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Physico-chemical and Nutritional Characterization of *Phaseolus vulgaris* L. Germplasm

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ABSTRACT

Background: Beans constitute one of the most important grain legume species from the socioeconomic point of view, playing an essential role in a sustainable agriculture and food safety and nutrition. In fact, beans contain a rich diversity in nutrients, highlighting their high protein, starch and fiber content. Canary Islands have a considerable diversity of beans, including three of the five cultivated species of *Phaseolus: P. coccineus*, *P. lunatus* and *P. vulgaris*, the latter being the most cultivated.

Methods: Proximate composition, total phenolics, pH, acidity, minerals and trace elements were determined in 23 common bean accessions (*P. vulgaris*) in order to find out their nutritional potential and promote their cultivation.

Result: Parameters found fell well into the ranges of the data described in the literature for beans. The consumption of beans contributes remarkedly to the daily intake of protein (although is deficient in sulfur amino-acids), fiber, phenolic compounds, minerals such as Mg and K and trace elements as Fe (although with low bioavailability), Cu and Mn. Phenolic compounds in beans increases when pH decreased and acidity increased. Protein content was positively correlated with trace elements content, except Se. Color of the seed influenced on content protein, starch, fiber, P, K, Mg, Fe, Cu and Zn, while shape only affected on starch, fiber, P and K.

Key words: Bean, Chemical composition, Germplasm diversity, Morphology.

INTRODUCTION

Legumes including common beans (*Phaseolus vulgaris* L.) are a group of highly recommended foods for the maintenance of a healthy and balanced diet. They are rich in protein, although they are deficient in methionine; complex carbohydrates including starch and dietary fiber. They also contain micronutrients such as vitamins, mineral and trace elements (Kamboj and Nanda, 2018; Carbas *et al*., 2020). The consumption of dietary fiber has been linked to a protective effect against cardiovascular diseases, diabetes, obesity, diverticular diseases and certain types of cancer. Legumes also have a prebiotic effect, as they favor the growth of colonies of beneficial bacteria for the activity of the intestine. Common beans have high amounts of bioactive compounds including phenolic compounds, which could be associated with health properties such as decrease of the risk of cardiovascular diseases, diabetes, some types of cancer, Alzheimer's and Parkinson's diseases (Chávez-Mendoza and Sánchez, 2017; Kamboj and Nanda, 2018). Studies on phenolic extracts have shown a highly significant correlation between total phenolic contents and antioxidant capacity (Carbas *et al*., 2020). Beans together with soybeans are the most important legumes in the diet of more than 500 million people, especially in Latin America and Africa (FAO, 2022). Despite the numerous benefits provided by the intake of beans to maintain a good health, its consumption in Spain and, in general, throughout Europe, has significantly decreased in recent years (FAO, 2022).

Canary Islands is home to a large bean landraces growing on the islands belonging to three botanical species: *P. coccineus, P. lunatus* and *P. vulgaris* (Dorta Estévez, 2006). Chemical composition and nutritional value of local beans "manteca" accessions from Canary Islands were determined. The outcome of the research will help in selection of accessions with the highest nutrient content to promote their cultivation, consumption and future research.

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MATERIALS AND METHODS

Ninety samples of common beans (*Phaseolus vulgaris* L.) named "manteca" belonging to 23 accessions from the Canary Islands were analyzed. These were supplied by the Center for Biodiversity Agricultural Conservation of Tenerife. The cultivation was conducted in a randomized complete block design with four repetitions. Table 1 shows the main descriptors of each accession, including the number of samples analyzed and shape and color of the legume. The shape of the beans was rounded or ovoid, more or less elongated and five color shades were identified as pale pink, strong pink, cream yellow, sulfur yellow and brown.

The samples were transferred to the Laboratory of Nutrition and Bromatology of the University of La Laguna to carry out the analysis. Bean samples were weighed and the number of seeds counted to determine the average weight per seed. Next, a fraction of each sample was homogenized using a mill (Mill, IKA® A 11 Basic, Ika) until a fine flour was obtained. Part of this flour was stored in polypropylene tubes at -20°C, which was used for the determination of moisture (oven drying method), ash (heated at 550°C for 24 h), starch (enzymatic method), pH and acidity (titration with NaOH 0.1N until pH 8.1, results were expressed as g citric acid per 100 g) (AOAC, 2006) and phenolic compounds. Another fraction was washed with milli-Q water, dried at 100°C, homogenized and stored in polypropylene tubes at room temperature. On this fraction, the protein (Kjeldahl method, factor of 6.25), dietary fiber (enzymatic-gravimetric method) (AOAC, 2006), mineral and trace elements analysis were carried out.

