



Physicochemical characterization, antioxidant activity, and sensory analysis of beers brewed with cashew peduncle (*Anacardium occidentale*) and orange peel (*Citrus sinensis*)

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Abstract

This study aimed at brewing wheat beer with cashew peduncle (CP) and orange peel (OP). Six formulations (F) were assessed for their physicochemical characteristics and total amount of polyphenols and antioxidant activity. The flavors of F1 and F6 were evaluated via sensory analysis. The results showed that the evaluated beers were in accordance with the parameters required by the Brazilian legislation. Moreover, the addition of CP and OP improved total amounts of polyphenols, antioxidant activity, and flavor. We conclude that the use of by-products from the food industry brings new possibilities of innovation into the beverage sector.

Keywords: polyphenols; antioxidants; beverages; fermentation; flavors.

Practical Application: The use of by-products in brewing.

1 Introduction

Beer is one of the oldest alcoholic beverages, manufactured by fermenting the brewer's wort from barley malt using yeast, with the addition of hops (Veljovic et al., 2015). Craft beer is one of the fastest-growing alcoholic beverage industries (Gómez-Corona et al., 2016). In Brazil, these types of beers accounted for 8% of the national beverage market in 2012, reaching 11% in 2014, with a projected estimate of 20% in 2020 (Serviço Brasileiro de Apoio às Micro e Pequenas Empresas, 2016). The search for authentic products and new taste experiences are the main motivators behind the consumption of craft beers (Gómez-Corona et al., 2016). Adjuncts are used to impart elements of beer product quality such as color, flavor, foam, and drinkability (Bamforth, 2017). The search for new sensory characteristics of craft beers has been a challenge for microbreweries to win over consumers (Aquilani et al., 2015). The use of by-products from the food industry can be an interesting alternative in the brewing of beer, because besides adding economic value to wasted raw materials, it reduces costs and environmental contamination problems, incorporating flavor and aroma into the beer (Helkar et al., 2016).

Cashew (*Anacardium occidentale*) is a tropical plant cultivated in a range of countries, including Brazil (Kapasoba et al., 2017). Its peduncle, or cashew apple, is a pseudofruit with great potential for biotechnological development owing to the presence of many technological options for industrialization such as the production of whole juice, sweets, and cajuína (a refreshing, slightly astringent, clarified, and pasteurized juice

obtained from cashew). However, these activities account only about 10% of its use, because much of it is wasted in the field and when its chestnut is removed for the chestnut industry (Prommajak et al., 2014). Moreover, its nutritional composition containing vitamin C, phenolic compounds, flavonoids, tannins, minerals, and fermentable sugars, which favor its use as an adjunct ingredient in fermented beverages (Figueiredo et al., 2002; Medeiros et al., 2017).

Orange (*Citrus sinensis*), in the same way as cashew, generates large amounts of residues (peel, pulp, and seeds) after it is processed to produce juice in the food industry (Negro et al., 2017). However, from these residues, by-products with high commercial value can be obtained, providing economic and environmental benefits (Rezzadori et al., 2012). It is believed that the reuse of orange peels may improve physicochemical characteristics and add flavor and aroma to beer owing to its essential oils. Citrus peel essential oils are rich sources of bioactive compounds such as flavonoids, terpenes, carotenes, and linalool (Ahmad et al., 2006; Mondello et al., 2005; Kamal et al., 2011). Its compounds in conjunction with hops could counterbalance the sweetness of the beverage carbohydrate content.

In this context, this study aimed to investigate wheat craft beers brewed with cashew peduncle (*Anacardium occidentale*) and orange peel (*Citrus sinensis*) in addition to performing physicochemical and microbiological characterization and evaluating their antioxidant activity.

