples showed no significant differences, with the latter having moderately lower bulk density (Figure 3). These differences are caused by the grain morphology, dimensions, and surfaces of rice varieties. The bulk density of varieties with uniform and dense grains increases. Nádvorníková et al. (2018) discovered fluctuating bulk densities in rice varieties. Moreover, medium-grain varieties demonstrated a greater bulk density for both brown and white rice compared to long-grain varieties (Fan et al., 1998).

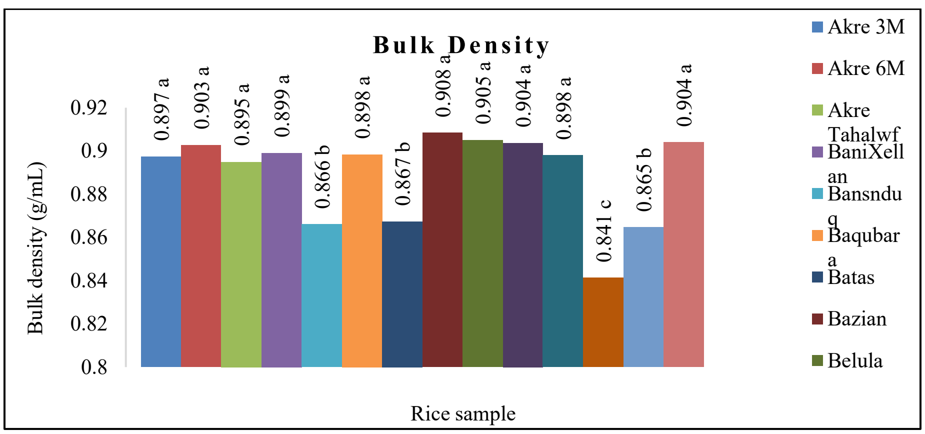


Figure 3. Bulk Density of rice samples

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***Percentage of Chalky Rice Grain***

The Shex Tawil sample demonstrated the highest chalkiness percentage at 19.54%, matching previous studies that suggest specific genotypes are more vulnerable to environmental stresses (Hayashi, 2012). The lowest chalkiness percentage was 4.864% from the Kani Krmanj sample, indicating its potential as a valuable parental line in breeding programmes focused on improving grain quality, a strategy demonstrated to be effective in other regions (Yin et al., 2015), (Figure 4). This study identified substantial variation in chalkiness, confirming earlier research that indicates this quality trait is hereditary (Chandusingh et al., 2013).

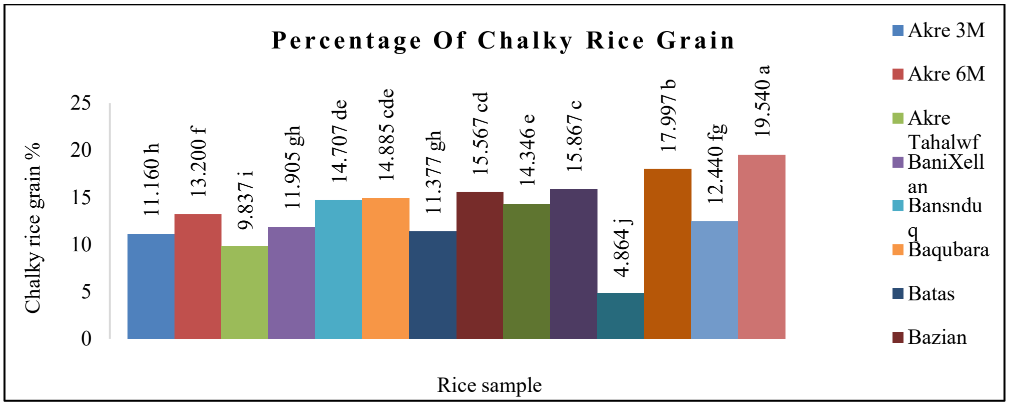


Figure 4. Percentage of chalky grain of rice samples

***Moisture Content***

The moisture content of the rice samples varied from approximately 10% to 12%, with BaniXellan demonstrating the highest levels and Akre 3M the lowest (Figure 5). The findings correspond with existing research, which advocates for a moisture content of 12% to 14% for secure storage and efficient milling (IRRI, 2013). All samples are within or below this ideal range, indicating their stability for storage. Lower moisture levels (e.g., Akre 3M) are excellent for long-term preservation, whereas higher levels (e.g., BaniXellan) are preferable for milling, as they mitigate grain breakage (Juliano, 1985).

