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SHORT COMMUNICATION

Nutritional and functional potential of pumpkin (*Cucurbita moschata*) pulp and pequi (*Caryocar brasiliense* Camb.) peel flours

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Abstract The purpose of this paper was to develop and characterize pumpkin pulp flour (*Cucurbita moschata*) and pequi peel flour (*Caryocar brasiliense* Camb.) in order to evaluate their nutritional and functional potential for the development of healthier products. The flours were developed and characterized by proximal composition, sodium, total sugars, phenolic compounds and carotenoids content, and in vitro antioxidant capacity by ABTS, FRAP and β-carotene/linoleic acid system methods. The means and the standard deviations were calculated for all data. Pearson correlation analysis between phenolics and antioxidant activities results was carried out, using SPSS Statistics 17.0 software. The pumpkin pulp flour presented high levels of dietary fiber (21.95 g/100 g), total sugars (51.88 g/100 g), protein (11.08 g/100 g) and carotenoids (249.04 µg/g), low levels of sodium (27.28 mg/100 g), and high antioxidant capacity by the β-carotene/linoleic acid system (73.00% protection). The pequi peel flour presented high levels of dietary fiber (42.09 g/100 g) and phenolic compounds (20,893.73 mg GAE/100 g), low levels of sodium (22.84 mg/100 g), and high antioxidant capacity by ABTS (2105.18 µM trolox/g), FRAP (6292.11 µM ferrous sulfate/g) and β-carotene/linoleic acid system (92.94% protection) methods. Both flours can be used for the development of healthy foods.

Keywords Bioactive compounds · Antioxidant capacity · Nutritional composition · Healthy food

Introduction

Increased attention to functional food products and consumer health and well-being over the past decade has led to an increased interest in vitamins, minerals, unsaturated fatty acids, bioactive compounds, and fibers in food products (Khoozani et al. 2019). Therefore, there is a growing interest in nutritious ingredients, rich in bioactive compounds which can be easily produced, stored and transported to be used in the development of healthier products.

Among different food groups, fruit and vegetables stand out for their high levels of bioactive compounds (Shashirakha et al. 2015). As an alternative to facilitate their transport and reduce their perishability, different flours have been developed from these raw materials. Ferreira et al. (2015) developed flours from different fruit and vegetables and rich in dietary fibers, minerals, bioactive compounds, or antioxidant activity.

In this scenario, fruits still underexploited, such those with little industrial application (for example: pumpkin) or fruits from the Brazilian Savanna (which is called Cerrado), appear as alternative ingredients to be studied.

From the Brazilian Cerrado, the pequizeiro (*Caryocar brasiliense* Camb.) is distinguished by the high content of bioactive compounds, presented mainly in the fruit's peel, which is composed of the exocarp and external mesocarp and is considered a by-product of fruit processing, being usually discarded (Siqueira et al. 2012).

Pumpkins are usually rich in carotenoids, vitamins, and dietary fibers (Jin et al. 2013). In Brazil, the pumpkin

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Cucurbita moschata presents wide availability, which can facilitate its use in the elaboration of industrialized foods.

In general, there is a lot of literature about the carotenoid content of pumpkin, but very few studies are available on the phenolic content and antioxidant activity of pumpkin (Aydin and Gocmen 2015). Although there are studies on the proximal composition of pumpkin pulp (Nakhon et al. 2017; Aydin and Gocmen 2015) and pequi peel (Lago 2018; Leão et al. 2017) flours, in general, these studies do not carry out analyzes of the levels of total sugar and sodium, which are important nutrients to indicate the nutritional quality of flour. It is known that high sodium consumption increases the risk of cardiovascular diseases (WHO 2012) and that sugar consumption influences blood pressure and serum lipids and may also be associated with the risk of these diseases (Te Morenga et al. 2014). Thus, it is increasingly important to know the sodium and sugar content of the ingredients used in the food industry. In this context, to contribute to the development of healthy foods, in addition to investigating the functional potential of these flours, it is important to research whether they are nutritious.