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2 Materials and methods

2.1 Raw materials, adjuncts and yeast

The following malts were used in the brewing process: Pilsen Cargil (Argentina), Caramalte Muntons (English), and Wheat Castle Malting (Belgium). The ripe fruits, cashew peduncles, and oranges were obtained in the local market in the city of Fortaleza (Ceará State, Brazil). The bitter hops (Zythos 8.7% a.a., USA) had a concentration of 0.3% (m/m) and aroma hops (Hull Melon 6.5% a.a., Germany) had a concentration of 0.4% (m/m) in relation to the total malt; *saccharomyces cerevisiae* yeast (Safbrew WB-06, Belgium) was used.

2.2 Physicochemical analysis of adjuncts

The cashew peduncle was subjected to pH, total acidity, reducing and non-reducing sugars, total sugar, and total soluble solids analyses; and the orange peel was subjected to pH, total acidity and moisture analyses, according to the Brazilian legislation (Instituto Adolfo Lutz, 2008).

2.3 Beer brewing

The formulations [patent application BR102017001261-1 with the National Patents Institute (INPI) on January 20, 2017] were defined through experimental design with two variables: orange peel concentrations of 0 and 0.6% (m/m), and cashew peduncle concentrations of 5 and 10% (m/m), making possible six different combinations (Table 1)

The manufacturing process was carried out following these steps (Pires & Brányik, 2015): beers were prepared by milling the grains in a standard disc mill, followed by a mashing process with 9 L of water at a temperature between 53 and 55 °C. Then, the wort was maintained at a temperature between 63 and 66 °C for 1 h, and soon thereafter, the temperature was raised to 76 °C for 10 min. An iodine test was carried out, and then, the grains were filtered and washed with 9 L of water at 75 °C. In the hopping process, the bitter hops were added during the first 5 min of boiling, and the aroma hops were added 5 min before the end of the process. The wort was cooled and decanted with the addition of a Whirlfloc-T tablet (2.5 g) for each 100 L of wort. The final volume obtained was 12 L, with a 66.67% yield. The orange peel and the cashew peduncle were placed in contact with the hydrated yeast for 1 h. Then, they were added to the wort to be fermented for 15 days at 13 °C, followed by maturation for 15 days at 7 °C. Subsequently, the beers were transferred to

glass bottles (350 mL), and 0.15% (m/v) of sucrose was added for the process of carbonation for 15 days at 7 °C. Finally, they were pasteurized in a water bath at a standard temperature (65 °C for 10 min) and stored in a refrigerator at 7 °C until the analysis (Figure 1).

2.4 Physicochemical analysis of beer

The six formulations of beer were characterized as: pH, total acidity (%), total soluble solids (°Brix), original extract (°P), real extract (% m/m) and apparent extract (°P), alcohol content (% v/v; % m/v), density, non-reducing, reducing, and total sugars (% m/m) according to the Brazilian legislation (Instituto Adolfo Lutz, 2008). Protein analysis was performed by the Kjeldahl method and the result was multiplied by 6.25 to convert the total Nitrogen into protein (Association of Official Analytical Chemists, 2000). The lipid content was obtained by extraction using hexane in a Soxhlet apparatus according to the Association of Official Analytical Chemists (2005). The ashes were determined

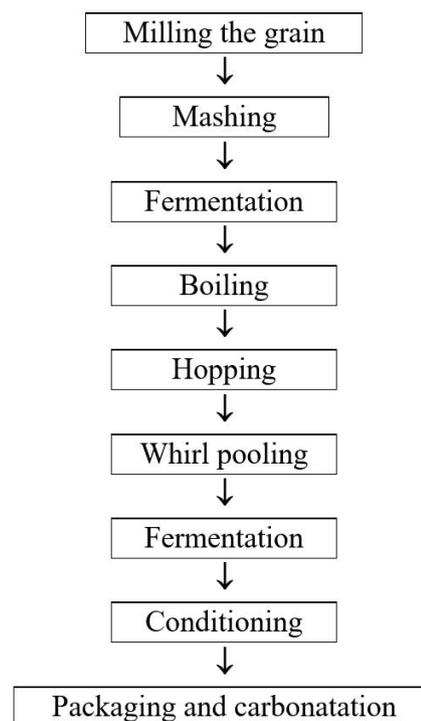


Figure 1. Schematic of the beer brewing process.

