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Research article

Evaluation of cooking methods on the bioactive compounds of cashew apple fibre and its application in plant-based foods

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ABSTRACT

Plant co-products currently represent an attractive alternative to the food industry, especially to the growing market of development low-fat products. Among the co-products resulting from tropical fruits' processing, the cashew apple's fibre presents unusual nutritional and sensory characteristics. In several food preparations could use it as an ingredient. In this work, the bioactive compounds of both artisanal and industrialized cashew apple fibre were studied and the influence of the different cooking methods on their bioactive content, and the acceptance and sensory preference of products new plants-based products formulated. It was observed that both artisanal and industrial cashew apple fibres presented a rich composition in the bioactive compounds, especially regarding the content of ascorbic acid found in artisanal (147.8 mg.100g^{-1}) and carotenoids in industrialized fibre (1.87 mg 100 g^{-1}), which resulted in a higher antioxidant activity for both samples in each method evaluated. Frying (180 °C/3 min) and cooking in a combination oven (98 °C/10 min) exhibited higher averages regarding the retention of the bioactive compounds in the fibres, resulting in a higher antioxidant activity for the products processed by these methods.

In contrast, it was boiling processing (100 °C/18min) leads to leach of water-soluble biocompounds and, consequently, their products presented a reduced antioxidant activity. The cashew apple "paçoca" and "meatballs" were judged in terms of their attributes (appearance, aroma, taste, overall impression) and buy intention. In general, the average of these results indicated a high sensorial acceptance and a partial possibility in their purchase of these products. The cashew apple fibres are a source of nutrients. Its incorporation in culinary preparations can be a friendly way to avoid waste and promote new food products.

1. Introduction

The increase in the incidence of diseases as obesity, high cholesterol and hypertension, often related to an irregular diet, are stimulating the modern consumers to change their food habits, choosing natural foods instead of industrialized. The production of tropical fruits presented a significant increase in national and international markets due to their sensory properties and the recognition of their nutritional and therapeutic properties. Vegetables are a source of essential nutrients and micronutrients (i.e., minerals, fibres, vitamins, phenolic compounds, and antioxidants). Their consumption is recommended due to the benefits that these substances bring to human health (Vasco et al. 2008; Veer et al., 2000; Cai et al., 2013). There is a direct relation between vegetable intake with the prevention of chronic degenerative diseases caused by the damage promoted by free radicals (Dendena and Corsi, 2014; Wolfe et al., 2008). The elevated concentration of phytochemicals in vegetal tissues results in a higher stabilization of free radicals and, consequently, represents additional protection to the organism (Avello and Suwalsky, 2006).

According to FAO (2017), fruit production for 2017 was approximately 141 million tons and Brazil corresponded to 45.2% of all world production. In the next years, it is expected an increase of more than 50% on this volume (FAO, 2017). Brazil presents a large number of underexploited fruits, which may represent a new opportunity for local

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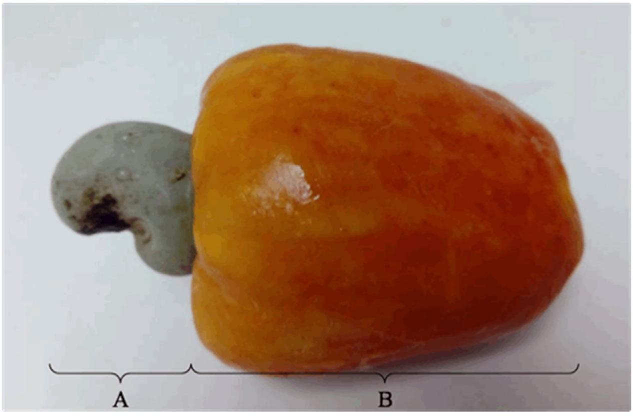

Figure 1. Cashew Apple fruit: cashew nut (A) and cashew apple peduncle (B).

producers to access new markets due to the emphasis on their exotic characteristics and also due to the presence of bioactive compounds that could prevent degenerative diseases (Alves et al. 2008).

The cashew tree belongs to the *Anacardiaceae* family, native from tropical America, mainly in North and Northeast of Brazil and several parts of India, Mozambique, and Tanzania (Zepka et al., 2009; Petinari and Tarsitano, 2002). Undoubtedly, the cashew tree fruit is one of the most consumed fruits in the Brazilian Northeast, exhibiting an elevate economic and social importance for this region. Botanically, the cashew tree fruit is a nut (Figure 1), an almond surrounded by a hard shell. In contrast, the peduncle (pseudo fruit or "apple"), known as the cashew apple, has a similar structure to fruit, being fibrous, juicy (Figueiredo et al., 2002). After extracting the almond (the main product), the cashew apple represents 90% of the fruit's total mass and can be used to produce juice, wine, jam, and ice cream. After pulp processing, around 15% of cashew apple fibre are remaining, and this lignocellulosic material corresponds to the main residue generated from this agroindustrial activity (Padilha et al., 2020). The vitamin C content present in cashew apple is, in average, equal to 269 mg/100 ml of juice, being this value five times higher than the level found in orange juice (Contreras-Calderón et al., 2011). Furthermore, it is a rich source of precursors of vitamin A, carotenoids, and phenolic compounds (Rufino et al., 2010). Thus, the development of natural products, especially those derivated from plants by-products, which are recognized sources of several natural antioxidants, beyond represents a proposal for the integral valorization of plants, may result in positive effects on the economic and environmental sustainability of agroindustry (Kowalska et al., 2017).

The cashew tree has one of Brazil's most important productions and its fruit is mainly destined for exportation. The processing of its peduncle results in a concentrated pulp, and it can be derivate different beverages and candies, for example. The by-product generated by this operation is a lignocellulosic fibre, which presents a low added value and usually is handled as garbage. Different nutritional evaluations being demonstrated its rich composition in macro and micronutrients as well as bioactive substances. Thus, other culinary preparations can introduce cashew apple fibre.

