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RESEARCH ARTICLE

Determination of Mineral Content of Seeds Belonging to Different Quinoa Varieties and their Evaluation for Daily Mineral Requirements of Laying Hens

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ABSTRACT

No study has been conducted to determine the mineral content of seeds belonging to different quinoa varieties under the conditions of Turkey. In addition, there is no study on whether quinoa seeds that containing high amounts of minerals can be utilized for mineral needs of laying hens in particular. In this study, which was carried out under Erzurum irrigated conditions, it was aimed to determine the mineral content of seeds belonging to nine quinoa varieties and whether they can appropriately utilize for meeting mineral requirements (as recommended by NRC) of laying hens. Significant differences were observed in the mineral contents of the varieties. The phosphorus, potassium, calcium, magnesium, iron, copper, manganese, zinc and boron contents of the seeds varied between 0.18-0.25%, 0.76-1.08%, 0.07-0.12%, 3427-5453 mg kg^{-1}, 233.8-577.8 mg kg^{-1}, 45.6-107.8 mg kg^{-1}, 40.2-72.9 mg kg^{-1}, 29.8-55.4 mg kg^{-1} and 48.3-94.7 mg kg^{-1}, respectively. When these results were compared with the values recommended by NRC, it was seen that quinoa seeds could exceedingly meet the daily mineral requirements (except calcium) of laying hens. As a result, it has been revealed that the seeds of all quinoa varieties can be evaluated as an organic mineral source in the feeding of laying hens.

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Introduction

Quinoa (*Chenopodium quinoa* Willd.), an annual pseudo cereal, is seen as an alternative crop in human and animal nutrition in many regions of the World since it adapts well to different climate and soil conditions and has a high nutritional value (Jacobsen et al., 2007; Geerts et al., 2008; González et al., 2012; Abtahi Adolf et al., 2013; Ruiz et al., 2014; Tan and Temel, 2017a; Tan and Temel, 2018; Temel and Yolcu, 2020). The fact that the seeds and vegetative parts (leaf + stem) having quality fiber, balanced amino acid, high protein and energy content is an important factor in the consideration of the plant as a valuable alternative source of nutrition (González et al., 2012; Rojas and Pinto, 2015; Tan and Temel, 2017b; Tan and Temel, 2019; Temel and Keskin, 2020; Temel and Tan, 2020).

In addition, quinoa seeds have a higher content of mineral substances, such as Ca, K, Fe, P, Zn, Mg, Cu and Mn, than such grains as wheat, barley, rice, oats and corn, and are good organic mineral sources for meeting the nutritional needs of humans and animals (Repo-Carrasco-Valencia et al., 2003; Konishi et al., 2004; Stikic et al., 2012). On the other hand, the mineral content of seeds may differ depending on the environmental factors, cultural practices and varieties. However, a small number of studies have been conducted for this purpose and it has been revealed that the mineral contents of seeds differ according to environmental conditions and varieties. In these previous studies, the Ca, K, Fe, P, Mg, Zn, Cu and Mn contents of the seeds were reported to vary between 251-1490 mg kg^{-1}, 4984-12595 mg kg^{-1}, 47-240 mg kg^{-1}, 12371-4543 mg kg^{-1}, 855-5020 mg kg^{-1}, 16-80.0 mg kg-1, 3.48-70.0 mg kg^{-1} and 15.6-38.53 mg kg^{-1}, respectively (Karyotis et al., 2003; González et al., 2014; Prado et al., 2014). However, there is no study conducted to determine the mineral content of seeds belonging to different quinoa varieties under the conditions of Turkey. Therefore, it

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is important to determine the most suitable varieties in terms of mineral composition by means of adaptation studies.

On the other hand, needs of mineral nutrients, which are important for living creatures to survive and meet their physiological needs, must be known well and these needs must be met. Providing adequate and balanced amounts of mineral substances, especially for poultry (laying hens), is very important for the development of the skeletal system and the formation of a strong egg shell as well as reproductive performance (Dikmen et al., 2015). In this respect, minerals such as Ca, P, Mn, Zn, Cu and Cr play a particularly important role (NRC, 1994; Manangi et al., 2015). Moreover, it was explained that minerals such as Mg, K, Na, Fe and B were important for obtaining a strong and high quality shell in laying hens (NRC, 1984; NRC, 1994). However, in order to obtain the expected benefits, the daily mineral needs of the animal must be calculated in advance and the appropriate rations must be prepared.

