



Protein and mineral content of bean grains from landrace cultivars grown under organic farming

Teor de proteína e minerais de grãos de cultivares crioulas de feijão provenientes de sistema de cultivo orgânico

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ABSTRACT

Bean grains have very important nutritional components, ensuring a balanced diet especially because of their levels of proteins, carbohydrates, and minerals. Year after year, there is an increasing demand for healthy foods grown under organic farming systems, whose strategies include the use of landrace cultivars. The objective of this study was to quantify the protein and mineral content in bean grains from landrace cultivars grown under an organic and conventional farming system. A total of 26 cultivars were used: 22 landrace and four commercial cultivars. There was variability between landrace and commercial cultivars for all study nutrients in both organic and conventional farming systems. In general, bean grains grown under organic farming showed nutrient contents higher or similar to those of the conventionally grown grains, especially the BAFs (Bean Germoplasm Collection) landrace cultivars 47, 55 and 75.

Keywords: Agroecology; Genetic diversity; Nutrient content; *Phaseolus vulgaris* L.

RESUMO

O feijão apresenta componentes de grande importância nutricional, garantindo uma dieta equilibrada principalmente quanto aos teores de proteínas e minerais. Aliados aos fatores nutricionais crescem anualmente a busca por alimentos saudáveis produzidos em sistemas de produção com base ecológica, sendo uma estratégia o uso de cultivares crioulas. O objetivo deste trabalho foi quantificar os teores de proteína e minerais nos grãos de cultivares crioulas de feijão produzidas em sistema de cultivo orgânico e convencional. Foram utilizados 26 cultivares sendo 22 crioulas e quatro comerciais. Foi observada variabilidade entre as cultivares crioulas e comerciais para todos os nutrientes analisados em ambos sistemas de cultivo, orgânico e convencional. De maneira geral os grãos de feijão produzidos no sistema de cultivo orgânico apresentaram teores de nutrientes superiores ou semelhantes aos grãos produzidos no sistema de cultivo convencional, com destaque para as cultivares crioulas BAFs (Banco de Germoplasma de Feijão) 47, 55 e 75.

Palavras-chave: Agroecologia; Diversidade genética; *Phaseolus vulgaris* L.; Teor de nutrientes.

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1 INTRODUCTION

The intake of essential proteins and amino acids is necessary for adequate human nutrition, and in the face of the continuous population growth, the regular and low-cost consumption of these nutrients is currently a challenge. Many plant species offer the population affordable food choices for a balanced diet (Sá *et al.*, 2020). The common bean (*Phaseolus vulgaris* L.) is one of the most widely grown plants of the family Fabaceae worldwide (Murube *et al.*, 2021), and it is described as an important source of protein, carbohydrates, fiber, vitamins, and minerals (Karavidas *et al.*, 2022). The elements iron, zinc, copper, phosphorus, and aluminum are the major mineral micronutrients present in beans (Murube *et al.*, 2021).

Foods of plant origin, for example, the ones from the family Fabaceae, contain not only nutritional substances that are essential for health, but also antinutritional factors (Higashijima *et al.*, 2020). Antinutritional factors are called as such because they may compromise the absorption of nutrients, acting as chelators of minerals such as calcium, iron, magnesium, zinc, copper, and potassium, and interfering with the availability of these minerals and essential amino acids (Kumar *et al.*, 2010).

In addition to the nutrients mentioned above, beans have phenolic compounds like phytate, which is the main form of phosphorus storage in bean seeds (Higashijima *et al.*, 2020). Although phytate is considered antinutritional (Barreto *et al.*, 2021), because of its interaction with proteins and minerals, it has beneficial health effects when present in small concentrations; for example, it has antioxidant and anticarcinogenic properties, among others (Pinheiro *et al.*, 2020).

