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Chemical characterization, bioactive compounds, and functional technological properties of flour from two cultivars of landrace common beans (*Phaseolus vulgaris* L.)

*Alves, J. S., Rodrigues, A. S., Moro, K. I. B., Boeira, C. P., Londero, P. M. G. and Rosa, C. S.

Department of Food Science and Technology, Federal University of Santa Maria, Rio Grande do Sul, Brazil

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Abstract

The aim of the present work was to study the chemical characterization and to determine the bioactive compounds and functional technological properties of flour made from two cultivars (Manteigão and Carioca) of landrace common bean (hulled and unhulled) in order to evaluate its potential use by the food industry. To this end, the following were performed: analysis of yield; chemical composition, pH, colour, total phenolic compounds, flavonoids and *in vitro* antioxidant activity (DPPH and FRAP), as well as evaluations of functional technological properties, water and oil absorption capacity, and emulsifying properties. The landrace common bean flours (LCBF) were shown to be important sources of protein and dietary fibre. The levels of phenolic compounds were higher in the unhulled LCBF. The LCBF made from the Manteigão cultivar had a higher reducing power by the FRAP method, as well as higher phenolic compound content and antioxidant capacity as compared to the Carioca cultivar. The LCBF made from unhulled beans from both cultivars had better water absorption capacity and oil absorption capacity, indicating that it could be used in food systems such as soups, as well as bakery and meat products.

Introduction

Legumes occupy an important place in human nutrition, especially among the people in low-incomes and developing countries (Siddiq *et al*., 2010). The common bean (*Phaseolus vulgaris* L.) is the most important legume worldwide as a source of protein, resistant starch, dietary fibre, antioxidants, minerals and vitamins (Sgarbieri, 1989; Broughton *et al*., 2003; Aguilera *et al*., 2011; Pedrosa *et al*., 2015). There is a growing awareness and interest about the importance of including legumes in the human diet and using them as ingredients in the development of new food products due to their beneficial physiological effects in the control and prevention of various metabolic diseases such as diabetes, heart diseases and colon cancer (Tharanathan and Mahadevamma, 2003; Boye *et al*., 2010). A study carried out with 21 ecotypes of P. vulgaris showed that they have hypoglycaemic activity, suggesting that its consumption might reduce the absorption of carbohydrates with less negative effects than drugs. All 21 bean ecotypes showed similar metabolic profiles, such as nitrogen compounds, saponins and alkaloids, all of which have been reported as the bioactive compounds responsible for the antidiabetic activity (Pascale *et al*., 2018; Bianco *et al*., 2018).

Landrace cultivars are traditionally developed, adapted or produced by family farmers with phenotypic characteristics well determined and recognized by the respective communities (Brasil, 2003). Its use is of great importance for the local development, generating autonomy and profitability since there is no need for the use of chemical inputs nor the purchase of seeds for each new plantation (Correa and Weid, 2006), and for food security by providing individuals safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2009). The flour produced from landrace common bean is a way of processing this grain that can help to reduce post-harvest losses, promote its commercialisation and add

*Corresponding author.
Email: jamizinha_sm@hotmail.com

value to this legume. Furthermore, it is also another way of consuming this legume, which can also be used as a functional ingredient, thereby improving the nutritional quality of a wide range of products.

Considering the importance of legumes in the human diet, the aim of the present work was to characterise flours produced from two landrace common bean cultivars (Manteigão and Carioca; hulled and unhulled) in order to assess their potential use in the food industry.

Materials and methods

Raw material

Two landrace common bean cultivars were used in the present work: the black cultivar (Manteigão) and the coloured cultivar (Carioca). The samples were provided by the Association of Landrace Seed Keepers of Ibarama (29°25'10"S; 53°08'05"W, altitude: 317 m), which is situated in the central sierra region of the state of Rio Grande do Sul. The samples were from the 2014-2015 harvest.

