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FOOD TECHNOLOGY

Physicochemical composition and antioxidant activity of sweet potato flours from different cultivars produced in the Sub-middle São Francisco region

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ABSTRACT: *This research determined the nutritional composition, antioxidant activity and total phenolic compound content of sweet potato flour from different cultivars: Beauregard cv. sweet potato (BF) and the common sweet potato Brazlândia Rosada cv. (CF). Total lipids, proteins, moisture, carbohydrates, pH, titratable acidity, fiber, ash, iron, zinc, beta-carotene, vitamin A and determination of caloric value were analyzed. Antioxidant activity and total phenolic compounds were also determined by the DPPH (2,2-diphenyl-1-picryl-hydrazyl), ABTS (2,2-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) and FRAP (Ferric Reducing Antioxidant Power) methods. CF showed higher levels of carbohydrates, ash, fiber, pH and antioxidant activity by the ABTS method. Protein and zinc contents were similar between the two flours. BF had higher moisture content, caloric value, lipids, iron, DPPH radical scavenging capacity and antioxidant activity by the FRAP method, as well as total phenolic compounds, beta-carotene and vitamin A content. The data revealed good nutritional composition for both analyzed flours. The Beauregard flour can be highlightedregarding its higher beta-carotene and iron content. Moreover, the Beauregard sweet potato flour is a good source of provitamin A, in addition to being a source of fiber.*
Key words: *sweet potato, flour, biofortification, nutritional value.*

Composição físico-química e atividade antioxidante de farinhas de batata-doce de diferentes cultivares produzidas na região do Submédio São Francisco

RESUMO: *O objetivo deste trabalho foi determinar a composição nutricional, atividade antioxidante e teor de compostos fenólicos totais de farinhas de batata-doce de diferentes cultivares: batata-doce Beauregard (FB) e batata-doce comum, cv. Brazlândia Rosada (FC). Foram realizadas as análises de lipídeos, proteínas, umidade, carboidratos, pH, acidez titulável, fibras, cinzas, ferro, zinco, betacaroteno, vitamina A e determinação do valor calórico. Também foram determinadas a atividade antioxidante, pelos métodos DPPH (2,2-difenil-1-picril-hidrazil), ABTS (2,2-azinobis (3-etilbenzotiazolina-6-ácido sulfônico) e FRAP (Ferric Reducing Antioxidant Power), e compostos fenólicos totais. A FC apresentou maiores teores de carboidratos, cinzas, fibras, pH e atividade antioxidante pelo método ABTS. Os teores de proteínas e zinco foram semelhantes entre as duas farinhas. A FB apresentou maiores teores de umidade, valor calórico, lipídeos, ferro, capacidade sequestradora de radicais DPPH e atividade antioxidante pelo método FRAP, compostos fenólicos totais, conteúdo de betacaroteno e vitamina A. Os dados revelaram uma boa composição nutricional para ambas as farinhas analisadas. O destaque para a farinha da batata-doce Beauregard é maior em relação ao seu teor de betacaroteno e ferro. Sendo a farinha obtida pela batata-doce Beauregard uma boa fonte de pró-vitamina A, além de ser fonte de fibras.*
Palavras-chave: *batata-doce, farinha, biofortificação, valor nutricional.*

INTRODUCTION

The sweet potato (*Ipomea batatas L. Lam*) which comes from Tropical America is rustic, perennial, easy to grow and adapt, is resistant to droughts and has a low production cost, thus being able to be cultivated throughout the year, thereby constituting characteristics which elevate its economic and social importance. Sweet potatoes have high nutritional value due to their potential to retain nutrients in their roots, being a source of carbohydrates, dietary fiber, ascorbic acid, B vitamins, minerals such as calcium and potassium, anthocyanins and beta-carotene. The amount of these compounds influences the color of the potato pulp (SANTOS et al., 2012; VIZZOTTO et al., 2018).

This crop is produced all over the world, especially in developing countries, and has a wide possibility of use, constituting a staple food in several regions (NEUNFELD, 2019). It can be consumed

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roasted or cooked, and has multiple uses such as in producing sweets, pasta, industrialized desserts and flour (ERTHAL et al., 2018; MAINO et al., 2019). Its production in Brazil increased by 36% between 2009 (when 477,472 tons were produced) to 2018 with production of 741, 203 tons (IBGE, 2020).