It is known that the nutritional quality of bean seeds may vary according to several factors, for example, the genetic constitution and the edaphoclimatic characteristics of farming sites (Sica *et al.*, 2021). However, little is still known about the nutritional composition of seeds grown under different farming systems (Barreto *et al.*, 2021), especially organic ones. The growing concern in producing and consuming healthier foods, with better nutritional composition, decreased use of pesticides, and lower impact on the environment, emphasizes the importance of research on organic farming systems.

Moreover, the use of landrace cultivars has a strategic role in developing ecologically-based farming systems. They are extremely important for ensuring the food safety of the world population, since they have wide genetic variability and offer greater socioeconomic autonomy (Bai *et al.*, 2024). Given the need for valuable insights into the subject, the objective of this study was to evaluate the protein and mineral content of seeds of landrace bean cultivars grown under an organic and conventional farming system.

2 MATERIAL AND METHODS

The experiment was conducted at Epagri (Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina) experimental station, in the municipality of Campos Novos/SC. The grains were grown in two cropping seasons, in the same place, considering 2012/2013 as season 1 and 2013/2014 as season 2. Organic and conventional farming systems were used in both seasons. The study used a randomized block design with four

replications. The plots were composed of four 4-meter rows, spaced 0.5 m each, with density of 15 seeds m⁻¹. The usable area of each plot was composed of two central rows, excluding 0.5m of each end.

In both systems, white oats (*Avena sativa*) and vetch (*Vicia sativa*) were used at the densities of 50 kg.ha⁻¹ and 30 kg.ha⁻¹, respectively. Broadcast seeding was performed to implement the winter cover crop. For organic production, the soil was fertilized with 5.000 kg.ha⁻¹ of poultry manure: 1/3 for basal application and 2/3 for topdressing fertilization. For pest and disease management, 0.5% of neem oil was used in the initial phase and then 1%, until the end of the crop cycle. The applications were based on weekly crop monitoring to identify the basal level of infestation, and the products were applied every ten days as a preventive measure. Along with neem oil, 40 mL.20 L⁻¹ of pepper extract (Plantil Plus) and diatomaceous earth at 1% were applied for insect repellency. For weed control, weeding was performed four times throughout the cycle.

Crop management in the area under conventional farming was performed using a soluble chemical fertilizer N-P₂O₅-K₂O at the time of sowing at the rate of 400 kg.ha⁻¹; 15 days after plant emergence, topdressing fertilization with urea (45-00-00) was performed at a rate of 80 kg.ha⁻¹, divided into two application times (stages V3 and R5 of the crop).

A total of 26 bean cultivars were used: 22 landrace cultivars from the active bean germplasm collection (BAF) of Santa Catarina State University – Agroveterinary Sciences Center (UDESC/CAV), and four commercial cultivars. Landrace cultivars from the BAF are: 3 (Manchinha), 4 (Amendoim), 7 (Preto), 13 (Taquara), 23 (Preto), 36 (Rasga), 42 (Vagem Branca), 44 (Vermelho), 46 (unnamed), 47 (Preto precoce), 50 (Carioca Brilhante), 55 (Preto), 57 (Preto), 60 (Preto 60 days), 68 (Vermelho), 75 (Serrano), 81 (Preto 70 days), 84 (Carioca Rosado), 97 (Charque), 102 (México 309), 108 (Branco) and 120 (Roxinho). Commercial cultivars from the BAF are 110 (SC 202 Guará), 112 (IPR 88 Uirapuru), 115 (BRS Valente), and 121 (IAPAR 81).

After reaching physiological maturity, bean pods were harvested when their moisture content was close to 12% and after that, the grains were threshed manually. The grains were placed in paper bags and stored in a dry chamber (10 ± 2 °C and relative air humidity 45 ± 5%) until analyses, which were performed in the Seed Analysis Laboratory, of the UDESC/CAV. In previous studies, under the same cropping system and cultivars evaluated, Zilio *et al.*, (2011) and Prezzi *et al.*, (2014) had already conducted works characterizing grain productivity.