The dirt was initially manually removed from the beans in order to obtain the flour. The unhulled beans were ground in a micro-mill (Marconi, model MA 630) and sieved (0.25 mm mesh size) to obtain a uniformed size flour. To obtain hulled bean flour, the bean skins were removed prior to grinding. The flours were subsequently refrigerated (4°C) in low-density polyethylene plastic bags.

Yield

The yield determination of the landrace common bean flours (LCBF) was performed gravimetrically using the ratio between the weight of the intact grains and the amount of the flour obtained after milling.

Chemical composition

The contents of moisture, ash, crude protein and the dietary fibre of the LCBF were determined by the method described by the Association of Official Analytical Chemists (AOAC, 2005). The lipids were determined based on the method described by Bligh and Dyer (1959). The carbohydrates were obtained by difference from the other fractions.

Determination of pH and colour

The pH of the LCBF was determined based on the method of Reyes-Bastidas *et al*. (2010).

The colour analyses were performed using a Minolta® (CR-310) colorimetric spectrophotometer with D65 illuminant. The CIE *L* a* b** (CIELAB) colour system was used.

Preparation of LCBF extracts

The extraction of compounds was performed based on the methodology described by Xu and Chang (2007), with adaptations, where 5 g samples were weighed and 50 mL solvent (80% acetone) was added. After the addition of the solvent, the mixture was stirred in a shaker (Logen Scientific LS, model 4600, Shaker Incubator) at 250 rpm for 3 h at room temperature (25 ± 2°C). The extracts were subsequently centrifuged at 1,109 g for 10 min and filtered. The supernatants were collected and the waste underwent a second extraction with another 50 mL solvent. Then, both extracts were combined and concentrated in a rotary evaporator (Buchi R-3) with a -760 mm Hg vacuum and water temperature of 50°C to remove the solvent. Subsequently, the extracts had their volumes supplemented with distilled water to maintain the initial concentration and they were then packaged in amber bottles and stored in a freezer (-18°C) until analysis.

Determination of total phenolic compounds

The determination of total phenolic compounds was performed based on the spectrophotometric method (using Folin-Ciocalteu reagent) described by Singleton *et al*. (1999) with adaptations. The unhulled LCBF extracts were diluted in 80% acetone at a ratio of 1:50 (v/v), and the hulled LCBF extracts were not diluted. Subsequently, an aliquot of 400 µL of each solution was transferred to test tubes and 2,000 µL diluted (1:10) 2 N Folin-Ciocalteu reagent was added. After 8 min of rest, 1,600 µL 7.5% Na_2CO_3 solution (v/v) was added to the mixture. The solutions were incubated in the dark at room temperature for 2 h following which the absorbance reading was taken at 765 nm using a spectrophotometer (Biospectro SP-220, São Paulo, Brazil) and compared to a gallic acid calibration curve y = 0.0012x -00025, R^2 = 0.9981 (range 0 to 50 mg/L). The results were expressed in equivalent milligrams of gallic acid per gram of sample (mg GAE/g).

Determination of total flavonoids

The concentration of total flavonoids was determined based on the method described by Park *et al*. (1995) with adaptations. Briefly, 250 µL aliquot of each extract was transferred to a test tube, and 1,250 µL distilled water and 75 µL $NaNO_2$ were added. After 5 min rest, 150 µL aluminium chloride, 500 µL 1 M NaOH and 775 µL distilled water were added. The absorbance was measured immediately at 510 nm using a spectrophotometer (Biospectro, SP-220, São Paulo, Brazil) and compared to a quercetin calibration curve y = 0.0027x-0.0772, R^2 = 0.9672

(range 0 to 100 mg/L). The results were expressed in equivalent milligrams of quercetin per gram of sample (mg EQ/g).