To this end, the National Research Council made recommendations on the participation levels of minerals in poultry diets and on the nutrient contents of more than 70 feed ingredients which are used extensively in rations of the poultry. In the prepared rations, the use of organic minerals added at lower levels has gained importance compared to inorganic minerals due to its high absorption, improving egg shell quality and increasing the usefulness of some minerals and nutrients (Carvalho et al., 2015; Dikmen et al., 2015; Manangi et al., 2015; Singh et al., 2015; Yenice et al., 2015). However, it has been observed that commonly-used herbal sources are not sufficient to meet the mineral requirements of the poultry since they have low mineral composition content and do not contain some mineral substances (Okuyan and Fulya, 2003; Ozek, 2016). Thus, quinoa seeds with high mineral content can be seen as an advantage in terms of meeting mineral requirements of the poultry. However, considering the macro and micro nutrient composition of quinoa seeds as an alternative feed raw material, there is no evaluation as to whether laying hens can meet their mineral needs.

With this study carried out in Erzurum under irrigated conditions, it was primarily aimed to determine the most suitable varieties in terms of meeting the mineral needs of laying hens by revealing the macro and micro mineral contents of the seeds belonging to different quinoa varieties. Then, considering the recommendations of NRC, it was aimed to determine the suitability of the mineral composition of the seeds for laying hens.

Materials and Methods

Experimental Site

The research was carried out in Erzurum province located in the north-east of Turkey at an altitude of 1876 m during the 2015 growing season (May-September). In terms of climate conditions, summers in Erzurum (trial area) are relatively cool and dry while winters are cold and snowy. According to the long-years averages, while the total precipitation was 181.2 mm, the average temperature was 15.7 °C and the relative humidity was 53.3% in months during which the trial was carried out, the total rainfall, average monthly temperature and relative humidity values of 2015 were 158.5 mm, 17.7 °C and 47.3%, respectively (Table 1) (MGM, 2016). The textural class of the soil (0-30 cm) in which the research was carried out was clay-loam, and its organic matter (1.4%) and lime (2.5%) content was low, it had a slightly saline (0.48 dS cm^{-1}) and neutral (pH: 7.1) character, with moderate available phosphorus content (74 kg P_2O_5 ha^{-1}) and rich potassium (1380 kg K_2O ha^{-1}) content (Kacar, 2012).

Table 1. Some macro mineral contents of seeds belonging to different quinoa varieties

Varieties	P (%)	K (%)	Ca (%)	Mg (mg kg^{-1})
Cherry Vanilla	0.18 c	0.91 ab	0.09 b-d	3478 bc
French Vanilla	0.20 bc	1.01 a	0.10 ab	5233 a
Mint Vanilla	0.21 a-c	0.99 a	0.09 b-d	4468 a-c
Moqu Arrochilla	0.20 bc	1.08 a	0.12 a	5453 a
Oro de Valle	0.22 ab	0.77 b	0.07 de	3588 bc
Rainbow	0.20 bc	1.04 a	0.11 ab	5310 a
Red Head	0.20 bc	0.76 c	0.07 e	3427 c
Sandoval Mix	0.25 a	0.98 a	0.10 a-c	4938 ab
Titicaca	0.22 ab	1.04 a	0.08 c-e	4104 a-c
Mean	0.21	0.95	0.09	4444
LSD	0.04**	0.18**	0.02**	1511**

**Significant at P<0.01. Means followed by the same letter in the same column are not significantly different by LSD test (P<0.05)

Materials

Nine different quinoa (*Chenopodium quinoa* Willd.) varieties were used in the trial which was established under irrigated conditions according to randomized blocks experimental design in four replicates. Rainbow, Read Head, Cherry Vanilla, French Vanilla, Mint Vanilla and Oro de Valle varieties were procured from the U.S.A. while Moqu-Arrochilla were procured from Peru, Sandoval Mix from England and Titicaca from Denmark.