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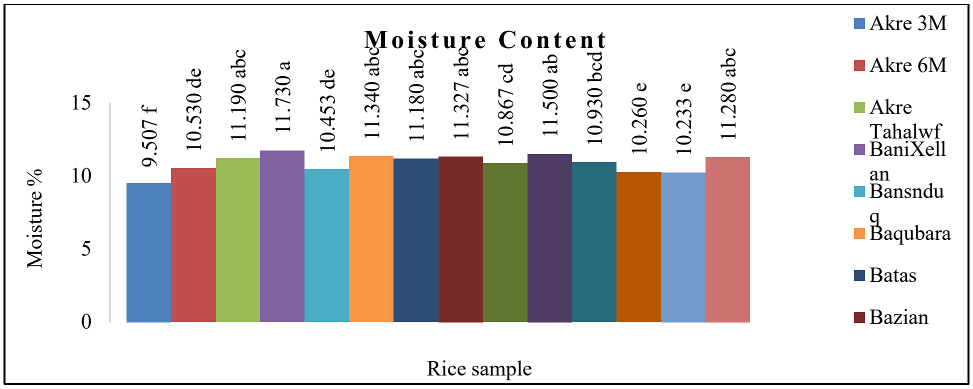


Figure 5. Moisture content of rice samples

***Ash Content***

The ash content of rice samples demonstrated significant variation, ranging from 0.75% to 0.95% (Figure 6). This variation emphasises disparities in their overall mineral composition. Shex Tawil showed the highest ash content at 0.95%, a statistically significant difference from all other samples, indicating it may be the most mineral-rich variety. The minimum ash content was observed in Niskalo (0.75%), suggesting either more thorough milling or varying cultivation conditions. These variations are likely attributable to a confluence of genetic factors, which affect a variety's natural mineral absorption, and agronomic factors such as soil composition (Anjum et al, 2007). The extent of processing, particularly milling, is significant as it eliminates the mineral-laden outer layers of the rice grain (Li, et al, 2025). This data is crucial for nutritional analysis and quality control, as it establishes the mineral profiles of various rice varieties.

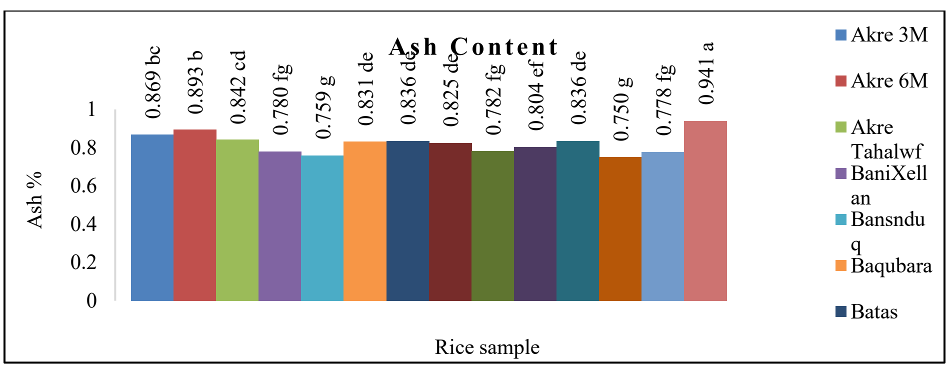


Figure 6. Ash content of rice samples

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***Gel consistency (GC)***

Gel consistency showed substantial differences among the rice varieties, ranging from 41% to 54% (Figure 7). Akre Tahalwf (54%) showed the highest gel consistency, signifying a softer texture post-cooking and cooling. Batas, Shex Tawil, Akre 6M, and Belula (47–49%) demonstrated moderately elevated GC, whereas NiskaJo and Kani Krmanj (44%) were classified as intermediate. The minimum GC was noted for Baqubara, Daradoen, Akre 3M, Bazian, and Salah Agha (41–42%), indicating more hardy cooked grains. These results correspond with recent studies indicating that high gel consistency correlates with low amylose content and a softer texture (Sirinon & Pechampai, 2024; Wei et al., 2022). Lu et al. (2025) indicated that genetic variation significantly affects gel consistency, whereas Gong et al. (2024) highlighted the importance of amylopectin branching in improving gel softness. The softer varieties, particularly Akre Tahalwf, align with the preferences of markets that favour tender rice, whereas lower gel consistency types may be appropriate for cuisines that require firmer grains.