Therefore, the aim of this study was to develop and characterize pumpkin pulp flour and pequi peel flour in order to investigate its nutritional and functional potential to be applied as ingredients in the development of healthy products.

Materials and methods

Pumpkin pulp flour and pequi peel flour processing

The pumpkin (*Cucurbita moschata*) was purchased from CEASA (State Supply Centers) of Belo Horizonte/MG, Brazil. The pequi (*Caryocar brasiliense* Camb.) was purchased from producers of Montes Claros/MG, Brazil.

The pumpkin pulp flour was obtained according to Nakhon et al. (2017) method, with modifications. The pulp was sliced into pieces of approximately 0.5 cm high, distributed in stainless steel trays and submitted to the oven drying process (model 320—SE, FANEM®) with mechanical air circulation, at 58 ± 2 °C for 34.5 h. The dehydrated pulp was crushed in an industrial mill (model TE-631/3, TECNAL®), and sieved in a 9 mesh sieve to obtain the flour.

The pequi peel flour was obtained according to Lago (2018) method, with modifications. The pequi peels were blanched in steam (approximately 100 °C for 12 min), sliced into pieces (0.5 cm high) and submitted to drying (60 ± 1 °C for 22 h), milling and sieving process (9 mesh).

Both flours were vacuum packaged and the packages were wrapped in foil and stored at −18 °C.

Pumpkin pulp flour and pequi peel flour characterization

Proximal composition

Moisture, ash, ether extract and protein content were determined according to the AOAC methodology (AOAC 2016). Dietary fiber content (soluble and insoluble) was determined by the enzymatic–gravimetric method, according to AOAC (1999). The carbohydrates fraction (nitrogen-free extract) was calculated by subtracting the sum of the percentages of moisture, ash, ether extract, protein and dietary fiber from 100. Calorific value was calculated considering the following conversion factors: 4 kcal/g for carbohydrates and proteins and 9 kcal/g for lipids.

Determination of total soluble sugar

The determination of total soluble sugars was performed by spectrophotometry at 620 nm, according to the anthrone method (Dische 1962).

Determination of sodium content

The determination of the sodium content was performed according to Malavolta et al. (1997) method.

Determination of total phenolics, total carotenoids and in vitro antioxidant capacity

The extracts for phenolic compounds and antioxidant capacity analysis were prepared according to Larrauri et al. (1997) method.

The determination of total phenolic compounds was performed according to the Folin–Ciocalteau method, using gallic acid as the standard for the calibration curve. The results were expressed as gallic acid equivalent (mg GAE per 100 g of dry matter) (Waterhouse 2002).

In vitro antioxidant capacity was evaluated according to the ABTS, FRAP and β-carotene/linoleic acid system methods. The ABTS and FRAP methods were performed according to Rufino et al. (2007, 2006), with results expressed in Trolox equivalent and ferrous sulphate equivalent, respectively.

The determination of the antioxidant capacity by the β-carotene/linoleic acid system method was performed according to Rufino et al. (2006) method, with modifications. Approximately 0.4 mL of the extract was mixed with 5 mL of the system solution in test tubes. Then, two spectrophotometer (UV–Visible 50 Probe-Cary) readings were performed at 470 nm: after 2 min and 2 h of immersion in a water bath at 40 °C. The system solution was used as control. The results were expressed as percentage of protection against oxidation.

Evaluation of total carotenoids was performed according to Rodriguez-Amaya (1999) method. The quantification was calculated using the absorption at the maximum absorption wavelength and the A value (specific absorption coefficient) of 2592 in petroleum ether.

Data analysis

All data from the analyses were evaluated by calculation of the means and the standard deviations. *Pearson* correlation analysis between phenolics and antioxidant activities results was carried out. For the data analysis, was used the software SPSS Statistics 17.0 (Norusis 2008). The analysis were performed in five replications and in triplicate.

