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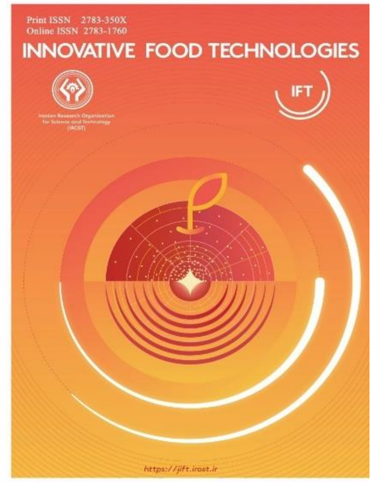

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DOI: https://doi.org/ 10.22104/ift.2025.7925.2244

To appear in: Innovative Food Technologies (IFT)

Received Date: 8 October 2025
Revised Date: 7 November 2025
Accepted Date: 16 November 2025

Please cite this article as: Sepideh Vejdanivahid, Fakhreddin Salehi, Comparison of physicochemical properties of Iranian and Peruvian quinoa powders and the influence of magnetic field on sprouting behavior, *Innovative Food Technologies (2025)*,

doi: https://doi.org/ 10.22104/ift.2025.7925.2244

Comparison of physicochemical properties of Iranian and Peruvian quinoa powders and the influence of magnetic field on sprouting behavior

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Abstract
Quinoa seeds have a higher nutritional value than other grains. In this study, the moisture and ash contents, pH, acidity, color indexes, total phenolic content (TPC), and antioxidant capacity (AC) of powder prepared from Iranian and Peruvian quinoa seeds were examined and compared. Also, the impacts of untreated water, magnetized water, and magnetic field on the water absorption and weight gain of quinoa seeds following soaking (1 h at 25°C) and sprouting (72 h at 25°C) periods were studied. There were no significant difference in the diameter and thickness between the two quinoa groups ($p>0.05$). The average diameter of Iranian and Peruvian quinoa seeds was 1.685 mm and 1.757 mm, respectively, and, the average thickness of Iranian and Peruvian quinoa seeds was 1.020 mm and 1.042 mm, respectively. The moisture content, ash content, acidity, and lightness index of Peruvian quinoa seeds powder (QSP) were noticeably higher than that of Iranian QSP ($p<0.05$). The pH, and redness index of Iranian QSP were noticeably higher than that of Peruvian QSP ($p<0.05$). The two powders exhibited similar levels of yellowness, TPC, and AC, showing no significant variation ($p>0.05$). The application of magnetized water and magnetic field accelerated the growth rate of quinoa seeds. Furthermore, they enhanced the amount of water absorbed by the seeds after soaking, as well as their weight following sprouting.

Keywords: Magnetized water, Quinoa sprout, Total phenolic content, Water absorption

1. Introduction

Quinoa (*Chenopodium quinoa* Willd.) is a highly nutritious pseudo-cereal recognized for its potential to contribute to global food security. Owing to its exceptional nutritional profile and adaptability to diverse environmental conditions, the United Nations declared 2013 as the "International Year of Quinoa" [1, 2]. Quinoa is versatile in culinary applications, as its seeds can be cooked directly or ground into flour for use in various cereal-based products. While the seeds are typically pale yellow, they also occur in a range of colors, including pink, orange, red, brown, and black [1, 3]. Quinoa protein is considered a complete protein because it contains all essential amino acids along with other vital nutrients. With a protein content ranging from 14% to 18%, quinoa serves as an excellent alternative to conventional cereals, particularly in gluten-free diets [1, 4]. Quinoa's recent popularity has made it one of the world's most popular crops, and it is now used in many cuisines around the world as a substitute for rice or couscous. Peru is one of the top ten countries that export quinoa [5].

Due to the growing trend of functional food products, sprouted cereals and legumes are of particular interest, and these sprouted products can be used as potential sources of nutritional compounds in functional food formulations [6, 7]. Enzymes are activated throughout the germination procedure, which helps to improve the digestibility of compounds contained in the grains. The germination process increases vitamins, phenolic compounds, and dietary fibers, and enhances antioxidant activity through the accessibility of reducing sugars and free amino acids (FAAs), especially lysine [8].

Searching for techniques to decrease utilization of water and protect water resources is extremely important. The use of magnetized water is effective in this respect. To magnetize water, it is passed through a magnetic field. The use of magnetized water improves the quantity and quality of agricultural products [9-11]. Magnetized water enhances plant growth by increasing the levels of essential substances required for development, such as photosynthetic pigments, indole, and proteins [12].

Exposure to a magnetic field can influence plant physiology and biophysics through multiple mechanisms. On a biophysical level, magnetic fields may alter cell-membrane permeability and ion transport by affecting the movement of charged particles and changing membrane potential, leading to modified uptake of water and nutrients [13, 14]. On the physiological/biochemical side, magnetic field exposure has been shown to impact the production of reactive oxygen species, activate antioxidant enzyme systems, and modulate gene expression, thus affecting processes such as germination, growth, metabolic activity, and stress tolerance [11, 14]. For example, static magnetic fields have been reported to influence photosynthetic efficiency, cellular ultrastructure, and the expression of genes related to growth and metabolism [13, 14]. These combined biophysical and physiological responses provide a basis for using magnetic treatments in seed priming and crop improvement research [9].