All analyses were performed in duplicate, except minerals and trace elements that were analyzed in triplicate and the results were expressed in dry weight (dw) total phenolic compounds (TP) determination was performed by colorimetry using the Folin-Ciocalteu reagent, expressing the results in mg of gallic acid/100 g. The elements (K, Mg, Ca, Fe, Cu, Zn and Mn) were determined using a Varian SpectraAA 50B (Varian Iberica S.L., Madrid, Spain) atomic absorption spectrometry (Hernández Suárez *et al.*, 2007) and phosphorous by the colorimetric method with Vanadate-Molybdate reagent.

The software SPSS 25.0 (Statistical Package for the Social Sciences Inc., Chicago, USA) was used for statistical testing. An analysis of variance (ANOVA) was applied considering that there are significant differences between the mean values when the value of $p<0.05$. The Duncan test was used to classify mean values in homogeneous groups (Duncan, 1955). Pearson's correlation analysis was carried out to establish the degree of relationship between the variables (Cleophas and Zwinderman, 2016).

RESULTS AND DISCUSSION

Significant differences ($p<0.05$) between the bean accessions were detected in all parameters analyzed (except moisture, TP, pH, Na, Ca, Mg, Mn and Se) (Tables 2 and 3). These differences could be due to genetic and environmental characteristics, particularly the mineral composition of the culture soils. The weight of beans "manteca" analyzed was low. This ranged between 0.41-0.68 g (Table 1). Similar results were reported by several authors (Herrera-Hernández *et al.*, 2018; Prolla *et al.*, 2010; Rezende *et al.*, 2018). Moisture contents were within the range (5-14%) shown by other researchers (Felix *et al.*, 2021; Herrera-Hernández *et al.*, 2018; Prolla *et al.*, 2010). The starch

Table 1: Description of "Manteca" bean landraces.

Landrace	Number of samples	Color	Shape	Seed weight (g)
1	4	Brown	Rounded	0.47±0.01
2	4	Cream yellow	Rounded	0.62±0.04
3	4	Cream yellow	Rounded	0.63±0.06
4	4	Cream yellow	Elongated	0.63±0.04
5	4	Cream yellow	Rounded	0.65±0.08
6	4	Cream yellow	Rounded	0.64±0.04
7	4	Cream yellow	Rounded	0.68±0.14
8	4	Cream yellow	Rounded	0.64±0.06
9	4	Cream yellow	Elongated	0.57±0.13
10	4	Cream yellow	Rounded	0.66±0.07
11	4	Cream yellow	Rounded	0.65±0.04
12	4	Cream yellow	Rounded	0.66±0.07
13	4	Cream yellow	Rounded	0.66±0.06
14	4	Cream yellow	Rounded	0.64±0.10
15	4	Cream yellow	Rounded	0.65±0.06
16	4	Strong Pink	Elongated	0.54±0.03
17	4	Pale Pink	Elongated	0.58±0.06
18	4	Cream yellow	Rounded	0.66±0.03
19	4	Yellow	Rounded	0.64±0.13
20	4	Cream yellow	Rounded	0.60±0.17
21	4	Cream yellow	Rounded	0.68±0.05
22	3	Yellow	Elongated	0.41±0.02
23	3	Pale Pink	Elongated	0.68±0.08

Table 2: Results (mean±standard deviation) of the mean major chemical components, total phenolic compounds, pH and acidity obtained in "manteca" bean landraces.