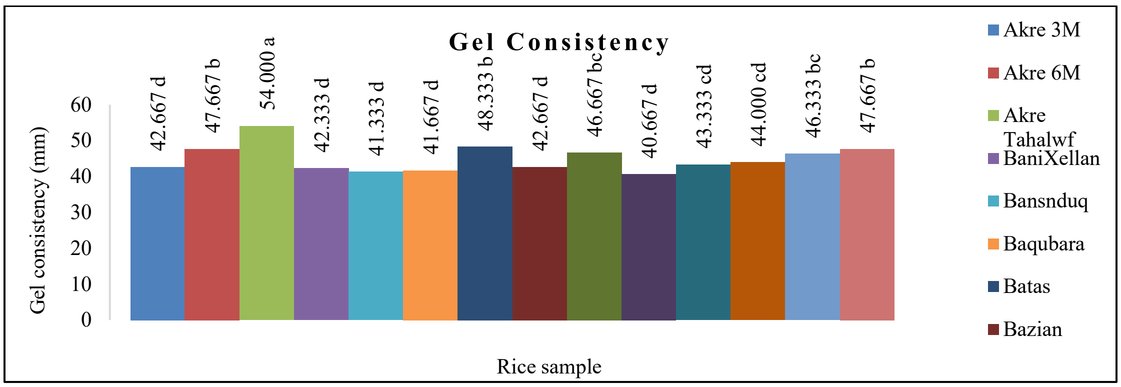


Figure 7. Gel consistency of rice samples

***Amylose Content***

The amylose content of the studied rice varieties varied from 16.2% to 19.1% ((Figure 8). Shex Tawil (19.03%) and Belula (19.02%) were showed the highest values, whereas NiskaJo, Kani Krmanj, and Salah Agha (~17.1%) demonstrated the lowest values. The majority of varieties were categorised within the intermediate range (16–20%), as described by Juliano (1985). High-amylose varieties (>19%) produce firmer, less sticky textures suitable for pilaf-type dishes, while lower-amylose varieties (<17.2%) result in softer, stickier rice (Bhattacharya, 2011). The results were corresponded with earlier studies conducted in Iraq and Asia, indicating that the majority of traditional varieties fall within the range of 15.8–20.4% (González et al., 2004). The observed narrow range indicates genetic regulation of amylose content (Fitzgerald et al., 2009), although minor yet significant differences permit selection based on cooking quality preferences.

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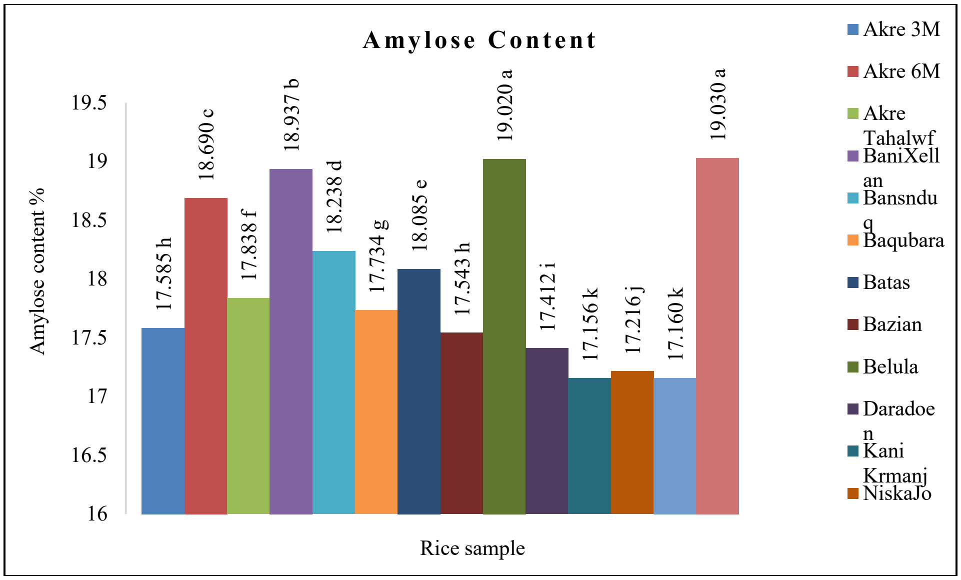


Figure 8. Amylose content of rice samples

### *Elemental Compositions*

### *Aluminum (Al)*

Aluminum concentrations showed significant variability among the rice samples. The highest mean was recorded in Bazian (38.1 mg/kg), followed by Akre 6M (31.2 mg/kg), whereas the lowest was noted in Akre Tahalwf (6.1 mg/kg) and Daradoen (5.7 mg/kg), (Figure 9). These results are comparable to findings in southern China (up to 35 mg/kg; Zhou et al., 2018) but exceed those documented in Bangladesh (<10 mg/kg; Rahman et al., 2014). The variation is primarily associated with soil acidity and genotypic tolerance, as acidic soils increase Al solubility and absorption (Kochian et al., 2015). Raised Al accumulation can negatively impact rice growth (Famoso et al., 2011) and raises concerns regarding food safety (Exley, 2013), emphasising the necessity of soil management and the use of aluminum-tolerant cultivars in affected areas.