Experimental Set-up

Sowings of all varieties were done on May 5, 2015 on plots designated to cover 8.4 m 2 (4 m x 2.1 m) with 1.5-2.0 kg seeds per ha-1 sown by hand into 1.5-2.0 cm deep furrows, with 35.0 cm row spacing, drawn by a marker (Geren et al., 2015). Fertilizer was applied to soil (125 kg N and 80 kg P_2O_5 per ha^{-1}) according to soil analysis results (Geren, 2015). During the vegetation period, the water requirement of the plants was provided by the flooding method, taking into account the precipitation and moisture condition of the soil. Also in this process, weeds seen in and between the parcels were taken under control by hoeing and plucking.

Measurement

Seed harvests were performed manually at physiological maturity, defined as when the seeds became resistant when compressed (Bertero et al., 2004). After the harvest, the plants were dried in the open air for five days and then in a drying oven set at 35 °C. The dried plants were then blended and the grains were separated from the stems. Then, unprocessed quinoa seeds were ground, so as to they can pass through 1 mm sieve, and thus made ready for analysis. Quinoa seeds often have saponin-containing pericarps that have a bitter taste. Therefore, these pericarps are removed when the product is sold commercially and used in human nutrition. However, since removing the pericarp requires an additional expense (Temel and Tan, 2019), it is recommended to use unprocessed (untestaed) seeds in animal nutrition. In addition, the mineral content of the quinoa is accumulated in the outer bran layer such as in cereals (Repo-Carrasco-Valencia and Serna, 2011). For this reason, in the current study, the mineral contents of the varieties were determined using unprocessed quinoa seeds. For nutritional composition, the grains were prepared by the wet digestion method using an H2SO4: HClO4 acid mixture (4:1 v/v) (Kacar and Inal, 2008). Nutritional composition (K, Mg, Ca, Fe, Zn, Mn and Cu) of each grain sample solution were determined by inductively coupled plasma-mass spectrometry (ICP-MS; Thermo Scientific, X Series, Cambridge, U.K.). P contents of the grains were measured by UV-Vis spectrophotometer (UV-1800, Shimadzu, Japan) (Kibar and Temel, 2016). The boron analysis was measured using the azomethine-H extraction method spectrophotometer.

Statistical Analysis

The obtained results were analyzed in JMP statistical software according to the randomized blocks experimental design. The grouping of significant means was done according to LSD test.

Results and Discussion

Phosphorus (P)

In this study, the phosphorus content of the seeds belonging to the quinoa varieties showed significant differences (Table 1). The highest phosphorus content was determined in the Sandoval Mix variety (0.25%) while the lowest P value was determined in Cherry Vanilla (0.18%). In previous studies, it was revealed that there were differences in the phosphorus content (0.27-0.45%) among the seeds of quinoa varieties (Stikic et al., 2012; González et al., 2014). This may be due to varieties used in the study have different genetic structures and react differently to environmental conditions. Indeed, Karyotis et al. (2003) and Prado et al. (2014) explained that the phosphorus content (0.12-0.39%) of the seeds varies significantly according to the variety and environmental conditions. Furthermore, the fact that the varieties have different embryo sizes may have caused this situation. It was reported by Konishi et al. (2004) that phosphorus in quinoa seeds was substantially found in embryos. Phosphorus enters the bone structure in laying hens and, in addition, acts as an essential mineral in the fat and amino acid metabolisms of carbohydrates. It also plays a role in the working of muscles and nervous tissue metabolism. Thus, available (usable) levels of phosphorus are needed for a healthy survival, good growth and egg yield. The phosphorus requirement by laying hens, as reported by NRC (1994), is 0.21%. When Figure 1a was examined, it was seen that while Oro de Valle, Sandoval Mix, Titicaca and Mint Vanilla varieties easily met the daily phosphorus requirements of laying hens, the P content of other varieties were insufficient.

