Acta Scientiarum. Agronomy
ISSN: 1807-8621
Editora da Universidade Estadual de Maringá - EDUEM

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Acta Scientiarum. Agronomy, vol. 42, 2020
Editora da Universidade Estadual de Maringá - EDUEM
Available in: http://www.redalyc.org/articulo.oa?id=303062597015
DOI: 10.4025/actasciagron.v42i1.43689

CROP PRODUCTION

Consumer preference and the technological and nutritional quality of different bean colours

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Acta Scientiarum. Agronomy, vol. 42, 2020

Editora da Universidade Estadual de Maringá - EDUEM

Received: 12 July 2018
Accepted: 03 September 2018

DOI: 10.4025/actasciagron.v42i1.43689

ABSTRACT. : Beans can be found in different grain colours, and for this reason, it is important to understand the technological and nutritional quality of the diverse types of beans that are consumed. The objectives of this work were to identify the traits that determine Brazilian consumer choice of different bean colours and to evaluate whether different bean colours present differences in technological and nutritional traits. For this purpose, beans of different colours (white, cranberry, matte red kidney, shiny red kidney, and black) were obtained from supermarkets. The samples were evaluated for consumer preference and the technological and nutritional traits of the beans. In southern Brazil, the majority of the survey participants (58%) preferred black beans, and their choice was based on consumption habit (66%) and grain colour (30%). Different bean colours presented differences for all traits related to technological and nutritional quality, except for potassium concentration. Consumption habit and grain colour defined consumer choice for black beans. Black beans were preferred by 58% of the participants, and this type of bean has high concentrations of calcium, magnesium, iron, zinc and copper.
Keywords: Phaseolus vulgaris, grains standard, cooking time, protein, minerals.

Introduction

Beans (*Phaseolus vulgaris* L.) are grown and consumed in several countries. Records of bean consumption in the world date as far back as Ancient Greece (Amouretti, 1998). In Brazil, indigenous people consumed beans even before the colonial period.

Brazil is a major world bean producer and consumer. In the country, carioca bean crops are predominant (beige seed coat with brown streaks), accounting for 70% of the national production, followed by the black cultivars (20%), and then other colour cultivars (10%) (Lemos, Mingotte, & Farinelli, 2015). However, the type of bean that is preferred by consumers varies in different regions of the country. In southern Brazil, consumers prefer black beans. In this region, black bean production accounts for 70% of the area cultivated with beans.

The habit of eating black beans dates back to slavery times. Beans were cooked with large pieces of pork in the slave quarters (Bassinello, 2009). The dish became known as *feijoada*. Black bean consumption was widespread in the country, in the form of a mixture of cooked beans, manioc flour, dried meat and bacon, which was carried by travellers, since this composition lasts for a long time. Today, *feijoada* is the typical Brazilian dish most known internationally. Beans have thereby promoted the cultural identification of Brazil.

The tradition of consuming black beans in southern Brazil is old and has been passed on from generation to generation. However, a paradigm shift in the consumption of black beans might be beneficial to health. Different bean genotypes vary in colouration and may also vary in the concentration of crude protein (Silva, Abreu, Ramalho, & Maia, 2012) and minerals (Hacisalihoglu & Settles, 2013; Ribeiro et al., 2014a) found in the grains. The nutritional quality of the beans available in the market for consumption in Brazil and in other countries is still little understood.

White, cranberry (cream seed coat with red streaks) and kidney beans are important in the international market because they are produced and consumed in several countries, but no previous studies assessing consumer preferences for black, white, cranberry and kidney beans were found in the literature. Additionally, no reports were found in the literature as to whether there are differences in the technological and nutritional qualities of these types of beans. If the nutritional quality of different types of beans varies, then varying the bean colour eaten during the week may represent nutritional dietary gains. Thus, the objectives of this work were to identify the traits that determine the bean choices of Brazilian consumers by colour and to evaluate whether different colours of beans represent differences in technological and nutritional traits.

Material and methods

Origin of beans and evaluation of consumer preference

One-kilogram packages of different colours of beans (white, cranberry, matte red kidney, shiny red kidney, and black) were purchased from supermarkets in Santa Maria, Rio Grande do Sul State, Brazil (Figure 1). All bean samples had similar manufacturing dates, characterizing lots with the same shelf life. The beans were refrigerated (temperature of 5°C and 95% relative air humidity) during the assessment period.