Novel food products are developed to satisfy the consumer demands for taste, appearance, value and convenience (Mazza, 2000). However, several methods employed in the preparation of both tradition and functional foods, especially those in which heat processing is involved, induce a significative change in their chemical composition, influencing the concentration and bioavailability of bioactive compounds and antioxidant activity, as in the case of vegetable matrices, resulting in loss of functionality (Miglio et al., 2008).

The development of plant-based products using the by-products from cashew apple peduncle processing is an interesting alternative for this fruit's integral use, stimulating new products' growth and reducing processing waste. Thus, considering the lack of data on this subject, this work's objective was to analyze the bioactive compounds of artisanal and industrialized cashew apple fibre cooked for differents cooking methods for obtaining basic cashew “meat”. Besides, new products based on cashew "meat" were prepared and evaluated sensorially.

2. Material and methods

2.1. Plant material

Two types of cashew apple fibres, industrial and artisan, common in commercial juice production in Brazil were used in this study (Figure 2). The cashew apples (*Anacardium* occidentale L.) used in this work were provided by producing companies located at Pacajus-Brazil.

2.1.1. Fibre obtaining

The industrial cashew apple fibre (IF) were provide and processed by a commercial juice company located at Pacajus-Brazil during the harvesting season.

In IF obtaining, cashew apple peduncles (including yellow and red types) were selected and sanitized chlorinated water solution (in a concentration of 100 mg.L^{-1}). The juice was extracted from the fruits (by the crushing and pulping of cashew apple peduncles), and the fibres remaining in the fine-mesh screen were collected and stored. 20 kg of fibres were received, and, for the experiment, three batches were taken randomly. It is essential to know that this sample volume was composed of various processing during the harvesting season. The IF fibres were stored at 4 °C, around two weeks before analysis.

For the artisanal fibre (AF), the same juice company donated around 20 kg of fresh fruits. The processing occurred on the same day that the fruits were received and carried out in a test kitchen. The fruits (both red and yellow peduncles) were sanitized using chlorinated water solution (100 mg.L^{-1}), the nuts were removed, and the juice was extracted in a

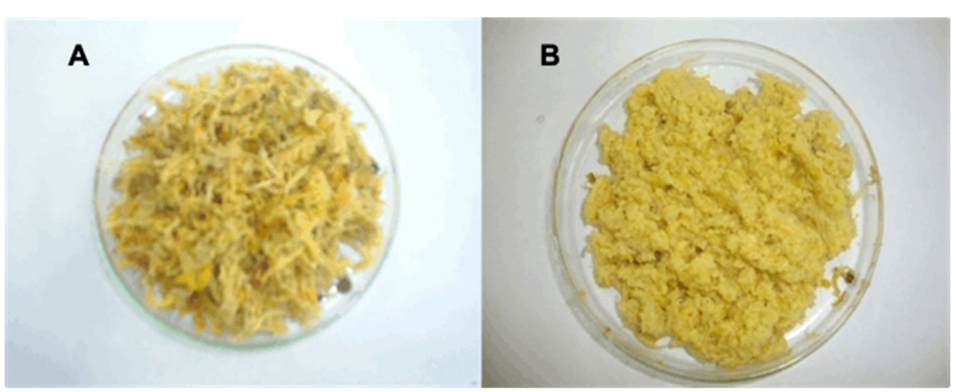

Figure 2. - Industrialized cashew apple fibre (A) and artisanal cashew apple fibre (B).