In recent years, quinoa has gained increasing attention as a functional ingredient in the development of various food products due to its high nutritional value, unique amino acid profile, and gluten-free nature [15-17]. Researchers have explored its incorporation into different formulations to improve both the quality and nutritional properties of bakery and fried products. For instance, quinoa flour has been utilized to enhance the texture and nutritional profile of gluten-free cakes, pancakes, donuts, cupcakes, and biscuits through diverse processing techniques such as sprouting, saponin removal, and the application of physical treatments including magnetic fields, ultrasound, and infrared drying [17-21]. These studies highlight the potential of quinoa as a valuable ingredient for developing healthier and higher-quality food products.

In recent years, the cultivation and production of quinoa have expanded in Iran, leading to increased research interest in evaluating its quality attributes and potential applications in various food products. Therefore, this study aimed to compare the physicochemical properties of powders obtained from Iranian and Peruvian quinoa seeds, including moisture content, ash content, pH, acidity, color indices, TPC, and AC. In addition, the effects of untreated water, magnetized water, and an applied magnetic field on the water absorption of quinoa seeds during soaking and on seed weight gain after sprouting were investigated.

2. Materials and Methods

2.1. Preparing Iranian and Peruvian quinoa seeds

In this study, Iranian white quinoa seeds, cultivated in Iran and packaged by OAB Company (Iran), were obtained directly from the company's authorized distributor. Similarly, Peruvian white quinoa seeds, originally grown in Peru and packaged in Iran, were also procured from the same source to ensure consistency in handling and quality.

2-2- Measuring the diameter and thickness of quinoa seeds

The diameter and thickness of Iranian and Peruvian white quinoa seeds were measured using an electronic caliper (INSIZE, Model 1114-150, China) with an accuracy of 0.01 mm. Twenty seeds were randomly selected, and their dimensions were precisely recorded. Measurements were performed both before and after the soaking and sprouting treatments to evaluate dimensional changes resulting from the experimental processes.

2.3. Preparation of quinoa seeds powder

An industrial electric grinder (Best, China) was used to grind and prepare powder from Iranian and Peruvian white quinoa seeds (Figure 1). The moisture content, ash content, pH, acidity, color indexes, TPC, and AC of the prepared powders were measured. The excess powders were stored in sealed, moisture-proof polyethylene bags and in a freezer at -18°C.

Figure 1

2.4. Moisture content of powder

The moisture content of QSP was determined using a digital moisture analyzer (Model DBS 60-3, Kern, Germany), which operates based on the thermogravimetric method by measuring weight loss during controlled heating [15].

2.5. Ash content of powder

The ash content of QSP was determined according to the method described by Amin Ekhlas et al. [22]. Empty crucibles were cleaned, dried, and weighed, after which 3 g of each powder sample were placed in the crucibles, pre-ashed over a gas flame, and then incinerated in a muffle furnace (Pars Azma Co., Iran) at 600°C for 8 h. The crucibles were cooled in a desiccator and reweighed using a precision balance (Sartorius, Switzerland; ±1 mg).

2.6. pH and acidity of powder

The pH and acidity of QSP samples were measured using the method explained by Samary et al. [23].

2.7. Color indexes of powder

Image processing methods were used to measure the color indexes of QSP. The images of powders were captured with a scanner (HP Scanjet-300). The color space of the photos was converted from RGB to L* (lightness), a* (green/red), and b* (blue/yellow) using ImageJ software (V.1.42e, USA) and the corresponding plugin [23].

2.8. Total phenolic content (TPC)

The TPC of QSP was measured using the method explained by Amin Ekhlas et al. [22]. The TPC of QSP was expressed as microgram gallic acid equivalent per g (μg GAE/g).

2.9. Antioxidant capacity (AC)

The AC of QSP was determined using the DPPH radical scavenging method as described by Samary et al. [23]. A 0.1 mM DPPH solution (Sigma-Aldrich, USA) was prepared for the assay. For extract preparation, 2 g of QSP were mixed with 20 mL of 80% methanol and stirred for 30 min using a magnetic stirrer (Shimaz, Iran). The mixture was centrifuged at 4000 rpm for 5 min (Universal 320R, Hettich, Germany), and the supernatant was collected as the extract. Then, 2 mL of the extract were reacted with 2 mL of the DPPH solution and incubated in the dark at

25°C for 30 min. The absorbance was measured at 517 nm using a spectrophotometer (XD-7500, Lovibond, Germany).

2.10. Soaking of quinoa seeds

For the soaking treatment, quinoa seeds were thoroughly washed and immersed for 1 h at 25°C in three different media: untreated water, magnetized water, and magnetized water under an applied magnetic field. The magnetized water was produced using a magnetic-alkaline ionized water generator (Meghnatis Sazan Hayat Co., Iran). Two liters of tap water were placed in a polyethylene container and exposed to the device for 2 h. The magnetic field intensity was determined using a Gauss meter (TES-3196, Taiwan). The device generated a magnetic field strength of 2.8 Gauss, while the magnetized water exhibited intensities of 1.4 Gauss within the device and 0.6 Gauss after removal [15].

2.11. Water absorption of quinoa seeds after soaking

The effect of experimental treatments on the water absorption of Iranian and Peruvian quinoa seeds after soaking process was investigated. The water absorption (%) of quinoa seeds after soaking was calculated using the weight of seeds before and after soaking process (1 h at 25°C). Water absorption was determined according to Equation 1:

$$\text{Water absorption} = \frac{W_2 - W_1}{W_1} \times 100 \qquad (1)$$

Where, W_1 is the fresh quinoa seeds weight (g) before soaking, and W_2 is the soaked quinoa seeds weight (g).