A multiple choice questionnaire was developed with five questions to evaluate which traits are considered by consumers when choosing a certain bean colour. The analysis was carried out in the Quality Laboratory of the Federal University of Santa Maria (UFSM), which is equipped with fluorescent lights and individual tables. Fifty people were invited to participate, including students, administrative clerks, and teachers from the UFSM, as well as some others external to the UFSM. The surveyed group consisted of people between 17 and 69 years old, of different gender, ethnicity, educational level, and household income.

The sample was therefore representative of the population that consumes beans in Brazil. All survey participants declared that they consumed beans and were motivated to participate in the research.

The evaluation was performed with samples of 200 g of raw grains of each type of bean. The bean samples were arranged in clear plastic containers, containing a number, and displayed on a table. The order of presentation of the samples was defined by draw. Each participant analysed the five bean samples shown and marked the alternative that best represented his/her preference for each question on the form.

Evaluation of technological and nutritional quality of beans

The evaluation of the technological and nutritional quality traits of common beans was carried out in a completely randomized design with three replications. The bean colours were determined by a portable colorimeter, using the Cielab numerical system. On this scale, L represents the grain's luminosity, which ranges from 0 (black) to 100 (white); a* values range from -60 (dark green) to +60 (dark red); and b* can range from -60 (dark blue) to +60 (dark yellow). Fifty-gram samples of grains were evenly distributed on a petri dish, completely covering the bottom of the container. The petri dish was placed on a white paper, so as not to absorb other possible colours from the environment. The measurement head of the colorimeter was vertically placed on the beans, and three readings were made for each replication.

Figure 1
Representative image of the five samples of the bean colours evaluated.

Three samples of 100 g of each colour were counted and placed on a precision balance to determine the mass of 100 grains; masses were assessed at 13% moisture. The length, width and thickness of the beans were measured with a digital calliper. For this purpose, 10 grains were randomly sampled from each replication. The length-to-width ratio defined the grain shape, whereas the thickness-to-width ratio defined the degree of flatness of the beans (Romero, 1961).

Samples of 25 grains, previously weighed, were soaked in 50 mL of distilled water for eight hours, at ambient temperature (20 ± 2ºC). Then, the grain samples were partially dried on a paper towel. The normal grains value, expressed as a percentage, was obtained by counting the number of grains that absorbed water after soaking. Water uptake was measured by the difference in grain weight before and after soaking and was expressed as a percentage. The bean samples were then used to evaluate the cooking time. Beans were cooked on a gas stove using a Mattson cooker with 25 pegs, as described by Ribeiro et al. (2014a). The mean falling time of the first 13 pegs was considered as the cooking time of each sample.

To evaluate the nutritional quality of the beans, 50 grains samples of raw g were ground in an analytical micro-mill until all particles were smaller than 1 mm in diameter, not sieved. An aliquot of 0.1 g of bean flour was used in the nitrogen digestion process, which was carried out following the Kjeldahl method, according to the methodology proposed by the Association of Official Analytical Chemists (AOAC, 1995). The total nitrogen value obtained was multiplied by the correction factor of 6.25 to obtain the crude protein value.

A sample of 0.5 g of the raw bean flour was used for the nitric-perchloric digestion (3:1), according to the methodology described by Jost et al. (2013). Potassium concentration was determined by a flame photometer, and phosphorus concentration was obtained by an optical emission spectrophotometer. Concentrations of calcium, magnesium, iron, zinc and copper were determined by an atomic absorption spectrophotometer.

Statistical analyses

Based on the answers obtained in the consumer preference evaluation form, frequency distribution graphs were developed. The horizontal axis of the graphs corresponded to the class intervals, and the vertical axis represented an absolute frequency (number of people).

The data obtained for the technological and nutritional quality traits of different beans were subjected to analysis of variance. For those traits expressed as percentages, i.e., normal grains and water uptake, the values were transformed with the equation , where x = trait value. The Scott-Knott test at 5% probability was used to compare the means. Experimental precision was evaluated by the coefficient of experimental variation and selective accuracy, as described by Ribeiro et al. (2017).

The selection index (index) was estimated as described by Mendes, Ramalho, and Abreu (2009) for the quantitative traits when a significant difference was observed in an F-test. A constant equal to three was added to the mean index of the traits found in the three replications to avoid negative values. The contribution of each standardized trait in the index value was shown in charts. The charts were made using Microsoft Office

Excel spreadsheets, and the statistical analyses were carried out in the Genes software (Cruz, 2016).