Given the presence of nutritional deficiencies, supplementation of microminerals in the diet and food fortification are the main measures adopted in an attempt to reduce the large number of people with micronutrient deficiencies; however, they are not effective because they are not able to reach the entire population in need (BRIGIDE et al., 2020).

Due to its important nutritional composition, sweet potatoes are seen as a promising food to eradicate nutritional deficiencies in populations which are deficient in nutrient and calorie consumption, and also in population groups such as children, athletes, pregnant women and women in childbearing age (KEHOE et al., 2015), who need greater nutritional support in their diet.

The Brazlândia Rosada sweet potato cultivar has a pink outer skin and cream-colored pulp which takes on a more yellowish color after cooking, and represents a good source of carbohydrates (EMBRAPA, 2021). This type of sweet potato with a cream pulp is the most common type compared to cultivars with yellow, purple or orange pulp.

Beauregard sweet potato cultivar is a biofortified American cultivar, in which each kilo of the root can contain up to 115 milligrams of beta-carotene (NUNES et al., 2016). UCHÔA et al. (2016) compared the composition of a common sweet potato and a biofortified sweet potato, finding an overlap between the second and the first regarding the presence of beta-carotene. The authors also compared the results with another study which investigated beta-carotene in carrots, verifying that the values reported were similar to those of biofortified sweet potatoes. Beta-carotene is a precursor of vitamin A, which has several functions in the body, and its daily needs can be met with the consumption of approximately 25 to 50 grams of this cultivar (NUNES et al., 2016).

Beauregard sweet potato cultivation has increased in recent years in Brazil due to its nutritional potential and bioactive compounds which positively affect human health (VIZZOTTO et al., 2018). Biofortified products are improved varieties that have a higher amount of micronutrients, such as minerals and vitamins. In addition, this process is low-cost, reaching populations that have limited access, reducing malnutrition and ensuring food security (EMBRAPA, 2015).

Due to its good bioavailability of beta-carotene, the consumption of biofortified sweet potato in various culinary preparations has a positive impact on health, improving immunity, reducing degenerative diseases, and acting in the fight against hypovitaminosis A (ALVES et al., 2012). In addition to the reported functions, it is known that beta-carotene has antioxidant action, scavenging free radicals and acting as a protector of lipids from damage caused by peroxidation (FILHO et al., 2019), which also constitutes an important characteristic of this compound in protecting the body.

Biofortified food consumption can help to reduce micronutrient deficiencies, as well as contribute to improving the nutritional status of individuals (BRIGIDE et al., 2020). In this context, the flour obtained by processing Beauregard biofortified sweet potato presents itself as a way to introduce this root in to the diet. It emerges as a nutritious and aggregate option for preparations, it can be used by the food industry in producing various products, such as dietetics, bakery products (breads, cakes, cookies), and in infant foods, serving as a rich source of beta-carotene (REMONATO et al., 2017). In addition, obtaining the flour increases the shelf life of the product and makes it possible to reduce the food volume, which reduces transport costs (SANTOS et al., 2012).

Thus, this result determined the nutritional composition, antioxidant activity, and total phenolic compounds content of sweet potato flours from different cultivars: Beauregard sweet potato and common sweet potato (Brazlandia Rosada cv.).

MATERIALS AND METHODS

Raw material

The input used in the study (*Ipomoea batatas (L.) Lam*.) was purchased at an open-air market for organic products, located in the city of Juazeiro, BA, Brazil. Two types of sweet potato were purchased from the same producer, resulting in two types of flour: Beauregard cv. sweet potato, biofortified, orange in color (BF); and a common sweet potato (Brazlândia Rosada cv.), with cream pulp and pink outer skin (CF).

Flour preparation

The sweet potato flour of the analyzed cultivars was made byadapting the methodology used by NASCIMENTO et al. (2013). The potatoes were initially sanitized and peeled to produce the flour. Soon after, they were blanched in order to avoid