2.12. Sprouting of quinoa seeds

For sprouting, quinoa seeds were placed in flat containers and covered with a thin towel. Three treatments were applied: (1) irrigation with untreated water, (2) irrigation with magnetized water, and (3) exposure of seeds, container, and towel to a magnetic field during sprouting. Seeds were moistened every 6 h using a spray bottle and maintained at approximately 25 °C for 72 h until germination occurred [2].

2.13. Weight gain of quinoa seeds after sprouting

The effect of experimental treatments on the weight gain of Iranian and Peruvian quinoa seeds after sprouting period was investigated. The weight gain parameter was calculated using the weight of seeds before and after sprouting period (72 h at 25°C). Weight gain (%) of quinoa seeds after sprouting period was determined according to Equation 2:

$$\text{Weight gain} = \frac{W_3 - W_1}{W_1} \times 100 \qquad (2)$$

Where, W_1 is the weight (g) of fresh quinoa seeds before soaking, and W_3 is the weight (g) of sprouted quinoa seeds.

2.14. Drying of sprouted quinoa seeds

Sprouted quinoa seeds were dried in a convection oven (Shimaz, Iran) at 70°C, and their weight was recorded at 5-min intervals using a digital balance (GM-300p, Lutron, Taiwan; accuracy ±0.01 g) until a constant weight was obtained [2].

2.15. Statistical analysis

All measurements were performed in at least three replicates, and the results were reported as mean ± standard deviation. The findings of this work were analyzed using SPSS software (version 21). The results of the diameter, thickness, moisture, ash, pH, acidity, color indexes, TPC, and AC tests were analyzed using an independent T-test statistical method, with a significance level set at less than 0.05. The effects of the experimental treatments on the diameter, thickness, water absorption, and weight gain of Iranian and Peruvian quinoa seeds were statistically evaluated using Duncan's multiple range test at a 95% confidence level to compare the mean values of the measured parameters. Excel 2013 was used to draw the graphs.

3. Results and Discussion

3.1. Diameter and thickness of quinoa seeds

The results of the independent samples t-test for comparing the diameter and thickness of Iranian and Peruvian quinoa seeds are shown in Table 1. To understand the findings from the t-test table, we first look at the column labeled Levene's test for equality of variances. This is a test to see if the two groups of quinoa (from Iran and Peru) have similar or different levels of variation in their properties. In this section, we look at the important *p*-value column. If the significant value is higher than 0.05, it means that the differences in the two quinoa groups are pretty similar. In simple terms, the differences between the two quinoa groups are not significantly different [24]. Table 1 shows that the diameter and thickness of Iranian and Peruvian quinoa seeds have *p*-values greater than 0.05 (0.248 and 0.105, respectively). This means that the differences in size between the two groups of quinoa are similar. Finally, the significant (2-tailed) value in the T-test column verifies if the averages of two groups are statistically distinct. If the significant value is more than 0.05, it means there isn't a noticeably distinct among the two groups. From Table 1, there was no significant difference in the diameter and thickness values between the two quinoa groups ($p>0.05$). The average diameter of Iranian and Peruvian quinoa seeds was 1.685 mm and 1.757 mm, respectively. Also, the average thickness of Iranian and Peruvian quinoa seeds was 1.020 mm and 1.042 mm, respectively. Shi et al. [25] determined the physical parameters of two quinoa seeds grown in Gansu (China): Long and Meng. The mean diameter and thickness of the Long variety were 2.23 mm and 1.21 mm, respectively. Furthermore, the mean diameter and thickness of the Meng variety were 2.00 mm and 1.08 mm, respectively.

Table 1

Figure 2 shows the impact of using untreated water, magnetized water, and magnetic field on the diameter of Iranian and Peruvian quinoa seeds after soaking and sprouting. The use of magnetized water and magnetic field accelerated the growth rate and increased the diameter of the quinoa seeds after soaking and sprouting. The largest diameter was for Peruvian quinoa soaked and sprouted in the magnetic field, and the smallest diameter was for Iranian quinoa soaked and sprouted in untreated water. The diameter of Peruvian quinoa seeds sprouted with untreated water, magnetized water, and magnetic field was 1.552 mm, 1.887 mm, and 2.363 mm, respectively. The observed increase in the size of quinoa seeds exposed to the magnetic field can be attributed to the physiological and biochemical effects induced by magnetic treatments. Magnetic fields are known to modify cell shape and membrane structure, thereby increasing membrane permeability and facilitating greater water and nutrient uptake during soaking and sprouting. This enhanced permeability, together with the stimulation of metabolic pathways and upregulation of genes associated with growth and biosynthesis, promotes higher accumulation of proteins, carbohydrates, and soluble sugars within the seed tissues [14]. Consequently, these combined effects lead to improved cellular expansion and biomass accumulation, which can explain the larger diameter and thickness observed in magnetically treated quinoa seeds.