Nutrient content was determined in the Seed Analysis Laboratory, of the UDESC/CAV and at the Soil Laboratory of the University of Western Santa Catarina – UNOESC, in Campos Novos/SC. Sulfuric acid digestion was performed to determine nitrogen (crude protein), potassium (K), and phosphorus (P), and nitric/perchloric digestion was performed for determination of zinc (Zn) and iron (Fe). Crude protein analysis was based on the Kjeldahl method, using a conversion factor of 6.25 (N x 6.25). The results were calculated as a percentage, according to the AOAC method (1995). The diluted aliquot resulting from digestions was used to determine iron, zinc, and potassium concentrations by atomic absorption spectrophotometry. Phosphorus content was determined by spectrophotometry in an aliquot of the extract after the addition of ammonium molybdate and amino-naphthol-sulfonic acid. The nutrient results were expressed in g.kg⁻¹ for P and K, and mg.kg⁻¹ for Fe and Zn.

The methodology proposed by Latta and Eskin (1980) was used to determine phytate content in grains. Phytate was extracted with HCl 2.4% and anion exchange resin (Dowex 1x 8-400 Sigma) was used to clean the sample. The samples were read by removing an aliquot of the supernatant and adding Wade reagent (0.03g of hexahydrate ferric chloride and 0.3g of sulfosalicylic acid in a volume of 100 mL). The results were read in a spectrophotometer, at a wavelength of 500 nm, and the results were expressed in g.kg^{-1} .

The data underwent analysis of variance by the F-test. The Scott-Knott test was used for comparisons between the mean values of each of the study variables in the different cultivars in each cropping season. Tukey's test, at the level of 5% probability, was used for comparisons between farming systems for each cultivar and cropping season. The seasons were not considered as factors for statistical analyses, but for data reliability; thus, comparisons were not made. The tests were performed with the statistical software packages SAS® 9.1.3 and GENES.

3 RESULTS AND DISCUSSION

The results of both cropping seasons indicate the presence of high genetic variability for the mineral and protein contents in grains from the landrace and commercial study cultivars. There was also wide genetic variability in mineral concentration in beans genotypes in several studies, which reported that nutrient content can be influenced by the environment (e.g. harvests, seasons, and/or locations) (Zilio *et al.*, 2017; Yeken *et al.*, 2019; Delfini *et al.*, 2020; Jan *et al.*, 2021).

Crude protein (CP) levels ranged from 18.21 to 27.40% for the two cropping seasons and farming systems (Table 1). A similar variation in CP values, that is, 19.30 to 24.80 %, was also found in the study conducted by Murube *et al.*, (2021), aimed at characterizing and describing the nutritional quality of landrace and commercial bean cultivars grown under conventional farming. Another study comparing the protein content of landrace and commercial bean cultivars, showed that landrace beans showed variations in CP content owing to genetic characteristics, environmental influence, and agroecological management of the crop (Flores-Sosa *et al.*, 2020). The authors also reported that grains protein content was 19.90%, indicating a valuable low-cost nutritional contribution to families in rural communities.

In the present study, the cultivars that had the highest CP values resulted in an average of 26.90 and 21.97% in season 1; and in 22.34 and 25.04% in season 2, for the organic and conventional farming systems, respectively. The BAF cultivars 3, 4, 47, 60, 50, 57, 75, 81 and 115 differed significantly between farming systems, and for all above-mentioned cultivars, except for 04 and 115, CP content was higher in the grains managed in organic farming system. This result was also found for the overall mean (Table 1).

In a study conducted by Barreto *et al.* (2021), whose objective was to investigate the nutritional differences between black beans grown in conventional and organic crops, it was found that the grains grown in the organic system had a protein content that was 20 % higher. Those authors also argued that, in conventional farming, protein content may be lower owing to the use of pesticides that affect the development of nitrogen-fixing

bacteria and, consequently, N fixation, as symbiosis is one of the main forms of N absorption by Fabaceae plants.