Results and discussion

Proximal composition, total sugar and sodium content

The pumpkin pulp flour and pequi peel flour presented moisture content compatible with Brazilian legislation (maximum 15% for flours) (Brazil 2005) (Table 1).

The pumpkin pulp flour showed high levels of protein, dietary fiber, carbohydrates and total soluble sugar and the pequi peel flour presented high levels of dietary fiber and carbohydrates. Both flours presented “very low content” of sodium per 100 g, according to RDC 54 of 2012 (Brazil 2012), and low levels of ether extract content (Table 1).

Compared with wheat flour, one of the most important flours sources of protein, with 9.8 g protein per 100 g of flour (TACO 2011), pumpkin flour has similar protein content, and can be considered an alternative source for this ingredient. In contrast, the pequi flour presents approximately half of the protein content presented in wheat flour.

As the consumption of dietary fiber contribute to the good functioning of the intestine (Ismaiel et al. 2016), the ingestion of these flours could be beneficial for human health. The high proportion of insoluble fiber for soluble fiber obtained for the pequi peel flour occurred due to the fact that the insoluble fraction of the fibers, composed of cellulose, lignin and some hemicelluloses, is found in abundance in the fruits and vegetables peels, as well as in the outer layer of grains (Bernaud and Rodrigues 2013).

Regarding to carbohydrates and total sugars, the consumption of the pumpkin pulp flour should be more moderate to avoid the occurrence of high glycemic peaks in the blood, due to its high content of total sugar. However, both flours are important sources of energy due to their high carbohydrate content.

The low levels obtained for ether extract from both flours were expected, as observed in other studies (Lago 2018; Leão et al. 2017; TACO 2011).

For the calorific value, both flours had lower results than those found for flours commonly used in the elaboration of different foods, such as wheat flour (360 kcal/100 g) (TACO 2011).

It is concluded that the high levels of dietary fibers and carbohydrates and the low levels of sodium presented in pumpkin and pequi flours, as well as the high protein content found in the pumpkin flour, indicate these raw materials as potential ingredients for the development of nutritious foods. It is important to note that pequi peel flour

Table 1 Proximal composition, total sugar and sodium content of the pumpkin pulp flour and the pequi peel flour

	Pumpkin pulp flour[a]	Pequi peel flour[a]
Moisture (g/100 g)[b]	7.06 ± 0.16	8.18 ± 0.25
Ether extract (g/100 g)	1.88 ± 0.07	1.11 ± 0.17
Protein (g/100 g)	11.08 ± 0.44	5.30 ± 0.25
Ash (g/100 g)	6.37 ± 0.09	2.94 ± 0.15
Dietary fiber (g/100 g)	21.95 ± 0.30	42.09 ± 0.01
Soluble (g/100 g)	7.49 ± 2.79	10.45 ± 0.21
Insoluble (g/100 g)	11.25 ± 0.19	31.64 ± 0.22
Carbohydrates (g/100 g)	64.07 ± 0.41	48.56 ± 0.28
Calorific value (kcal/100 g)	317.53 ± 1.38	225.42 ± 1.83
Total soluble sugar (g/100 g)	51.88 ± 4.11	21.92 ± 0.84
Sodium (mg/100 g)	27.28 ± 2.53	22.84 ± 1.85

[a] Mean values ± standard deviations. Data on dry-matter base

[b] Moisture on wet-matter base

usually has antinutritional factors, which can limit its consumption in large quantities (Lago 2018). The consumption of the pumpkin flour should be moderated due to its higher sugar content. However, its use can increase the sweet taste of the products, reducing the need to add sugars in them.

Total phenolics, total carotenoids and in vitro antioxidant capacity

For phenolic compounds, pequi peel flour showed higher levels than pumpkin pulp flour. In contrast, pumpkin pulp flour presented higher levels of carotenoids. Both flours presented antioxidant capacity by the ABTS, FRAP and β-carotene/linoleic acid system methods (Table 2).