Figure 2

Researchers discovered that a magnetic field promotes seed sprouting and growth, enhances plant height, boosts their weight, and increases both the quantity and weight of the fruit produced by each plant [12]. The employ of magnetized water and magnetic field improved the sprouting rate of the quinoa compared to the use of untreated water. Figure 3 shows the impact of experimental treatments on the thickness of Iranian and Peruvian quinoa seeds after soaking and sprouting. In this study, the highest thickness values were for Peruvian quinoa soaked and sprouted in the magnetic field, and the lowest thickness values were for Iranian quinoa soaked and sprouted in untreated water. The thickness of Peruvian quinoa seeds sprouted with untreated water, magnetized water, and magnetic field was 0.848 mm, 0.893 mm, and 1.363 mm, respectively.

Figure 3

3.2. Moisture content

From Table 2, for the moisture content of Iranian and Peruvian QSP, the significant (2-tailed) value is 0.000, which is lower than 0.05. In simple terms, this means that there is a noticeable difference in the averages of moisture content between Iranian (average = 7.12 ± 0.317 %) and Peruvian (average = 9.94 ± 0.272 %) QSP. Arafa and Elseedy [26] reported that the moisture and ash contents of QSP purchased from Cairo (Egypt) are 8.74 % and 1.87 %, respectively. Elbasuony et al. [27] examined the production of high-protein extruded corn snacks formulated with QSP. In this study, the moisture, protein, ash, fat, fiber, and carbohydrate contents of QSP were 11.44 %, 16.22 %, 3.25 %, 7.52 %, 7.58 %, and 65.43 %, respectively. The findings showed that as the amount of QSP increased, the levels of protein, ash, and fat in the extrudates improved ($p \leq 0.05$), while the carbohydrate reduced.

Table 2

3.3. Ash content

Quinoa is a rich source of essential minerals, particularly iron, magnesium, phosphorus, and potassium, surpassing many other cereals. This mineral composition supports anemia prevention, bone health, muscle and nerve function, and the regulation of metabolic and blood glucose levels [1, 4]. The results of the T-test for comparing the ash content of Iranian and Peruvian QSP are reported in Table 2. There was a significant difference in the ash content among the two quinoa groups ($p<0.05$). Peruvian quinoa has higher ash content, indicating that this product contains more minerals. The ash content of Iranian and Peruvian quinoa seeds was 2.04 % and 2.36 %, respectively. AL-Sayed et al. [1] reported that the moisture and ash contents of QSP purchased from Tabuk (Saudi Arabia) are 11.78 % and 2.50 %, respectively. O ELKatry and A Elsawy [28] indicate that the averages of moisture and ash contents in QSP purchased from Giza (Egypt) are 12.8 % and 3.4 %, respectively.

3.4. pH of powder

As shown in Table 3, the pH values of powders prepared from Iranian and Peruvian quinoa seeds exhibited a significant difference at the 95% confidence level ($p<0.05$). The mean pH of the Iranian QSP (6.56 ± 0.134) was higher than that of the Peruvian QSP (6.30 ± 0.081). This indicates that the Iranian QSP had a slightly less acidic nature compared to the Peruvian counterpart. Such variation in pH may be related to genetic differences between the two varieties, environmental growing conditions, and differences in mineral composition and buffering capacity. A higher pH value in the Iranian QSP may also influence its stability and interactions in food formulations, potentially affecting color and flavor characteristics. Kenawi et al. [29] examined the stability of vacuum-packaged low-fat chicken burgers with the inclusion of sprouted QSP. In this study, the pH level, moisture content, and ash content of sprouted QSP were 5.70, 11.71 %, and 3.09 %, respectively.

Table 3

3.5. Acidity of powder

According to Table 3, the acidity of the Peruvian QSP (1.00%) was significantly higher than that of the Iranian QSP (0.67%), with the difference being highly significant ($p < 0.01$). The greater acidity of the Peruvian QSP could be attributed to its higher content of organic acids, which are known to vary among quinoa genotypes and environmental conditions [4, 30]. The elevated acidity level may contribute to enhanced flavor sharpness and potential preservation properties of the Peruvian quinoa powder. In contrast, the lower acidity of the Iranian quinoa powder suggests a milder taste profile and possibly different processing behavior in food applications.

3.6. Color indexes

The results of the T-test for comparing the lightness, redness, and yellowness of Iranian and Peruvian QSP are reported in Table 4. The lightness index of Peruvian QSP was noticeably higher than that of Iranian QSP ($p<0.05$); while, the redness index of Iranian QSP was noticeably higher than that of Peruvian QSP ($p<0.05$). The two powders exhibited similar levels of yellowness, showing no significant variation ($p>0.05$). In this study, the L^*, a^*, and b^* values of the Iranian QSP used in this study were 88.62, 2.38, and 13.28, respectively. In addition, the L^*, a^*, and b^* values of the Peruvian QSP were 95.60, -0.92, and 13.29, respectively.

Table 4

3.7. Total phenolic content (TPC)

Polyphenols are natural chemicals made up of many connected phenol units. They are often found in plants and are the most common antioxidants in the foods people eat [3]. Quinoa seeds have more phenolic compounds than whole cereal grains like wheat, barley, millet, rice, and buckwheat. They contain at least 23 different types of phenolic compounds [3, 31]. The T-test results for the TPC of Iranian and Peruvian QSP are reported in Table 5. There was no significant difference in the TPC among the two quinoa groups ($p>0.05$). The TPC of Iranian and Peruvian quinoa seeds were 758.80 µg galic acid/g and 816.15 µg galic acid/g, respectively. Bastidas et al. [3] reported that the TPC of white, red, and black quinoa is 466.99 µg galic acid/g, 634.66 µg galic acid/g, and 682.05 µg galic acid/g, respectively. The most abundant phenols are ferulic acid and quercetin. AL-Sayed et al. [1] observed that in QSP (purchased from Tabuk, Saudi Arabia) a relatively high concentration of total phenolics 2630 µg galic acid /g. In the O ELKatry and A Elsawy [28] study, the TPC in QSP was 184 µg galic acid /g.