Table 1. Crude protein (CP) content (%) of grains of landrace and commercial bean cultivars grown under organic and conventional farming systems, in two cropping seasons.

BAF	Season 1		Season 2	
	Organic	Conventional	Organic	Conventional
3	23.93 B ¹	23.89 A	23.76 A	20.77 B*
4	25.08 B	24.08 A	21.61 A*	24.26 A
7	25.40 B	25.59 A	21.83 A	20.67 B
13	26.39 A	25.06 A	22.67 A	22.91 A
23	23.21 C	23.21 B	20.16 B	22.00 A
36	27.40 A	26.24 A	22.12 A	22.55 A
42	22.18 C	21.61 B	21.71 A	20.23 B
44	20.74 C	22.18 B	20.68 B	22.14 A
46	21.31 C	23.02 B	20.78 B	21.33 A
47	25.67 B	21.23 B*	21.64 A	19.87 B
50	21.88 C	20.48 B	22.37 A	18.81 B*
55	26.92 A	26.16 A	22.52 A	21.28 A
57	20.76 C	20.66 B	21.87 A	18.46 B*
60	24.15 B	20.44 B*	21.51 A	22.17 A
68	25.45 B	25.40 A	22.61 A	22.98 A
75	23.20 C	21.65 B	23.72 A	21.29 A*
81	21.23 C	21.95 B	22.24 A	18.96 B*
84	24.87 B	24.23 A	23.30 A	21.72 A
97	21.01 C	21.48 B	21.44 A	19.75 B
102	21.16 C	22.06 B	20.84 B	21.84 A
108	25.25 B	25.30 A	22.88 A	21.74 A
110	25.17 B	24.46 A	22.25 A	21.13 A
112	20.70 C	20.19 B	21.28 B	20.07 B
115	22.01 C	21.99 B	18.21 C*	21.20 A
120	21.66 C	21.65 B	20.60 B	21.01 A
121	22.13 C	21.84 B	20.33 B	20.77 B
Mean	23.41 a	22.92 b	21.73 a	21.15 b
CV (%) ²	5.10		5.52	

¹Means followed by the same capital letter do not differ between cultivars by the Scott-Knott test. Overall means followed by the same lowercase letter do not differ between cultivation systems; and * is the significant difference between cultivation systems in the same season for each cultivar, by Tukey's test at 5% probability. ²Coefficient of variation.

Regarding phosphorus content, the study cultivars showed variation between 2.89 and 5.90 g.kg⁻¹, for the two cropping seasons and farming systems. The cultivars with the highest P content showed mean values of 5.76 and 5.61 g.kg⁻¹ in season 1, and 5.65 and 3.93 g.kg⁻¹ in season 2 for organic and conventional farming systems, respectively (Table 2). Other studies that investigated the mineral content in beans, found variations for P contents from 4.00 to 5.60 g.kg⁻¹ and from 3.18 to 5.18 g.kg⁻¹, respectively, by Marquez *et al.* (2024) and Kläsener *et al.* (2020). In season 1, there were no significant differences between farming systems regarding phosphorus contents. However, in season 2, there was a significant difference between farming systems in 42% of the study cultivars, indicating

higher levels of phosphorus, in the overall means, in grains grown under organic farming systems (Table 2).

Phytate content was the characteristic that showed most variability among cultivars, resulting in contents between 3.13 and 10.44 g.kg⁻¹, for the two cropping seasons and farming systems (Table 2). There was also a great variation in phytate contents in the study conducted by Caproni *et al.* (2020) with 192 common bean landrace cultivars, with values ranging between 4.8 and 19.9 g.kg⁻¹, and showing the influence of the genotype factor on the results.

Table 2. Phosphorus (P) (g.kg⁻¹) and phytate (Phyt) (g.kg⁻¹) contents of grains of landrace and commercial bean cultivars grown under organic (Org.) and conventional (Conv.) farming systems, in two cropping seasons.