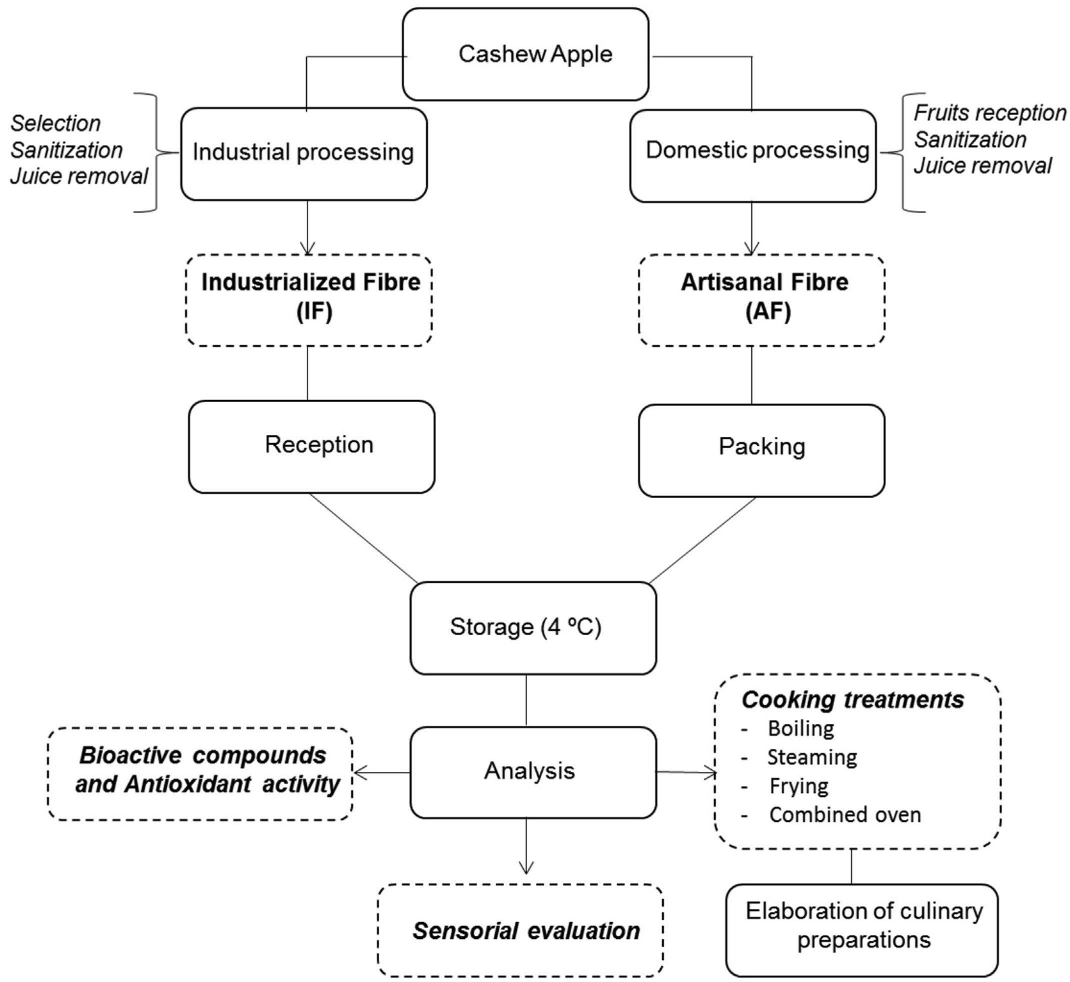

Figure 3. Scheme of preparing cashew fibres and gastronomic products.

centrifugal juicer, Philips Walita, model RI 1861. Finally, the fibre resulting was hand-cut, and the juice remaining was removed by pressing in a sieve. The analysis was carried out in triplicate, considering three separate lots of fibre. The AF fibre was stored in the refrigerator (4 °C), using plastic bags sealed by vacuum. The fibre remained under these conditions until the time of the analysis or processing.

2.2. Bioactive compounds and total antioxidant activity

2.2.1. Ascorbic acid (AA)

The Ascorbic acid (AA) content was determined using the 2,6-DCFI (dichlorophenol-indophenol; Sigma- Aldrich) titration method, described by IAL- Instituto Adolfo Lutz (2008). The results were expressed in mg of ascorbic acid per 100 g of sample on a dry base (d.b.).

2.2.2. Total carotenoids (TC)

Total carotenoids (TC) were measured using the methods described by Talcott and Howard (1999), in which the pigment was measured using 2 g of the sample with 25 mL of an extraction solution containing acetone/ethanol (1:1) and a solution containing BHT 200 mg L^{-1} added to this mixture. It was read in a spectrophotometer Shimadzu Model UV – 1800 at 470 nm, and the results were expressed in mg.100 g^{-1} on a dry base (d.b.)

2.2.3. Total polyphenols (TP)

The extract for determination of total polyphenols (TP) was obtained as described by Larrauri et al. (1997) with modification. The extraction was performed using 10 g of each sample, 20 mL of ethanol 50% (first extraction solution), and 20 ml of acetone 70% (second extraction solution). The mixture stood for 1 h, and then, in two extractions, the sample was centrifuged in an Excelsa II, 206 BL model, at 1,509.30 g (at 3.000 rpm) for 10 min. The second supernatant obtained was mixed with the first in the same flask, measured with distilled water up to 50 ml. The amounts of phenolic compounds in acetone extracts were measured using Folin-Ciocalteu's reagent (Sigma-Aldrich, USA), and the results were expressed as mg of gallic acid equivalents (GAE).100 g^{-1} of the sample on a dry base (d.b.). The measures were carried at 700 nm in a UV – 1800 Shimadzu spectrophotometer, using as reference a standard curve between 0 µg mL^{-1} to 50 µg mL^{-1}.gallic acid.

2.2.4. Total antioxidant activity (TAA)

The total antioxidant activity (TAA) was determined following the 2,2-azino-bis 3-ethylbenzothiazoline- 6-sulphonic acid radical (ABTS, Sigma-Aldrich, USA) method described by Re et al. (1999) with minor modifications. The absorbance was measured in a spectrophotometer (Shimadzu Model UV – 1800) to 734 nm. The results were expressed as equivalent to the Trolox antioxidant (TEAC) (mM Trolox per g of sample on a dry base (d.b.).

The 1,1-Diphenyl-2-picrylhydrazyl radicals (DPPH, Sigma-Aldrich, USA) assay was carried out according to the procedure described by Brand-Williams et al. (1995) with some modifications by Almeida et al. (2011). The assay procedure was similar to the ABTS method described above. DPPH (600µM) solution was diluted with ethanol to obtain an absorbance of 0.7 ± 0.02 units at 517 nm. Fruit extracts (30µL) or controls (Trolox, Vitamin C) were allowed to react with 3 mL of DPPH radical solution for 30 min in the dark, and decrease absorbance from the

Table 1. Processing conditions used for cashew apple fibres cooking procedures.

Cooking procedure	Equipment	Proportion Fibre:water	Temperature	Time	Cooling
Boiling	Triple bottomed stainless steel cookware	1:4	Boiling (∼100 °C)	18 min	room temperature (∼25 °C.)
Steaming	Triple bottomed "*cozi-vapore*" stainless steel cookware	-	(∼100 °C)	20 min	room temperature (∼25 °C.)
Frying	Teflon frying pan without a lid	1:5.5*	-	3 min	180 °C
Combined oven (dry heat + wet heat)	RationalMod 61 Selfcooking ® (Germany)	-	(∼98 °C) (UR: 100%)	10 min	—

* Soybean oil:fibre.

Table 2. Ingredients of cashew apple paçoca and cashew apple ball.

Ingredientes	Cashew apple paçoca	Cashew apple ball
Cashew apple fiber (g)	470	470
Cassava flour, sifted (g)	300	-
Purple onion (g)	100	92
Ghee, bottled butter fat (ml)	50	-
Chopped garlic (g)	12	15
Broth in tablet (g)	10,5	10,8
Paprika (g)	5	7
Salt (g)	3	5
Parsley (g)	2,5	5
Black pepper, freshly ground (g)	2	3
Slices of crustless toast bread (g)	-	183
Eggs (unity)	-	2
Cherry pepper (g)	-	12
Soy oil (ml)	-	540

resulting solution was monitored. The standard curve was linear between 0–20μM Trolox (final concentration) and 0–20 mg of ascorbic acid/100 mL. The results were expressed as equivalent to the Trolox antioxidant (mM Trolox per g of sample on a dry base (d.b.)).