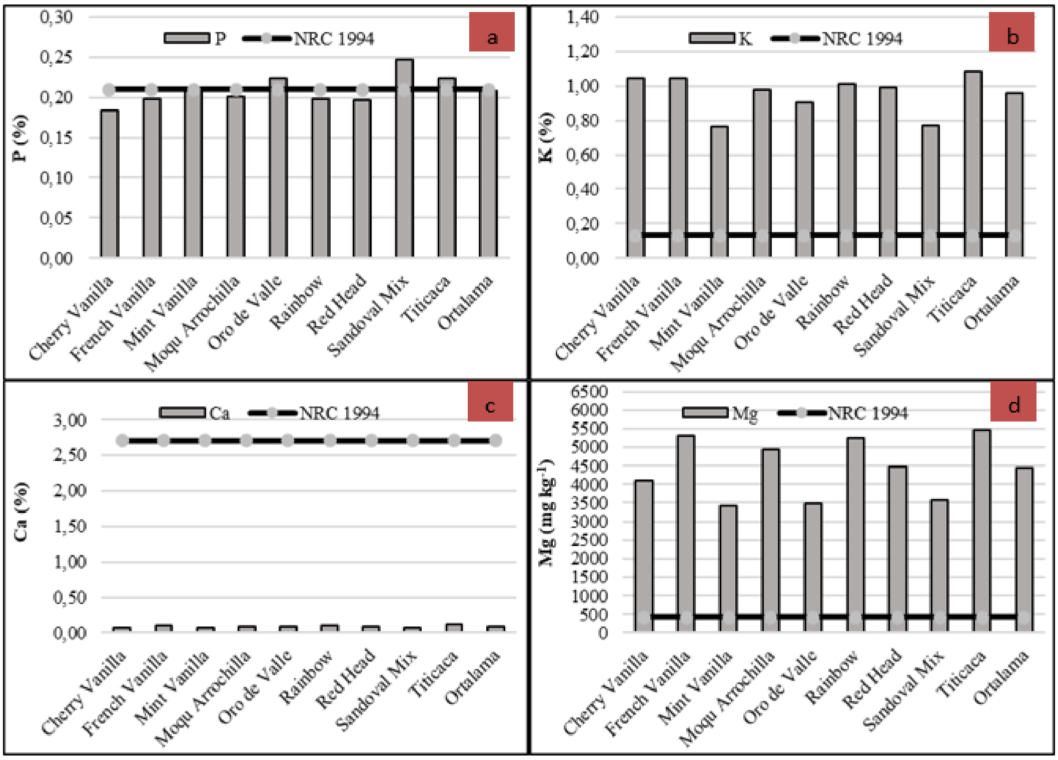

Figure 1. The P (a), K (b), Ca (c) and Mg (d) contents of quinoa varieties necessary to meet the requirements of laying hens according to NRC (1994)

Potassium (K)

Among the quinoa varieties examined, the potassium content of the seeds was found to be significantly different, and the seed potassium contents varied between 0.76-1.08% (Table 1). In particular, the potassium contents of other varieties, except Red Head, Cherry Vanilla and Oro de Valle, were found to be in the same statistical group and were at the highest level (Table 1). In previously conducted studies, the seed potassium content was reported to be varying according to the varieties, however, it was determined as 0.95% on average (Konishi et al., 2004; Stikic et al., 2012). This value was similar to the average potassium content (0.95%) of the quinoa varieties examined in our current study. Yet, this finding was significantly lower than the value (1.82%) found by Karyotis et al. (2003). This variation between the varieties may have resulted from the fact that the varieties have different pericarp thickness or ratio besides the environmental factors. Because potassium is found in pericarp of quinoa at the maximum (Konishi et al., 2004). Indeed, it was reported by Prado et al. (2014) that the varieties had a different potassium content (0.50-1.13 %) depending on the pericarp in quinoa. Potassium, which is one of the important determinants of acid-base balance, is a mineral that laying hens need for growth, bone development, egg shell quality and amino acid utilization. Therefore, the potassium requirement (0.13%) recommended by the NRC (1994) for laying hens must be met and be available in the prepared rations. In the present study, K content (0.95%) of the quinoa seeds studied was found to be higher than that of wheat (0.50%), rice (0.12%), corn (0.38%), barley (0.58%) and oat (0.46%), which are widely used in poultry nutrition. Thus, it was observed that quinoa seeds have high potassium content and meet the daily potassium requirements of laying hens (Figure 1b).