Landrace	Moisture (%)	Starch (%)	Protein (%)	Fiber (%)	Ash (%)	TP	pH	Acidity (%)
1	6.44±0.63^{a}	41.4±1.3^{cde}	22.4±1.6^{ab}	24.3±0.7^{a}	4.83±0.10^{abc}	241±67^{a}	6.64±0.17^{a}	0.46±0.05^{abc}
2	6.55±0.61^{a}	42.1±2.0^{de}	24.8±0.8^{bcd}	26.5±1.3^{ab}	4.82±0.03^{abc}	203±41^{a}	6.68±0.08^{a}	0.48±0.04^{abcd}
3	6.56±0.20^{a}	39.8±2.4^{bcde}	24.0±0.7^{bcd}	27.2±1.8^{bc}	4.81±0.08^{abc}	260±17^{a}	6.58±0.21^{a}	0.49±0.06^{bcd}
4	6.33±0.77^{a}	38.3±1.6^{bc}	26.4±1.3^{cd}	27.0±2.1^{cde}	4.67±0.24^{ab}	241±31^{a}	6.57±0.11^{a}	0.48±0.05^{abc}
5	6.68±0.43^{a}	42.6±2.0^{de}	24.0±1.6^{bcd}	28.7±1.9^{cde}	4.71±0.27^{ab}	214±51^{a}	6.49±0.18^{a}	0.51±0.06^{bcd}
6	6.57±1.15^{a}	41.6±1.9^{cde}	25.1±2.6^{cd}	26.3±1.7^{ab}	4.69±0.34^{ab}	308±68^{a}	6.44±0.34^{a}	0.50±0.05^{bcd}
7	6.46±0.59^{a}	39.8±2.1^{bcd}	25.9±2.5^{cd}	28.2±2.0^{bcd}	5.02±0.09^{cd}	218±59^{a}	6.43±0.25^{a}	0.48±0.07^{abcd}
8	6.05±0.56^{a}	39.8±2.3^{bcd}	23.1±1.5^{ab}	27.5±1.6^{bc}	4.77±0.15^{abc}	277±53^{a}	6.39±027^{a}	0.56±0.05^{d}
9	6.45±0.85^{a}	38.8±1.9^{bcd}	24.9±0.8^{bcd}	27.3±0.6^{bc}	4.55±0.08^{a}	237±73^{a}	6.49±0.30^{a}	0.54±0.05^{cd}
10	6.05±0.29^{a}	39.9±1.5^{bcde}	24.2±1.4^{bcd}	25.9±0.6^{ab}	4.54±0.15^{a}	285±67^{a}	6.50±0.27^{a}	0.43±0.03^{ab}
11	7.10±0.70^{a}	40.8±1.9^{bcde}	22.9±0.5^{ab}	26.9±1.7^{ab}	4.97±0.32^{bcd}	304±98^{a}	6.51±0.30^{a}	0.48±0.06^{abcd}
12	7.05±0.46^{a}	42.6±2.0^{de}	23.6±1.6^{abc}	26.8±1.0^{ab}	4.57±0.19^{a}	249±52^{a}	6.47±0.26^{a}	0.43±0.03^{ab}
13	7.05±0.67^{a}	40.8±1.6^{bcde}	24.3±0.8^{bcd}	29.1±1.6^{cde}	4.88±0.09^{abcd}	252±63^{a}	6.54±0.30^{a}	0.43±0.01^{ab}
14	6.69±0.82^{a}	41.1±1.8^{cde}	23.5±1.8^{abc}	27.1±1.3^{bc}	4.70±0.04^{ab}	242±48^{a}	6.56±0.13^{a}	0.51±0.03^{bcd}
15	7.24±0.90^{a}	42.0±1.4^{de}	23.4±2.4^{abc}	25.1±1.2^{ab}	4.81±0.25^{abc}	222±76^{a}	6.48±0.21^{a}	0.52±0.10^{cd}
16	6.21±0.45^{a}	40.4±2.2^{bcde}	24.7±1.9^{bcd}	30.5±1.6^{de}	5.19±0.22^{d}	250±60^{a}	6.76±0.12^{a}	0.41±0.03^{a}
17	6.72±0.36^{a}	34.5±1.0^{a}	25.9±0.5^{cd}	27.9±2.9^{bc}	5.07±0.10^{cd}	301±25^{a}	6.50±0.16^{a}	0.52±0.03^{cd}
18	6.35±0.52^{a}	40.3±1.2^{bcde}	24.1±0.3^{bcd}	26.7±1.9^{ab}	4.66±0.26^{ab}	237±74^{a}	6.64±0.12^{a}	0.47±0.04^{abc}
19	6.73±0.37^{a}	40.3±2.6^{bcde}	22.7±1.7^{ab}	27.0±1.7^{ab}	4.88±0.27^{abcd}	230±59^{a}	6.72±0.18^{a}	0.47±0.02^{abc}
20	6.96±0.69^{a}	37.6±1.3^{b}	23.8±1.3^{bc}	26.1±1.0^{ab}	4.84±0.37^{abc}	295±60^{a}	6.56±0.31^{a}	0.46±0.04^{abc}
21	6.24±0.57^{a}	38.7±1.9^{bcd}	23.5±1.4^{abc}	26.9±1.9^{ab}	4.87±0.09^{abcd}	232±50^{a}	6.71±0.08^{a}	0.42±0.05^{ab}
22	6.41±0.16^{a}	43.1±1.9^{e}	21.2±0.1^{a}	28.6±0.8^{bcde}	4.60±0.06^{a}	173±7.7^{a}	6.61±0.04^{a}	0.42±0.01^{ab}
23	6.24±0.25^{a}	40.8±3.0^{bcde}	23.3±1.0^{abc}	30.9±0.6^{e}	4.79±0.04^{abc}	238±27^{a}	6.71±0.08^{a}	0.50±0.02^{bcd}
Total	6.58±0.63	40.3±2.5	24.0±1.7	27.3±2.0	4.79±0.24	249±60	6.56±0.21	0.48±0.06