enzymatic browning, being submerged in boiling water (about 100 ºC) for 4 minutes. Then, they were cooled in ice water for 4 minutes. After the blanching process, the potatoes were frozen in a duplex-type domestic refrigerator freezer (with a temperature below 0 ºC) for approximately 15 days. This step was important, as there was a more intense browning in the flour produced when grinding the potatoes without prior freezing. Then, they were crushed in a food shredder for domestic use and taken to a gas stove oven at an approximate temperature of 180 ºC until drying. After drying, they were crushed again to prepare the flour and finally sieved in a nylon plastic sieve, thereby promoting better refinement and better texture. The produced flour was stored in transparent plastic bags, removing as much oxygen as possible, but without using a vacuum sealer. Each plastic bag with flour was wrapped in dark packaging (Kraft paper bag) to avoid alterations due to light exposure, and stored in the freezer until the moment of its use in the later stages. The entire procedure was carried out with household utensils and equipment as a way of demonstrating the possibility of carrying out all the steps to obtain the flour at home without the need for more sophisticated equipment. Although, there are variations, a 1 kg amount of fresh sweet potato (before peeling or any processing) yields approximately 200 g of flour.

Physico-chemical composition

This step consisted of analytically determining the physico-chemical composition of each of the types of flour produced: BF and CF. The physico-chemical analyzes of phenolic compounds and antioxidant activity were performed in the following laboratories: Laboratory of Teaching and Research in Food Analysis (Laboratório de Ensino e Pesquisa em Análises de Alimentos - LEPAA) of the Nutrition undergraduate course at the University of Pernambuco (UPE), Petrolina/PE campus; at the Food, Beverage and Environment Analysis Laboratory (Laboratório de Análise de Alimentos, Bebidas e Meio Ambiente) at SENAI Petrolina/PE; and at the Food Technology Institute (Instituto de Tecnologia de Alimentos- ITAL) in Campinas/SP. The following analyzes were performed to determine the physicochemical composition of the flours: lipids, proteins, moisture, carbohydrates, pH, titratable acidity, fiber, ash, iron, zinc and beta-carotene. In addition, the caloric value, phenolic compounds and antioxidant activity was determined.

Analytical determinations were performed in triplicate. The direct extraction method in Soxhlet was used to determine total lipids (IAL, 2008), while total proteins were determined by the Kjeldahl method using the nitrogen conversion factor of 6.25 (AOAC, 1995). The moisture content was determined by the direct drying method in an oven at 105 ºC (IAL, 2008). The total carbohydrate content was determined through the difference between 100 and the sum of the values obtained from the triplicates for moisture, proteins, total lipids, fibers and ash (BRASIL, 2003). The pH analysis was performed with the pH meter according to the IAL methodology (2008). Titratable acidity was also performed using sodium hydroxide and phenolphthalein solution (IAL, 2008). In addition, the following values were used as a basis to calculate the energy value of the flour: carbohydrates 4 kcal/g, proteins 4 kcal/g and lipids 9 kcal/g (TERRA et al., 2010).

The fiber and ash contents were determined by incineration in a muffle furnace at 550 ºC, each one following the methodologies of the INSTITUTO ADOLFO LUTZ (2008). Moreover, zinc and iron were determined by flame atomic absorption spectrometry of these minerals in a previously digested food sample (IAL, 2008). Next, the High Performance Liquid Chromatography (HPLC) method was used to analyze beta-carotene and vitamin A (CARVALHO et al., 1992) with an Agilent chromatograph (Infinity 1260 model, DAD detector G4212B model, California, USA). Extraction was carried out with cold acetone, partition into petroleum ether, concentration and column separation. The separated provitamin A fractions were spectrophotometrically quantified. Identification was based on visible absorption spectra, chemical reactions and chromatographic behavior. The pigments were saponified by the presence of carotenol esters. This was done after transferring the carotenoids to petroleum ether, adding an equal volume of 10% methanolic KOH (potassium hydroxide), and leaving the mixture overnight at room temperature in the dark. Vitamin A was calculated by converting 6 µg of beta-carotene to 1 RE (CARVALHO et al., 1992).

Antioxidant activity and phenolic compounds
Extract preparation

First, a 0.5 g sample of the flour was mixed in 50 ml of methanol to prepare the extract. Then, the solution was stirred for 20 minutes and centrifuged at 230 × g for 15 minutes (DONADO-PESTANA et al., 2012).

Total phenolic compound content

The total phenol content (TPC) of the extracts was determined using the Folin Ciocalteau

(FC) reagent, as described by CICCO et al. (2009), with modifications. Aliquots of 120 µl of extracts and 180 µl of water were placed in test tubes to obtain 4% methanol concentration in the final solution. Then, 300 µl of the FC reagent was added to each tube and then 2.4 ml of a 5% sodium carbonate solution after 2 minutes. The mixture was stirred and heated at 40 ºC in a water bath for 20 minutes. The tubes were quickly cooled and the color developed an intense blue-green color, which was read at 767 nm in a spectrophotometer. Results were expressed in gallic acid equivalent (GAE mg/100g).