Table 5

3.8. Antioxidant capacity (AC)

Quinoa exhibits remarkable therapeutic potential due to its pronounced antioxidant, hypolipidemic, antidiabetic, anti-inflammatory, and anticancer activities. Numerous studies have demonstrated that quinoa seeds are an abundant source of bioactive phytochemicals, which act as natural antioxidants. These compounds include phenolic acids, flavonoids, fat-soluble vitamins, essential trace minerals, unsaturated fatty acids, and squalene, all of which contribute to the nutritional and functional value of quinoa [1, 3, 4]. The results of the T-test for comparing the

AC of Iranian and Peruvian QSP are reported in Table 5. Similarly to TPC, for the AC of Iranian and Peruvian QSP, the findings reveal that there exists no significant difference (p value=0.841). In simple words, this means that there are no noticeable differences in the TPC and AC between Iranian and Peruvian QSP. The AC of Iranian and Peruvian quinoa seed was 83.18 % and 83.07 %, respectively. Tang et al. [32] reported that the AC of lipophilic extracts of quinoa seeds was related to the amount of polyunsaturated fatty acids, carotenoids, and tocopherols.

3.9. Water absorption after soaking

Figure 4 illustrates the effects of untreated water, magnetized water, and magnetic field treatments on the water absorption capacity of Iranian and Peruvian quinoa seeds after soaking. In this study, the highest water absorption was for Peruvian quinoa soaked in the magnetic field, and the lowest water absorption was for Iranian quinoa soaked in untreated water. The water absorption of Peruvian quinoa seeds soaked with untreated water, magnetized water, and magnetic field was 46.00 %, 63.60 %, and 98.13 %, respectively.

Figure 4

3.10. Weight gain after sprouting

Magnetic fields can markedly influence photosynthetic efficiency, biomass production, and vigor accumulation indices in plants. Exposure to static magnetic fields has been reported to stimulate metabolic activity by accelerating the formation and accumulation of reactive oxygen species, which may act as signaling molecules in regulating plant growth and stress responses [14]. The application of magnetized water and exposure to a magnetic field significantly enhanced the sprouting rate of quinoa seeds compared to irrigation with untreated water [33]. As illustrated in Figure 5, the experimental treatments exerted a notable influence on the weight gain of both Iranian and Peruvian quinoa seeds after sprouting. Among the treatments, the highest increase in seed weight was observed in Peruvian quinoa exposed to the magnetic field, whereas the lowest weight gain occurred in Iranian quinoa irrigated with untreated water. Specifically, the weight gain percentages of Peruvian quinoa seeds sprouted with untreated water, magnetized water, and under a magnetic field were 67.93%, 85.10%, and 119.60%, respectively. These findings suggest that magnetic treatments, particularly the application of a magnetic field, can substantially improve the physiological performance and sprouting vigor of quinoa, with Peruvian quinoa showing greater responsiveness compared to the Iranian variety.

Figure 5

4. Conclusion

Quinoa is a gluten-free product (proper for people with celiac disease) and contains fiber, as well as various vitamins, phenolic compounds, antioxidants, and nutrients, and its flour can be used to improve the quality of various foods. In this study, an independent sample t-test was employed to analyze and compare the physicochemical and quality characteristics of powder made from quinoa seeds from Iran and Peru. The moisture and ash contents of Peruvian QSP were significantly higher than that of Iranian QSP ($p<0.05$). Peruvian quinoa has a higher amount of organic acids, so its pH is lower than that of Iranian quinoa. The lightness index of the Peruvian QSP was noticeably higher than that of the Iranian QSP ($p<0.05$); while, the redness index of the Iranian QSP was noticeably higher than that of the Peruvian QSP ($p<0.05$). The size of Peruvian quinoa was slightly larger than that of Iranian quinoa, but there were no significant differences in terms of diameter and thickness of Iranian and Peruvian QSP ($p>0.05$). Also, there were no noticeable differences in the TPC and AC among Iranian and Peruvian QSP ($p>0.05$). Magnetic field treatment of quinoa seeds simultaneously with soaking and sprouting improves the size (diameter and thickness), water absorption, and weight gain of the sprouted Iranian and Peruvian quinoa.

The findings of this study have practical implications for both the food and agricultural industries. The superior physicochemical properties observed in quinoa powder suggest its potential as a functional ingredient for improving the nutritional and sensory quality of bakery and cereal-based products. Moreover, the positive effects of magnetized water and magnetic field treatments on quinoa seed sprouting indicate a promising, non-chemical, and energy-efficient approach to enhance seed germination and biomass production. These results can be effectively utilized in developing value-added quinoa-based products and optimizing sprouting technologies for large-scale applications.

FOUNDING SOURCE: This work was supported by a grant from the Bu-Ali Sina University, Hamedan, Iran (Grant No. 40346 to Fakhreddin Salehi).