TP= Total phenolics (mg GAE/100 mg). All the minerals are expressed in mg/100 g, except for Se µg/100 g. Data expressed in dry weight (dw).
Values with the same lowercase letter within the same column are statistically equal based on the Duncan's test (p<0.05).

Table 3: Results (mean±standard deviation) of mineral and trace elements in “manteca” bean landraces.

Landrace	P	Na	K	Ca	Mg	Fe	Cu	Zn	Mn	Se
1	538±59^{abc}	50.3±5.8^{a}	1921±72^{bcd}	133±15^{a}	202±17^{a}	6.66±0.82^{abc}	0.56±0.05^{bcd}	2.92±0.15^{abcd}	0.98±0.10^{a}	3.03±0.82^{a}
2	561±27^{abcd}	59.0±14^{a}	1836±42^{ab}	143±20^{a}	190±13^{a}	7.06±0.97^{cd}	0.54±0.04^{bcd}	2.86±0.16^{abc}	0.99±0.09^{a}	2.11±0.61^{a}
3	574±40^{bcd}	60.2±20^{a}	1839±53^{ab}	143±20^{a}	193±3.7^{a}	8.17±0.95^{cd}	0.54±0.02^{bcd}	2.95±0.06^{bcd}	0.99±0.04^{a}	2.62±0.91^{a}
4	586±28^{cd}	56.4±22^{a}	1826±114^{ab}	115±6.9^{a}	196±8.3^{a}	7.41±1.3^{cd}	0.52±0.05^{bc}	3.15±0.18^{cd}	0.95±0.02^{a}	2.51±0.64^{a}
5	503±79^{ab}	62.9±15^{a}	1804±95^{ab}	132±23^{a}	179±7.6^{a}	6.83±0.26^{bc}	0.43±0.01^{a}	2.88±0.20^{abcd}	0.93±0.06^{a}	2.41±0.98^{a}
6	587±65^{cd}	61.1±14^{a}	1792±33^{ab}	149±24^{a}	189±16^{a}	7.77±1.0^{cd}	0.55±0.03^{bcd}	3.13±0.24^{cd}	1.03±0.06^{a}	2.19±0.79^{a}
7	486±21^{a}	60.1±22^{a}	1796±45^{ab}	160±15^{a}	179±14^{a}	7.29±1.0^{cd}	0.53±0.07^{bcd}	2.95±0.29^{bcd}	1.02±0.10^{a}	2.20±0.71^{a}
8	490±30^{ab}	69.0±5.8^{a}	1815±61^{ab}	150±13^{a}	191±18^{a}	6.98±0.89^{cd}	0.50±0.06^{ab}	2.84±0.21^{abc}	0.97±0.10^{a}	2.68±0.84^{a}
9	580±45^{bcd}	65.3±12^{a}	1896±123^{abc}	134±16^{a}	189±18^{a}	7.57±0.30^{cd}	0.53±0.06^{bcd}	3.02±0.14^{bcd}	1.02±0.06^{a}	2.44±0.88^{a}
10	532±57^{abc}	55.2±4.5^{a}	1872±87^{abc}	136±26^{a}	190±13^{a}	7.13±0.70^{cd}	0.49±0.04^{ab}	2.70±0.14^{ab}	0.98±0.07^{a}	1.78±0.46^{a}
11	534±12^{abc}	81.1±9.2^{a}	1855±99^{abc}	127±10^{a}	198±11^{a}	6.83±0.48^{bc}	0.55±0.04^{bcd}	2.91±0.29^{abcd}	0.99±0.06^{a}	2.02±0.43^{a}
12	563±29^{abcd}	47.5±26^{a}	1787±58^{ab}	146±11^{a}	193±9.3^{a}	7.73±1.0^{cd}	0.59±0.05^{cd}	2.90±0.14^{abcd}	1.00±0.05^{a}	2.05±0.50^{a}
13	579±37^{bcd}	56.6±19^{a}	1869±70^{abc}	113±2.8^{a}	203±19^{a}	7.34±1.1^{cd}	0.58±0.04^{bcd}	3.06±0.06^{cd}	0.96±0.06^{a}	1.75±0.38^{a}
14	567±30^{bcd}	65.0±14^{a}	1842±108^{abc}	132±9.3^{a}	190±14^{a}	6.67±0.44^{abc}	0.51±0.09^{abc}	2.94±0.09^{bcd}	0.91±0.04^{a}	2.12±0.87^{a}
15	559±52^{abcd}	62.3±21^{a}	1842±57^{abc}	129±19^{a}	196±11^{a}	7.17±0.20^{cd}	0.55±0.02^{bcd}	2.87±0.28^{abc}	1.01±0.07^{a}	2.34±0.62^{a}
16	536±48^{abc}	71.3±18^{a}	2044±134^{d}	139±17^{a}	212±8.9^{a}	5.43±0.52^{a}	0.55±0.05^{bcd}	2.67±0.11^{ab}	1.01±0.08^{a}	2.09±0.66^{a}