2.3. Cooking treatments

Each sample was prepared in batches of 300 g to obtain more homogeneous samples. Each batch was then divided into five equal portions. One portion was retained raw; the others were cooked in three repetitions with four different methods, as given below (Figure 3).

Cooking conditions were optimized by preliminary experiments for each fibre. According to the Brazilian eating habits, the samples were considered cooked according to the minimum cooking time to reach tenderness for acceptable palatability and taste (Table 1).

2.3.1. Boiling

Two-handled triple bottomed stainless-steel pan (Tramontina, São Paulo, Brazil) was used, into which 65 g of fibre was placed in 275 mL of cold water, brought cooked at 100 °C for 18 min on a moderate flame. The resulting sample was separated from boiling water with the help of a household filter. Cooking time was measured, starting from putting samples in the boiling water.

2.3.2. Steaming

For the steaming, a pan-cooked vapore (Tramontina, São Paulo, Brazil) with triple bottom was used, containing 600 mL of water, whose vapor came into contact with 65 g fibre for 20 min. Cooking time was

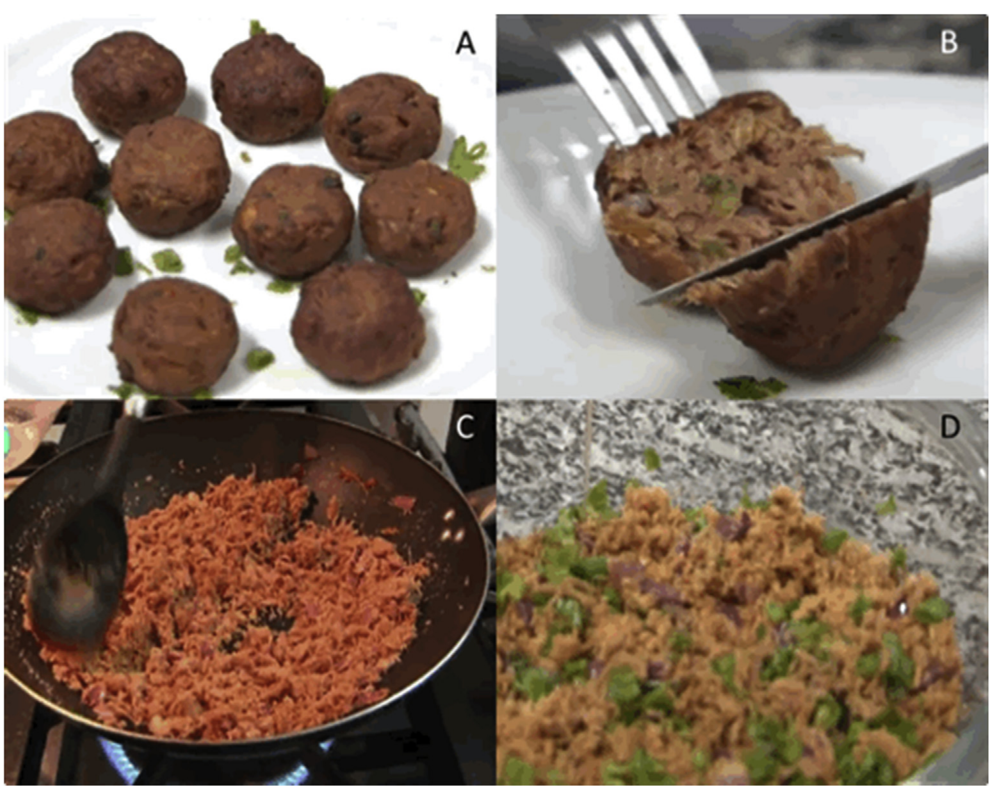

Figure 4. Industrialized (A) and artisanal (B) cashew apple paçoca and and industrialized (C) and artisanal (D) meatball "meatball" cashew apple.

Table 3. - Contents of ascorbic acid (AA), total carotenoids (TC), total phenolics and total antioxidant activity (TAA) in artisanal and industrialized cashew apple fibres on a dry base (d.b.).

Determinations	Artisanal Fibre (AF)	Industrialized Fibre (IF)
Ascorbic acid (AA) (mg $100g^{-1}$)	901.2 ± 74.88^{a}	20.3 ± 0.02^{b}
Total carotenoids (TC) (mg $100g^{-1}$)	5.24 ± 0.37^{a}	5.27 ± 0.04^{a}
Total phenolics (TP) (mg GAE $100g^{-1}$)	97.44 ± 6.65^{a}	49.80 ± 0.22^{b}
Total antioxidant activity ABTS (TAA) (μM Trolox g^{-1})	49.76 ± 18.96^{a}	32.68 ± 7.05^{a}
Total antioxidant activity DPPH (TAA) (μM Trolox g^{-1})	109.76 ± 13.66^{a}	31.92 ± 2.31^{b}

Values are means ± SD. Means within a row with a different superscript letter are significantly different at $p \leq 0.05$.

measured starting from the moment in which the sample was suspended above boiling water.

2.3.3. Frying

For the process of pan frying, a Teflon frying pan without a lid (Tramontina, São Paulo, Brazil) was used containing 12 mL of soybean oil, which came into direct contact with 65 g of the sample, for three minutes at 180 °C long enough to brown the fibre.

2.3.4. Combined oven (CO) - combined dry heat cooking with moist heat

For combined dry heat with moist heat cooking, it was used an oven (Rational Mod 61 SelfCooking Oven, Germany), where the fibre remained inside the oven with 100% relative humidity at a temperature of 98 °C for 10 min.