Results and discussion

Different bean colours and consumer preference

Of the 50 people surveyed for this study, 22 eat beans three to four days a week, and 22 include beans in their meals five to six days a week (Figure 2A). Therefore, 88% of the participants have the habit of consuming beans from three to six days a week, which is very healthy. The health value of beans comes from the fact that most of the dry matter of beans contains carbohydrates and crude protein (Silva, Rocha, & Brazaca, 2009). In addition, beans are an important source of minerals in the diet, with the predominant mineral being potassium, followed by phosphorus, magnesium, sulfur, calcium, iron, zinc, manganese, copper and boron (Ribeiro, Jost, Cerutti, Maziero, & Poersch, 2008; Jost, Ribeiro, Cargnelutti Filho, & Antunes, 2010).

Black beans were preferred by the majority of the participants (58%) among the samples presented (Figure 2B). Shiny red kidney beans ranked second in the preference of the participants, followed by cranberry, white and matte red kidney beans. The preference for black beans can be justified by the tradition of consumption of this kind of bean in the southern region of Brazil. According to historians Pilla and Ribeiro (2018), black beans constituted a staple subsistence crop and were part of the diets of most producers and the low-income population since the colonial period in Brazil. The higher consumption of black beans in the southern region of Brazil is also associated with a greater production of this kind of grain. The higher supply of black beans in the market and the tradition of consuming this kind of bean contributed to the preservation of the people's habit of eating black beans, which was inherited from their ancestors and perpetuated through generations.

The main criteria considered by the participants when choosing their preferred bean type was consumption habit (66%), followed by grain colour (30%) and size (4%) (Figure 2C). None of the participants considered the shape of the grain when choosing bean type. Thus, participants preferred black beans due to their habit of consuming this type of grain. Although the composition of survey participants in the sample was very diverse, the preference for black beans was presumably associated with the customs and traditions of consumption of the people who live in the southern region of Brazil. In addition, the preference for consumption of black beans can also be related to broth quality because black beans produce a thicker broth when compared to the broth of the other types of beans (Oliveira, Ribeiro, Jost, Colpo, & Poersch, 2013).

Of the 50 survey participants in the present study, only four participants revealed that they read the nutrition information displayed on the packages when they buy beans (Figure 2D). In Brazil, the nutritional facts label has been mandatory and regulated by the National

Health Surveillance Agency (Anvisa) since 2001. Such information is vitally important to consumers because it allows for the analysis of the nutritional composition of the food being bought. However, 92% of the participants said that they do not consider the nutritional information presented on the packages when they buy beans.