Antioxidant activity (assay with DPPH and FRAP)

The antioxidant activity of the compounds present in the LCBF extracts was determined by the sequestration capacity of the free radical DPPH (2,2-diphenyl-1-picryl-hydrazyl) based on the methodology described by Brand-Williams *et al*. (1995) with adaptations. The technique consisted of incubation for 30 min of 5 mL ethanolic solution (80% v/v) of 0.1 mM DPPH with 5 mL solutions containing increasing concentrations of extract of the LCBF (0.07; 0.15; 0.3; 0.6; 1.25; 2.5; 5.0; 10; 20 and 30 mg/L). After incubation, the readings of the samples were measured using a spectrophotometer (Biospectro, SP-220, São Paulo, Brazil) at a wavelength of 517 nm. The percentage of antioxidant activity (%AA) was calculated by the percentage of uptake of the DPPH radical by using Equation 1:

$$(\%)AA = \frac{100 - [(\text{Absorbance of sample} - \text{Absorbance of blank}) \times 100]}{\text{Absorbance of control}} \quad (1)$$

After evaluating the optimal concentration range, the concentration required to capture 50% of the free radical DDPH (IC_{50}) was calculated.

The method described by Benzie and Strain (1996) and adapted by Rockembach *et al*. (2011) was used to determine the ferric reducing antioxidant power. The FRAP reagent (Fe (III) -TPTZ solution) was obtained by mixing 11 mL acetate buffer (0.3 M, pH: 3.6), 1.1 mL TPTZ solution (10 mM in 40 mM HCl) and 1.1 mL aqueous ferric chloride solution (20 mM), which should be used immediately after preparation. At low pH, when ferric-tripyridyltriazine (Fe (III) -TPTZ) is reduced to the ferrous form (Fe (II)) it develops an intense blue colour with a maximum absorption at 593 nm. A 200 µL aliquot of previously diluted extract was added to a test tube along with 1,800 µL FRAP reagent, and the mixture was incubated at 37°C in a water bath for 30 min. The absorbance of the coloured complex that formed was then measured at 593 nm using a spectrophotometer (Biospectro SP-220, São Paulo, Brazil). Trolox (range 0 to 25 µM) was used as standard for the calibration curve y = 0.0601x - 0.0679, R^2 = 0.9937, and the results were expressed in microM TEAC/100 g.

Technological functional properties

Water absorption capacity and oil absorption capacity

To determine the water absorption capacity (WAC) and the oil absorption capacity (OAC), the methodology proposed by Glória and Regitano D'Arce (2000) was followed.

Emulsifying capacity

The emulsifying capacity was determined according to Kaur and Singh (2005). The LCBF samples (0.35 g) were homogenised for 30 sec with 5 mL water in a vortex. Then, 2.5 mL refined soybean oil was added, and the mixture was homogenised again for 30 sec. Subsequently, another 2.5 mL soy oil was added, and the mixture was homogenised for another 90 sec. The mixture was then centrifuged for 5 min at 356 g. The emulsifying activity (EA) was calculated by dividing the volume of the emulsified layer by the total volume before centrifugation. The emulsion stability (ES) was determined using the prepared samples for measuring the emulsifying activity. The tubes were heated for 15 min at 85°C, cooled and centrifuged for 5 min at 356 g. The emulsion stability was expressed as % of the emulsion activity remaining after heating.

Statistical analysis

The data were submitted to analysis of variance and the means were compared using the Tukey's test at 5% level of significance. The results were analysed using Statistica® software version 8.0 (Statsoft Inc., Tulsa, OK, USA).

Results and discussion

Yield

For yield, 100 g unhulled Manteigão cultivar beans yielded 98.60 g flour, and hulled beans yielded 97.50 g flour. From 100 g unhulled Carioca cultivar beans, 98.43 g flour was obtained, and 97.21 g flour was obtained from the hulled beans.

Chemical composition

Brazilian legislation limits the maximum moisture for flours to 15% (ANVISA, 2005). The results obtained in the present work showed that all the samples had levels of humidity that were lower than 15% (Table 1). There was no statistical difference between the hulled LCBF from the Manteigão and Carioca cultivars. This was also the case with the unhulled LCBF. However, there was significant difference between the hulled and unhulled LCBF from the two cultivars.