2.4. Development of paçoca and meatballs using cashew apple fibre

For the culinary preparations, were used both AF and IF. The preparations were done two times, considering the type of fibre. The list of the ingredients used for elaborating the "paçoca" and the "meatball" is shown in Table 2.

To prepare the cashew apple "paçoca" (Figure 4A and 4B), in the first step, the boiled cashew fibres were watered with the broth previously prepared soon after they were drained, then seasoned with ground black pepper, paprika and salt and set aside. After this stage, in a saucepan over low heat, if-braised onions and garlic in ghee (bottled butterfat). The seasoned fibre was then added carefully and stirred in a circular motion with a rubber spatula's aid for about 5 min. Later, slowly, sifted cassava flour was added, stirring it constantly. Finally, the burner was turned off, and chopped parsley was put on top. The cashew apple "paçoca" were stored in plastic containers and then immediately taken for sensory analysis.

For apple "meatball", the fibre was added to the stock and after drained. Sequentially, the fibre was mixed with the sliced bread cut into pieces, and with all other spices (Table 2). Eggs were added to the mixture. After a vigorous mixture, the meatballs (50g) were hand-modeled, fried in hot oil for around 5 min (Figure 4C and 4D). Finally, after cooking, the excess of oil present in the "meatballs" was removed using towel paper, and the preparations were placed on sensory evaluation.

2.5. Sensorial evaluation

The culinary preparations of cashew apple fibre were sensory evaluated one-by-one for the tests were elaborated sheets containing individual questions for each preparation. Sixty panelists evaluated the products' overall acceptance after their production (around 2 h after). The acceptance was judged considering the attributes: aroma, appearance, flavour, and overall impression.

The project was approved by the National Council of Scientific and Technological Development (under registration number 261/11) and obeyed all the preconized aspects (ethic and legal) for its development. The panelists consented with the performance of sensory tests and the dissemination of the results obtained. Four products were subjugated from sensory tests, being evaluated by possible consumers. For the analysis's application, 30 g of each product was considered alone, being each sample codified (three-digit numbers), and their distribution occurred following to the previously described by MacFie et al. (1989). The analysis was carried out individually for each panelist, and white light was kept throughout the experiment. According to Meilgaard et al. (1999), the answers were evaluated in the sensory tests. A nine-point structured hedonic scale was elaborated to evaluate the products' attributes. A five-point structured scale was elaborated to evaluate the purchase intent.

2.6. Statistical analysis

A split-plot design was used to carry out the experiments, considering the fibres (IF and AF) in the plots and the four subplots' treatments. The experiment's design was factorial and completely randomized and performed three repetitions for each experiment. The data obtained were statistically treated and subjugated to analyze the interaction among the fibre and cooking methods by one-way analysis of variance (ANOVA). It was applied to the average teste (Tukey's), and the differences were reputable in a significant level of $p \leq 0.05$.

The software XLSTAT 2020 for Windows version 1.3 (Adinsoft, Paris, France) was used for statistical analysis.

3. Results and discussion

3.1. Bioactive compounds and total antioxidant activity of artisanal and industrial raw cashew fibre

The bioactive compounds content in artisanal (AF) and industrial (IF) cashew fibre are presented in Table 3. The values of all compounds evaluated for AF and IF samples were expressed on a dry basis. Due to the absence of similar information in the literature, an approximate comparison was adopted when convenient. A significant difference in ascorbic acid contents was observed between artisanal fibre (901.2 mg 100 g^{-1}) and industrial fibre (20.3 mg 100 g^{-1}). Several factors may be responsible for the difference in the content of ascorbic acid between the samples. However, the difference in these samples' processing and storage conditions was certainly the main responsible for the difference between the values exhibited. It is not known, completely, which procedures were adopted by the juice company immediately after IF obtaining it. However, it is known that fibres from different operations composed IF. Thus, it is impossible to affirm the freshness of this raw material, which could indicate its reduced content in ascorbic acid. For the AF obtaining, all process was experimentally monitored, and the fibre was composed of fruits from only one process. Due to the high concentration of vitamin C found in AF, this sample can be considered a good source of this compound, i.e., 100g of the product contained vitamin C (901.2 mg), which is a concentration enough to provide twenty times the recommended daily value (RDV) for adults, which are 45 mg (FAO/WHO, 2001). The concentration of vitamin C was for cashew fibre was previously evaluated in the literature. Andrade et al. (2015) found

Table 4. Bioactive compounds on a dry base (d.b.) and their relation with cooking methods for cashew apple fibre processing.

Fibre	Cooking Methods	Determinations				
		Ascorbic Acid (mg $100g^{-1}$)	Total Carotenoids (mg $100g^{-1}$)	Total Phenolics (mg GAE $100g^{-1}$)	Total Antioxidant Activity (ABTS) (μM Trolox g^{-1})	Total Antioxidant Activity (DPPH) (μM Trolox g^{-1})
Artisanal	Before cooking (Raw)	901.2 ± 74.88^{a}	5.24 ± 0.37^{c}	97.44 ± 6.65^{a}	49.76 ± 18.96^{d}	109.76 ± 13.66^{a}
	Boiled	149.4 ± 18.0^{d}	5.04 ± 0.50^{c}	66.68 ± 5.91^{c}	28.54 ± 12.91^{e}	31.62 ± 1.89^{f}
	Steamed	260.6 ± 15.7^{c}	5.94 ± 0.14^{c}	91.67 ± 0.67^{ab}	81.59 ± 16.72^{bc}	78.82 ± 4.32^{b}
	Fried	319.0 ± 11.7^{b}	7.17 ± 1.16^{bc}	43.45 ± 7.26^{de}	104.95 ± 1.73^{b}	71.42 ± 7.14^{bc}
	Combined Oven	242.2 ± 11.4^{c}	12.14 ± 1.14^{a}	95.69 ± 4.35^{a}	74.66 ± 3.46^{c}	61.82 ± 0.33^{cd}
Industrialized	Before cooking (Raw)	20.3 ± 0.02^{d}	5.27 ± 0.04^{c}	49.80 ± 0.22^{d}	32.68 ± 7.05^{e}	31.92 ± 2.31^{f}
	Boiled	13.7 ± 1.0^{e}	5.69 ± 0.85^{c}	29.44 ± 3.20^{e}	30.49 ± 4.50^{e}	37.35 ± 2.94^{f}
	Steamed	33.1 ± 3.7^{d}	5.29 ± 0.20^{c}	42.85 ± 4.43^{de}	142.25 ± 6.50^{a}	45.62 ± 3.99^{ef}
	Fried	27.5 ± 15.4^{d}	10.18 ± 1.68^{ab}	74.66 ± 7.05^{bc}	83.85 ± 2.68^{bc}	100.29 ± 1.67^{a}
	Combined Oven	22.8 ± 5.6^{d}	6.19 ± 0.81^{c}	47.69 ± 1.58^{d}	102.24 ± 7.62^{bc}	51.11 ± 1.79^{de}