BAF	P Season 1		P Season 2		Phyt Season 1		Phyt Season 2	
	Org.	Conv.	Org.	Conv.	Org.	Conv.	Org.	Conv.
3	4.73 C ¹	4.63 C	5.85 A	4.43 A*	6.83 D	4.18 F*	6.47 D	5.61 C*
4	4.98 B	4.94 B	3.80 C	3.85 A	4.69 F	4.57 E	5.53 E	5.83 C
7	5.09 B	4.97 B	4.12 C	3.98 A	8.35 B	7.64 A*	7.17 C	5.77 C*
13	5.07 B	4.96 B	4.11 C	3.37 B	7.50 C	6.47 B*	7.94 B	7.20 A*
23	4.67 C	4.58 C	3.72 C	3.18 B	6.88 D	5.18 D*	4.80 F	4.77 D
36	4.68 C	4.55 C	3.70 C	3.46 B	5.80 E	4.86 E*	4.93 F	4.42 D
42	4.78 C	4.66 C	4.33 C	3.71 A	4.95 F	4.82 E	4.74 F*	5.51 C
44	4.61 C	4.50 C	4.42 B	3.46 B*	4.81 F	4.77 E	4.78 F	4.79 D
46	3.93 D	3.74 E	3.67 C	3.00 B	3.16 G	3.13 G	4.57 F	3.95 D
47	5.72 A	5.64 A	5.59 A	2.89 B*	6.89 D	3.52 G*	6.20 D	6.51 B
50	4.89 C	4.76 C	4.80 B	3.61 B*	8.37 B	3.67 G*	5.05 F*	5.90 C
55	5.90 A	5.81 A	4.91 B	3.85 A*	8.09 B	6.50 B*	8.90 A	6.42 B*
57	3.72 D	3.59 E	4.68 B	3.38 B*	8.54 B	5.48 D*	6.63 D	6.93 A
60	4.12 D	4.02 D	3.47 D	3.15 B	6.02 E	4.78 E*	4.78 F	5.39 C
68	4.60 C	4.50 C	4.94 B	4.17 A	7.68 C	3.89 F*	6.07 D	6.37 B
75	5.42 B	5.38 A	5.65 A	4.31 A*	10.44 A	7.72 A*	8.95 A	7.24 A*
81	4.76 C	4.65 C	5.00 B	3.50 B*	5.72 E	4.73 E*	6.43 D	6.62 B
84	4.86 C	4.77 C	5.73 A	3.53 B*	8.81 B	5.46 D*	6.67 D	6.98 A
97	4.00 D	3.92 D	4.51 B	2.91 B*	7.03 D	4.32 F*	5.95 D	6.33 B
102	4.54 C	4.14 D	2.92 D	3.59 B	5.73 E	5.21 D	5.49 E	5.73 C
108	5.68 A	5.60 A	4.26 C	3.69 A	5.80 E	3.97 F*	5.54 E	5.84 C
110	5.31 B	5.28 B	5.43 A	3.71 A*	10.35 A	7.58 A*	8.59 A	6.51 B*
112	4.76 C	4.38 C	3.07 D	3.16 B	5.11 F	4.49 E	5.05 F	5.37 C
115	4.24 D	4.20 D	3.07 D*	3.94 A	6.24 E	5.82 C	5.29 E	5.34 C
120	4.12 D	4.00 D	3.27 D	3.64 A	5.33 F	4.43 E*	5.21 E	5.56 C
121	4.17 D	4.09 D	3.54 D	3.55 B	5.29 F	5.73 C	5.82 D	5.42 C
Mean	4.77 a	4.63 a	4.33 a	3.58 b	6.71 a	5.11 b	6.07 a	5.86 b
CV (%) ²	5.40		12.07		7.19		7.39	

¹Means followed by the same capital letter do not differ between cultivars by the Scott-Knott test. Overall means followed by the same lowercase letter do not differ between cultivation systems; and * is the significant difference between cultivation systems in the same cropping season for each cultivar, by Tukey's test at 5% probability. ²Coefficient of variation.