The LCBF made from unhulled beans from both cultivars did not differ from each other in terms of ash content and showed higher values than the

Table 1. Chemical composition of flour made from unhulled and hulled landrace common beans (g/100 g).

Constituents	Bean cultivars			
	Manteigão		Carioca	
	Unhulled	Hulled	Unhulled	Hulled
Moisture	11.91 ± 0.10[a]	10.84 ± 0.11[b]	11.60 ± 0.46[a]	10.90 ± 0.67[b]
Ash	5.18 ± 0.11[a]	4.82 ± 0.08[b]	5.08 ± 0.02[a]	4.73 ± 0.14[b]
Protein	21.17 ± 0.06[b]	22.74 ± 0.12[a]	21.16 ± 0.06[b]	22.44 ± 0.07[a]
Lipids	1.51 ± 0.03[a]	1.46 ± 0.03[a]	1.33 ± 0.04[b]	1.30 ± 0.03[b]
Total carbohydrates	60.19 ± 0.11[a]	60.14 ± 0.28[a]	60.63 ± 0.45[a]	60.39 ± 0.90[a]
Total dietary fibre	26.05 ± 0.17[b]	18.44 ± 0.09[d]	31.19 ± 0.80[a]	21.21 ± 1.03[c]
Insoluble dietary fibre	24.75 ± 0.42[b]	18.06 ± 0.10[d]	29.05 ± 0.81[a]	20.65 ± 1.08[c]
Soluble dietary fibre	1.31 ± 0.32[b]	0.39 ± 0.17[c]	2.12 ± 0.52[a]	0.57 ± 0.12[c]

Values expressed as mean ± standard deviation, $n = 3$. Different letters in the same line indicate significant difference ($p < 0.05$) by Tukey's test.

LCBF made from hulled beans (Table 1). According to Oomah *et al*. (2010), the skins of beans are a relatively small portion of the bean but they are rich in minerals. Similar results were reported by Siddiq *et al*. (2010) who assessed the ash content of flour from different bean cultivars and found values ranging from 4.60 to 5.00 g/100 g ash. The protein content (Table 1) of the LCBF from hulled beans had higher values and statistically differed from the flour made from unhulled beans; the values varied from 21.16 (Carioca unhulled) to 22.74 g/100 g (Manteigão hulled). According to Yin *et al*. (2009), the protein content in beans varies from 20 to 30%, depending on the type of beans, and the values obtained in the present work were within those limits. It can be inferred that when the bean skin was removed, the concentration of protein increased since the stored protein in legumes seed, as well as beans, represents about 80% of the total proteins of the seeds, and is located in the protein corpuscles of the cotyledons (Duranti and Gius, 1997).

The LCBF from the Manteigão cultivar (unhulled and hulled) significantly differed in relation to the Carioca LCBF (unhulled and hulled), and had a higher lipid content. Soares Júnior *et al*. (2012) analysed different cultivars of common bean and found that the lipid content ranged from 2.31 - 3.36 g/100 g, which were higher than those found in the present work. However, it is noteworthy that the differences that were observed in the present work might have been attributed to genetic variation among the cultivars and also the method used in the extraction, which might have influenced the quantification of the lipid content in the samples.

The LCBF from the unhulled Carioca cultivar had the highest total dietary fibre content (Table 1) and was statistically different from the others. The results obtained in the present work [18.44 (Manteigão hulled) and 31.19 g/100 g (Carioca unhulled)] were in agreement with those found by Londero *et al*. (2008), who studied 19 bean cultivars from the cities of Santa Maria and Pelotas (20.85 – 31.35 g/100 g) in Brazil.