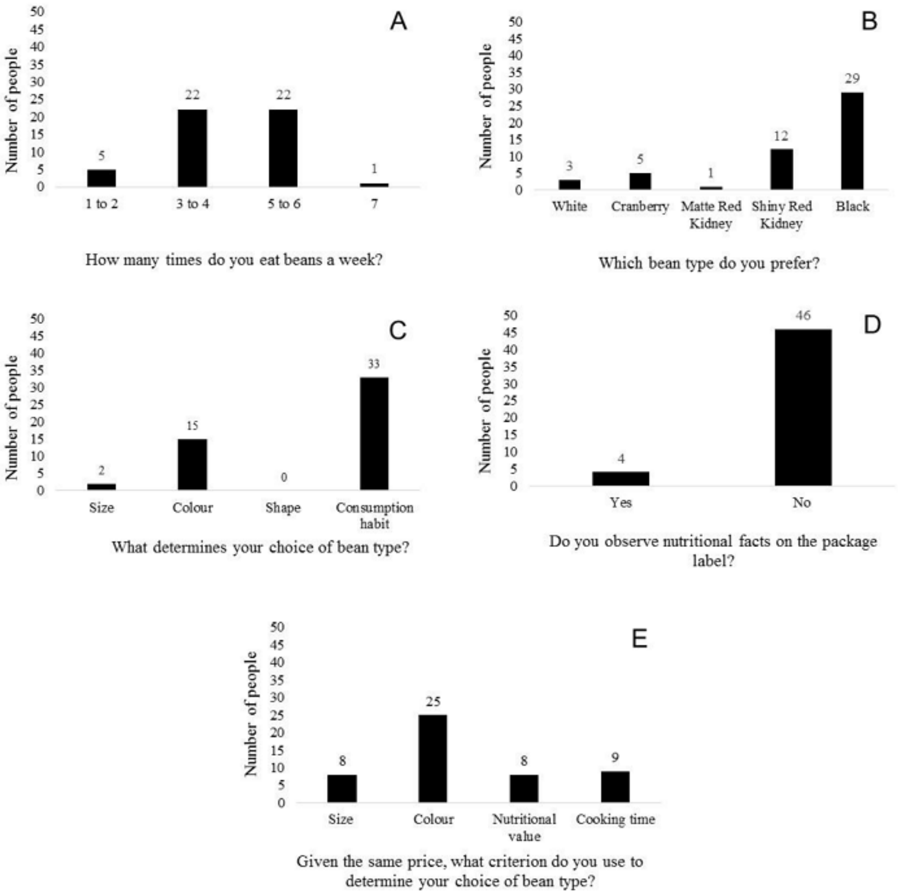

Figure 2

Graphical representation of the answers obtained in the multiple choice questionnaire used to evaluate bean colour consumption preference.

Another criterion that has importance for the consumer choice of beans is price. If the price of different colours of beans is held constant, then 50% of survey participants would choose beans based on the grain colour, 18% on the cooking time, 16% on the grain size, and 16% on the nutritional value (Figure 2E). This result suggests that Brazilian bean consumers are very traditional in their choice and define their purchase based on the type of beans that they usually consume, black beans.

The results obtained in the present study allow us to infer that if the price of black beans were the same for white, cranberry, shiny red or matte red kidney beans, then consumers would still prefer black beans. This scenario is because the preference for black beans has a historical connotation in the southern region of Brazil, whose population has preserved these eating habits for centuries. Those who traditionally eat black beans show some resistance to varying bean colour in their diets.

In the analysis of variance, a significant effect for treatment regarding all technological quality traits was observed, showing that the beans differed for grain colour, mass of 100 grains, size, shape, and cooking parameters. Such diversity found in beans meets the demand of consumers for differentiated foods and can meet the most varied consumption needs.

The coefficient of experimental variation varied from 1.841 (grain width) to 12.958% (cooking time) (Table 1). Similar coefficient of experimental variation values were previously described for the technological quality traits of beans (Corrêa et al., 2010; Ribeiro, Domingues, Gruhn, Zemolin, & Rodrigues, 2014b; Cichy, Wiesinger, & Mendoza, 2015; Santos, Ribeiro, & Maziero, 2016). Additionally, a selective accuracy ≥ 0.893 was obtained for these traits, characterizing high experimental precision, according with the classes established by Resende and Duarte (2007). Thus, all technological quality traits of the beans were evaluated with high experimental precision in the present study.

Table 1

Values, mean, coefficient of experimental variation (CV%) and selective accuracy (SA%) obtained for luminosity (L), chromaticity a* (a*), chromaticity b* (b*), mass of 100 grains (mass), grain length (length), width (width), thickness (thickness), shape (shape), degree of flatness (flatness), normal grains (normal), water uptake (uptake), cooking time (cooking), concentrations of protein, potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), and copper (Cu) in different bean colours.

Treatments	L		a*		b*		Mass g		Length mm		Width mm		Thickness mm	
White	77.61	a	-2.25	d	21.56	b	65.90	a	15.44	a	7.91	b	6.57	a
Cranberry	52.46	b	10.54	b	26.33	a	54.20	b	13.71	b	8.40	a	6.45	a
Shiny red	32.46	c	19.94	a	13.16	c	54.37	b	14.14	b	7.37	c	5.79	b
Matte red	30.59	d	20.25	a	12.73	c	53.97	b	13.64	b	7.27	c	5.93	b
Black	24.20	e	-0.53	c	3.72	d	25.07	c	9.81	c	6.37	d	5.00	c
Mean	43.46		9.59		15.5		50.70		13.35		7.46		5.95	
CV%	2.160		8.616		7.902		4.757		1.996		1.841		1.927	
AS	0.999		0.999		0.997		0.996		0.997		0.994		0.994	

Treatments	Shape[1]	Flatness	Normal %		Uptake %		Cooking Min.:s		Protein %		K g kg^{-1}	
White	Oblong/KM	Full	96	b	69.15	b	40:04	b	24.94	a	11.55	ns
Cranberry	Elliptical	Semi-Full	100	a	84.00	a	26:35	a	21.87	b	11.90	
Shiny red	Oblong/KM	Semi-Full	100	a	89.88	a	21:13	a	24.94	a	10.85	
Matte red	Oblong/KM	Full	99	a	79.10	a	24:23	a	21.06	b	10.78	
Black	Elliptical	Semi-Full	100	a	77.34	a	24:21	a	20.33	b	11.20	
Mean	-	-	99		79.90		27:19		22.63		11.26	
CV%	2.134	2.244	0.511		3.779		12.958		2.871		4.087	
AS	0.993	0.914	0.94		0.893		0.961		0.985		0.828	