Considering the average results, phytate content was higher in beans cultivars grown under an organic farming system (Table 2). The phytate values found in the present study were lower than those of the study conducted by Barreto *et al.* (2021), which showed

mean phytate values of 19.70 and 17.90 g.kg⁻¹ in bean grains grown under conventional and organic farming systems, respectively. In the latter system, the grains actually had 10% less phytate. Another study analyzed the nutritional value of bean grains grown under conventional and organic systems. In line with the present study, the authors found that in the conventional system, the grains presented lower phytate value, with values in the range of 10.30 to 13.20 g.kg⁻¹ (Madrera *et al.*, 2024).

It is known that the use of synthetic fertilizers rich in phosphorus can increase phytate levels (Barreto *et al.*, 2021), which could occur in grains grown under conventional farming systems. However, the highest levels of phytate found to be associated with organic farming. This result demonstrates that the landrace cultivars can be more adapted to this system, absorbing phosphorus from the soil through non-mineral sources and consequently result in higher values for phytate content. Generally, studies point to the antinutritional factor of phytate owing to its chelating capacity with other minerals. However, this capacity is also associated with possible health benefits such as reduced risk of heart disease and cancer (Feizollahi *et al.*, 2021), may be an important nutritional indicator.

Another macronutrient that was assessed was potassium, whose contents ranged from 10.05 to 23.78 g.kg⁻¹, for the two cropping seasons and two farming systems. For K values, Marquez *et al.* (2024) found results between 13.41 and 19.80 g.kg⁻¹. When studying the concentration of minerals in bean grains, Ribeiro *et al.* (2023) found an average K value of 12.59 g.kg⁻¹; this value was classified as high concentration in bean grains (> 12 g.kg⁻¹) in the study developed by Steckling *et al.* (2017). Based on this classification, the bean grains in the present study have high K values, which is an advantage from a nutritional point of view and a benefit to health because K has several properties; for example, it helps control hypertension (McDonough; Youn, 2017).

In general, in both cropping seasons, higher K values were found in organically grown grains (Table 3). A similar behavior was reported in the studies developed by Madrera *et al.* (2024) and Barreto *et al.* (2021). In the latter study, bean grains grown under organic farming presented 7 % higher levels of K, compared to conventional farming.

Table 3. Potassium (K) (g.kg⁻¹) contents of grains of landrace and commercial bean cultivars grown under organic and conventional farming systems in two cropping seasons.

BAF	Season 1		Season 2	
	Organic	Conventional	Organic	Conventional
3	17.18 D ^{1*}	19.37 B	14.46 C	12.60 C*
4	18.85 C	17.67 C	15.64 B	12.91 C*
7	20.66 B*	22.69 A	15.13 B	14.21 A
13	19.24 C	18.63 B	13.24 D	13.96 A
23	17.96 D	18.99 B	13.27 D	12.55 C
36	17.24 D	17.24 C	15.08 B	14.46 A
42	19.26 C	16.78 C*	15.42 B	13.54 B*
44	20.67 B	17.00 C*	15.74 B	12.18 C*
46	21.74 B	15.92 C*	15.14 B	13.15 B*
47	23.78 A	13.58 D*	16.96 A	11.54 C*
50	18.17 D	14.42 D*	14.45 C	11.32 C*
55	19.08 C	14.82 D*	14.64 C	11.69 C*
57	19.60 C	14.78 D*	13.50 D	12.21 C*
60	18.58 C	15.88 C*	14.53 C	14.57 A
68	19.40 C	16.60 C*	15.81 B	12.21 C*