17	622±46^{d}	57.6±17^{a}	1984±72^{cd}	136±17^{a}	196±12^{a}	8.28±0.39^{d}	0.58±0.02^{bcd}	3.21±0.30^{d}	1.05±0.07^{a}	2.07±0.32^{a}
18	543±50^{abcd}	60.8±14^{a}	1797±95^{ab}	154±18^{a}	186±6.9^{a}	6.37±0.43^{abc}	0.50±0.06^{ab}	3.01±0.08^{bcd}	0.98±0.08^{a}	2.31±0.84^{a}
19	596±64^{cd}	57.5±18^{a}	1808±67^{ab}	141±12^{a}	180±16^{a}	7.33±0.28^{cd}	0.53±0.05^{bcd}	2.94±0.27^{bcd}	0.92±0.02^{a}	2.74±1.1^{a}
20	560±50^{abcd}	59.6±17^{a}	1908±67^{bc}	150±25^{a}	200±19^{a}	5.41±1.1^{a}	0.48±0.05^{ab}	2.79±0.17^{abc}	0.91±0.04^{a}	2.45±0.99^{a}
21	505±23^{ab}	54.6±13^{a}	1854±30^{abc}	145±20^{a}	183±14^{a}	6.79±0.84^{bc}	0.51±0.07^{abc}	2.89±0.13^{abcd}	0.95±0.11^{a}	2.35±0.88^{a}
22	518±14^{abc}	57.4±17^{a}	1757±13^{a}	135±15^{a}	192±4.1^{a}	5.60±0.15^{ab}	0.44±0.02^{a}	2.60±0.10^{a}	0.94±0.02^{a}	1.74±0.24^{a}
23	603±79^{cd}	62.7±8.3^{a}	1872±179 ^{abc}	138±20^{a}	197±5.7^{a}	7.77±1.4^{cd}	0.61±0.02^{d}	3.16±0.21^{cd}	1.00±0.05^{a}	1.78±0.23^{a}
Total	553±54	60.6±15	1854±97	138±19	192±14	7.00±1.0	0.53±0.06	2.91±0.22	0.98±0.07	2.32±0.72

All the results are expressed in mg/100 g referred dry weight (dw), except for Se µg/100 g of dw.

Values with the same lowercase letter within the same column are statistically equal based on the Duncan’s test ($p<0.05$).

contents (34.5-43.1% dw) were similar to most of data published (Martinez Meyer *et al*., 2013; Pedrosa *et al*., 2015; Rezende *et al*., 2018). Common beans constitute an interesting source of protein and no large differences were observed between the results obtained for proteins in this paper (21.2-26.4% dw) and those published in other studies (Florvil *et al*., 2022; Herrera-Hernández *et al*., 2018; Rezende *et al*., 2018). Samples beans analyzed also have considerable levels of dietary fiber (24.3-30.9% dw) and ash (4.54-5.19% dw) and these data were similar o higher than those reported by others authors (Florvil *et al*., 2022; Herrera-Hernández *et al*., 2018; Rezende *et al*., 2018). The values of TP obtained (173-308 mg GAE/100 dw) were similar than those shown by Carbas *et al*. (2020), Florvil *et al.* (2022) and Huertas *et al*. (2022). Differences found in the contents of phenolic compounds between the different authors (Chávez-Mendoza *et al*., 2017; Felix *et al*., 2021; Rezende *et al*., 2018) can be attributed to many factors such as genotype, agricultural practices, the degree of maturity of the grain, post-harvest conservation, storage conditions or climatic and crop conditions.