Treatments	P g kg^{-1}		Ca g kg^{-1}		Mg g kg^{-1}		Fe mg kg^{-1}		Zn mg kg^{-1}		Cu mg kg^{-1}	
White	3.95	b	2.84	b	1.41	a	75.47	c	35.33	a	12.00	a
Cranberry	5.18	a	2.49	c	1.39	a	91.37	b	42.00	a	12.73	a
Shiny red	3.18	b	1.35	e	1.24	b	60.97	c	37.43	a	8.30	b
Matte red	3.48	b	1.75	d	1.25	b	75.60	c	32.60	a	8.20	b
Black	3.34	b	3.37	a	1.37	a	109	a	36.70	a	13.07	a
Mean	3.83		2.36		1.33		82.48		36.81		10.86	
CV%	13.346		6.623		2.848		11.532		7.687		5.920	
AS	0.932		0.994		0.961		0.954		0.880		0.988	

*Means followed by the same letter in each column do not differ from each other by the Scott-Knott's test, at 5% probability. ns = non-significant by F test. 1Shape: Oblong/KM: oblong/kidney-medium.

The highest luminosity value was observed in white beans (L = 77.61), followed by cranberry beans (L = 52.46). Similar L values were verified in white and cranberry bean cultivars by Ribeiro et al. (2014b). In the present study, cranberry beans were more red (higher a* value) and more yellow (higher b* value) in colour than white beans. This result is because cranberry beans have two colours (cream seed coat with red streaks), while white beans have a single seed coat colour (Figure 1). Therefore, white beans must then present a* and b* values close to zero, due to the absence of a secondary colour. A positive and high b* value for white beans, as observed in the present study, means yellower grains, which is not desirable, because according to Karathanos, Bakalis, Kyritsi, and Rodis (2006), this indicates a loss of technological quality.

For white and cranberry beans, the higher L values indicate clearer grains. A high clarity is often associated by consumers with freshly harvested grains and better quality. However, when the bean colour is determined by L, a*, and b* values, a more detailed analysis can be performed, allowing us to assess the intensity of the red and yellow shades and providing preliminary data on the technological quality of beans.

Matte red kidney and shiny red kidney beans differed only by L values, and did not present variation in their a* and b* values. Similarly, Ribeiro et al. (2014b) and Parmar, Singh, Kaur, and Thakur (2017) observed that kidney bean genotypes were different for grain luminosity (L value). However, Parmar et al. (2017) found a large variation in the a* and b* values in grains of 11 kidney bean genotypes, probably due to the greater diversity of red shades in the samples evaluated.

The black beans presented an L value = 24.20, and a* and b* values close to zero. For black beans, less clarity (a lower L value) is desirable, because this indicates the absence of purplish grains, which consumers associate with higher technological quality. Ribeiro, Possebom, and Storck (2003) suggested as the standard colour for black beans a L value ≤ 22.00. In the present study, the L value observed in the black bean sample did not meet this previously defined standard. However, black beans were preferred by the majority of the survey participants in this study (Figure 2B). This result can be justified by the fact that the ideal colour standard for black beans was previously defined considering only the L value. In addition to the L value, it is also necessary to measure the a* and b* values, so that a better evaluation can be made of the visual quality of black beans.

The mass of 100 grains ranged from 25.07 (black beans) to 65.90 g (white beans). According to the size classification presented by Blair, Gonzáles, and Kimani (2010), all bean samples evaluated have large-sized grains (> 40 g 100 grains^{-1}), except for black beans, which were classified as medium-sized grains (25 to 40 g 100 grains^{-1}). Small- and medium-sized beans belong to the Middle American gene pool, whereas large grains are typical of beans of the Andean gene pool. In Brazil, consumers prefer medium-sized beans, according to Carbonell, Chiorato, Gonçalves, Perina, and Carvalho (2010). No references were found for the most accepted grain sizes of white, cranberry and kidney beans by consumers. However, in the present study, the mass of 100 grains values obtained for white, cranberry and kidney beans correspond to those observed in bean cultivars of these groups of colours grown in Brazil (Ribeiro et al., 2014b). This result allows us to infer that all the bean samples evaluated in this study meet Brazilian consumers' demand related to bean size.