BAF	Season 1		Season 2	
	Organic	Conventional	Organic	Conventional
75	23.12 A	16.24 C*	16.53 A	13.91 A*
81	21.24 B	16.93 C*	14.58 C	12.85 C*
84	22.21 B	16.50 C*	17.31 A	13.22 B*
97	18.55 C	15.82 C*	12.21 E	12.02 C
102	17.28 D*	19.83 B	15.35 B	12.19 C*
108	17.16 D	13.20 D*	14.02 D	12.84 C*
110	18.75 C	15.43 D*	10.05 F*	12.20 C
112	17.50 D*	19.49 B	13.53 D	12.22 C*
115	18.32 C*	21.40 A	14.35 C	13.06 B*
120	15.54 E*	17.76 C	15.32 B	11.71 C*
121	13.85 E*	17.73 C	13.85 D	12.20 C*
Mean	19.24 a	17.10 b	14.65 a	12.75 b
CV (%) ²	6.21		4.94	

¹Means followed by the same capital letter do not differ between cultivars by the Scott-Knott test. Overall means followed by the same lowercase letter do not differ between cultivation systems; and * is the significant difference between cultivation systems in the same season for each cultivar, by Tukey's test at 5% probability. ²Coefficient of variation.

Beans are also considered a source of micronutrients such as iron and zinc. It is known that mineral deficiency can cause pathologies harmful to human health, such as anemia, and damage to physiological functions, caused by the shortage of iron and zinc, respectively (Caproni *et al.*, 2020). Regarding iron and zinc contents, the study cultivars showed variation from 46.96 to 127.10 mg.kg⁻¹ and from 20.80 to 49.22 mg.kg⁻¹, respectively, for the two cropping seasons and farming systems (Table 4). Such values are similar to the ones reported by Marquez *et al.* (2024), which ranged from 48.67 to 109.00 mg.kg⁻¹ for iron and from 23.00 to 52.67 mg.kg⁻¹ for zinc.

In the present study, the beans grains showed average contents of 73.20 mg.kg⁻¹ iron and 32.84 mg.kg⁻¹ zinc. Both levels are considered high (from 60.4 to 105.5 mg.kg⁻¹ of iron and 31.00 to 56.13 mg.kg⁻¹ of zinc) by the classification proposed by Tryphone and Nchimbi-Msolla (2010) and satisfactory from a nutritional point of view. When comparing the farming systems for iron and zinc contents, the present study was inconclusive, because the results were different in each cropping season (Table 4). A similar behavior was found in the study by Barreto *et al.* (2021), there was no significant difference in the iron content of beans grown under an organic farming system compared to the conventional one. For zinc content, the same authors found a significant difference for grains from different systems for one region of farming but not for another. In comparison, in the study conducted by Madrera *et al.* (2024), organically grown beans presented higher levels of iron and zinc.

There was a wide genetic diversity of the study cultivars in relation to nutrient contents, and in general, these contents were higher for landrace cultivars, since for commercial cultivars, the focus is on productivity. This fact was reinforced by studies conducted by Zilio *et al.*, (2011) and Prezzi *et al.*, (2014) with the same cultivars as the present study, in organic and conventional farming systems, where it was found that only some landrace genotypes were superior to commercial ones in productivity, thus highlighting the nutritional potential of landrace cultivars. Along these lines, Zilio *et al.*

(2017) reported that bean genotypes with high seed yield showed lower nutrient concentrations, mainly phosphorus and crude protein. Thus, organic farming and landrace cultivars can be considered feasible for bean production when aiming at nutritional quality and food safety.

Table 4. Iron (Fe) (mg.kg⁻¹) and zinc (Zn) (mg.kg⁻¹) contents of grains of landrace and commercial bean cultivars produced under organic farming (Org.) and conventional farming (Conv.), in two cropping seasons.