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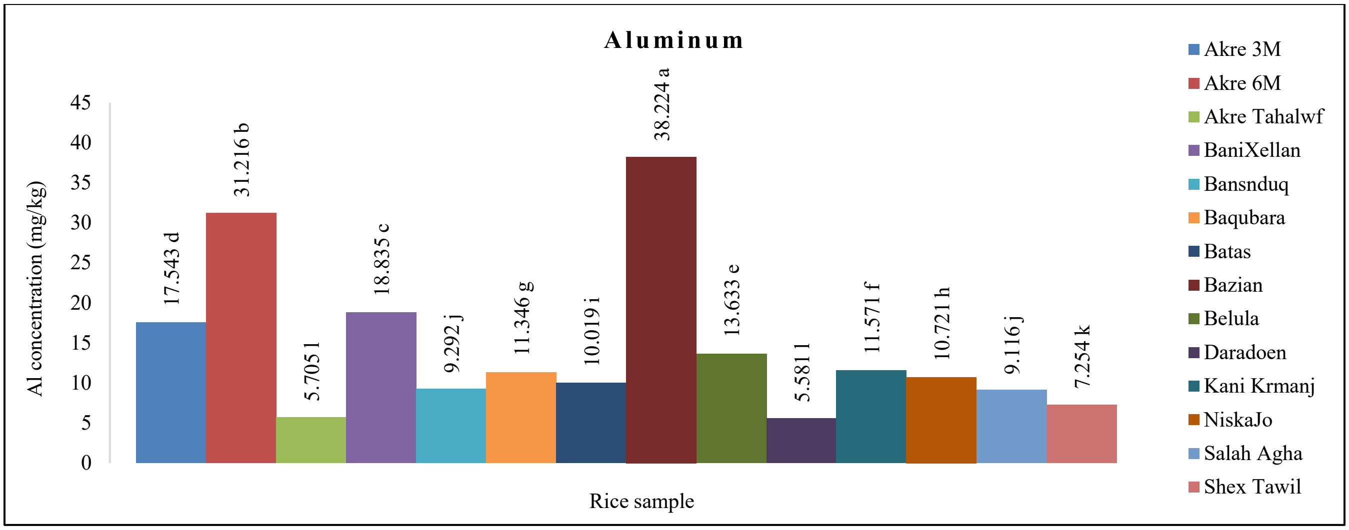


Figure 9. Aluminum concentration in rice samples

***Barium (Ba)***

The concentration of Barium in the rice samples varied significantly, with the highest level recorded in Belula (0.86 mg/kg) and the lowest concentrations were measured in BaniXellan (0.32 mg/kg), (Figure 10). The differences in Ba concentrations among rice samples may be attributed to variations in soil mineral composition, sources of irrigation water, and varietal uptake efficiency, as previously documented (Kabata-Pendias, 2011; Saravanakumar et al., 2016). The concentrations observed in this study fall within the established global range of Ba in cereals (0.1–1.0 mg/kg) (FAO/WHO, 2011). Although these values remain within food safety limits, elevated levels, such as those found in Belula, may lead to increased dietary Ba intake in populations dependent on rice as a staple food. Continuous monitoring is thus advised, in accordance with international guidelines (EFSA/SCHER, 2012).