The bean samples evaluated showed variation in their grain measures. The white beans were larger in length and thickness. However, cranberry beans did not differ from white beans in thickness but were superior in width. The ratio between these measures allowed us to obtain both the grains' shape and degree of flatness.

The samples of cranberry and black beans presented an elliptical shape and a semi-full degree of grain flatness, while the other samples have an oblong/kidney-medium shape with a full (white and shiny red kidney beans) or semi-full (matte red kidney beans) degree of grain flatness. Black beans had an elliptical shape and a semi-full degree of grain flatness, meeting the consumer preference, according to Carbonell et al. (2010). For white, cranberry and kidney beans, no previous works were found in the literature defining the shape and degree of grain flatness best accepted by consumers. However, it was possible to verify that the shape and degree of grain flatness of cranberry and kidney bean cultivars recently developed by research (Mambrin, Ribeiro, Henning, Henning, & Barkert, 2015) may be different from the results obtained in this study.

White beans presented the lowest normal grains and water uptake values and the highest cooking time of all samples evaluated. White beans showed more resistance to water absorption, probably due to their yellower grain colour (higher b* value). This condition usually occurs when white beans are stored at high air temperatures (Karathanos et al., 2006). In addition, white beans presented the highest mass of 100 grains (65.90 g) and thicker grains (6.57 cm), and this resulted in an increase in the cook time (40 min. and 4 s) for the grains to reach the softness considered suitable for consumption. This result is justified by the fact that grain thickness has a high correlation with cooking time ($r = 0.973$) in beans (Santos et al., 2016).

Cranberry, matte red kidney, shiny red kidney, and black beans did not differ for normal grains, water uptake and cooking time. For these bean samples, cooking time varied from 21 min. and 13 s to 26 min. and 35 s. A higher cooking time was observed for Andean beans of different colours evaluated in the United States (Cichy et al., 2015). However, a similar range for cooking time was verified in Andean bean genotypes of different colours cultivated in Brazil (Corrêa et al., 2010; Ribeiro et al., 2014b). Therefore, all bean samples evaluated presented a fast cooking time, i.e., less than 25 min. for Middle American beans (Santos et al., 2016) and less than 27 min. for Andean beans (Cichy et al., 2015), except for white beans, which required more time to cook.

Different bean colours and their nutritional quality

A significant difference was obtained in the F-test for all nutritional quality traits, except for the potassium concentration. Similarly, beans of different colours showed variations in crude protein concentration (Saha, Singh, Mahajan, & Gupta, 2009; Silva et al., 2012; Hacisalihoglu & Settles, 2013) and minerals (Akond, Crawford, Berthold, Talukder, & Hossain, 2011; Silva et al., 2012; Hacisalihoglu & Settles, 2013; Ribeiro et al., 2014a). Thus, different colour beans present variability in their nutritional composition, and this information should be on the product labels.

The coefficient of experimental variation ranged from 2.848 to 13.346, and selective accuracy values of 0.828 a 0.994 were observed for the nutritional quality traits (Table 1). A similar variation amplitude was verified when the experimental precision of the crude protein and mineral concentrations in the different bean genotypes were evaluated by the coefficient of experimental variation (Saha et al., 2009) and selective accuracy (Silva et al., 2012). Selective accuracy ≥ 0.850 indicates high experimental precision in the evaluation of traits (Resende & Duarte, 2007). Thus, in the present study, all nutritional quality traits were evaluated with high experimental precision.

Crude protein concentrations varied from 20.33 (black bean) to 24.94% (white and matte red kidney beans). Similar crude protein values (Saha et al., 2009; Parmar et al., 2017) or higher values (Pinheiro, Baeta, Pereira, Domingues, & Ricardo, 2010; Silva et al., 2012; Hacisalihoglu & Settles, 2013) were previously described for bean genotypes of different colours. However, Silva et al. (2012) observed higher crude protein values in black bean genotypes, in contrast to the present study.

In the beans evaluated, the mineral with the highest concentration was potassium, followed by phosphorus, calcium, magnesium, iron, zinc and copper, which is in agreement with previous results obtained by Pinheiro et al. (2010) and Steckling, Ribeiro, Arns, Mezzomo, and Possobom (2017). For the potassium concentration, there was no significant difference among the different colours of beans. In addition, the values obtained for potassium concentration in the different bean types are considered low (< 11.90 g kg^{-1} of dry matter - DM) for beans, according to the classes established by Steckling et al. (2017).