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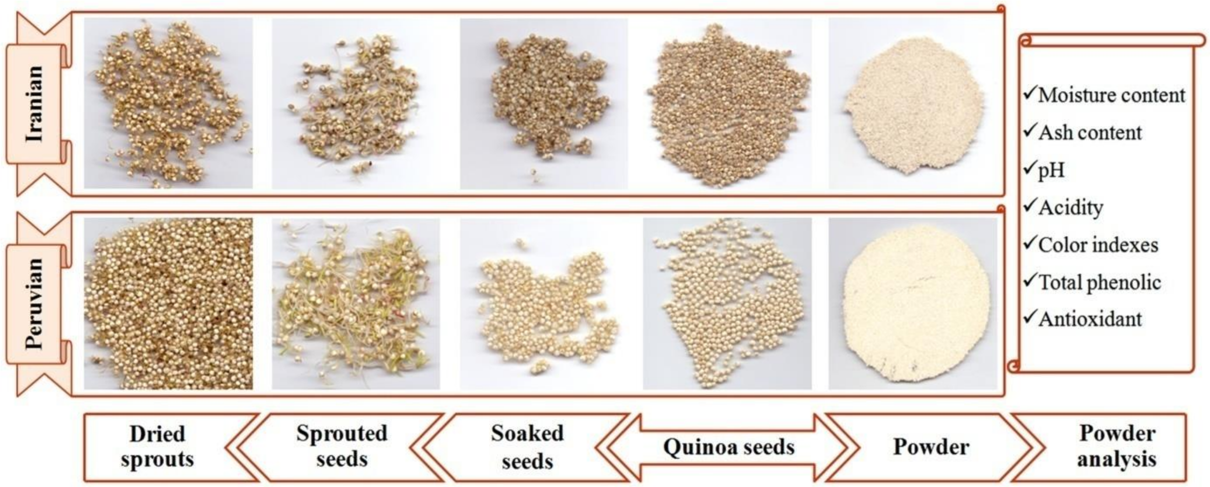

Figure (1) Physicochemical properties of powder prepared from Iranian and Peruvian quinoa, and the steps of soaking, sprouting, and drying quinoa sprouts

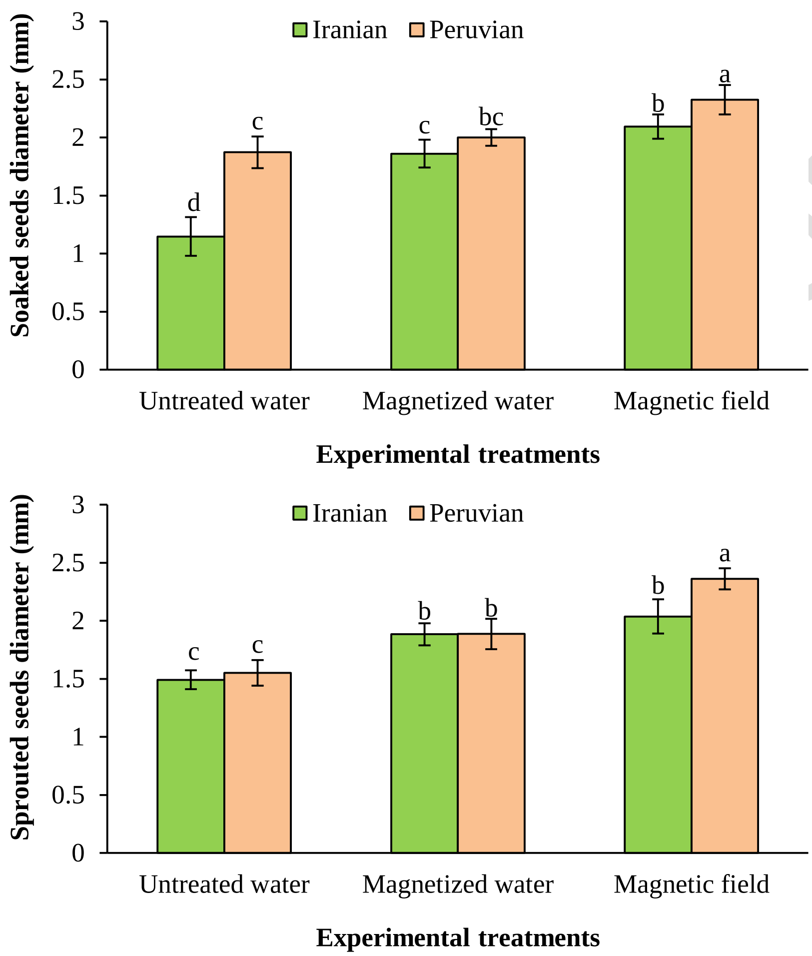

Figure (2) Effect of experimental treatments on the diameter of Iranian and Peruvian quinoa seeds after soaking and sprouting

Different letters above the columns indicate significant differences ($p<0.05$)