The insoluble fibre content, which is responsible for the improvement of the intestinal transit, ranged from 18.06 (Manteigão hulled) to 29.05 g/100 g (Carioca unhulled). There was a significant difference between all the treatments. The soluble fibre, which is responsible for delaying gastric emptying, reducing serum cholesterol and modulating glucose, showed values between 0.39 (Manteigão hulled) to 2.12 g/100 g (Carioca unhulled). In all the fractions, the LCBF from unhulled beans showed higher values; according Oomah *et al*. (2010) the skin of beans contains a high amount of fibre.

The LCBF from the unhulled Carioca beans had the highest amount of total carbohydrates (60.63 g/100 g) and did not statistically differ from the other treatments. The largest fraction found in the LCBF was total carbohydrates. According to the Brazilian Center for Studies and Research in Food (NEPA) (2011), the carbohydrate contents for Manteigão and Carioca beans are 58.8 g/100 g and 61.20 g/100 g, similar to those found in the present work.

Determination of pH and colour

The pH of the LCBF showed values near neutrality and ranged from 6.29 (Carioca unhulled) to 6.47 (Manteigão hulled). The LCBF of both hulled cultivars showed higher values when compared with unhulled beans. Aguillera *et al*. (2011) found that the raw flour of Cannellini and Pinto cultivars had pH of 6.64 and 6.90, respectively.

The L^* values of the LCBF from hulled beans were the highest (Table 2) and indicated a higher degree of brightness when compared to the LCBF from unhulled beans. This result was expected, due to the removal of the skin from the beans. The LCBF

Table 2. Values of pH, *L**, *a** and *b** parameters of flour made from unhulled and hulled landrace common beans.

Parameters	Cultivars			
	Manteigão		Carioca	
	Unhulled	Hulled	Unhulled	Hulled
pH	6.41 ± 0.06^{ab}	6.47 ± 0.03^{a}	6.29 ± 0.0 ^{c}	6.36 ± 0.05^{bc}
*L**	82.68 ± 0.71^{c}	89.40 ± 0.41^{a}	87.41 ± 0.95^{b}	90.20 ± 1.02^{a}
*a**	0.17 ± 0.11^{c}	0.15 ± 0.13 ^{d}	0.44 ± 0.27^{b}	1.43 ± 0.16^{a}
*b**	6.85 ± 0.67^{c}	10.15 ± 0.39^{a}	6.53 ± 0.29^{c}	7.98 ± 0.27^{b}

Values expressed as mean ± standard deviation, $n = 3$. Different letters in the same line indicate significant difference ($p < 0.05$) by Tukey's test.

from hulled Carioca beans showed higher *a** values and significantly differed from all the other flours. Regarding the *b** parameter, the LCBF from hulled Manteigão beans presented the highest value and significantly differed from other flours, showing a greater degree of yellowing of the cotyledon.

Total phenolic compounds and total flavonoids

Table 3 shows that the extracts of LCBF from unhulled beans had a higher level of total phenolic compounds when compared with the LCBF made from hulled beans. However, the LCBF from unhulled Manteigão beans differed statistically from the others and showed a higher value (82.78 mg GAE/g). In contrast, the extracts of LCBF from hulled beans had the lowest levels [5.70 (Carioca) and 5.78 mg GAE/g (Manteigão)]. The findings of the present work are consistent with the literature because phenolic compounds are found in smaller amounts in the cotyledons and in higher concentrations in the skin (Mojica *et al*., 2015). Pellegrini *et al*. (2006) also found that dark-coloured beans had higher levels of phenolic compounds as compared to clear-coloured beans.

Xu and Chang (2007) analysed different extracts of legumes and used different solvents; the values found for the extracts that used 80% acetone were 1.07 (green peas), 1.34 (yellow peas), 1.41 (chickpeas), 2.27 (yellow soybeans), 5.36 (black soybean), 5.54 (black beans) and 6.81 mg GAE/g (lentil). It should be noted that the values found in the quantification of phenolic compounds are greatly influenced by the type of solvent used (since the solubility of the phenolic compounds varies according to the polarity of the solvent), the degree of polymerisation of the phenolic compounds, and their interactions with other constituents of foods (Angelo and Jorge, 2007; Mira *et al*., 2008).