Cranberry beans showed the highest phosphorus concentration among the types of grains evaluated. Only cranberry beans presented high phosphorus concentrations (> 5.00 g kg^{-1} of DM), according to the classification proposed for beans by Steckling et al. (2017). Thus, a regular dietary intake of cranberry beans could contribute to the prevention of fatigue and anxiety, which, according to Martínez-Ballesta et al. (2010), are observed when there is a diagnosis of phosphorus deficiency in the human body.

Black beans showed the highest calcium and iron concentrations, exceeding the other beans. However, white, cranberry, shiny red kidney and black beans exhibited high calcium concentrations (> 1.40 g kg^{-1} of DM), according to the classes established for beans by Ribeiro, Domingues, Zemolin, and Possobom (2013). Only black beans presented iron concentrations > 95.00 mg kg^{-1} of DM, which characterizes a high concentration of this mineral in beans, as proposed by Ribeiro et al.

(2013). Black bean genotypes with high calcium concentrations were previously described by Ribeiro et al. (2013). Hacisalihoglu and Settles (2013) and Meyer, Rojas, Santanem, and Stoddard (2013), in turn, identified black bean genotypes with higher iron concentration in the grains. A regular dietary intake of black beans might help prevent the development of osteoporosis, that is associated with calcium deficiency (Souza, 2010), and anaemia, which is common in cases of iron deficiency (Abbaspour, Hurrel, & Kelishadi, 2014).

White, cranberry and black beans showed the highest values for magnesium and copper concentrations, differing significantly from the other beans studied. Silva et al. (2012) observed that the mean magnesium and copper concentrations determined in 13 genotypes of black bean and 36 genotypes of other colours of beans were not significantly different. Foods rich in magnesium and copper represent benefits to health because magnesium acts in enzymatic reactions, in cardiac function and in glucose metabolism (Elin, 2010), and copper plays a role in the mobilization of iron for the synthesis of haemoglobin (Franco, 2005). Thus, white, cranberry and black beans represent an important dietary source of magnesium and copper.

For zinc, the application of the Scott-Knott test did not result in stratification between treatments for the same level of significance. However, all types of beans evaluated have high zinc concentrations, i.e., a value higher than 31 mg kg^{-1} of DM, according to Tryphone and Nchimbi-Msolla (2010). Zinc acts in the immune system and in the prevention of dermatitis (Gibson, 2012). Therefore, a regular dietary intake of white, cranberry, matte red kidney, shiny red kidney and black beans constitutes an important zinc supplement to the human body.

Black beans were highlighted in relation to high calcium, magnesium, iron, zinc and copper concentrations. Therefore, black beans presented the highest nutritional quality among the types of beans evaluated. The habit of eating black beans in the southern region of Brazil is healthy due to its high nutritional value.

Different bean colours with high technological and nutritional quality

The index allowed a graphic view of the main differences among different bean colours regarding technological and nutritional quality traits. White beans presented a higher index for L, b*, mass of 100 grains, grain length, width and thickness, cooking time, and concentrations of protein, phosphorus, calcium and magnesium (Figure 3). In addition, cranberry beans showed a higher index for L, b*, grain width and thickness, normal grains, water uptake, cooking time, and concentrations of phosphorus, magnesium, iron, zinc and copper, and white beans have a higher protein and macro-mineral concentration than cranberry beans. However, cranberry beans present high micromineral concentration and reduced cooking time.

Red kidney beans had lower technological and nutritional quality than the other types of beans evaluated. Matte red kidney beans exhibited higher water uptake, protein and zinc concentrations, and lower cooking time. Conversely, shiny red kidney beans showed a higher index for a* value, which is not desirable.

Black beans were preferred by 58% of the participants (Figure 2B), and the criteria that defined their choice were consumption habit and grain colour (Figure 2C). The black beans presented a lower index for L, a*, and b* values, mass of 100 grains, grain size measures, water uptake, cooking time and protein concentration. However, black beans showed the highest index for normal grains and concentrations of calcium, magnesium, iron, zinc and copper. Therefore, black beans with their dark colour and medium-sized, fast cooking grains, are nutritionally richer than the other types of beans evaluated. The index has shown to be promising for the identification of bean genotypes of different colours with higher mineral concentrations (Silva et al., 2012; Ribeiro et al., 2014a).