Table 1. Beer formulations.

Formulations (F)	Pilsen Cargil (g)	Wheat Castle Malte (g)	Caramalte Muntons (g)	Bitter hops (%)	Aroma hops (%)	Cashew Peduncle (%)	Orange Peel (%)
F1 (CP 0%; OP 0%)	47.5	47.5	5	0.3	0.4	0	0
F2 (CP 5%; OP 0%)	45.1	45.1	4.75	0.3	0.4	5	0
F3 (CP 10%; OP 0%)	42.7	42.7	4.5	0.3	0.4	10	0
F4 (CP 0%; OP 0.6%)	47.5	47.5	5	0.3	0.4	0	0.6
F5 (CP 5%; OP 0.6%)	45.1	45.1	4.75	0.3	0.4	5	0.6
F6 (CP 10%; OP 0.6%)	42.7	42.7	4.5	0.3	0.4	10	0.6

Cashew Peduncle (CP) and Orange Peel (OP).

in a muffle furnace at 550 °C for 12 h, moisture was determined by oven drying, the total carbohydrate content was calculated by difference of the other constituents (proteins, lipids, ashes, moisture), and the caloric value was determined according to the ATWATER coefficient (Atwater, 1910).

2.5 Total phenolic compounds

The amounts of total phenolic in beer samples were determined according to the Folin–Ciocalteu spectrophotometric method (Singleton & Rossi, 1965). In brief, 0.5 mL of diluted beers were mixed with 2.5 mL of Folin–Ciocalteu reagent diluted 10 times and allowed to react for 5 min. Two milliliters of sodium carbonate solution (Na₂CO₃) 7.5% was added to the mixture and then shaken. After 2 h of reaction at room temperature, the reading held at 760 nm. The measurement was then compared to a standard curve of gallic acid equivalent and the result was expressed in mg of gallic acid equivalents per L of sample (GAE mg /L). Triplicate measurements were performed.

2.6 ABTS assay

The evaluation of antioxidant activity by 2,2'-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) (ABTS) assay was performed according to the methodology proposed by Oliveira et al. (2017). The working solution was then prepared by mixing 5 mL of the ABTS (7 mmol/L) with 88 µL of potassium persulfate (140 mmol/L) and by allowing them to react for 16 h at room temperature in the dark. The ABTS solution was diluted with methanol to obtain the absorbance of 0.70 ± 0.02 at 734 nm. An aliquot of each beer (25 µL) was mixed with 3 mL of diluted ABTS radical cation solution; the reaction was centrifuged at room

temperature for 5 min. The antioxidant activity was expressed as IC₅₀, which represents the amount (L) of sample solution required to produce 50% of discoloration of the ABTS relative to blank control. All measurements were performed in triplicates.

2.7 Microbiological analysis

The analysis of coliforms at 35 °C and 45 °C (NMP/mL) of molds and yeasts (UFC/mL) according to ICMSF (International Commission on Microbiological Specifications for Foods, 2006) were performed as described in the BAM manual (Bacteriological Analytical Manual, 1998).

2.8 Sensory tests

The flavor of the F1 and F6 formulations were evaluated using a hedonic scale of nine points. The project followed was reviewed and approved by a Committee of Ethics in Research Involving Human Subjects at Federal University of Ceará (protocol number 2.525.834). 50 mL samples were served monadically, in glass cups codified with three-digit numbers, at 3 ± 1°C. The order of presentation was balanced according to the design proposed by MacFie et al. (1989). Water and bread were also provided after the evaluation of each sample. For data analysis, numerical values were associated to each category, from 1 = disliked extremely to 9 = liked extremely (Table 2) (Peryam & Pilgrim 1957; Veeramachaneni et al., 2010).

