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Determination of nutritional value of some quinoa varieties

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Abstract: The purpose of this study was to determine the nutritive value of 5 quinoa varieties (Inia431- Altiplano, White, Titicaca, Illpa Inia, and Carmen). As a result of the study, it was found that there were statistically significant differences between the quinoa varieties in terms of dry matter (DM), crude ash (CA), crude protein (CP), crude fat (CF), neutral-detergent fiber (NDF), acid-detergent fiber (ADF), crude cellulose (CC), hemicellulose (HC), total digestible nutrients (TDN), digestible energy (DE), metabolizable energy (ME), and net energy lactation (NEL) ($P < 0.05$). This is a preliminary study. In vivo and vitro studies are required.

Key words: Quinoa, chemical composition, digestibility, energy, variety

1. Introduction

An increase in the global population, irregular eating habits and malnutrition, and the increasing incidence of genetic diseases (such as celiac), obesity, and different types of cancers have made people more inclined to try different foods. Originating from Andean region of South America and called "the mother of cereals", quinoa (*Chenopodium quinoa willd*) is a gluten-free, high-nutrient plant belonging to the family *Chenopodiaceae* [1,2].

Quinoa, a 1-year plant, has become an alternative to corn in the rations of cattle and poultry in recent years. Quinoa has been of interest for human nutrition due to its balanced amino acid content, fatty acid profile, and vitamin and mineral content. Furthermore, the remaining part of the plant after harvest has been used in animal nutrition. For the human diet, bread and soup are made from quinoa. In every recipe in which we use rice, bulgur wheat, or wheat, it is possible to use quinoa instead.

Quinoa contains 87.4% DM, 13.8% CP, 5.0% CF, 59.7% carbohydrate, 3.4% crude ash (CA), 4.1% fiber, and an energy of 424.2 kcal/100 g in its structure. Compared to other cereal products, quinoa is valuable in that it is superior to other cereals in terms of essential amino acids such as methionine and lysine [3,4,5]. However, the presence of antinutritional substances such as saponin (0.1%–5%), phytic acid, trypsin inhibitor (<50 ppm), and tannin (0.53%) in quinoa limits its use [6]. In another study, it was found that the structure of quinoa grain contained 14.31% CP, which was in line with the rates (12%–23% CP) asserted in other works in the literature [7].

Kaya and Karaer [8] stated that quinoa seeds were rich in calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), iron (Fe), copper (Cu), manganese (Mn), and zinc (Zn), but poor in terms of sodium (Na). Turp and Sucu [9] reported that the amount of protein in quinoa was similar to that in milk, and its protein content was richer than other cereals; therefore, it is a very good source of vegetable protein.

In Turkey, studies on quinoa have been carried out in both universities and research institutes. Geren et al. [10] stated that quinoa is produced on a small scale in Adana and Konya. In another study, it was predicted that acceptable yield could be obtained by means of using drainage water in semiarid and arid areas in order to ensure the food safety of quinoa plants, which are identified as the potential product of the 21st century by the United Nations Food and Agriculture Organization (FAO) [11].

The study was carried out in order to determine the nutritional value of different quinoa varieties (Inia431-Altiplano, White, Titicaca, Illpa Inia, and Carmen) obtained from the Eastern Mediterranean Agricultural Research Institute.

2. Materials and methods

The feed material of the study consisted of different quinoa varieties (Inia431-Altiplano, White, Titicaca, Illpa Inia, and Carmen) obtained from Adana Eastern Mediterranean Agricultural Research Institute. Each variety was planted in 4 parcels, and a sample of 1 kg was taken from each parcel for each variety. The replicate number was 3.

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Samples of the 5 quinoa varieties were sent to the feed laboratory in the Department of Zootechnics, Faculty of Agriculture, Erciyes University, where the nutrient analyses were carried out.