Antioxidant activity

The DPPH, ABTS and FRAP methodologies were used to determine the total antioxidant activity. The DPPH technique was adapted from RUFINO et al. (2007b). The method is based on electron transfer where DPPH (2,2-diphenyl-1-picrylhydrazyl) is reduced to form diphenyl-picrylhydrazine. Results obtained were expressed as the remaining DPPH percentage (R DPPH%), DPPH radical scavenging capacity (DPPHRSC%), and IC50 or I% (inhibition percentage). Determinations were performed in triplicate. Test tubes were used to homogenize 0.1 mL of extract with 3.9 mL of the DPPH radical.

Then, the method described by RUFINO et al. (2007a) was used in the assay with the 2,2-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) – ABTS radical. Stock solutions of 50 mL were prepared, one containing ABTS (7mmol.L^{-1}) and another containing potassium persulfate (140 mmol.L^{-1}). The reaction mixture was; subsequently, prepared by mixing the two stock solutions in equal volumes and allowing the reaction to run for 16 hours at room temperature in test tubes in the dark. The final solution was diluted by mixing 5 ml of ABTS solution (7 mmol.L^{-1}) with 88 µl of methanol to obtain an absorbance of 0.70 ± 0.50 at 734 nm. Next, 30 µl aliquots were taken from the extracts to react with 3.0 mL of the ABTS solution for 6 minutes in the dark, and the absorbance was verified at 734 nm. The Trolox calibration curve was linear between 100 mmol.L^{-1} and 1,600 mmol.L^{-1}. Results were expressed in mmol Trolox equivalent (TE)/g flour.

The Ferric Reducing Antioxidant Power (FRAP) assay was performed according to the method described by RUFINO et al. (2006), in which the reduction of the Fe^{3+}-TPTZ (ferri tripyridyl triazine) [2,4,6-tri(2-pyridyl)-1,3,5-triazine] complex to ferrous-tripyridyltriazine (Fe^{2+}-TPTZ) occurs. It is based on the ability of a compound to reduce Fe^{2+} from Fe^{3+}, defining its antioxidant strength. The Fe^{2+}-TPTZ complex has an intense blue color and can be monitored at 593 nm in a spectrophotometer. The FRAP reagent was prepared by mixing 2.5 mL of a solution of 2,4,6-Tris(2-pyridyl)-s-triazine (TPTZ) 10 mmol.L^{-1} [the TPTZ solution was prepared with a solution of HCl 40 mmol.L^{-1}], 2.5 mL of an aqueous solution of $FeCl_3$ 20 mmol.L^{-1} and 25 mL of 0.30 mol.L^{-1} acetate buffer (pH=3.6), being used immediately after its preparation. Then, 90 µl aliquots of the extracts were mixed in a dark environment with 270 µl of distilled water and 2.7 ml of the FRAP reagent, being homogenized and subsequently incubated at 37 ºC for 30 minutes in test tubes. The absorbance of the reaction mixture was checked at 595 nm and a calibration curve was prepared with Trolox (160 µmol/L - 800 µmol/L). Results were expressed as TEAC FRAP (Trolox Equivalent Antioxidant Capacities) in mmol of Trolox.g^{-1}.

Statistical analysis

Descriptive analysis was performed and data were presented as means and standard deviation. The comparison between the physical-chemical composition of BF and CF was made by applying the Student'sT-test with a significance level of 5% to determine the difference between the means. The Bio Estat 5.0 program was used for statistical analysis (AYRES et al., 2007).

RESULTS AND DISCUSSION

The results of the analytical determinations performed are shown in table 1.Both types of sweet potato were obtained from an organic producer. The use of organic fertilizer improves the physical conditions of the soil, in addition to its chemical composition and biological properties, which reflects on moisture retention and nutrient conservation (MUNHOZ et al., 2009).

The humidity of BF (5.90%) was higher than that of CF (3.96%). However, both flours are within the maximum moisture limit determined by ANVISA, which is 15% (BRASIL, 2005). A study using biofortified sweet potato flour reported higher moisture values of 9.76% and 9.95% (JAIME et al., 2020). Moisture levels above the limits established by ANVISA are not recommended, as it can facilitate deterioration and modify the characteristics of the flour, which could also interfere with the final product that uses it as a base.