Calcium (Ca)

Quinoa seeds are rich in calcium (Repo-Carrasco-Valencia et al., 2003; Stikic et al., 2012) and it was reported that the Ca content of the seeds varied between 0.03-0.13% (González et al., 2014) as to varieties. In the present study, the Ca content of the seeds also showed significant differences between the varieties. The Ca ratio of quinoa varieties varied between 0.07-0.12% and the highest Ca ratio was determined in Moqu Arrochilla variety (Table 1). This may have been caused by the fact that the varieties have different genetic structures and react differently to environmental conditions. It was explained by Prado et al. (2014) that seed calcium contents differ by 0.03-0.12% between the varieties as well as between the same varieties grown under different ecological conditions. These values are similar to the results of our study. On the other hand, Ca is mostly found in pericarp and testa in quinoa seeds (Konishi et al., 2004). Therefore, the fact that pericarps depending on the varieties have a different Ca content cause the seeds to have different levels of Ca content (Prado et al., 2014). Calcium is a mineral that plays a primary role in the synthesis of egg shell as well as skeletal formation. In addition, over 2 grams of calcium is eliminated from the body during egg-laying. For this reason, calcium requirement of laying hens is quite high, and this is very closely related to the calcium that the chicken takes with the feed. It was recommended by NRC (1994) that the daily required Ca value for laying hens should be 2.71%. In this respect, the Ca contents of the quinoa varieties investigated in this study were found to be far from meeting the daily requirements of laying hens (Figure 1c). However, it can be said that quinoa seeds have a higher mineral content than cereals (0.015-0.094%) (Konishi et al., 2004; Stikic et al., 2012) that are widely used in feeding of laying hens.

Magnesium (Mg)

The seed magnesium content was found to be differing significantly among varieties investigated in this study and Mg content of the varieties varied between 3427-5453 mg kg^{-1} (Table 1). Looking at Table 1, it was seen that Moqu Arrochilla (5453 mg kg^{-1}), Rainbow (5310 mg kg^{-1}) and French Vanilla (5223 mg kg^{-1}) varieties, which were in the same statistical group, had the highest Mg content. In studies conducted with different quinoa varieties, it was also revealed that the seeds had different Mg content (Stikic et al., 2012). These values obtained from our current study were similar to the results of some previously-conducted studies, whereas they were found to be higher than the results of some previous research. These differences may have resulted from different responses to climate and soil conditions, depending on the genetic structure of the varieties. Indeed, it was explained by Prado et al. (2014) that Mg contents of the same varieties grown in different locations with different climate characteristics varied substantially (855-3620 mg kg^{-1}). Nevertheless, it was reported by Karyotis et al. (2003) that varieties grown in two locations with different soil properties had different Mg (3460-6490 mg kg^{-1}) content. Mg is the most abundant element in all tissues and bones of laying hens, following calcium and phosphorus. Magnesium is also the most common enzyme activator and is a necessary mineral for the formation of a robust and quality egg shell (Venglovska et al., 2014). Therefore, 400 mg $kg^{-1}$of magnesium, which is the amount recommended by NRC (1994) for laying hens, should be included in prepared rations. When Figure 1d was examined, it was seen that the Mg content (3427-5453 mg kg^{-1}) of the quinoa seeds belonging to different varieties met the daily Mg requirement of laying hens and was below the 11200 mg kg^{-1}, which is considered as the toxic level.