The K was the element with a higher concentration (1757-2044 mg/100 g dw), with results higher than published (Florvil *et al.,* 2022; Herrera-Hernández *et al*., 2018). The high K concentrations observed in bean accessions can be a consequence of the usually high contents of this element observed in the culture soils of the islands. The results of P (486-622 mg/100 g dw) were in the range reported by some researchers (Martinez Meyer *et al*., 2013), or higher than those reported in other papers (Florvil *et al.,* 2022; Herrera-Hernández *et al*., 2018; Rassol *et al*., 2019). The concentrations of Na obtained (47.5 and 81.1 mg/100 g dw) were, in general, higher than those published in the literature (Herrera-Hernández *et al*., 2018; Pedrosa *et al*., 2015). These results are explained due to the deposit of marine aerosol on crop soils and the concentrations observed in waters for irrigation. The Ca (114-160 mg/kg dw) and Mg (179-212 mg/100 g dw) found during the investigation were within the wide range described in other studies (Herrera-Hernández *et al*., 2018; Pedrosa *et al*., 2015; Rassol *et al*., 2019). Fe was the trace element with the highest concentration (5.4-8.3 mg/100 g dw), followed by Zn (2.60-3.21 mg/100 g dw), Mn (0.91-1.05 mg/100 g dw) and Cu (0.43-0.61 mg/100 g dw). Se concentrations (1.7-3.0 ìg/100 g dw) were much lower than the previous four metals. In general, these values were generally within the range described by other researchers (Celmeli *et al*., 2018; Florvil *et al.,* 2022; Herrera-Hernández *et al*., 2018).

Dietary fiber, phenolic compounds, Fe, Mn, Ca and Mg were the nutrients used to nutritionally evaluate the bean accessions, because its consumption can contribute to their daily intake. Therefore, some accessions (n°6, 13 and 17) could be emphasized since they had relatively high levels of these nutrients. Likewise, these accessions also had higher mean concentrations of ash and protein. These three entries could be selected for their high nutrient content in order to promote their cultivation and consumption in the Canary Islands.

The consumption of a portion of dry beans (≈ 60 g, equivalent to 150-180 g of boiled beans) contributes a high percentage of the recommended intakes for the adult population (men and woman, respectively) (FNB, 2006) of the following nutrients: proteins (26% and 31%), fiber (43% and 66%), P (47%), Fe (53% and 23%), Cu (35%), Zn (16% and 22%) and Mn (25% and 33%). It should be noted that the protein is deficient in sulfur amino acids (Chávez-Mendoza *et al*., 2017). There are no recommended dietary intakes for phenolic compounds, but the consumption of a serving of beans has a considerable contribution, although variable depending on the variety. Likewise, the contribution to the K intake by the consumption of a portion of beans is high (24% of the adequate intake), while the contribution of Na is low (2-2.5%). This relationship between both electrolytes is interesting from the point of view of defense against hypertension and associated cardiovascular diseases. The relatively high contribution of Mg (27-36%) with respect to the recommended intakes can be highlighted, while that the Ca did not reach 10%. The contribution of Se by the bean consumption is low, only 2-3% of the recommended intakes for adults (FNB, 2006).

Significant and positive correlations were observed which allowed to establish relationships between the variables studied (Table 4). So, it is deduced that the phenolic compounds increased when the pH decreased (r= -0.540) and the medium was more acidic. The high and inverse correlation (r= -0.567) found between acidity and pH reflects the known relationship between both parameters. Protein concentration was moderately correlated (p<0.02) with all the trace elements studied, except Se. Highly significant (p<0.001) correlations were found between all the trace elements (except Se), which has also been reported by other investigators (Celmeli *et al*., 2018; Rassol *et al*., 2019; Ribeiro and Kläsener, 2020).