The caloric value of BF (349.89 kcal/100 g) was slightly higher than that of CF (340.77 kcal/100 g). JAIME et al. (2020) reported similar values for biofortified

Table 1 - Physicochemical characterization of Beauregard sweet potato (BF) and common sweet potato (CF) flours.

Component	BF Mean ± SD	CF Mean ± SD
Titratableacidity (%)	0.99 ± 0.01[a]	0.91 ± 0.02[b]
Beta carotene (mcg/100 g)	17584 ± 744[a]	9.61 ± 0.84[b]
Carbohydrates (g/100 g)	81.89 ± 0.33[a]	82.59 ± 0.13[b]
Ash (g/100 g)	2.92 ± 0.02[a]	3.36 ± 0.03[b]
Iron (mg/100 g)	2.21 ± 0.05[a]	1.88 ± 0.13[b]
Crudefiber (g/100 g)	5.72 ± 0.04[a]	7.76 ± 0.04[b]
Lipids (g/100 g)	1.61 ± 0.52[a]	0.21 ± 0.01[b]
pH	5.77 ± 0.00[a]	5.97 ± 0.07[b]
Proteins (g/100 g)	1.96 ± 0.39[a]	2.12 ± 0.03[a]
Humidity (g/100 g)	5.90 ± 0.34[a]	3.96 ± 0.06[b]
Caloricvalue (kcal/100 g)	349.89 ± 3.11[a]	340.77 ± 0.39[b]
Vitamin A (IU/100 g)	9769 ± 412.98[a]	5.67 ± 0.58[b]
Zinc (mg/100 g)	0.82 ± 0.32[a]	1.09 ± 0.10[a]

Values expressed as mean ± standard deviation followed by letters that indicate a statistically significant difference in the lines at a 5% level of significance by the Student's t-test.

sweet potato flour of 339.35 kcal/100 g and 351.92 kcal/100 g, for each of the two flours analyzed. The energetic values of BF and CF cannot be considered low, since they are higher than 40 kcal/100 g (BRASIL, 2012).

The BF lipid content (1.61 g/100 g) was higher than that of CF (0.21 g/100 g), which can be explained by the higher carotenoid content present in Beauregard sweet potato, since they belong to the group of lipids. This was also observed in another study which reported1.09% of lipids in biofortified sweet potato, and 0.94% in common sweet potato (UCHÔA et al., 2016). In another study, flours obtained from biofortified sweet potato cultivars had lipid content between 0.76% and 1.39% (JAIME et al., 2020), constituting lower amounts than those reported in Beauregard sweet potato flour (biofortified) used in this study.

There was no statistically significant difference between the amount of protein content present in BF (1.96%) and in CF (2.12%). The values found for the protein content in a study which analyzed the composition of biofortified sweet potato flour were higher, ranging between 7.38% and 9.85% (JAIME et al., 2020). SILVA et al. (2020) analyzed an *in natura* sweet potato and also its flour, finding 2.78% of the protein in the flour. This value is closer to what was found in BF and CF.

CF carbohydrates (82.59%) were reported in greater quantity when compared to BF (81.89%). JAIME et al. (2020) obtained a carbohydrate content ranging from 71.86% to 78.89% in biofortified sweet potato flour, constituting lower results than those found in this research. SILVA et al. (2020) found 90.09% carbohydrates in sweet potato flour.

The number of fibers reported in CF (7.76 g/100 g) was higher than in BF (5.72 g/100 g). According to the Technical Regulation on Complementary Nutritional Information, the food must have at least 3 g of fiber in every 100 g to be considered a source of fiber; and it is considered to have a high content of 6 g/100 g of food (BRASIL, 2012). Thus, both CF and BF can be considered sources of fiber, which confers an important characteristic regarding the nutritional composition of the obtained flours. Intake of dietary fiber can improve serum lipid levels, assist in glycemic control, and also in reducing blood pressure levels (BERNAUD; RODRIGUES, 2013), in addition to being important for good intestinal functioning.

The ash value was 2.92% for BF, lower than the CF content (3.36%). The mean FL was lower than the values reported by JAIME et al. (2020) when analyzing biofortified sweet potato flour and found values between 3.66% and 6.95%. Another study that analyzed sweet potato flour reported an ash value closer to that of BF and CF of 3.01% (SILVA et al., 2020).