2.9 Statistical analysis

All results were expressed as mean ± standard deviation (SD). Statistical evaluation was performed with the Student's t test for paired data or an ANOVA followed by a Tukey test for multiple comparisons at a significance level of 5%, using the STATISTICA software, version 10.

3 Results and discussion

The results of the physicochemical analysis of the raw materials used in beer brewing (Table 3) were close to those established by the current legislation (Brasil, 2000). The beers considered in this study were characterized as “Lager” because they were obtained by the process of low fermentation (Beer Judge Certification Program, 2015). Fermentation stabilization started between the 4th and 5th day, and it ended between the 12th and 14th day.

Table 2. Category anchoring of the 9-point hedonic scale (Veeramachaneni et al., 2010).

Panelist Hedonic Rating	Liking Score
Like Extremely	9
Like Very Much	8
Like Moderately	7
Like Slightly	6
Neither Like Nor Dislike	5
Dislike Slightly	4
Dislike Moderately	3
Dislike Very Much	2
Dislike Extremely	1

Table 3. Results of the physicochemical analysis performed for the cashew peduncle and orange peel.

	CP	NI to CP	OP
Ph	4.6 ± 0.0	4.6	5.4 ± 0.0
Total acidity (%)	3.2 ± 0.3	Minimum 0.3	3.5 ± 0.1
Reducing sugars (%)	9.4 ± 0.8	NS	ND
Non-reducing sugars (%)	1.1 ± 0.1	NS	ND
Total sugars (%)	10.4 ± 0.8	Maximum 15	ND
Total soluble solids (°Brix)	11.2 ± 0.3	10	ND
Moisture (%)	-	NS	0.9 ± 0.2

The values were presented as Mean ± Standard Deviation (SD), n=3. NI: Normative Instruction n°01, of 7 January 2000 (Brasil, 2000). Cashew Peduncle (CP), Orange Peel (OP), Not Specified (NS) and Not Determined (ND).

In this process, sugar is consumed during fermentation, which results in alcohol and CO₂ (Grassi et al., 2014).

Physicochemical analyses were carried out to evaluate the quality, standardize and identify possible fraud, and to ensure the microbiological stability of beers (Table 4) (Piacentini et al., 2015). The pH values of the beers were within the desirable parameters, generally between 3.8 and 4.7, protecting the product against pathogens (Suzuki et al., 2006). The addition of cashew peduncle caused a reduction in the pH of the formulations F2, F3, F5, and F6. Formulation F4, which contained only orange peel, showed an opposite effect, with a pH value higher than that observed in the control and other formulations. The addition of orange peel together with cashew peduncle promoted an increase in the acidity of the beers, compared to the control. For the cashew peduncle, this increase was proportional to its concentration. It is expected that the addition of fruits causes a decrease in the beer pH, but the acidity should not be inappropriately intense so that there is no decharacterization of the drink (Beer Judge Certification Program, 2015). Regarding the total soluble solids, formulations F4, F5, and F6 containing orange peel had the lowest values of °Brix, and they were statistically different from formulations F1, F2, and F3, which indicates the addition of orange peel could have influenced the reduction of the total soluble solids in the beers.

The original extract values obtained in the present study characterize the beers as light, according to the Brazilian legislation (between 5% and 10.5% by weight) (Brasil, 2009). Since the original extract directly influences the beverage alcohol content, formulations with medium alcohol content (3.73 to 4.23%) were obtained.

The density values (1.047-1.056) were lower than those found by Faltermaier et al. (2014) in wheat beers. The non-reducing sugars ranged from 0.67% to 0.95%, showing a significant

difference between the beverages. The reducing sugars ranged from 0.03 to 0.27%, and the highest values were found in formulations 3 (0.27%) and 6 (0.22%), which had been made with the highest cashew peduncle concentrations (10%). Total sugar content values (0.6-0.98%) were similar to those found by Espinosa-Ramírez et al., (2014) in low fermentation beers.