Color of the seed influenced on the analyzed physico-chemical parameters studied (Tables 5 and 6). Bean accessions with cream yellow color, predominant color in the beans analyzed, had a mean weight per grain higher than those mean weights found for accessions with other colors and brown color accessions had the lowest. Beans with pale pink color had the highest mean P, Fe and Zn concentrations and lowest mean starch concentration; in addition, beans with pale or strong pink color showed the highest mean protein, ash and fiber concentrations and the strong pink accessions also showed the highest mean K and Mg concentrations and the lowest mean Fe and Zn. The mean Cu concentration in yellow sulfur accession was lower (p<0.05) than the mean concentrations observed in the pale pink and brown accessions. Low influence of the shape of the seed on the studied parameters was detected (data not shown). So, the rounded accessions showed higher (p<0.05) weights per grain and higher mean starch concentration than the elongated accessions, while that the

Table 4: Correlation among variables studied.

	Moisture	Starch	Protein	Fiber	Ash	TP	pH	Acidity	P	Na	K	Ca	Mg	Fe	Cu	Zn	Mn	Se
Seed weight	-0.005	0.096	0.138	0.071	-0.131	0.006	-0.035	-0.035	-0.001	-0.133	-0.328**	0.124	-0.343**	0.285**	0.067	0.134	-0.122	-0.220*
Moisture		0.062	0.082	-0.237*	0.196	0.275**	-0.351**	0.270**	-0.030	0.069	0.052	-0.061	0.180	-0.013	0.073	0.193	0.040	-0.084
Starch			-0.271**	0.033	-0.258*	-0.290**	0.118	-0.209*	-0.061	-0.100	-0.327**	-0.078	-0.159	-0.199	-0.101	-0.231*	-0.202	-0.101
Protein				-0.012	0.036	0.136	-0.290**	0.184	-0.003	-0.036	0.229*	-0.019	0.049	0.292**	0.262*	00.410**	0.330**	-0.047
Fiber					0.118	-0.155	0.159	-0.165	0.035	0.267*	0.032	0.023	-0.001	-0.071	0.011	-0.013	-0.040	-0.320**
Ash						0.118	-0.011	0.108	0.032	0.248*	0.266*	0.144	0.254*	-0.099	0.238*	0.133	0.137	0.132
TP							-0.540**	0.241*	-0.019	0.172	0.153	0.161	0.119	0.041	0.043	0.216*	0.267*	-0.028
pH								-0.567**	0.245*	-0.151	0.037	-0.089	0.014	-0.161	0.068	-0.246*	-0.369**	0.089
Acidity									-0.118	0.269*	-0.060	0.046	-0.014	0.194	-0.004	0.349**	0.278**	0.100
P										-0.041	0.174	-0.232*	0.011	0.158	0.275**	0.238*	-0.102	-0.023
Na											0.106	-0.036	-0.006	-0.169	-0.121	0.016	0.144	-0.156
K												-0.127	0.358**	-0.065	0.124	0.140	0.200	0.084
Ca													-0.122	-0.064	-0.049	0.057	0.113	0.167
Mg														-0.125	0.352**	-0.102	00.249*	0.240*
Fe															0.354**	0.475**	0.436**	-0.022
Cu																0.391**	0.368**	0.112
Zn																	0.314**	0.020
Mn																		0.008

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Table 5: Results (mean±standard deviation) of the mean major chemical components, total phenolic compounds, pH and acidity obtained in "manteca" bean landraces according to the colour and shape of the seed.

Landrace	Seed weight (g)	Moisture (%)	Starch (%)	Protein (%)	Fiber (%)	Ash (%)	TP	pH	Acidity (%)
					Seed colour				
Pale pink	0.62±0.08[bc]	6.51±0.39[a]	37.2±3.9[a]	24.8±1.5[c]	29.2±2.7[cd]	4.95±0.17[ab]	274±4[a]	6.59±0.17[a]	0.51±0.03[b]
Strong pink	0.54±0.03[ab]	6.21±0.45[a]	40.5±2.2[b]	24.7±1.9[c]	30.5±1.6[d]	5.19±0.22[b]	250±60[a]	6.76±0.12[a]	0.41±0.03[a]
Cream yellow	0.64±0.08[c]	6.61±0.69[a]	40.4±2.2[b]	24.2±1.6[bc]	27.0±1.7[bc]	4.76±0.23[a]	251±61[a]	6.53±0.22[a]	0.48±0.06[b]
Sulfur yellow	0.54±0.15[ab]	6.59±0.33[a]	41.5±2.6[b]	22.1±1.5[a]	27.7±1.5[bc]	4.76±0.24[a]	206±52[a]	6.67±0.14[a]	0.45±0.03[ab]
Brown	0.47±0.01[a]	6.44±0.63[a]	41.4±1.3[b]	22.4±1.6[ab]	24.3±0.7[a]	4.83±0.10[a]	241±67[a]	6.64±0.17[a]	0.46±0.05[ab]
					Seed shape				
Rounded	0.64±0.09[b]	6.63±0.66[a]	40.7±2.1[b]	23.8±1.6[a]	26.9±1.8[a]	4.79±0.22[a]	251±62[a]	6.55±0.22[a]	0.48±0.06[a]
Elongated	0.57±0.10[a]	6.40±0.52[a]	39.1±3.2[a]	24.6±1.9[a]	28.6±2.2[b]	4.82±0.28[a]	243±54[a]	6.60±0.18[a]	0.48±0.06[a]