Regarding the amount of minerals reported in Beauregard sweet potato, other authors found iron values from 0.63 to 15.26 mg/100 g and zinc values from 0.24 to 1.30 mg/100 g (NEELA & FANTA, 2019). As can be seen in table 1, both the iron content (2.21 mg/100 g) and the zinc content (0.82 mg/100 g) reported in the BF are in the range of the results mentioned in the revision article. The iron value of CF (1.88 mg/100 g) was lower than that of BF, demonstrating that the Beauregard sweet potato has a higher iron content when compared to the common sweet potato.

According to Ordinance SVS no. 33/98, the RDI (Recommended Daily Intake) for adults is 14 mg of iron and 15 mg of zinc (BRASIL, 1998). Thus, 100 g of BF provides 15.79% of the RDI of iron; and 5.47% of the zinc RDI. To be considered a food source, it is necessary to provide at least 15% RDI of the mineral in 100 g (BRASIL, 2012). This demonstrated that the iron content of Beauregard biofortified sweet potato flour meets this requirement, which makes it an iron source. The mean HR zinc values (1.09 mg/100 g) were not statistically different from the mean BF values. CF zinc and iron values are higher than those found in another study, which analyzed the composition of sweet potato with organic white pulp, obtaining 0.481 mg/100 g of iron and 0.261 mg/100 g of zinc. (DOS SANTOS et al., 2019).

The beta-carotene and vitamin A content of BF (17584 mcg/100 g and 9769 IU/100 g, respectively) was higher than that of CF (9.61 mcg/100 g of beta-carotene and 5.67 IU/100 g of vitamin A). This result was already expected, as the BF was obtained from the Beauregard biofortified sweet potato, which has a high content of beta-carotene (on average 11,500 mcg/100 g of root), while the cream pulp (common sweet potato) and white cultivars have less than 1000 mcg/100 g of root (EMBRAPA, 2014). A similar value was reported in a study that analyzed the carotenoid content in colored pulp sweet potato flour, obtaining a beta-carotene value of 17100 mcg/100 g in the flour of the "Beauregard Original" cultivar (WARAMBOI et al., 2013). Beta-carotene is of great importance for human health because it has pro-vitamin A activity, conferring positive effects on the body. This is because vitamin A plays important roles such as providing proper vision functioning, protection against oxidative stress and support for the immune system, among other benefits (MESQUITA et al., 2017).

A review by NEELA & FANTA (2019) conducted by surveying other studies showed pH values of 6.52 and acidity of 0.91% for orange-fleshed sweet potato dry flour, approaching the results obtained for BF: pH 5.77 and acidity 0.99%. Despite being statistically different from each other, the pH (5.97) and acidity (0.91%) values of CF are close to those of BF. Divergent values were found by SILVA et al. (2020) who obtained a result of 9.16% acidity for sweet potato flour, and by VIZZOTTO et al. (2018) who reported a value of 0.13% for roasted Beauregard sweet potato.

In addition to determining the physicochemical composition, the antioxidant activity and the total phenolic compound content were also analyzed. Antioxidant compounds help to reduce oxidative stress produced by free radicals, protecting cells and body tissues (DONADO-PESTANA et al., 2012). Results of the antioxidant activity of BF and CF are shown in table 2.

The highest remaining DPPH percentage (R DPPH%) was in CF (82.85). The DPPH radical scavenging capacity (DPPH RSC%) was higher in BF (21.76). The IC50 (I%), which is the sample concentration that causes 50% inhibition of the initial DPPH concentration, was higher for BF (9.57). All results showed a significant difference ($P < 0.05$) between the two types of flour analyzed.

The result for CF was higher than the result for BF by the ABTS method. Despite the approximate numerical values obtained in the FRAP methodology for both flours, there was a significant difference ($P < 0.05$) with BF (1772.26 mmol Trolox.g^{-1}) which was a little higher than CF (1771.43 mmol Trolox.g^{-1}).

The results of the total phenolic compound determination of CF and BF are described in table 3. The BF showed a total phenolic content of 591.50 AGE mg/100 g, significantly higher than the CF value (396.18 AGE mg/100 g), with a significant difference ($P < 0.05$).