The dry feed samples were first ground in a mill having a sieve diameter of 1 mm and then used for the analyses. In order to determine the DM content, the ground samples were kept in an oven at 70 °C for 24 h; the differences between the weights before and after baking were computed and expressed in DM %. In order to determine the crude ash (CA) content, the samples were burned in a muffle furnace at 550 °C for 4 h. Kjeldahl's method was used to determine the nitrogen (N) content. The crude protein (CP) content was computed using the following formula: CP% = N × 6.25 [12]. The crude fat (CF) analysis was carried out as per the method reported by AOAC [12] using a SER148 Soxhlet (Velp Scientifica, Milan, Italy). The NDF and ADF contents constituting the cell wall components of the feeds were determined using the methods reported by Van Soest et al. [13] using an ANKOM 200 fiber analyzer (ANKOM Technology, Macedon, NY, USA). In computing the crude cellulose (CC) values, the following equation, reported by Pinkerton [14], was used: CC% = 0.80 × ADF%. The hemicellulose (HC) contents were computed by subtracting the ADF values from the NDF values [15]. The TDN, DE, ME, and NEL values were computed using the equations reported by MAFF [16] and are given below:

TDN (%) = 27.66 × ME (Mcal/kg DM)

DE (Mcal/kg DM) = 0.04409 × TDN (%)

ME (Mcal/kg DM) = [3227 – {35.85 × ADF (%) + 33.46 × CP (%) – 35.85 × CA (%)} / 1000]

NEL (Mcal/kg DM) = {0.0245 × TDN (%)} – 0.12

2.1. Statistical analysis

In the statistical evaluation of the data obtained from the study, the variance analysis (one-way ANOVA) was conducted using SAS [17] to determine the differences between the means, and Duncan's multiple comparison test was carried out to determine the significance levels of the differences.

3. Results

Dry matter (DM), CA, CP, and CF contents of the quinoa varieties are given in Table 1. As seen in Table 1, the differences between the varieties in terms of DM, CA, CP, and CF contents were found to be statistically significant ($P < 0.05$). ADF, NDF, CC, and HC contents of the quinoa varieties are given in Table 2. As seen in Table 2, the differences between the varieties in terms of ADF, NDF, CC, and HC contents were found to be statistically significant ($P < 0.05$).

The TDN, DE, ME, and NEL contents of the quinoa varieties are given in Table 3.

As seen in Table 3, the differences between the varieties in terms of TDN, DE, ME, and NEL contents were found to be statistically significant ($P < 0.05$).

4. Discussion

The DM contents of the different quinoa varieties are given in Table 1. The DM values of quinoa ranged between 91.17% and 93.35% ($P < 0.05$). Ayaşan and Ayaşan [6] and Gül and Tekçe [18] stated that quinoa contained 87.4% DM, 13.8% CP, 5.0% CF, 59.7% carbohydrate, 3.4% CA, 4.1% fiber, and an energy of 424.2 kcal/100 g in its structure. While Repo Carrasco Valencia and Serna [19] reported that the DM content ranged between 87.38% and 89.22%, Miranda et al. [20] found it to be within the range of 84.82%–92.26%, and Villa et al. [21] found it to be 85.3%. The DM content of the quinoa grains depends on the variety of the plant, the weather conditions during the cultivation and harvesting periods, and storage conditions.

When Table 1 is examined, it may be seen that while the highest CP level was obtained from Inia431-Altiplano

Table 1. Dry matter, crude ash, crude protein, and crude fat contents of the quinoa varieties.

Varieties	DM, %	CA, % DM	CP, % DM	CF, % DM
Inia431-Altiplano	93.25^{a}	18.04^{a}	16.89^{a}	3.67^{b}
White	91.45^{b}	5.63^{b}	12.73^{b}	4.62^{ab}
Titicaca	91.33^{bc}	5.91^{b}	12.84^{b}	4.35^{ab}
Illpa Inia	93.35^{a}	16.94^{a}	16.13^{a}	4.44^{ab}
Carmen	91.17^{c}	4.94^{b}	12.96^{b}	5.02^{a}
SEM	0.192	1.163	0.434	0.157
P	<0.001	<0.001	<0.001	0.044

DM: Dry matter; CA: Crude ash; CP: Crude protein; CF: Crude fat; SEM: Standard error of mean; P: Probability; $^{a–c}$: The differences between the means indicated by different letters in the same column are statistically significant ($P < 0.05$).

Table 2. ADF, NDF, crude cellulose, and hemicellulose contents of the quinoa varieties.