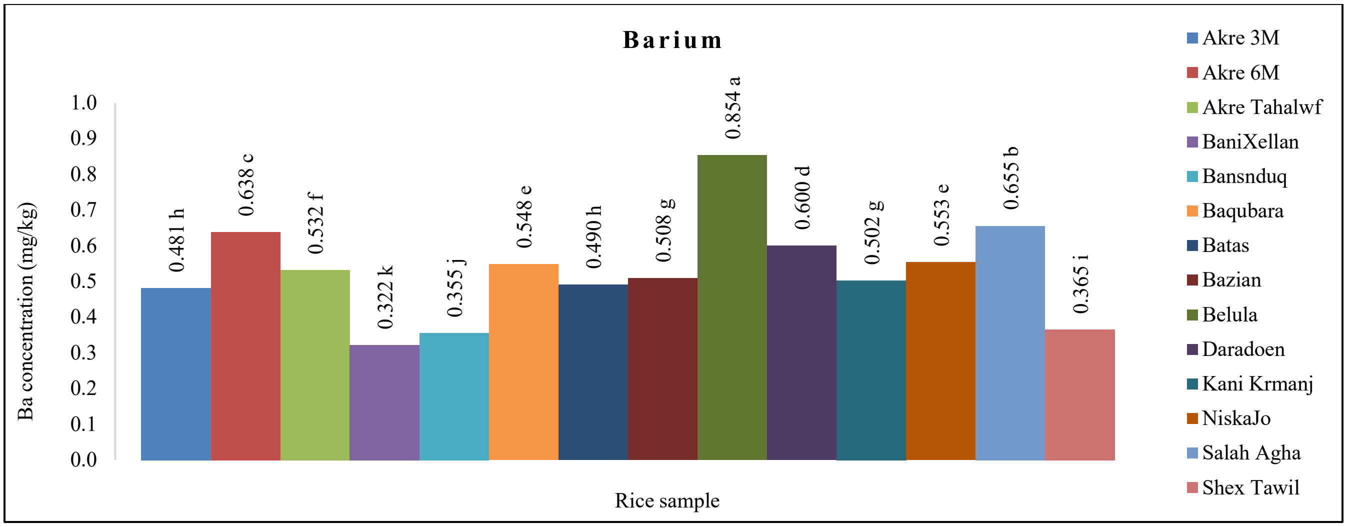


Figure 10. Barium concentration in rice samples

### *Calcium (Ca)*

The Calcium content in the rice samples varied from 333.52 mg/kg in NiskaJo to 535.60 mg/kg in Akre 3M (Figure 11). The observed variation indicates that both genotypic differences and environmental factors, including soil mineral composition and irrigation practices, affect Ca accumulation (Meharg & Zhao, 2012). The values were within the global range for rice grains (300–600 mg/kg) (FAO/WHO, 2011). While rice typically serves as a minor source of calcium, higher-calcium varieties such as Akre 3M and Belula may positively impact human nutrition. For instance, 100 g of these grains may yield 33–54 mg of calcium, representing approximately 3–5% of the daily adult requirement (Weaver & Heaney, 2006).

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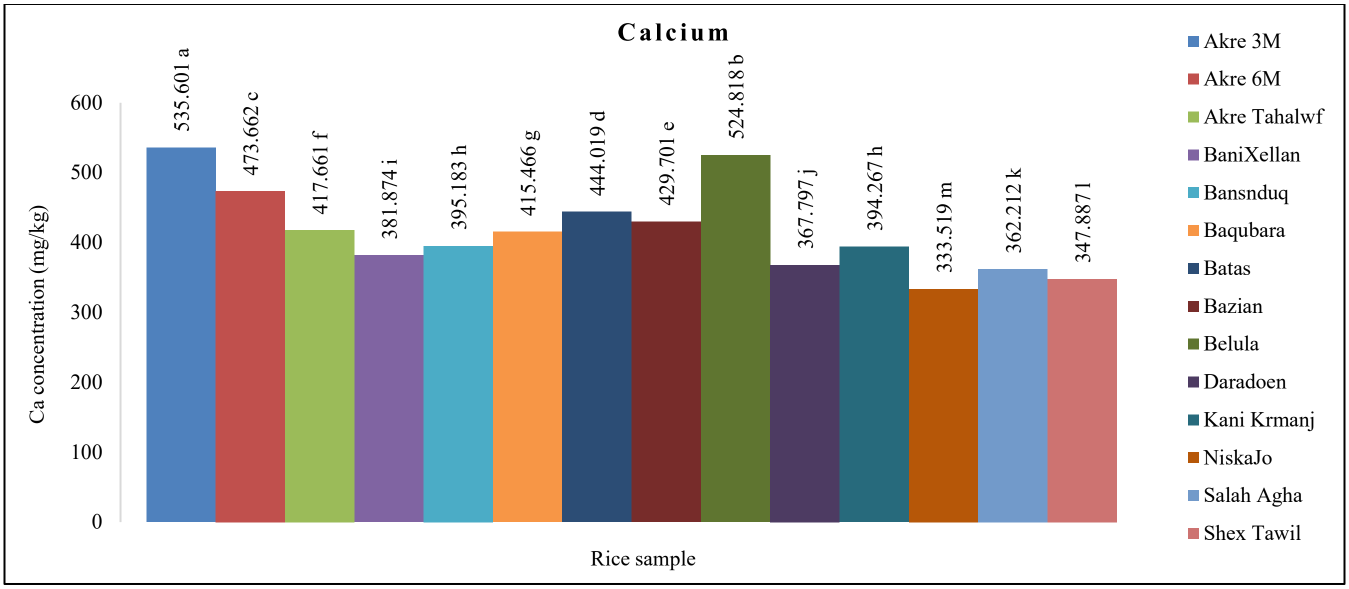


Figure 11. Calcium concentration in rice samples

***Potassium (K)***

The potassium concentration in the rice samples exhibited significant variability. The highest concentration was recorded in Akre Tahalwf (1148.38 mg/kg), while the lowest values were noted in BaniXellan (501.56 mg/kg) and Salah Agha (500.76 mg/kg), (Figurer 12). The values align with earlier studies indicating that rice generally contains 600–1200 mg/kg of potassium, contingent upon genotype and cultivation conditions (Sompong et al., 2011). The experiential variation likely indicates genotypic differences and soil nutrient availability, consistent with previous research on potassium uptake efficiency in rice (Zörb et al., 2014). Higher potassium varieties, such as Akre Tahalwf, may offer enhanced nutritional benefits for consumers in rice-dependent regions.