The mean values of the carbohydrates, proteins, lipids, ashes, moisture, and caloric value of the beers are listed in Table 4. The carbohydrate content was lower than the one recommended by Cortacero-Ramírez et al. (2003), who states that beer should contain between 3.3 to 4.4 g/100 of carbohydrates. The protein values obtained in this study were close to zero (0.12-0.26%); excess protein is undesirable because it can bind to the polysaccharides in the beer and form insoluble complexes, causing turbidity, and compromising beverage stability (Rovaletti et al., 2014). The ash content ranged from 0.15 to 0.21% (Table 4). These results are within the range found by Alcázar et al. (2001), who found the total ash values ranging from 0.061–0.158%.

The values resulting from the lipid analysis were close to zero, as expected, and they were especially for the formation of foam, because the lipids act negatively, breaking the protein network (Bamforth, 2000). The moisture values are in agreement with those recommended by Taylor (2006), who states that the minimum percentage of moisture in the beer must be 90%. The caloric content is close to the maximum limit allowed for commercial beers (35 Kcal/100 mL) according to Decree No. 6.871, of June 4, 2009 (Brasil, 2009).

The polyphenols content and antioxidant activity are shown in Table 5. The results showed that the increase in polyphenol content depends proportionally on cashew peduncle concentration in beers. Formulations containing 10% (m/m) of cashew peduncle (F3 and F6) showed a higher increase in polyphenol content compared to formulations (F2 and F5) which contains

Table 4. Experimental values of the results obtained in the physicochemical analysis of beers.