DONADO-PESTANA et al. (2012) determined the antioxidant composition and total phenolic compounds of four orange-fleshed sweet potato cultivars (CNPH 1007, CNH 1194, CNPH 1202 and CNPH 1205). Both raw and processed samples (boiled, roasted, steamed or processed flour) were used. A lyophilized sample and ethanol at a concentration of 50 g/L were used to obtain the extract. The antioxidant activity was determined by the DPPH and ABTS assays, where a decrease was observed as a function of different thermal processing methods in the analyzed cultivars.

RUMBAOA et al. (2009) also analyzed the DPPH radical scavenging activity, verifying a variation from 0.7 to 6.4 mg/mL of dry sample in the EC50 values of the five analyzed (Dakol, Emelda,

Table 2 - Antioxidant activity of Beauregard sweet potato (BF) and common sweet potato (CF) flours.

Flours	----------DPPH----------				
	R DPPH%	DPPH RSC%	I%	ABTS (mmol Trolox equivalent (TE)/g)	FRAP (mmol Trolox.g^{-1})
			Mean ± SD		
BF	74.95 ± 0.60^{a}	21.76 ± 0.60^{a}	9.57 ± 0.13^{a}	10.96 ± 0.02^{a}	1772.26 ± 0.02^{a}
CF	82.85 ± 0.77^{b}	13.86 ± 0.77^{b}	2.00 ± 0.74^{b}	11.29 ± 0.03^{b}	1771.43 ± 0.02^{b}

R DPPH= Remaining DPPH, DPPH RSC = DPPH Radical scavenging capacity, I= inhibition percentage.
Values expressed as mean ± standard deviation followed by letters that indicate a statistically significant difference in the columns at a 5% level of significance by the Student's t-test.

PSBSP, Haponita and Violet) freeze-dried and ground varieties, with greater emphasis on the purple-fleshed varieties (Dakol, Haponita,and Violet). The extract concentration used by the authors was 50 g/L.

BACKES & GENENA (2020) analyzed the antioxidant activity of English potato, purple sweet potato, and white sweet potato peels using dried and crushed samples by the DPPH method, using extract at a concentration of 125 g/L. The EC50 of each of the potato varieties mentioned was 3.92; 1.92; and 5.49 mg/mL^{-1}, respectively. The ABTS method was also used by BACKES & GENENA (2020) to determine the antioxidant activity, which found 8.83 µmol Trolox g^{-1} for the purple sweet potato peel extract and 29.17 for the white color variety.

In a study by RAUTENBACH et al. (2010), the antioxidant activities of four sweet potato varieties with cream and orange pulp colors in raw and cooked forms were evaluated. The antioxidant activity by the ABTS method ranged from 127.5 to 365.7 µmol TE/100 g of raw sample and from 182.2 to 394.1 µmol TE/100 g in cooked samples among the analyzed varieties (RAUTENBACH et al., 2010).

When analyzing the antioxidant activity of flours from three sweet potato varieties (Orange Sunser, Purple Dawn and Red) using the FRAP methodology, CUI & ZHU (2019) found values of 7.34; 2.77 and 0.51 µmol TE/100 g for each of the samples, using 40 g/L extract (a concentration higher than that of our study).

LIAO et al. (2019) reported higher values than 160 and lower than 200 µM TE/g using the FRAP methodology to determine the antioxidant capacity of a purple-fleshed sweet potato cultivar subjected to different cooking methods, with extracts at a concentration of 66.66 g/L. A study by PEREIRA et al. (2016) was also analyzed as a way of comparison due to the scarcity of articles using the same methodologies for analyzing the antioxidant activity of the present research; these authors reported 8.456 µmol TE g^{-1} in yacon tuber peel flour and 2.564 µmol TE g^{-1} in yacon pulp flour using the ABTS method. Although we used extract at a concentration of 10 g/L, the authors used 75 g/L.

Table 3 - Total phenolic compound content of Beauregard sweet potato (BF) and common sweet potato (CF) flours.

Flours	Total phenolic compounds (mg GAE/g) (Mean ± SD)
BF	591.50 ± 0.016^{a}
CF	396.18 ± 0.016^{b}

Values expressed as mean ± standard deviation followed by letters that indicate a statistically significant difference in the columns at a 5% level of significance by the Student's t-test.