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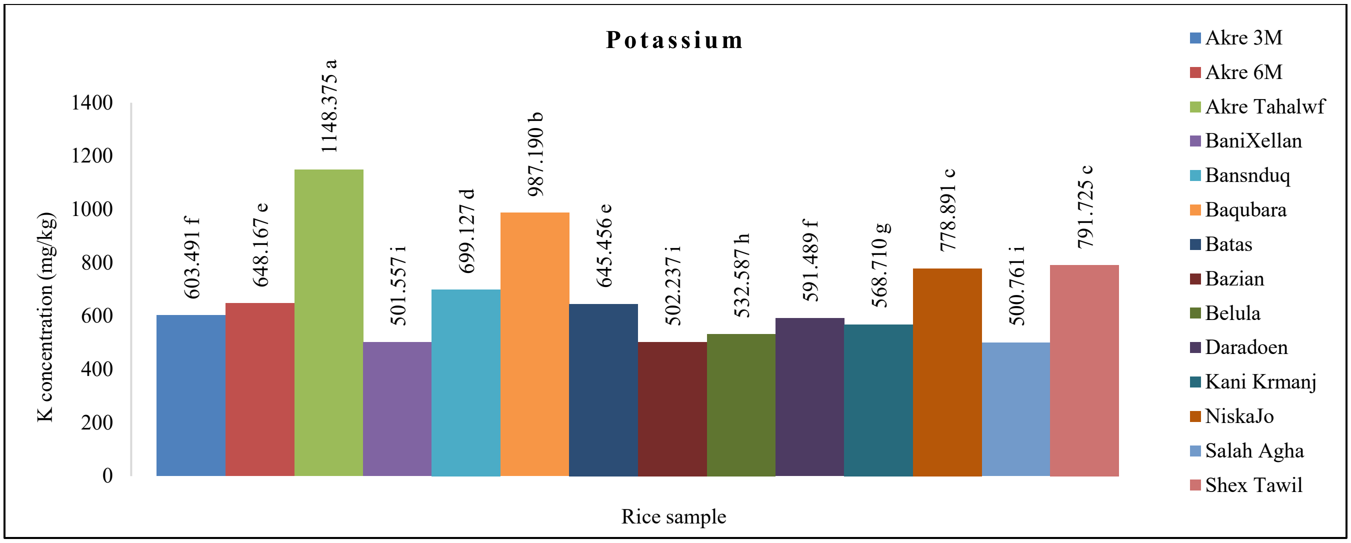


Figure 12. Potassium concentration in rice samples

***Magnesium (Mg)***

Magnesium concentrations in the rice samples varied from 319.24 mg/kg in Salah Agha to 660.81 mg/kg in Baqubara, with notable values of 588.43 mg/kg in Akre Tahalwf and 558.05 mg/kg in NiskaJo (Figurer 13). These results align with recent research. Desalew, and Mehari (2023) documented magnesium concentrations in Ethiopian rice between 504 and 1,209 mg/kg, with Fogera (561 ± 21 mg/kg) and Pawe (546 ± 21 mg/kg) exhibiting values comparable to the present study. Volpe (2013) similarly noted that polished rice typically has significantly lower magnesium concentrations (~37.7 mg/100 g) than whole grain rice (~107.8 mg/100 g), indicating that the elevated magnesium levels in the current samples may result from minimal processing. The elevated magnesium concentrations in varieties like Baqubara and Akre Tahalwf emphasise their nutritional importance as potential dietary sources of magnesium.

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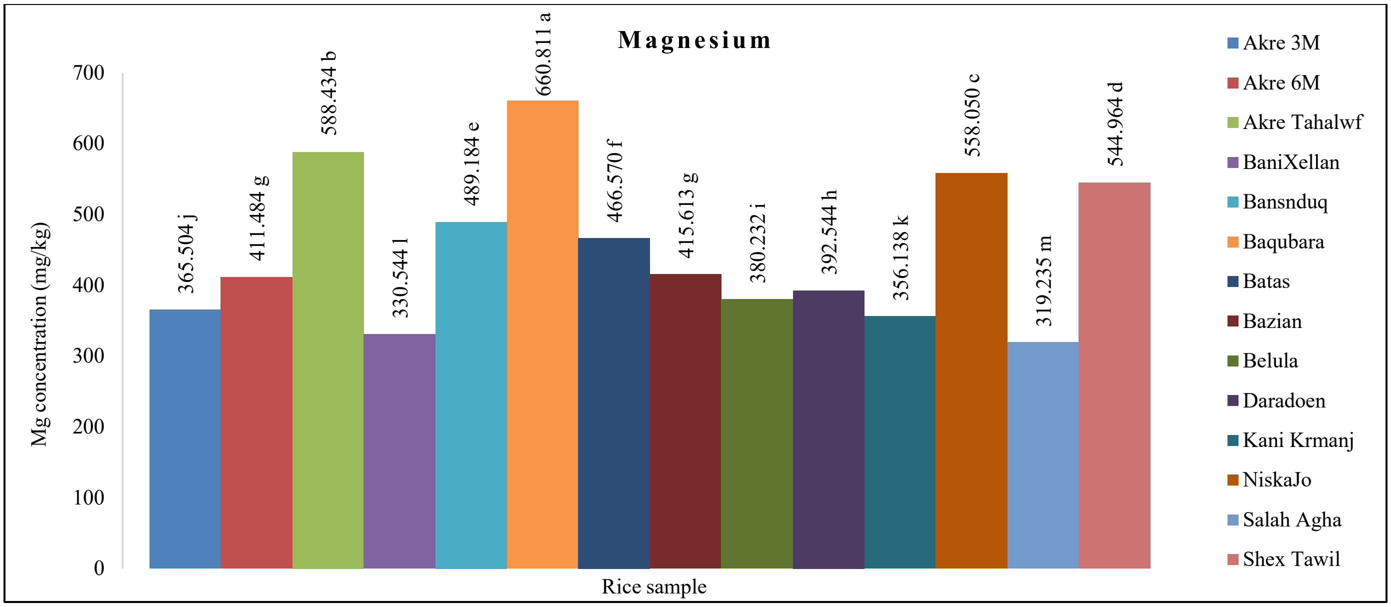