BAF	Fe Season 1		Fe Season 2		Zn Season 1		Zn Season 2	
	Org.	Conv.	Org.	Conv.	Org.	Conv.	Org.	Conv.
3	77.5 C ¹	75.3 D	73.6 B*	79.5 A	32.3 C*	35.7 C	31.7 C*	39.8 A
4	55.7 E	56.1 F	60.2 D	65.68C	31.32C	24.70G*	26.04D*	31.98 B
7	77.10C*	91.90 B	70.35C*	79.80 A	35.84 B*	45.52 B	30.66C*	36.73 A
13	58.85E*	86.89 B	64.59D*	79.00 A	36.37 B*	35.62C	34.06 B	39.40 A
23	56.52E*	127.1 A	66.50C*	75.85 B	33.24 B*	38.53C	26.39D*	32.85 B
36	72.16 D	70.75D	70.04C*	83.11 A	36.31 B	31.15E*	33.53 B	38.76 A
42	81.93C	69.74D*	73.42 B	76.47 B	27.78D	29.96E	34.89 B	31.61 B
44	70.77D	77.30C	59.45 D	60.28D	28.50D	30.61E	31.34C	31.21 B
46	74.88D	48.88G*	60.61 D	61.77D	28.52D	21.95H*	34.30 B	26.70C*
47	94.58 A	46.96G*	80.07 A	56.97D*	43.04 A	20.80H*	40.30 A	24.23C*
50	97.20 A	66.11E*	76.80 A	63.23C*	32.81 B	26.77F*	29.74C	34.88 A
55	95.38 A	74.01D*	81.10 A	79.20 A	31.87C	25.95F*	32.40C	34.39 A
57	75.19D	52.08F*	61.90 D	61.61D	24.55D	21.42H	25.97D	26.26C
60	86.02 B	82.44 C	68.22C*	76.51 B	35.08 B	28.40F*	30.41C*	38.96 A
68	71.16D	69.60 D	72.66 B	59.86D*	26.21D	26.61F	30.90C	28.35C
75	84.82 B	79.92 C	68.03C*	83.15 A	34.43 B	33.13D	35.20 B	37.12 A
81	80.13C*	91.78 B	65.54C*	74.34 B	28.63D	27.76F	26.72D*	32.95 B
84	70.31D*	83.63 C	67.84 C	64.94 C	28.77D	26.08F	27.77D	27.01C
97	69.40D*	81.74 C	75.30 B	67.45C*	29.78C*	32.97D	27.80D	32.33 B
102	79.54C	65.42E*	77.61 A*	83.12 A	26.67D*	49.22 A	34.55 B*	41.89 A
108	51.17E*	72.54 D	63.69D*	82.99 A	43.70 A	36.62C*	32.09C*	40.00 A
110	69.58D*	85.95 B	77.90 A	71.49 B*	26.44D*	35.13D	31.36C*	37.97 A
112	84.41 B	56.33F*	76.93 A	77.58 B	34.89 B	34.88D	41.81 A	37.31 A
115	86.25 B	64.23E*	80.65 A	82.49 A	28.37D*	34.17D	30.56C*	37.12 A
120	67.06 D	64.80 E	60.62 D	63.47 C	31.83C*	37.56C	25.66D*	33.61 B
121	74.49 D	74.94 D	68.48C*	80.15 A	26.89D*	36.44C	26.94D*	38.57 A
Mean	75.86 a	73.71 b	70.54 b	72.70 a	32.05 a	31.83 a	31.74 b	34.31 a
CV (%) ²	5.96		4.67		6.04		6.83	

¹Means followed by the same capital letter do not differ between cultivars by the Scott-Knot test. Overall means followed by the same lowercase letter do not differ between cultivation systems; and * is the significant difference between cultivation systems in the same season for each cultivar, by Tukey's test at 5% probability. ²Coefficient of variation.

4 CONCLUSIONS

For the beans produced in the organic farming system, nutrient contents are higher or similar to those of the beans produced under conventional farming. The BAF

landrace cultivars 47, 55 and 75 grown under the organic farming system, demonstrate the highest levels of nutrients, and they can be considered as naturally biofortified and suitable for use in breeding programs, or directly by farmers themselves for consumption, production, and marketing.

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