Values are means ± SD. Means with a different superscript letter in the column are significantly different at $p \leq 0.05$.

mean values of vitamin C of 78.50 mg.$100g^{-1}$ for cashew residues while Lima et al. (2017), analyzing hamburger obtained from processed cashew fibre and soy protein, found an average value of 33.96 mg.$100g^{-1}$. Even that the values of vitamin C have been expressed on a dry basis, the higher concentration of this compound in AF is remarkable compared to those obtained from literature; however, the concentration of vitamin C for industrialized cashew fibre (IF) was lower in all cases evaluated.

No significant difference ($P > 0.05$) was noted for AF and IF's carotenoid content, which were 5.24 mg 100 g^{-1} and 5.27 mg $100g^{-1}$, respectively. Thus, it is possible to affirm that both fibres' process did not result in a substantial difference in their concentration of carotenoids (Table 3). Different results for carotenoid concentration in cashew apple fibre were previously reported in the literature. For example, the value of 2.7 mg 100 g^{-1} by Azeredo et al. (2006) and the range of .02–0.9 mg.100 g^{-1} found by Broinizi et al. (2007). These results may be attributed to storage conditions, soil, and climate to which the cashew apple was submitted. The isomerization of carotenoids through the actions of oxygen, light, heat, and alkali may also contribute to these differences (Regal et al., 2014).

It was observed a significant difference ($P \leq 0.05$) between the mean values for the phenolic compounds found in AF (97.44mg of GA 100 g^{-1}) and IF (49.80 mg of GA 100 g^{-1}), suggesting that these compounds were affected by the processing did in each fibre. The phenolics represent one of the most diverse families of compounds found in vegetal matrices. Like other phytochemicals, their concentration is related to soil, climate, maturity, and extraction methods. Thus, the literature presents different results regarding the concentration of phenolics in the cashew fruit. Mendes et al. (2019), for example, reported a concentration of 78,46 mg of GA 100 g^{-1} in a raw extract obtained from the cashew apple. Queiroz, Lopes, Fialho and Valente-Mesquita (2011) found a value of 17.0 mg of GA 100 g^{-1} in minimally processed cashew apples. From these results, it is possible to have a reasonable idea about the number of phenolics remained in AF after processing the fresh fruit, previously evaluated by the authors.

Employing the ABTS method, the total antioxidant activity (TAA) of AF (49.76 mM of Trolox.g^{-1}) was statistically similar ($p > 0.05$) to than exhibited for IF (32.68 M of Trolox.g^{-1}). However, in the DPPH method, AF presented a TAA, which was approximate, 70% higher than that presented by IF (Table 3). Even so, using the DPPH method, both AF and IF presented a higher TAA when compared to the previous results Razali et al. (2008). The higher difference between the values observed in ABST and DPPH methods can be attributed to each compound's specific contribution and their impact on the mechanism of the reaction in each technique. For example, it is known that the carotenoids are potent antioxidants; thus, the results obtained for the ABTS method were reasonable to expect once these compounds were presented in similar concentrations in both AF and IF. In the DPPH case, the TAA was influenced by ascorbic acid's contribution, which was considerably higher in AF. The absorbance at 515 nm may interfere with other compounds such as the carotenoids, which would underestimate the remaining DPPH and, therefore, the sample's antioxidant activity (Prior et al. 2005). Mendes et al. (2019) described results similar to those found in our research, comparing the ABTS and DPPH methods for obtaining the TAA of cashew apple extract. The authors related a significant difference between the TAA measured by each method, being these values equal to 9.34 and 1420.19 mM Trolox g^{-1} for ABTS and DPPH method, respectively.

The evaluated fibres presented considerable antioxidant activity and can be considered a good source of natural antioxidants, which can be used for industrialization to obtain new or enrich food products.

3.2. Effect of cooking in bioactive compounds of cashew fibre

It was found that the concentration of ascorbic acid ranged from 27.5 to 260.6 mg 100 g^{-1} in AF and 13.7–319 mg 100 g^{-1} in IF (Table 4). As shown in Table 4, between the cooking methods evaluated, a significant difference in ascorbic acid values, indicating that the variation in the temperature and time of exposure employed in each technique, presented a significant influence on this compound's final concentration. Three external factors are involved in the destruction of vitamin C during cooking: heat, leaching, and exposure to air (oxidation); thus, the cooking and processing steps resulting in higher exposure of the food to these factors, resulting in higher losses. After cooking, the cashew apple fibre becomes softer, and its larger surface area favors contact with air and the consequent degradation of the vitamin (Love and Pavek, 2008).