Figure 13. Magnesium concentration in rice samples

***Sodium (Na)***

The concentration of Sodium in the rice samples demonstrated significant variability, spanning from 28.20 mg/kg in BaniXellan to 115.78 mg/kg in Batas, with elevated levels also observed in Belula (103.43 mg/kg) and Baqubara (102.20 mg/kg), (Figurer 14). These values are comparatively low in relation to polished rice documented in other regions. Zhang et al. (2021) identified sodium concentrations between 180 and 390 mg/kg in Chinese rice cultivars, whereas Desalew, and Mehari (2023) documented sodium levels of 214 to 356 mg/kg in Ethiopian rice. The diminished values noted in the present study may be attributed to varietal differences and the particular soil-water management techniques used in the Kurdish cultivation regions. The relatively low sodium levels in most samples, especially BaniXellan and Salah Agha (79.60 mg/kg), indicate possible health advantages for populations requiring low-sodium diets, thus improving the nutritional quality of these landraces.

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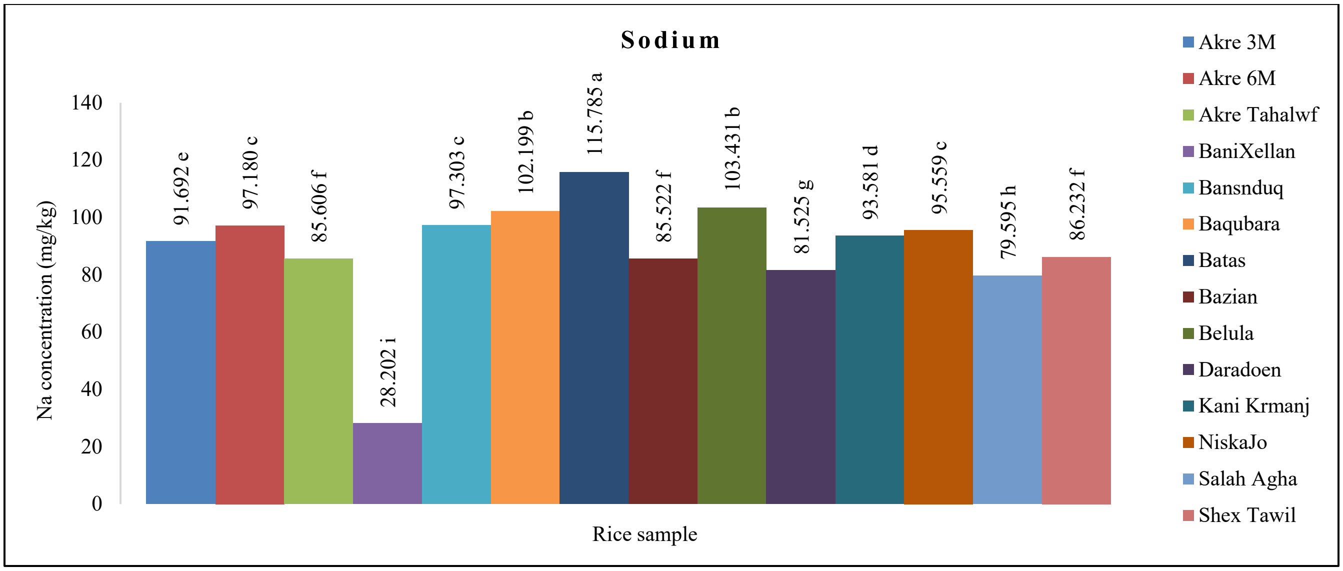