Iron (Fe)

The iron content of the seeds was found to be significant among the varieties and the highest Fe content was determined in Moqu Arrochilla variety with 577.8 mg kg^{-1}while the lowest value was determined in Mint Vanilla with 233.8 mg kg^{-1} (Table 2). It was also shown by González et al. (2014) that the Fe content of the quinoa varied between 0-948.5 mg kg^{-1}. Moreover, it was reported by Prado et al. (2014) that the Fe content of the seeds of quinoa varieties ranged between 47.6 and 240.4 mg kg^{-1}. Current results have shown that the seed Fe content in quinoa varies significantly depending on the genetic structure of the varieties. Fe, which is involved in many physiological and biosynthesis events in the organism, is required in low amounts in poultry feeding. However, it was emphasized that adding organic Fe source in the diets of laying hens had a significant effect on feed consumption, feed utilization and egg weight (Paik et al., 2009; Seo et al., 2010). In this study, it was observed that the Fe content of the quinoa varieties studied was quite sufficient for the daily requirements of the laying hens (Figure 2a). Indeed, the amount of Fe that should be added to the rations of laying hens was recommended as 38 mg kg^{-1} by NRC (1994).

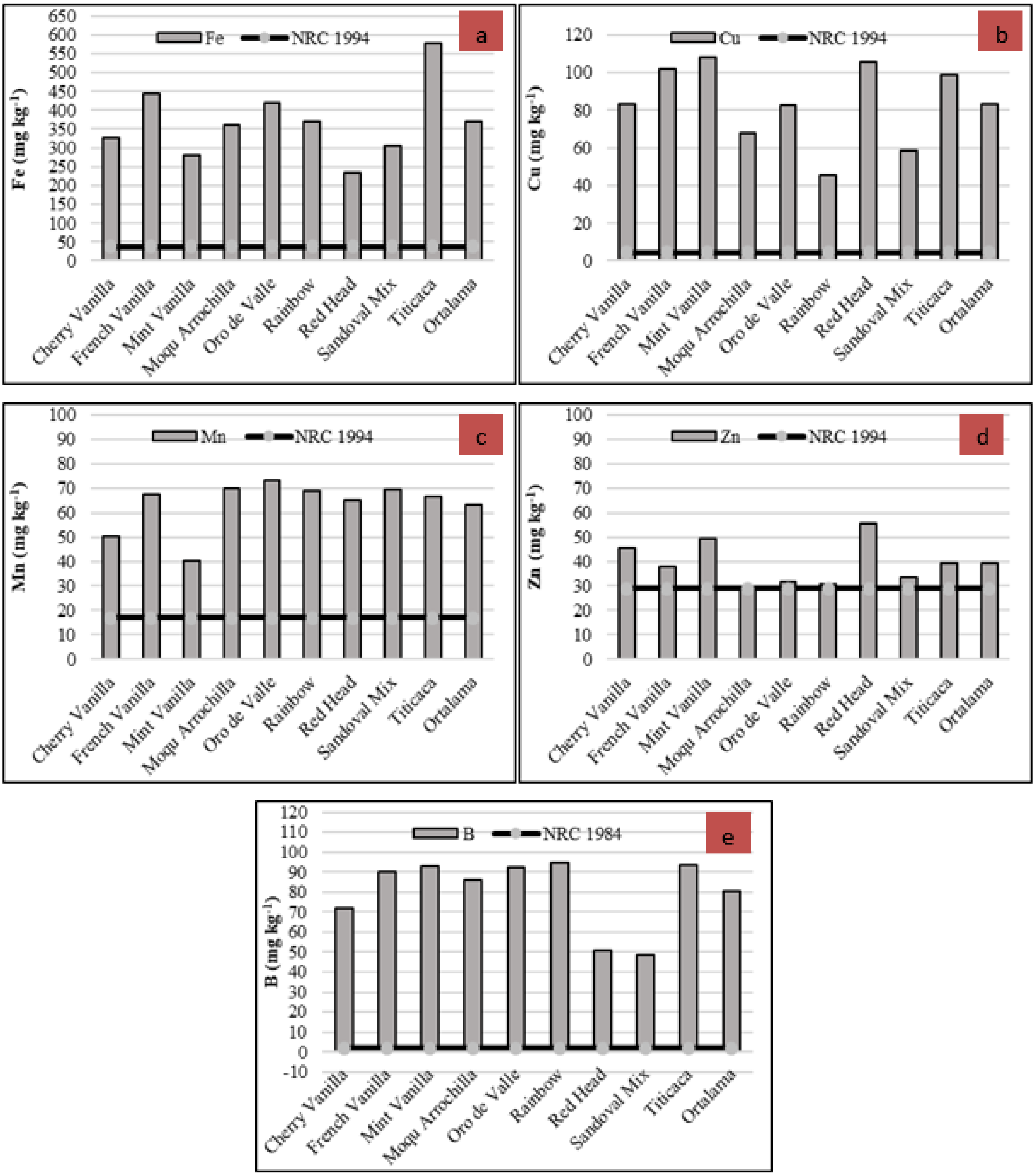

Figure 2. The Fe (a), Cu (b), Mn (c), Zn (d) and B (e) contents of quinoa varieties necessary to meet the requirements of laying hens according to NRC (1994)

Table 2. Some micro mineral contents of seeds belonging to different quinoa varieties (mg kg^{-1})

Varieties	Fe	Cu	Mn	Zn	B
Cherry Vanilla	420.5 bc	82.5 bc	72.9 a	31.9 ef	92.4 a
French Vanilla	369.5 cd	45.6 e	68.9 ab	30.9 ef	94.7 a
Mint Vanilla	233.8 f	105.4 a	64.9 ab	55.4 a	51.1 c
Moqu Arrochilla	577.8 a	98.5 a	66.5 ab	39.4 cd	93.7 a
Oro de Valle	304.8 d-f	58.8 de	69.1 ab	33.8 d-f	48.3 c
Rainbow	445.7 b	101.9 a	67.6 ab	38.0 de	90.4 a
Red Head	278.9 ef	107.8 a	40.2 c	49.1 ab	92.7 a
Sandoval Mix	359.2 cd	67.7 cd	69.7 ab	29.8 f	86.4 a
Titicaca	328.1 de	83.1 b	50.1 bc	45.3 bc	72.0 b
Mean	368.70	83.48	63.32	39.29	80.19
LSD	75.1**	15.2**	22.1**	7.1**	12.6*

**Significant at P<0.01. Means followed by the same letter in the same column are not significantly different by LSD test (P<0.05)

Copper (Cu)