Cooking processing resulted in different values for concentrations of carotenoids. The higher and lower concentrations of carotenoids were both found for AF, corresponding to 12.14 mg.100 g^{-1} for the combined oven from and 5.04 mg.100 g^{-1} for the processing by boiling (Table 4); however, statistically, the value of carotenoids obtained after the boiling processing in AF was similar ($P \leq 0.05$) to those obtained from the boiling (5.69 mg.100 g^{-1}), steaming (5.29 mg.100 g^{-1}) and combined oven (6.19 mg.100 g^{-1}) in IF. The carotenoids are pigments very susceptible to interactions with the environment. In the boiling, the fibre was exposed to heat for a longer time, causing a more significant destabilization of its structure. Most of the carotenoids found in nature are in the trans configuration due to its higher stability than the cis-isomer. However, during processing and storage, carotenoids can easily rearrange themselves in different geometric isomers and easily quantified (such as lycopene, astaxanthin, and zeaxanthin). The responses on the carotenoid content related to the cooking methods evaluated could be due to the differences in the carotenoid matrix and the difference in their structure, resulting in the tissue's different answers to heat stress (Linus

Table 5. Average scores of the acceptance tests and purchase intent of the artisanal and industrialized cashew apple paçocas.

Process	Sensorial atributes				
	Appearance	Aroma	Flavour	Overall acceptance	Purchase intent
Artisanal	7.41^{a}	7.01^{a}	6.75^{a}	6.86^{a}	3.80^{a}
Industrialized	7.40^{a}	6.35^{b}	6.33^{a}	6.48^{a}	3.53^{a}

Means within a column with different superscript letter are significantly different at $p \leq 0.05$ by the Tukey test.

Opara & Al-Ani, 2010). Further studies are required to unravel how different cooking and processing methods affect carotenoids increase in cashew fibre.

The content of total phenolic compounds observed for both fibre ranged from 95.69 GA 100 g^{-1} for the AF processed in the combined oven to 29.44 mg GA 100 g^{-1} for the IF processed by boiling (Table 4). Among the treatments, a significant loss of total phenols was noticed for the fibre cooked in boiling water. This result was similar to Ozcan et al. (2018) reported when evaluating the effect of heat treatment on peanut oil. Employing the boiling process, the authors observed a decrease in the values of total phenolics after the boiling process and TAA, suggesting that this process negatively affected these compounds' recovery. The boiling can lead to a collapse of the structure of lignocellulosic plant products, resulting in the components of the depolymerization of lignin.

As a consequence, the phenolic compounds are quickly released from vegetables. During this process, water-soluble compounds can migrate to the boiling water. On the other hand, the steam present in water non-contact methods prevents the compound's solubilization, explaining the values found for the combined oven method (Xu and Chang, 2008). The results found in this research are according to the previously reported by Miglio et al. (2008).

A significant interaction between the cashew fibre (artisanal and industrial) and cooking methods for the ABTS method's total antioxidant activity was found (Table 4). For AF, it was observed a statistical difference ($p < 0.05$) between the treatments. Boiling was significantly lower (28.54 μM Trolox.g^{-1}) than frying (104.95 μM Trolox.g^{-1}), which was similar to the results verified by Armesto et al. (2016), studying the effects of different cooking methods on Galega kale. For IF, the steaming process differed statistically ($p \leq 0.05$) from the other methods and resulted in higher antioxidant capacity. According to the points by Navarre et al. (2010), this result is pointed out. Pellegrini et al. (2010) studied the effect of domestic cooking methods on the total antioxidant capacity of cauliflower found a significant difference between boiling and steaming, which was statistically higher than others agreeing with the results found in this research. The frying process and combined oven (83.85 and 102.24 μM Trolox.g^{-1}) did not present difference statistical and also retained considerable values of TAA. In the case of frying, the result can be related to the use of soybean oil in the cooking process, which allowed the rapid heat transfer in short cooking time, resulting in better retention of the antioxidant compounds. The frying can also reduce leach of water-soluble compounds such as vitamin C and soluble phenolic compounds, but in a more significant loss of soluble molecules (carotenoids) (Fillion & Henry, 1998). Besides, Nicoli et al. (1999) pointed out that this processing can promote the oxidation of polyphenols to an intermediate oxidation state, which may have a higher free radical sequestration than non-oxidized. It is suggested that heat treatment may disrupt the cell wall and liberate antioxidant compounds from the insoluble portion of food, increasing the pool of bioaccessible antioxidant compounds. Besides, antioxidant activity improvement may be related to novel compounds with antioxidant activity during heat treatment or thermal processing.

Nicoli et al. (1997) showed that a prolonged heat treatment enhanced tomato and coffee's antioxidant activity. They reported that the samples' browning and antioxidant activities were increased with the extension in heating and roasting time.

Previous studies evaluated the antioxidant properties of Maillard's reaction products, and the results showed that the products resulted from this reaction can act in the chain breaking and oxygen scavenging activities (Choi et al., 2006, Manzocco et al., 2001).

Using the DPPH method, the TAA levels ranged from 31.62 μM Trolox. g^{-1} (boiling in AF) to 100.29 μM Trolox.g^{-1} (frying in IF). Similarly to found in our research, Subudhi and Bhoi (2014) investigated mustards in India under different processing methods and found that the steaming and boiling presented a lower TAA than frying processing. There is a relationship between the content of ascorbic acid, carotenoids, and phenolic compounds, showing that the highest average in these parameters contributed positively to the TAA, proving that the antioxidant potential of these compounds, e.g., at the frying. The values of TAA of the boiling (37.35 μM Trolox. g^{-1}) and steaming processing (45.62 μM Trolox. g^{-1}) in IF were no statistically different from the data obtained for the boiling process of AF (Table 4). In the steaming process, the reduced value may be attributed to the direct contact with water and the time of heat exposure (18–20 min), leading to the degradation of compounds and leaching of these compounds into the cooking water. Even though the concentration of carotenoids being smaller than polyphenols, their contribution to the increase of TAA cannot be neglected.