	F1	F2	F3	F4	F5	F6
Ph	4.47 ± 0.02 ^c	4.44 ± 0.01 ^{cd}	4.24 ± 0.01 ^b	4.50 ± 0.00 ^a	4.40 ± 0.00 ^e	4.41 ± 0.01 ^{de}
Total acidity (%)	18.84 ± 0.48 ^c	19.32 ± 0.00 ^c	22.22 ± 0.00 ^{ab}	19.64 ± 0.56 ^c	21.26 ± 0.96 ^b	22.87 ± 0.56 ^a
Total soluble solids (°Brix)	5.07 ± 0.05 ^a	5.10 ± 0.00 ^a	5.10 ± 0.00 ^a	5.00 ± 0.00 ^b	5.00 ± 0.00 ^b	5.00 ± 0.00 ^b
Original extracts (°P)	8.47 ± 0.06 ^c	9.12 ± 0.11 ^d	9.48 ± 0.08 ^b	9.88 ± 0.03 ^a	9.08 ± 0.05 ^d	8.99 ± 0.04 ^d
Real extracts (% m/m)	3.17 ± 0.04 ^{ab}	3.27 ± 0.11 ^a	3.05 ± 0.07 ^b	3.22 ± 0.03 ^{ab}	3.10 ± 0.05 ^{ab}	3.18 ± 0.04 ^{ab}
Apparent extracts (°P)	0.14 ± 0.08 ^a	0.06 ± 0.03 ^b	0.58 ± 0.33 ^b	0.12 ± 0.07 ^b	0.09 ± 0.05 ^a	0.20 ± 0.12 ^b
Alcohol content (% v/v)	3.40 ± 0.89 ^a	3.77 ± 0.12 ^a	4.23 ± 0.15 ^a	4.17 ± 0.21 ^a	3.84 ± 0.04 ^a	3.73 ± 0.03 ^a
Alcohol content (% m/v)	2.69 ± 0.70 ^a	2.98 ± 0.09 ^a	3.28 ± 0.04 ^a	3.40 ± 0.44 ^a	3.84 ± 0.04 ^a	2.95 ± 0.02 ^a
Density	1.02 ± 0.00 ^c	1.02 ± 0.00 ^b	1.02 ± 0.00 ^b	1.02 ± 0.00 ^{ac}	1.02 ± 0.00 ^c	1.02 ± 0.00 ^c
Non-reducing sugars (% m/m)	0.95 ± 0.01 ^a	0.74 ± 0.01 ^{bc}	0.67 ± 0.01 ^b	0.74 ± 0.02 ^{bc}	0.74 ± 0.03 ^{bc}	0.77 ± 0.04 ^c
Reducing sugars (% m/m)	0.03 ± 0.02 ^d	0.10 ± 0.05 ^{cd}	0.27 ± 0.01 ^a	0.10 ± 0.02 ^{cd}	0.16 ± 0.04 ^{bc}	0.22 ± 0.04 ^{ab}
Total sugars (% m/m)	0.98 ± 0.03 ^{bc}	0.84 ± 0.04 ^a	0.94 ± 0.02 ^{abc}	0.84 ± 0.04 ^a	0.91 ± 0.08 ^{ac}	0.98 ± 0.06 ^{bc}
Carbohydrate (%)	2.95 ± 0.05 ^{abc}	2.87 ± 0.02 ^c	3.00 ± 0.01 ^a	2.95 ± 0.01 ^{abc}	2.95 ± 0.01 ^{abc}	2.96 ± 0.05 ^{ab}
Protein (%)	0.24 ± 0.01 ^b	0.26 ± 0.00 ^a	0.18 ± 0.01 ^c	0.12 ± 0.01 ^d	0.15 ± 0.01 ^c	0.12 ± 0.01 ^d
Lipid (%)	0.02 ± 0.02 ^b	0.01 ± 0.02 ^a	0.02 ± 0.01 ^b	0.00 ± 0.01 ^c	0.00 ± 0.01 ^c	0.01 ± 0.01 ^a
Ash (%)	0.15 ± 0.01 ^b	0.18 ± 0.01 ^{ab}	0.14 ± 0.01 ^b	0.21 ± 0.04 ^a	0.16 ± 0.01 ^{ab}	0.16 ± 0.00 ^a
Moisture (%)	93.74 ± 0.01 ^b	92.49 ± 0.01 ^b	92.52 ± 0.03 ^b	92.54 ± 0.02 ^b	92.98 ± 0.03 ^a	92.69 ± 0.02 ^b
Caloric value (Kcal/100mL)	30.85 ± 0.06 ^b	33.28 ± 0.02 ^{bd}	35.46 ± 0.02 ^{cd}	36.18 ± 0.02 ^{ac}	38.88 ± 0.01 ^a	33.25 ± 0.01 ^{cd}

F1 (CP 0%; OP 0%), F2 (CP 5%; OP 0%), F3 (CP 10%; OP 0%), F4 (CP 0%; OP 0.6%), F5 (CP 5%; OP 0.6%) and F6 (CP 10%; OP 0.6%). Cashew Peduncle (CP), Orange Peel (OP) and Formulation (F). The values were presented as Mean ± Standard Deviation (SD), n=3. Means with different superscript letters in a row are significantly different (P < 0.05).

Table 5. Experimental values of the results obtained in the analysis of phenolic compounds and antioxidant activity.

	Polyphenol content (GAE mg/L)	Antioxidant activity ($\mu\text{M/L}$)
F1 (CP 0%; OP 0%)	516.4 \pm 20.9 ^a	1604.7 \pm 19.8 ^{ab}
F2 (CP 5%; OP 0%)	640.9 \pm 58.2 ^b	1567.9 \pm 58.5 ^b
F3 (CP 10%; OP 0%)	722.3 \pm 13.8 ^b	1725.1 \pm 24.7 ^c
F4 (CP 0%; OP 0.6%)	515.9 \pm 62.2 ^a	1580.6 \pm 39.9 ^{ab}
F5 (CP 5%; OP 0.6%)	652.2 \pm 28.7 ^b	1711.1 \pm 82.6 ^{ac}
F6 (CP 10%; OP 0.6%)	726.6 \pm 2.6 ^b	1736.9 \pm 58.8 ^c