Figure 14. Sodium concentration in rice samples

***Selenium (Se)***

The concentration of Selenium in the rice samples was predominantly low, varying from 0.000 mg/kg in Akre 6M to a peak of 0.319 mg/kg in Bazian. Multiple varieties, such as Daradoen (0.060 mg/kg) and Batas (0.011 mg/kg), showed low concentrations (Figurer 15). In comparison to global studies, these concentrations are within the lower spectrum of selenium content in rice. Wang et al. (2022) documented selenium levels between 0.05 and 0.62 mg/kg in rice from various Chinese regions, whereas Wang et al. (2013) noted concentrations of 0.12 to 0.54 mg/kg in selenium-enriched rice cultivars. The comparatively diminished selenium levels in Kurdish-grown rice may be attributed to the inherent soil composition, which is generally selenium-deficient, as noted in other non-seleniferous regions (Fairweather-Tait et al., 2011). From the perspective of nutrition, while selenium levels in certain samples like Bazian and Kani Krmanj near the lower global average, the majority of varieties offer minimal contributions to the recommended dietary intake. This highlights the potential of biofortification strategies to enhance selenium content in Kurdish rice cultivars.

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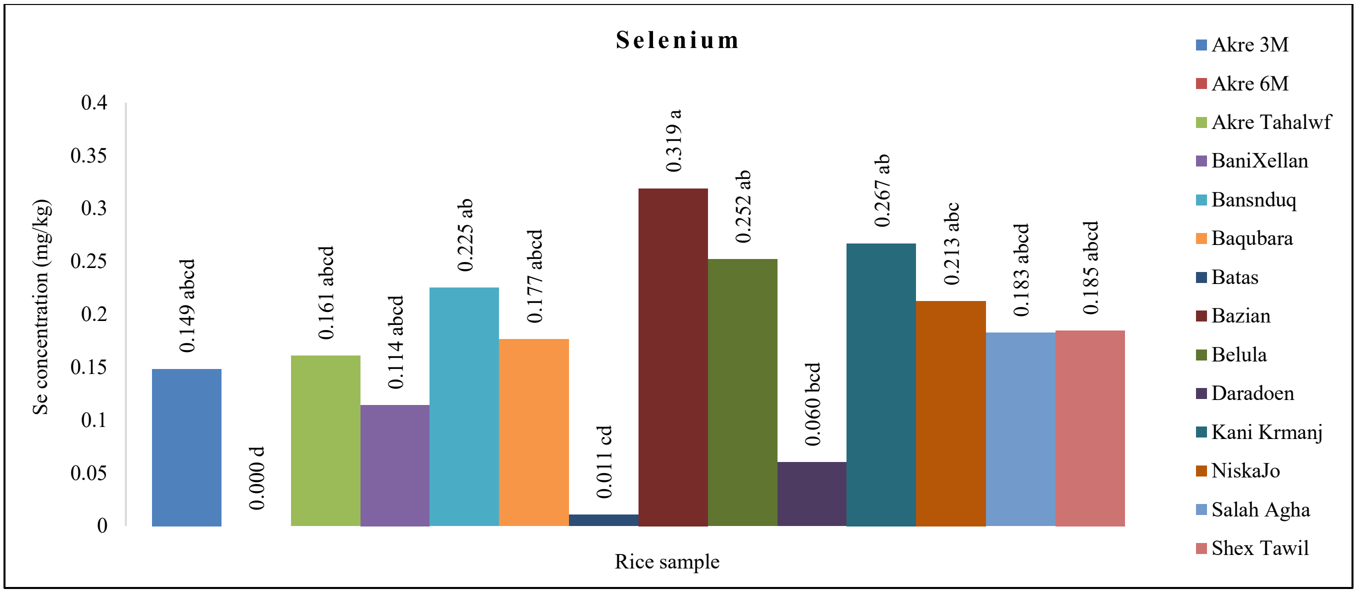


Figure 15. Selenium concentration in rice samples

## IV. CONCLUSION

Present study revealed significant differences in the physicochemical properties and elemental composition of rice grown in Iraqi Kurdistan. The grain size and shape were mostly medium or short-bold, similar to japonica-like landraces, while the TGW and bulk density showed considerable genotype dependence. Quality attributes, such as amylose content, gel consistency, and chalkiness, showed dissimilarity within internationally acknowledged ranges, reflecting both genetic and environmental influences. Elements, particularly Selenium and Aluminum, revealed notable differences among rice samples, with some values exceeding or falling below global averages. The results highlight the nutritional and qualitative potential of local Kurdish rice, while also presenting opportunities for targeted breeding and biofortification to enhance food quality and health advantages. Further studies should integrate sensory evaluation, agronomic performance, and environmental assessments to inform the development and promotion of rich in nutrients Kurdish rice.

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