TP = total phenolics (mg GAE/100 mg) except for Se μg/100 g. Data expressed in dry weight (dw).

Values with the same lowercase letters in the same column are statistically equal based on the Duncan's test ($p<0.05$).

Table 6: Results (mean±standard deviation) of mineral and trace elements in "manteca" bean landraces according to the colour and shape of the seed.

Landrace	P	Na	K	Ca	Mg	Fe	Cu	Zn	Mn	Se
Seed colour										
Pale pink	614±57^{b}	59.8±13^{a}	1936±130^{c}	137±17^{a}	196±8.9^{abc}	8.06±0.91^{c}	0.59±0.02^{b}	3.19±0.25^{c}	1.03±0.06^{a}	1.95±0.30^{a}
Strong pink	536±48^{a}	71.3±18^{a}	2044±134^{d}	139±17^{a}	212±8.9^{c}	5.43±0.52^{a}	0.55±0.05^{ab}	2.67±0.11^{a}	1.01±0.08^{a}	2.09±0.66^{a}
Cream yellow	547±50^{a}	61.0±16^{a}	1837±76^{ab}	139±20^{a}	191±13^{ab}	7.09±0.95^{bc}	0.52±0.06^{ab}	2.93±0.20^{b}	0.98±0.07^{a}	2.25±0.70^{a}
Sulfur yellow	562±62^{ab}	57.4±16^{a}	1786±155^{a}	138±12^{a}	185±13^{a}	6.59±0.95^{b}	0.49±0.06^{a}	2.79±0.27^{ab}	0.93±0.02^{a}	2.31±0.96^{a}
Brown	538±59^{a}	50.3±5.8^{a}	1921±72^{bc}	133±15^{a}	202±17^{bc}	6.66±0.82^{b}	0.56±0.05^{b}	2.92±0.15^{b}	0.98±0.10^{a}	3.03±0.82^{a}
Seed shape										
Rounded	546±52^{a}	60.2±16^{a}	1838±73^{a}	140±19^{a}	191±14^{a}	7.03±0.92^{a}	0.53±0.06^{a}	2.92±0.19^{a}	0.97±0.07^{a}	2.30±0.76^{a}
Elongated	575±54^{b}	62.0±16^{a}	1904±141^{b}	133±16^{a}	197±12^{a}	7.04±1.33^{a}	0.54±0.06^{a}	2.98±0.30^{a}	1.00±0.06^{a}	2.14±0.58^{a}

All the results are expressed in mg/100 g referred dry weight (dw), except for Se µg/100 g of dw.
Values with the same lowercase letter within the same column are statistically equal based on the Duncan's test ($p<0.05$).

fiber concentration was lower ($p<0.05$) in the rounded accessions. Elongated shape accessions had a greater richness ($p<0.05$) of P and K than the rest. No data were found in the literature on the influence of shape of seeds in the physicochemical parameters.

CONCLUSION

The physico-chemical and nutritional parameters determined fell well into the ranges described in the literature for beans, except electrolytes (Na and K) which were higher. Accession nº 6, 13 and 17 should be evaluated further because of their high nutrient content. The consumption of legumes represents an interesting contribution to the intake of phenolic compounds, minerals such as Mg and K and trace elements as Fe (although with low bioavailability), Cu and Mn. The contribution to the intake of protein and fiber was important, although protein of legumes is deficient in sulfur amino acids. Phenolic compounds in beans increased when pH was decreased and acidity increased; proteins were correlated with trace elements, except Se. Color of the seed influenced on the weight per grain and the contents of protein, starch, fiber, ash, P, K, Mg, Fe, Cu and Zn; while shape only affected on weight per grain, starch, fiber, P and K.

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