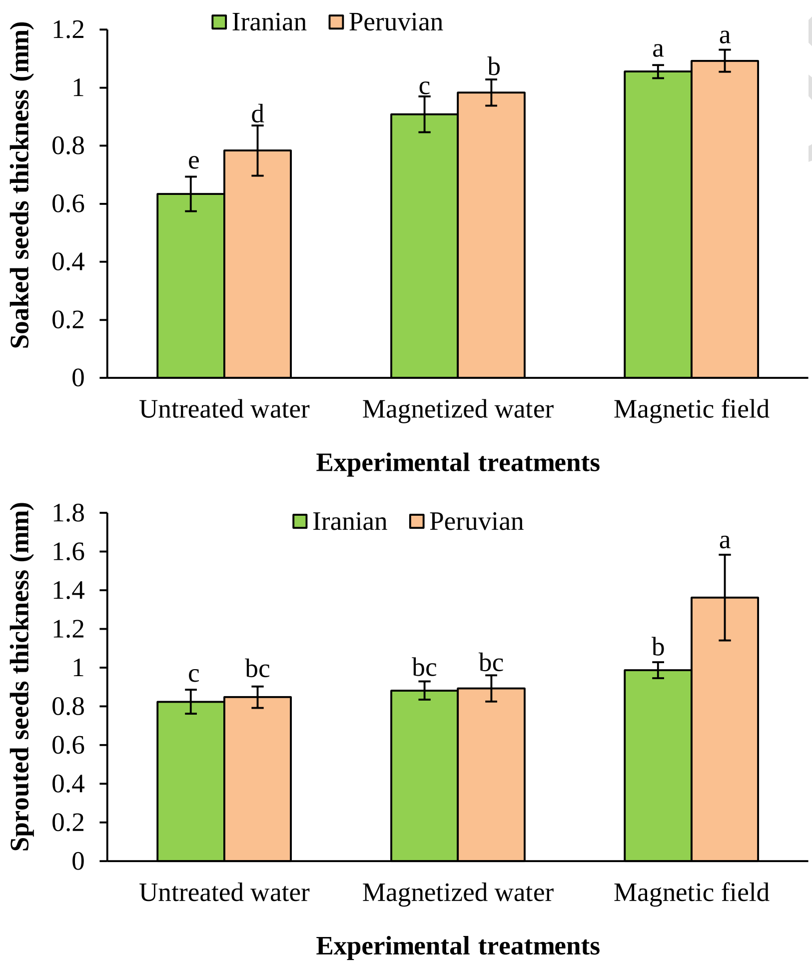

Figure (3) Effect of experimental treatments on the thickness of Iranian and Peruvian quinoa seeds after soaking and sprouting

Different letters above the columns indicate significant differences ($p<0.05$)

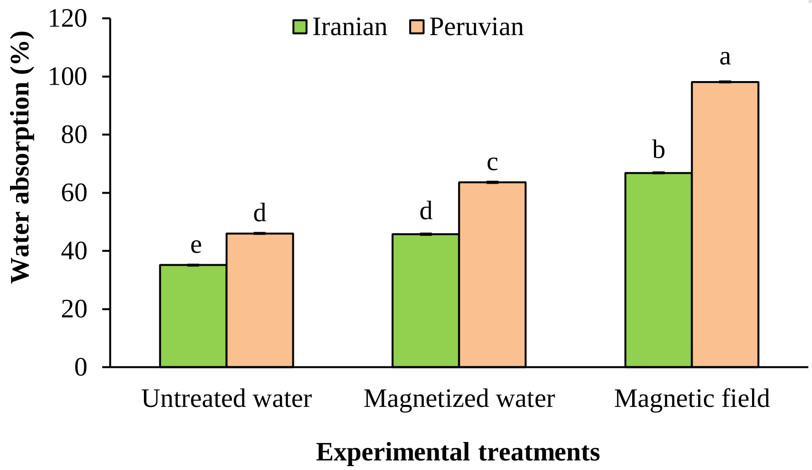

Figure (4) Effect of experimental treatments on the water absorption of Iranian and Peruvian quinoa seeds after soaking

Different letters above the columns indicate significant differences ($p<0.05$)

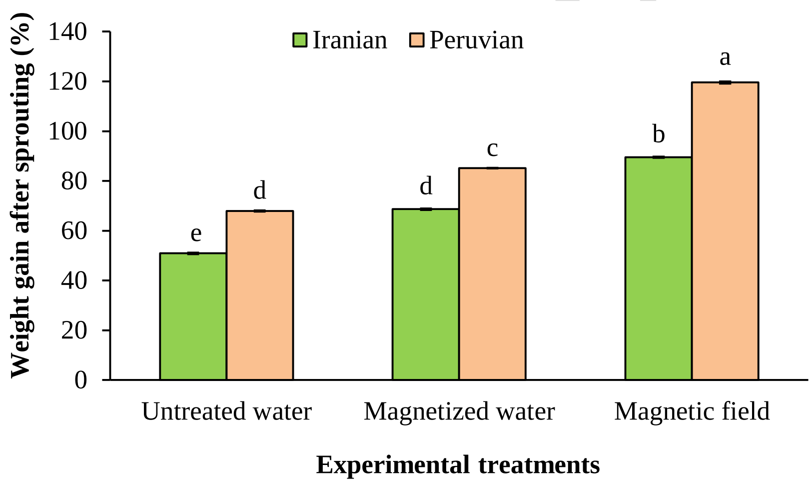

Figure (5) Effect of experimental treatments on the weight gain of Iranian and Peruvian quinoa seeds after sprouting

Different letters above the columns indicate significant differences ($p<0.05$)

Table (1) T-test results for comparing the diameter and thickness of Iranian and Peruvian quinoa seeds