The effect of varieties on copper content was found to be significant and the Cu content of seeds varied between 45.6-107.8 mg kg^{-1}. The highest Cu content was determined in Red Head (107.8 mg kg^{-1}), Mint Vanilla (105.4 mg kg^{-1}), Rainbow (101.9 mg kg^{-1}) and Moqu Arrochilla (98.5 mg kg^{-1}), which were also found to be statistically in the same group (Table 2). It was also found by Karyotis et al. (2003) that the copper content varied between 12.4-18.6 mg kg^{-1} as to varieties, however, the results obtained in the present study were higher than these values. These differences may have resulted from the genetic structure of the varieties and environmental conditions. Indeed, Prado et al. (2014) reported that the same varieties had different Cu contents at different locations. Copper is a mineral that poultry needs in low amounts. However, it is necessary for cell respiration, bone formation, keratination, tissue pigmentation, central nervous system, reproduction, immune system and lipid metabolism (Okuyan and Fulya, 2003). Thus, the amount recommended by NRC (1994) (4.5 mg kg^{-1}) for laying hens must be met. Looking at Figure 2b, it was seen that the quinoa varieties included in the present study can exceedingly meet the daily Cu requirement of laying hens.

Manganese (Mn)

The manganese contents of the quinoa seeds differed significantly among the varieties. The highest and lowest manganese contents were determined in Cherry vanilla (72.9 mg kg^{-1}) and Red Head (40.2 mg kg^{-1}), respectively, and the average manganese content of the varieties was found to be 66.5 mg kg^{-1} (Table 2). It was explained by Prado et al. (2014) that the Mn content differs as to quinoa varieties. In addition, Karyotis et al (2003) stated that the Mn content of the seeds differs between varieties and they have an average Mn content of 65.1 mg kg^{-1}. This value reported by Karyotis et al (2003) was similar to the result obtained in our current study. Egg yield, shell quality and laying power in laying hens are significantly affected by manganese (Mn), which enters the composition of bones and the structure of enzymes (Okuyan and Fulya, 2003). The Mn ratio that should be present in daily rations of laying hens was recommended by NRC (1994) as 17 mg kg^{-1}. Our research results showed that the quinoa varieties included in the study had higher Mn content than such grains as wheat (26 mg kg^{-1}), rice (25 mg kg^{-1}), corn (24 mg kg^{-1}), barley (15 mg kg^{-1}) and oat (22 mg kg^{-1}) (Konishi et al., 2004; Stikic et al., 2012) that are widely used in poultry feeding. Thus, our results have shown that quinoa seeds can meet the daily Mn requirements of laying hens (Figure 2c).