Varieties	ADF, % DM	NDF, % DM	CC, % DM	HC, % DM
Inia431-Altiplano	24.54[a]	43.82[a]	19.64[a]	18.78[a]
White	5.41[b]	13.29[b]	4.33[b]	7.88[b]
Titicaca	5.88[b]	13.37[b]	4.70[b]	7.49[b]
Illpa Inia	25.26[a]	43.92[a]	20.20[a]	18.67[a]
Carmen	5.11[b]	12.39[b]	4.09[b]	7.28[b]
SEM	1.882	2.958	1.506	1.108
P	<0.001	<0.001	<0.001	<0.001

ADF: Acid-detergent fiber; NDF: Neutral-detergent fiber; CC: Crude cellulose; HC: Hemicellulose, SEM: Standard error of mean; P: Probability; [a,b]: The differences between the means indicated by different letters in the same column are statistically significant ($P < 0.05$).

Table 3. The total digestible nutrients, digestible energy, metabolizable energy, and net energy lactation contents of the quinoa varieties.

Varieties	TDN, % DM	DE, Mcal/kg DM	ME, Mcal/kg DM	NEL, Mcal/kg DM
Inia431-Altiplano	62.66[b]	2.76[b]	2.27[b]	1.42[b]
White	90.09[a]	3.97[a]	3.26[a]	2.09[a]
Titicaca	89.46[a]	3.95[a]	3.23[a]	2.07[a]
Illpa Inia	59.86[b]	2.64[b]	2.16[b]	1.35[b]
Carmen	91.29[a]	4.03[a]	3.30[a]	2.12[a]
SEM	2.869	0.127	0.104	0.070
P	<0.001	<0.001	<0.001	<0.001

TDN: Total digestible nutrients; DE: Digestible energy; ME: Metabolizable energy; NEL: Net energy lactation. [a,b]: The differences between the means indicated by different letters in the same column are statistically significant ($P < 0.05$).

with 16.89%; the lowest value was obtained from White quinoa with 12.73% ($P < 0.05$). Bhargava et al. [22] and Shams [23] found that the CP content in the seed was within the range of 12.55%–21.02% and 16.0%–23.0%, respectively. Dumanlıoğlu et al. [24] asserted that CP in the quinoa grain was statistically affected by different salt concentrations; the CP in the grain in that study was within the range of 10.8%–18.5% (mean 15.6%). In their study carried out to determine the seed yield and some agronomical characteristics of different quinoa (*Chenopodium quinoa willd.*) varieties and populations in the dry conditions of Iğdır plain, Kır and Temel [25] found that the CP content in the seed was 14.64%. Gül and Tekçe [18] reported that quinoa contained the essential amino acids necessary for the body in a balanced ratio and that the quinoa seed was important in that it was superior to the cereal grains in terms of protein (120–180 g/kg) and essential amino acids such as methionine and lysine. The protein digestion and biological value of quinoa is high. The CP content varies within the range of 10.4%–17.0% depending on the variety [4].

The average CP values (14.31%) found for the quinoa varieties in this study were higher than that (13.8%) found by Ayaşan and Ayaşan [6]. On the other hand, Kır and Temel [26] reported that the level of CP was 14.75% in quinoa, which was higher than the CP level of 14.31% found in our study. In their study carried out to determine the nutritive value, gas production, methane production, ME, and organic matter digestibility (OMS) of quinoa plant harvested at 3 different stages (preflowering, flowering, and seeding maturity); Üke et al. [27] found that as the harvest period progressed, decreases were observed in the CP ratio. In their study, it was found that while the CP of the quinoa plant cutting before the flowering was 20.62%, it was 13.05% in the full flowering harvest and 11.17% in the seeding maturity period. It was thought that these different results were due to the location, cultivation conditions (e.g., arid or wet conditions), climate, timing of the fertilizer on grain protein, and fertilizer type.

In our study, it was found that there were statistically significant differences between the quinoa varieties in terms of the CF ratio ($P < 0.05$); while Inia431-Altiplano had the lowest CF ratio with 3.67%, Carmen had the highest CF with 5.02%. Repo Carrasco Valencia and Serna [19], Villa et al. [21], Üke et al. [27], and Miranda et al. [28] have stated that the CF ratio of the quinoa plant was within the range of 4.69%–6.85% (mean 5.70%), 5.88%–7.15%, 12.4%, and 2.03%–3.55%, respectively. Zülkadir et al. [29] found that the CF ratio varied between 5.95% and 6.05% depending on the sowing time.