Properties	Quinoa seed	Mean	Standard deviation	Levene's Test for Equality of Variances		T-test for Equality of Means		
				F	Significant	t	Degrees of freedom	Significant (2-tailed)
Diameter	Iranian	1.685 mm	0.139	1.379	0.248	1.308	38	0.199
	Peruvian	1.757 mm	0.204					
Thickness	Iranian	1.020 mm	0.077	2.754	0.105	0.601	38	0.551
	Peruvian	1.042 mm	0.144					

Table (2) T-test results for moisture and ash contents of powder prepared from Iranian and Peruvian quinoa seeds

Properties	Quinoa seed	Mean	Standard deviation	Levene's Test for Equality of Variances		T-test for Equality of Means		
				F	Significant	t	Degrees of freedom	Significant (2-tailed)
Moisture content	Iranian	7.12 %	0.317	0.181	0.692	11.669	4	0.000
	Peruvian	9.94 %	0.272					
Ash content	Iranian	2.04 %	0.041	4.749	0.095	12.656	4	0.000
	Peruvian	2.36 %	0.015					

Table (3) T-test results for pH and acidity of powder prepared from Iranian and Peruvian quinoa seeds

Properties	Quinoa seed	Mean	Standard deviation	Levene's Test for Equality of Variances		T-test for Equality of Means		
				F	Significant	t	Degrees of freedom	Significant (2-tailed)
pH	Iranian	6.56	0.134	1.525	0.284	2.799	4	0.049
	Peruvian	6.30	0.081					
Acidity	Iranian	0.67 %	0.021	2.571	0.184	9.546	4	0.001
	Peruvian	1.00 %	0.055					

Table (4) T-test results for color indexes of powder prepared from Iranian and Peruvian quinoa seeds

Color indexes	Quinoa seed	Mean	Standard deviation	Levene's Test for Equality of Variances		T-test for Equality of Means		
				F	Significant	t	Degrees of freedom	Significant (2-tailed)
Lightness	Iranian	88.62	0.813	0.813	0.418	12.150	4	0.000
	Peruvian	95.60	0.573					
Redness	Iranian	2.38	0.124	5.364	0.081	14.866	4	0.000
	Peruvian	-0.92	0.363					
Yellowness	Iranian	13.28	0.422	1.523	0.285	0.020	4	0.985
	Peruvian	13.29	0.194					

Table (5) T-test results for total phenolic content and antioxidant capacity of powder prepared from Iranian and Peruvian quinoa seeds

Properties	Quinoa seed	Mean	Standard deviation	Levene's Test for Equality of Variances		T-test for Equality of Means		
				F	Significant	t	Degrees of freedom	Significant (2-tailed)
Total phenolic content	Iranian	758.80 µg galic acid/g	61.050	2.238	0.209	1.590	4	0.187
	Peruvian	816.15 µg galic acid/g	13.341					
Antioxidant capacity	Iranian	83.18 %	0.621	0.080	0.791	0.215	4	0.841
	Peruvian	83.07 %	0.593					

مقایسه ویژگی‌های فیزیکوشیمیایی پودرهای کینوا ایرانی و پرویی و تأثیر میدان مغناطیسی بر رفتار جوانه‌زنی

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چکیده

دانه‌های کینوا دارای ارزش تغذیه‌ای بالاتری نسبت به سایر غلات هستند. در این مطالعه، میزان رطوبت و خاکستر، pH، اسیدیته، شاخص‌های رنگ، فنل کل و ظرفیت آنتی‌اکسیدانی پودر تهیه‌شده از دانه‌های کینوا ایرانی و پرویی بررسی و مقایسه شد. همچنین، تأثیر آب معمولی، آب مغناطیسی و میدان مغناطیسی بر جذب آب و افزایش وزن دانه‌های کینوا پس از خیساندن (به‌مدت ۱ ساعت در دمای ۲۵ درجه سانتی‌گراد) و جوانه‌زنی (به‌مدت ۷۲ ساعت در دمای ۲۵ درجه سانتی‌گراد) مورد مطالعه قرار گرفت. تفاوت معنی‌داری در قطر و ضخامت بین دو گروه کینوا مشاهده نشد ($p>۰/۰۵$). میانگین قطر دانه‌های کینوا ایرانی و پرویی به‌ترتیب ۱/۶۸۵ و ۱/۷۵۷ میلی‌متر، و میانگین ضخامت آن‌ها به‌ترتیب ۱/۰۲۰ و ۱/۰۴۲ میلی‌متر بود. میزان رطوبت، خاکستر، اسیدیته و شاخص روشنایی در پودر دانه‌های کینوا پرویی به‌طور معناداری بیشتر از پودر کینوا ایرانی بود ($p<۰/۰۵$). در مقابل، مقدار pH و شاخص قرمزی در پودر کینوا ایرانی به‌طور معناداری بالاتر از پودر کینوا پرویی بود ($p<۰/۰۵$). دو نوع پودر از نظر میزان زردی، فنل کل و ظرفیت آنتی‌اکسیدانی تفاوت معنی‌داری نشان ندادند ($p>۰/۰۵$). استفاده از آب مغناطیسی و میدان مغناطیسی باعث افزایش سرعت رشد دانه‌های کینوا شد. علاوه‌براین، این عوامل میزان جذب آب دانه‌ها پس از خیساندن و وزن آن‌ها پس از جوانه‌زنی را افزایش دادند.

واژه‌های کلیدی: آب مغناطیسی‌شده، جذب آب، جوانه کینوا، کل ترکیبات فنلی