The cooking process modifies the chemical composition of the sweet potato, influencing the concentration and bioavailability of carotenoids and phenolic compounds, which act as antioxidants (DONADO-PESTANA et al., 2012). The antioxidant activity (IC50) of gala apple pulp flour is 3.82 mg/mL, while this value is much higher in natura pulp, reaching 22.45 mg/mL (MORAIS et al., 2019). Although, the apple pulp had a lower IC50 than the FL, this analysis allows us to perceive the influence caused by thermal processing on the antioxidant activity of foods.

Thus, from the cited data, it is possible to perceive that the antioxidant activity found in this research characterized by the IC50 had very variable values reported in the literature, with some a little close to those found for BF and CF. The FRAP and ABTS methods were also quite different from those found in the analyzed studies. Such variation can be attributed to the fact that the analyzed studies used different extract concentrations, different from the concentration used to obtain the CF and BF extracts.

In the study by DONADO-PESTANA et al. (2012), the total phenolic compounds were obtained by the Folin-Ciocalteu method using extract at a concentration of 10 g/L, the same concentration used in this research. The total phenolic content for the four orange-fleshed sweet potato cultivars analyzed ranged from 0.96 to 1.56 mg GAE.g^{-1} of dry weight among the flours produced. The authors reported that the flour process provided greater losses when compared to raw, boiled, roasted or steamed sweet potatoes (DONADO-PESTANA et al., 2012).

SHAARI et al. (2020) analyzed the total phenolic content in sweet potato with skin, peeled root, and root skin from the Anggun variety, finding higher content in sweet potato with skin (41.14 mg GAE/100 g), and without skin (42.24 mg GAE/100 g). According to the authors it may be indicative of an accumulation of phenolic compounds in the pulp. The samples used by the authors were oven-dried and then sieved, and the powdered sweet potato extract was prepared with methanol at a concentration of 66.66 g/L (SHAARI et al., 2020). We used the extract at a concentration of 10 g/Lin this research, based on the methodology described by DONADO-PESTANA et al. (2012) in obtaining the extract for determining the phenolic compound contents.

The total phenolic content in the five sweet potato varieties analyzed by RUMBAOA et al. (2009) ranged from 50.1 to 362.8 mg GAE/100 g of fresh sample or 192.7 to 1159.0 mg GAE/100 g of dry sample. The authors found that the purple-fleshed varieties (Dakol, Haponita and Violet) had higher phenolic contents than the white and yellow-fleshed varieties (Emelda and PSBSP).

In the study by BACKES & GENENA (2020), the total phenolic content was 1.37 mg GAE g^{-1} for purple sweet potato skin and 3.73 mg GAE g^{-1} for white sweet potato skin. These data also bring higher values. The extract was at a concentration of 125 g/L, higher than the concentration used in this research (10 g/L).

Based on the cited data, the levels of total phenolic compounds were considerably high when compared to other studies that analyzed different varieties of sweet potato, being close to the range of values found by RUMBAOA et al. (2009). Again, the extract concentration used in the studies, which are quite different, may have influenced the obtained results. Among the studies analyzed, only the one by DONADO-PESTANA et al. (2012) used the same extract concentration as in the present work. Finally, processing and heating to obtain the BF and CF are important factors in determining the final phenolic compound content. Despite this, the results reported remained high when compared to other studies.

CONCLUSION

The data obtained in the present research demonstrated important information about the nutritional composition of Beauregard sweet potato flour. Biofortification is responsible for the high beta-carotene content found, which was considerably higher than in common sweet potato flour. The iron content of BF was also higher when compared to CF. Another important result is that BF has zinc in its composition, in addition to being considered a fiber source. The phenolic compound content was significantly higher in BF, even after processing. Although, low antioxidant activity was reported, it is interesting to explore other different methods for this analysis for further investigation. Furthermore, the analysis of all its physical-chemical composition already demonstrated that the Beauregard sweet potato flour is rich in nutrients, which makes it an important product option to nutritionally enrich culinary preparations, adding nutritional value to different recipes that use flour in their preparations.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest. The aforementioned financial support program and raw material suppliers had no role in the study design, data collection, analysis or interpretation, manuscript writing, or in the decision to publish the results.

AUTHORS' CONTRIBUTION

All authors performed the laboratory analyzes and ANSV performed the interpretation of the results. CMBOM and KWCV supervised and coordinated all stages of the research. ANSV, CMBOM and YLFL prepared the draft manuscript. ANSV and CMBOM critically reviewed the manuscript and approved the final version.

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