3.3. Sensory acceptance of products based on cashew fibre

3.3.1. Acceptance of "paçoca" cashew apple

No statistical difference was observed ($p > 0.05$) among the "paçoca" made with artisanal and industrialized cashew apple fibres concerning the sensorial attributes except for aroma (Table 5). The sensory analysis results for appearance, aroma, flavor, overall impression, and purchase intent presented themselves in the hedonic scale's acceptance zone, showing that the cashew "paçoca" was given a good evaluation by the panelists participating in the test.

The appearance averages were between "like moderately" and "liked" being in the zone of acceptance of the hedonic scale, in which the tasters did not notice differences ($P > 0.05$) between the formulations.

The results pointed out that most of the notes received from the "paçoca" samples were located in the region of approval of the product, i.e., values equal to or above 5, showing 96.6% acceptance. The aroma attribute was statistically different ($P \leq 0.05$) between the "paçocas", in which the product elaborated with AF presented a higher average, in which values on the hedonic scale ranging between "like moderately" and "liked". This difference may be due to the remaining juice presented in AF, which implies a higher concentration of volatile compounds than manufactured products (IF), contributing to the higher acceptance of "paçoca" elaborated with that fibre. However, even existing a significant difference, both "paçocas" produced with AF and IF were in the positive range of the scale, relating good acceptance of aroma. Lima (2008) evaluated the sensory cashew apple hamburger and found an average of 6.1 for the attribute aroma. In the same study, the authors found a mean of 5.7 for the flavor attribute, being the "neither liked nor disliked" and "slightly liked" and is lower than those obtained in this work concept.

For the flavor attribute (Table 5), there was no significant difference in the acceptance of the samples ($p \leq 0.05$). It was observed that most of the notes received were in the positive zone of the hedonic scale, being the acceptance rate of 78% and 86% for the "paçocas" elaborated with IF

Table 6. - Average scores of the acceptance tests and purchase intent of the artisanal and industrialized cashew apples balls.

Process	Sensorial atributes				
	Appearance	Aroma	Flavour	Overall acceptance	Purchase intent
Artisanal	7.20[a]	6.80[a]	6.68[a]	6.71[a]	3.60[a]
Industrialized	7.10[a]	6.93[a]	6.93[a]	6.86[a]	3.65[a]

Means within a column with different superscript letter are significantly different at $p \leq 0.05$ by the Tukey test.

and AF, respectively. The results showed that the panelists well accepted the samples.

The samples remained in the positive zone of acceptance for the overall impression. Barros et al. (2012) evaluated the hamburger's acceptance developed with cashew fibre concluded that the increase in the percentage of cashew residue decreased the hamburgers' approval. Mendes et al. (2019) evaluated yogurt's sensory acceptance supplemented with yacon syrup and cashew apple extract and observed mean values of 6.61, corroborating this research result.

For the overall impression, around 40% of the tasters cited “slightly liked” and “moderately liked” which may have influenced results in the average purchase intent, where over 40% of the panelists revealed that “maybe buy, maybe not buy” and “possibly buy”.

As for the purchase intent, the product made with AF an IF presented respectively, averages of 3.53 and 3.8; standing right next to the category “probably would buy” which is represented by the note 4.0. The results demonstrated that if the products were available on the market, they would have acceptance by potential consumers.

3.3.2. Acceptance of cashew apple “meatballs”

In the sensory analysis of “meatballs”, no statistical difference ($p > 0.05$) was observed among the attributes evaluated, which means that the products (elaborated with AF and IF) were statistically similar (Table 6). This result is expected; once for the formulation of both “meatballs”, the same proportion of ingredients was used. In this case, the difference between the fibres did not influence the sensory evaluation of the products.

The results pointed out that cashew apple ball was better accepted regarding its appearance. It was checked that the highest grades were for the “liked moderately” and “liked”, which corresponded to the point 7 and 8 of the hedonic scale, respectively in the case of the aroma and flavour attributes, the grades concentrated in the approval region (Table 6).

For the overall impression, the “meatballs” exhibited a great percentage of grades for “slightly liked” and “moderately liked”, which corresponded to points 6 and 7, respectively. Lima (2008) developed burgers using cashew apple fibre and subjugated this product to sensorial tests. Considering the overall impression attribute, the value reported by the author (5.9) was less compared to that found in this research. The responses for the buy intention of “meatballs” stayed in the zone of acceptance of the hedonic scale. For both cashew apple “meatballs”, the average for buy intention ranged from “maybe buy/maybe not buy” to “possibly buy” (Table 6), and this resulted implies in a good market acceptance if this product would be available in the market.

4. Conclusion

The cashew apple fibres demonstrated to be a valuable source of nutrients. Both fibres showed low values of total phenolic compounds and but exhibited elevated antioxidant activity due to other bioactive presented in their constitution. The processing methods evaluated in our research demonstrated influence in the cashew fibres' antioxidant activity. Between them, frying was considered the best cooking method in terms of the conservation of bioactive constituents and total antioxidant activity after the processing. However, boiling processing was the method that presented the lowest retention of bioactive compounds. Two preparations (“paçoca” and “meatball”) were developed using artisanal and industrial cashew apple fibre, and the results from sensorial evaluation indicated a positive evaluation of these new products. Cashew apple fibre is a viable raw material, with low price and easy obtention and nutritionally rich. Thus, our study brings valuable information about using cashew apple fibre in culinary preparations, prospecting other products, and research.

Declarations

Author contribution statement

Natália Rocha Sucupira: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Luiz Bruno de Sousa Sabino, Sandro Thomaz Gouveia: Analyzed and interpreted the data; Wrote the paper.

Leopoldo Gondim Neto: Performed the experiments.

Raimundo Wilane de Figueiredo: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Geraldo Arraes Maia: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Paulo Henrique Machado de Sousa: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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