Table 3. Content of total phenolics and flavonoids of the extracts of flour made from unhulled and hulled landrace common beans.

Extracts		Total phenolics*	Flavonoids**
Manteigão	Unhulled	82.78 ± 1.46^{a}	8.07 ± 0.47^{a}
	Hulled	5.78 ± 0.32^{c}	1.70 ± 0.41^{b}
Carioca	Unhulled	60.97 ± 1.58^{b}	7.71 ± 0.77^{a}
	Hulled	5.70 ± 0.55^{c}	1.42 ± 0.13^{b}

Values expressed as mean ± standard deviation, $n = 3$. Different letters in the same column indicate significant differences ($p < 0.05$) by Tukey's test.

*Values expressed in milligrams of gallic acid equivalent per gram of sample (mg GAE/g).

**Values expressed in equivalent milligrams of quercetin per gram of sample (mg EQ/g).

Regarding the flavonoid content (Table 3), the values obtained ranged from 1.42 (Carioca hulled) to 8.07 mg EQ/g (Manteigão unhulled). The LCBF of unhulled beans from both cultivars showed higher values and significantly differed from the hulled LCBF. The values for flavonoid content found in the present work were higher than those found by Renuka and Thakur (2014), who evaluated the flavonoid content in 10 bean genotypes and found values between 0.29 and 1.67 mg EQ/g.

Antioxidant activity – DPPH and FRAP methods

The results for *in vitro* antioxidant activity by the DPPH method (Table 4) showed lower antioxidant activity in the hulled LCBF (25.60% for Manteigão and 26.80% for Carioca). The highest antioxidant activity was found in the LCBF made from unhulled beans from both cultivars, and they showed no significant difference between each other.

The IC_{50} results showed that the LCBF made from unhulled beans of both cultivars had good ability to scavenge free radicals (4.04 mg/mL for Manteigão and 4.50 mg/mL for Carioca). According to Campos *et al*. (2005), IC_{50} values above 25 mg/mL are considered to be low. Pascale *et al*. (2018) studied 21 ecotypes of Fagioli di Sarconi beans (P. vulgaris) and found IC_{50} values that varied between 1.1 to 4.6 µg/mL. Lópes-Amorós *et al*. (2006) studied germinated legumes (peas, beans and lentils), with and without light, for two, four and six days and found values from 6.1 to 13.2 mg/mL for pea, 7.5 to 21.6 mg/mL

Table 4. In vitro antioxidant capacity (DPPH and FRAP) of extracts of flour made from unhulled and hulled landrace common beans.

Extracts		DPPH		FRAP**
		IC_{50}*	AA%	
Manteigão	Unhulled	4.04 ± 0.55[b]	92.54 ± 1.00[a]	2.57 ± 0.13[a]
	Hulled	54.55 ± 1.10[a]	25.60 ± 3.47[b]	0.27 ± 0.88[c]
Carioca	Unhulled	4.50 ± 1.11[b]	94.23 ± 0.32[a]	2.13 ± 0.15[b]
	Hulled	54.70 ± 3.90[a]	26.80 ± 1.89[b]	0.25 ± 0.03[c]

Values expressed as mean ± standard deviation, $n = 3$. Different letters in the same column indicate significant differences ($p < 0.05$) by Tukey's test.

*Values expressed in mg/mL; **values expressed in μmol TEAC 100/g

for beans and 5.9 to 9.3 mg/mL for lentil, which were lower than the values found in the present work.

The results for antioxidant capacity by the FRAP method (Table 4) varied from 0.25 (Carioca hulled) to 2.57 μmol TEAC/100 g (Manteigão unhulled). Bolanho and Beléia (2011) analysed soybeans and derived products, and found values of 3.1 (soy fibre flour) to 12.4 μmol TEAC/100 g (micronized soy protein).