Zinc (Zn)

Zinc contents of the seeds of quinoa varieties were found to be statistically significant at 1% significance level. The Zn content of the seeds varied between 29.8-55.4 mg kg^{-1} and the highest ratio was determined in Mint Vanilla variety (Table 2). This may be due to the fact that the varieties originated from different regions and react differently to environmental conditions. Indeed, Karyotis et al. (2003) stated that the zinc content of the seeds varied between 34-67 mg kg^{-1} among the quinoa varieties and that the varieties which can adapt well to the environmental conditions accumulate Zn in their seeds at a higher rate. Zinc (Zn), which acts as a cofactor in many enzymatic systems, takes part in important mechanisms such as hormone secretion, growth, reproduction, immune system and egg shell formation (Bulbul, 2004; Buff et al., 2005). Thus, the required Zn amount per day per hen recommended by NRC (1994) must be met. However, since most of the foods used as feed raw materials have Zn deficiency, requirements of this micronutrient is mostly unmet (Ravindran, 2010). However, except for the Moqu Arrochilla, Rainbow and Oro de Valle (which is found to be just at the limit significance value), it was seen that the daily Zn requirements of laying hens can be easily met by the varieties investigated in the study (Figure 2d).

Boron (B)

The boron content of the quinoa seeds varied significantly as to varieties, and it was measured to be between 48.3-97.7 mg kg^{-1}. The highest boron contents were determined in French Vanilla (94.7 mg kg^{-1}), Moqu Arrochilla (93.7 mg kg^{-1}), Red Head (92.7 mg kg^{-1}), Cherry Vanilla (92.4 mg kg^{-1}), Rainbow (90.4 mg kg^{-1}) and Sandoval Mix (86.4 mg kg^{-1}) varieties and these varieties were included in the same statistical group (Table 2). It was also reported by Karyotis et al (2003) that the seed boron content differs among quinoa varieties. It is thought that boron interacts with minerals such as Ca, Mg and P which play an effective role in animal metabolism, particularly in bone metabolism (Bintas, 2013). For this reason, it is recommended that a low ratio of boron as 2 mg kg^{-1} per day is appropriate in poultry rations (NRC

1984). However, since the grains used in poultry rations generally have low boron content, they cannot meet the daily requirements of hens. However, quinoa varieties researched in the present study are rich in boron content (48.3-94.7 mg kg-1) and can meet the daily needs of laying hens (Figure 2e).

Conclusion

As a result of the study, macro and micro mineral content of quinoa grains showed significant differences between varieties. The highest P, K, Ca and Mg content were determined in the Sandoval Mix variety and Fe, Cu, Mn, Zn and B content in the Moqu Arrochilla. In addition, it was observed that French Vanilla, Moqu Arrochilla and Rainbow varieties in terms of K, Ca and Mg content, Titicaca and Mint Vanilla varieties in terms of P, K and Mg content had a higher nutritional composition. On the other hand, the macro and micro mineral contents of quinoa grains were seen to be higher than the cereals commonly used in the feeding of laying hens. As a result, considering the average mineral composition of the varieties examined, it has been revealed that quinoa seeds can be an important alternative source of organic mineral in terms of meeting the daily mineral requirements (excluding calcium) of eggs hens.

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Compliance with Ethical Standards

a) Authors' Contributions

Author ST designed the study and interpreted data, performed the laboratory work and drafted the paper.

b) Conflict of Interest

c) Statement on the Welfare of Animals

Ethical approval: For this type of study, formal consent is not required.

d) Statement of Human Rights

Ethical approval is not required for this type of study.

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