There were differences between the quinoa varieties in term of the CA as well; the CA ratios varied within the range of 4.94%–18.04%. Koziol [30] found that the CA content of the quinoa plant was 3.8 g/100 g fresh weight. Repo Carrasco Valencia and Serna [19] asserted that the CA content varied depending on the processing technique (raw or extruded); the CA content of the raw quinoa varieties varied within the range of 3.04%–5.46%, and that of the extruded quinoa varied within the range of 2.45%–2.66%. Miranda et al. [28] found the CA content of quinoa to be within the range of 3.15%–3.65% DM. Dağ and Özkan [5] determined the CA content to be 3.8%.

While Geren et al. [10] found CA content to be 5% and Villa et al. [21] reported the content to be 3.0%, Üke et al. [27] reported that the CA ratios of the quinoa plant were within the range of 12.22%–15.24% and that the CA ratio decreased as the maturing period progressed. Some factors such as the differences in drying and storage conditions, harvest time and fertilization, vegetation, soil structure, climate, and irrigation also affect the CA contents. In cases where the soil gets mixed with the grains during harvesting and processing, the CA contents may be higher.

When the ADF contents of 5 different quinoa varieties were examined, it was found that the contents varied between 5.11% and 25.26% ($P < 0.05$) and the NDF contents were found to be between 12.39% and 43.92% ($P < 0.05$). In a study carried out by Üke et al. [27], it was observed that the ADF content of the quinoa plant was 24.47%–31.45% and the NDF content was 37.19%–46.21%; as the harvesting period increased, the ADF and NDF ratios also increased.

As for the NEL contents, while the highest NEL value was obtained from Carmen with 2.12 Mcal/kg DM, the lowest NEL value was obtained from Illpa Inia with 1.35 Mcal/kg DM.

It was found that there were statistical differences between the quinoa varieties in terms of the CC values. Illpa Inia yielded the highest CC with 20.20%. In a study carried out by Koziol [30], the CC content of quinoa was computed as 3.8 g/100 g fresh weight. Repo Carrasco Valencia and Serna [19] stated that the CC ratios of different quinoa varieties were within the range of 1.92%–3.38%. The CC content of 6 different quinoa varieties grown in 3 different regions was found to be between 1.33% and 2.81% with a mean of 1.82% [20]. Miranda et al. [28] found the CC content of the quinoa plant to be between 2.11% and 5.70%.

The HC values ranged between 7.28% and 18.78% depending on the variety of quinoa. The total digestible nutrients differed between the quinoa varieties. Carmen had the highest TDN with 91.29%, followed by White quinoa with 90.09%. While the highest DE was observed in Carmen with 4.03 Mcal/kg DM, the lowest DE was observed in Illpa Inia with 2.64 Mcal/kg DM.

The lowest and highest values for the ME contents were found to be 2.16 Mcal/kg DM in Illpa Inia and 3.30 Mcal/kg DM in Carmen, respectively. When the ME values of the quinoa plants harvested during different ripening periods were examined, they were determined to be 8.03 MJ/kg DM before flowering, 7.45 MJ/kg DM in the full flowering, and 6.85 MJ/kg DM in the seeding maturity period [27]. In a study carried out by Repo Carrasco Valencia and Serna [19], it was determined that in vitro protein digestibility of quinoa varieties was between 76.3% and 80.5%; on the other hand, their in-vitro starch digestibility was between 65.1% and 68.7%. Dumanlıoğlu et al. [24] found the CP content of quinoa grain to be between 10.8% and 18.5%. Vega-Galvez et al. [31] stated that the CPs of different quinoa varieties were within the range of 12.5%–16.7%.

In conclusion, when the findings obtained from this study were evaluated, it was concluded that there were statistically significant differences between the different quinoa varieties in terms of the nutrient contents. When it comes to CP, the Inia431-Altiplano and Illpa Inia varieties stand out. When it comes to ME, DE, and NEL, the Carmen variety stands out. This is a preliminary trial. We believe that there is a need for future studies on the in vitro gas production of quinoa.

Conflict of Interest

The author declared that no conflict of interest exists.

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