Technological functional properties

Water absorption capacity (WAC) and oil absorption capacity (OAC)

The WAC (Table 5) of the LCBF ranged from 154.88 to 188.87%. The LCBF from unhulled beans from both cultivars had higher values and statistically differed from the LCBF from hulled beans of both cultivars. These results were similar to those of Naves *et al*. (2010), who found 154.64% WAC for pumpkin seed flour. The presence of the skin influences the capacity of water absorption because the skin contains a high amount of total dietary fibre, which has a high water holding capacity (Mira *et al*., 2009). WAC is important for certain products because it affects factors such as moisture, starch retrogradation, and the subsequent hardening of products (Sathe, 2002).

Regarding OAC (Table 5), the samples of LCBF from unhulled beans had higher values and statistically differed compared to the LCBF from hulled beans. The results obtained in the present work are consistent with the findings of López *et al*. (1999), who found that lignin (insoluble dietary fibre) had a large oil absorption capacity. In the present work, the LCBF from unhulled beans had a higher amount of insoluble dietary fibre than the LCBF from hulled beans. Siddiq *et al*. (2010) reported that the OAC of flour made from different bean cultivars ranged from 123 to 152%, which were almost similar to that of the present study (117 to 118%). A high OAC is essential for the formulation of emulsified products, pasta, cakes, mayonnaise and salad dressings (Chandi and Sogi, 2007), and it contributes to the palatability and flavour retention of such products (Rodríguez-Ambriz *et al*., 2005). Knowledge about the OAC of flour is important for the development of new food products and the determination of storage stability, especially in the formation of the flavour characteristic in a matrix that is characteristically rancid or oxidative (Siddiq *et al*., 2010).

Emulsifying capacity

The emulsifying capacity of LCBF (Table 5) showed no significant difference between the samples, ranging from 42.57 to 42.81%. Kaur and Singh (2005) found values ranging from 58.2 to 68.2% for emulsifying capacity for flours made from different cultivars of Indian chickpeas. For emulsion stability (ES) (Table 5), it was found that even with heat treatment at 85°C for 15 min, there was

Table 5. Water absorption capacity (WAC) oil absorption capacity (OAC), emulsifying capacity (EC) and emulsion stability (ES) of flour made from unhulled and hulled landrace common beans.

Parameters	Cultivars			
	Manteigão		Carioca	
	Unhulled	Hulled	Unhulled	Hulled
WAC (%)	188.87 ± 0.05[a]	156.44 ± 0.23[b]	187.70 ± 0.64[a]	154.88 ± 0.27[b]
OAC (%)	118.90 ± 0.76[a]	88.61 ± 0.85[b]	117.44 ± 1.89[a]	85.59 ± 1.34[b]
EC (%)	42.81 ± 0.61[a]	42.69 ± 0.54[a]	42.67 ± 0.41[a]	42.57 ± 0.54[a]
ES (%)	42.81 ± 0.61[a]	42.69 ± 0.54[a]	42.67 ± 0.41[a]	42.57 ± 0.54[a]

Values expressed as mean ± standard deviation, $n = 3$. Different letters in the same line indicate significant difference ($p < 0.05$) by Tukey's test.

no breaking of the emulsion and it remained stable. Emulsion stability refers to the ability of protein to form an emulsion which remains unchanged for a specified length of time under specific temperature (Kinsella, 1976).

Conclusion

Flour made from common beans is an important source of protein and dietary fibre, especially insoluble dietary fibre. The levels of phenolic compounds, antioxidants and flavonoids were higher in the LCBF made from unhulled beans of both the studied cultivars. The LCBF made from unhulled Manteigão beans had a higher reducing power using the FRAP method, as well as higher content of phenolic compounds and antioxidant capacity as compared to the Carioca cultivar. The LCBF made from unhulled beans of both cultivars had better water absorption capacity and oil absorption capacity than the LCBF from hulled beans, which indicated that such flour can be used in food systems such as soups, baked goods and meat products that require high absorption of water and fat.

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