In the present study, it was possible to observe that beans of different colours had differences in technological and nutritional quality traits. A balanced and diversified diet has been associated with a healthy life. Similarly, varying the bean colour that is eaten during the week may be beneficial to health because beans of different colours showed variations in protein and mineral concentrations (Table 1).

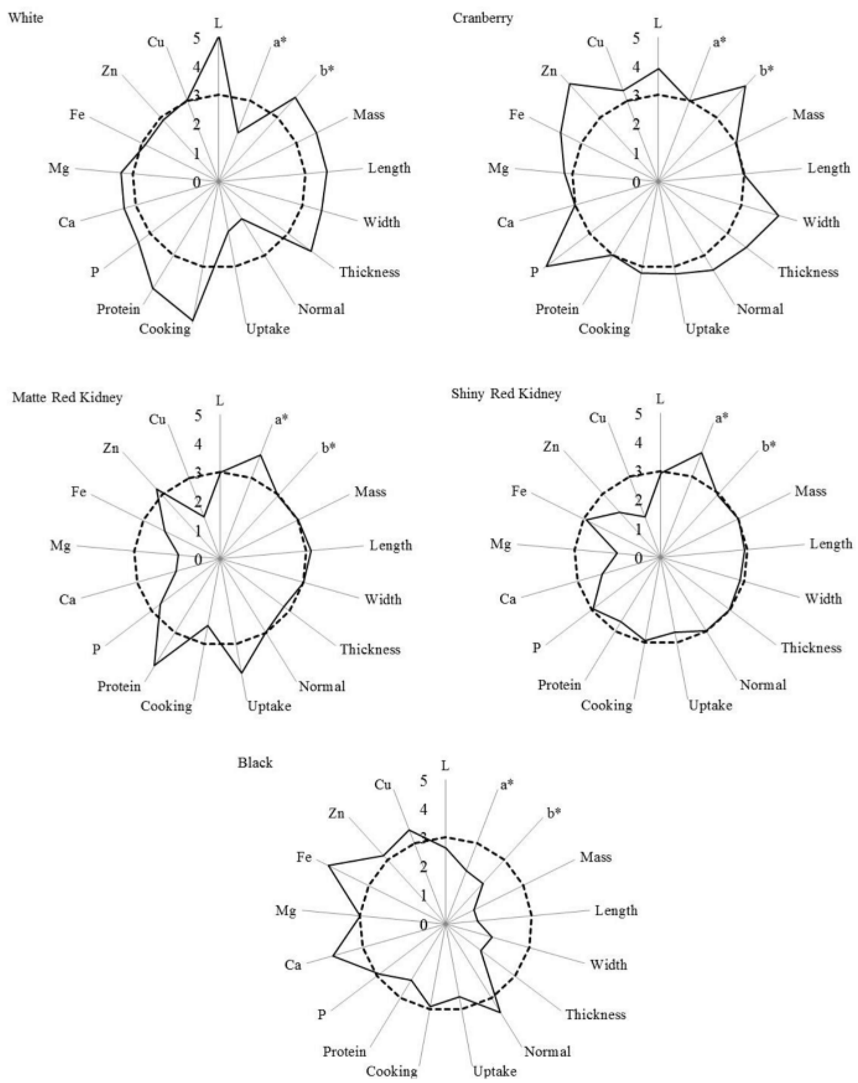

Figure 3

Representation of the index for luminosity (L), chromaticity a* (a*), chromaticity b* (b*), mass of 100 grains (g), length (mm), width (mm), thickness (mm), normal grains (normal, %), water uptake (uptake, %), cooking time (cooking, min.:s), concentrations of protein (%), phosphorus (P, g kg^{-1} of dry matter - DM), calcium (Ca, g kg^{-1} of DM), magnesium (Mg, g kg^{-1} of DM), iron (Fe, mg kg^{-1} of DM), zinc (Zn, mg kg^{-1} of DM), and copper (Cu, mg kg^{-1} of DM) in beans of different colours.

Conclusion

Consumption habit and grain colour define consumer choice for black beans. Technological and nutritional quality traits vary according to bean colour. Black beans are preferred by 58% of the survey participants, and this type of bean presents a high concentration of calcium, magnesium, iron, zinc, and copper.

Acknowledgements

To the National Council for Scientific and Technological Development (CNPq) for the financial support and scholarships and to the Coordination for the Improvement of Higher Education Personnel (Capes) for the grants awarded

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