The high levels of total phenolics found in pequi flour can be attributed to the fact that many phenolic compounds are associated with important plant functions, including defense functions, being expected high concentration of these compounds in exocarp (peels) of fruits (Leão et al. 2017). Some studies have shown that the phenolics are located preferably in peels and seeds, and to a lesser extent in pulps (Contreras-Calderón et al. 2011).

The high content of carotenoids in pumpkin flour, was already expected since pumpkins are generally considered important sources of these bioactive compounds. The carotenoid content found in pequi flour can be considered significant when compared to commonly used sources of these bioactive compounds, such as acerola (4.5–44.1 µg/g) (Rodriguez-Amaya et al. 2008). Due to the antioxidant properties and the pro-vitamin A activity of some carotenoids, the consumption, especially of the pumpkin flour, can be recommended as an alternative source of these bioactive compounds.

The high antioxidant capacity presented by pequi flour in ABTS and FRAP methods is probably associated with the high total phenolics content found in this flour. The antioxidant effectiveness of natural sources is often associated with the presence of phenolic compounds. Phenolics are composed of one or more aromatic rings, containing one or more hydroxyl groups and, therefore, are potentially capable of inactivating free radicals, forming phenoxyl radicals, stabilized by resonance (Bors and Michel 2002). Thus, although the carotenoids present antioxidant capacity, the higher phenolic content found in pumpkin and pequi flours seem to explain better the antioxidant responses observed.

The *Pearson* correlation analysis between phenolic content and antioxidant activities by FRAP and ABTS methods for pumpkin and pequi flours indicated strong positive correlation ($r > 0.98$) at 5%. This means the high content of phenolic compounds in pequi flour probably provided higher values of antioxidant capacity in this flour.

According to Hassimotto et al. (2005), the antioxidant capacity of the β-carotene/linoleic acid system is classified as: i) high levels (> 70% protection); ii) intermediate (40–70% protection) and iii) low (< 40% protection). Both flours were classified as presenting “high levels” of antioxidant capacity by this method, indicating an excellent protection capacity of β-carotene against oxidation.

These results demonstrate both flours have high levels of bioactive compounds. Pumpkin flour highlighted by the high content of carotenoids and pequi flour by the high content of total phenolics. Although the pequi flour had higher antioxidant capacity by the methods used, both flours indicated high protection capacity of β-carotene against oxidation, and can be used as potential ingredients to increase the functional potential of food products.

Conclusion

The pumpkin pulp flour (*Cucurbita moschata*) and the pequi peel flour (*Caryocar brasiliense* Camb.) are potential ingredients for the development of healthier foods. Pumpkin pulp flour stood out for its high content of protein, dietary fiber and carotenoids, low content of sodium, as well as the high antioxidant capacity by β-carotene/linoleic acid system. Pequi peel flour presented high levels of dietary fiber and phenolics compounds, low levels of sodium, and high antioxidant capacity by the three methods evaluated (ABTS, FRAP and β-carotene/linoleic acid system).

Table 2 Total phenolics, total carotenoids and antioxidant capacity of pumpkin pulp flour and pequi peel flour

	Pumpkin pulp flour[a]	Pequi peel flour[a]
Phenolics (mg GAE/100 g)	496.97 ± 4.35	20,893.73 ± 1462.14
Carotenoids (µg/g)	249.04 ± 11.78	33.80 ± 2.46
ABTS (µM trolox/g)	78.21 ± 18.95	2105.18 ± 207.83
FRAP (µM Fe_2SO_4/g)	69.37 ± 13.70	6292.11 ± 223.38
β-carotene/linoleic acid system (% protection)	73.00 ± 4.95	92.94 ± 3.04

[a] Mean values ± standard deviations. Data on dry-matter base

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