F1 (CP 0%; OP 0%), F2 (CP 5%; OP 0%), F3 (CP 10%; OP 0%), F4 (CP 0%; OP 0.6%), F5 (CP 5%; OP 0.6%) and F6 (CP 10%; OP 0.6%). Cashew Peduncle (CP), Orange Peel (OP), Gallic Acid Equivalent (GAE) and Formulation (F). The values were presented as Mean \pm Standard Deviation (SD), n=3. Means with different superscript letters in a column are significantly different ($P < 0.05$).

5% (m/m). Moreover, the polyphenols content was higher than that found by Piazzon et al. (2010), who quantified phenolics in several types of beers, among which, wheat beer presented 504 ± 44 GAE mg/L. This increase can be explained by the fact that the cashew peduncle has considerable amounts of phenolic compounds (Lima et al., 2013).

The antioxidant activity was significantly higher in F3 and F6, which contains high amounts of polyphenols, as well as cashews peduncle (10% m/m). In contrast, F2 (which contains 5% (m/m) of cashew peduncle) and F4 (0.6% (m/m) of orange peel) did not differ significantly from F1. These results suggest that there should be a threshold in the concentration of polyphenols content to promote a significant effect on antioxidant activity. The presence of phenolic compounds and antioxidant activity in orange peel (Kelebek et al., 2009; Hegazy & Ibrahim, 2012; Park et al., 2014; Davies et al., 2017) and cashew peduncle (Lopes et al., 2012; Lima et al., 2013; Andrade et al., 2015) have been confirmed in others studies. Moreover, formulations presented antioxidant activity values (Table 5) higher than those found by Marques et al. (2017) in craft beers.

Ours results also suggested that the combination of cashew peduncle and orange peel bioactive compounds could be acting synergistically, for promoting a greater effect on antioxidant activity, since F5 (which contained 5% of cashew peduncle and 0.6% of orange peel) had a higher antioxidant activity compared to F1. This hypothesis is reinforced by studies showing that polyphenols can act synergistically increasing antioxidant activity (Hajimehdipoor et al., 2014; Xu et al., 2014)

Microbiological analyses for coliforms at 35 °C and 45 °C obtained a value of <0.3 NMP/mL. Regarding the molds and yeasts (UFC/mL), the following results were obtained: 3.0×10^0 for formulations F1 and F2, and 1.2×10^0 , 1.0×10^0 , 2.9×10^0 , and 2.2×10^0 for formulations F3, F4, F5, and F6, respectively; no growth of mold was observed in any of the samples analyzed. These results agree with the Brazilian legislation, demonstrating the beers were under adequate hygienic-sanitary conditions for consumption (Brasil, 2001).

Sensory tests were performed with a group of 15 beer consumers, aged between 31 and 47 (4 females and 11 males), in a laboratory with individual booths, under white light. Among the beers, F1 (control) and F6 was submitted for sensory analysis. F6 was chosen because of its higher content of polyphenols and antioxidant activity. Our results showed that the addition of orange peel and cashew peduncle on beer (F6: 7.4 ± 1.12) improved the

flavor of this beverage significantly ($P < 0.05$) compared to that of control (F1: 6.47 ± 1.3).

4 Conclusions

The use of the cashew peduncle and orange peel in the brewing of wheat craft beer can be considered a viable alternative for the reuse of these by-products. The use of these ingredients in the brewing of beer brings new possibilities of innovation in the beverage sector, especially because it is currently expanding. In addition, such alternatives add value to the raw material and functional compounds to the product, and it contributes to environment improvement because the disposal of these residues in inappropriate places can cause serious environmental problems.

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