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Tecnologias Limpas

Potential of cassava by-product and lychee pulp in the production of reduced-fat ice cream

Potencial do subproduto da mandioca e da polpa de lichia na produção de sorvete com baixo teor de gordura

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ABSTRACT: The aim of this study was to develop and characterize reduced-fat ice cream formulations with the addition of dehydrated cassava bagasse (CB) and lychee pulp (LP). The ice cream formulations were prepared with different proportions of palm fat (0 to 5%), CB (0 to 5%) and LP (1 to 8%) and were evaluated in terms of chemical and microbiological composition, and in relation to the technological, antioxidant and sensory properties. The use of higher levels of CB (5%) and LP (8%) allowed obtaining a higher fiber content and lower fat content. All formulations were safe for consumption and showed adequate values for overrun, melting rate and color. The ice creams showed adequate sensory acceptance, with emphasis on the formulations containing different amounts of CB addition (2 to 5%) and until 3% LP. The higher LP content the higher total phenolic content and the antioxidant capacity were found in ice cream formulations. These results showed the viability of applying CB and LP in ice cream formulations, especially in the proportion of 5% and 1%, promoting the sustainability by using a natural source of antioxidants and a fiber-rich agro-industrial by-product.

Keywords: Fibers. Antioxidants. Sensory Acceptance.

RESUMO: O objetivo deste estudo foi desenvolver e caracterizar formulações de sorvete com reduzido teor de gordura, com a adição de bagaço de mandioca desidratado (BM) e polpa de lichia (PL). As formulações de sorvete foram elaboradas com diferentes proporções de gordura de palma (0 a 5%), BM (0 a 5%) e PL (1 a 8%) e foram avaliadas quanto à composição química e microbiológica, e em relação às propriedades tecnológicas, antioxidantes e sensoriais. A utilização de maiores teores de BM (5%) e PL (8%) permitiu obter maior teor de fibras e menor teor de gordura. Todas as formulações apresentaram segurança para consumo e adequados valores de overrun, taxa de derretimento e coloração. Os sorvetes apresentaram adequada aceitação sensorial, com destaque para as formulações contendo diferentes quantidades de adição de BM (2 a 5%) e até 3% de PL. Quanto maior a adição de PL maior foi o teor de fenólicos totais e a capacidade antioxidante das formulações de sorvete. Estes resultados demonstram a viabilidade da aplicação de BM e PL na formulação de sorvetes, em especial na proporção de 5% e 1%, promovendo a sustentabilidade, ao utilizar um subproduto agroindustrial rico em fibras e uma fonte natural de antioxidantes.

Palavras-chave: Fibras. Antioxidantes. Aceitação Sensorial.

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INTRODUCTIO

Ice cream is a frozen dairy product, widely consumed in Brazil. There was a significant increase in the production of ice cream in the country, raising from 687 million liters (2003) to 1.06 billion liters (2021), as well as its consumption, that increased from 3.83 L/year (2003) to 5.27 L per capita/year (2018) (ABIS, 2021). However, the low nutritional value of ice cream, due to its high fat and cholesterol contents and absence of bioactive compounds, can limit its consumption (SARWAR *et al.*, 2021).

Technology in food production has advanced in recent decades. At same time, the demand for healthier food products has increased, as examples, reduced-fat and low-caloric products or functional foods, which may have the addition of nutrients such as fibers, antioxidants, etc. The development of low-fat products is important, due to the association of excessive consumption of fats with chronic non transmissible diseases such as type 2 diabetes and obesity (BOESTEN *et al*., 2015). To meet this demand, researches can be conducted to the utilization of fat replacers, that also has lower energetic value and helps to maintain physical and sensorial properties of the food products (KALEDA *et al*., 2018).

There are several types of fat replacers, and the dietary fibers (DF) are an interesting option, because its addition to ice cream formulations can improve the textural properties due to the water-holding and gel-forming properties; and helps to control the crystallization during freezing storage (AKALIN *et al.*, 2018). It is known that recrystallization process and the loss of emulsion stability cause deterioration of ice cream texture during storage, with negative impact in the sensory parameters and consumer acceptability of ice cream (ATALAR *et al*., 2021).

Agro-industrial by-products are a low-cost source of dietary fibers. Cassava bagasse, a solid residue generated in the processing of starch, has low commercial value, in addition to being a source of DF, corresponding to almost 60% of the dry bagasse weight (FIORDA *et al.*, 2013). The consumption of DF is associate with health benefits, such as intestinal regulation, reduction of blood-glucose and blood cholesterol concentrations, and it can also help to avoid cardiovascular and carcinogenic diseases (REZENDE; LIMA; NAVES, 2021).

Besides the incorporation of dietary fibers, other components can be added to ice cream formulations, such as phenolic compounds (PC) (LÓPEZ-MARTÍNEZ; MORENO-FERNÁNDEZ; MIGUEL, 2021). PC can be found in several types of fruits, such as lychee (*Litchi chinensis* Sonn). The lychee pulp is rich in dietary fibers, sugars and has a floral-rose aroma and a sweet and slightly citrus flavor (CHEN; CHIA; LIU, 2014; XIN *et al.*, 2022). The pulp presents levels of soluble and total dietary fiber of 1.05 and 2.20 g 100g-1 respectively (GORINSTEIN *et al.*, 1999), as well as active compounds that can act as antioxidants, anti-inflammatories, with hypoglycemic and hypolipidemic effects (LV *et al.*, 2014; SU *et al.*, 2017). Commercially, lychee has been processed in the form of juice, powdered or dehydrated pulp, and as canned fruit (ZHENG *et al.*, 2014).

The aim of this work was to use cassava bagasse and lychee pulp, in replacement of vegetable fat (palm) to produce ice cream formulations, and so to characterize them in terms of nutritional, sensory and technological properties.

2 MATERIAL AND METHODS

2.1 PREPARATION OF CASSAVA BAGASSE AND LYCHEE PULP

The cassava by-product (bagasse) was obtained from the Amifec Agroindustry (Maria Helena, PR, Brazil, Latitude: 23 ° 35'30" south and Longitude: 53 ° 12 'W - GR and altitude of 630 m) and subjected to drying in forced air circulation oven (Marconi) at 90º C for 24 h. Afterward, it was ground in a Willye shredding mill (Solab, SL-031) to obtain a homogeneous flour.

The fruits of lychee 'Bengal' were obtained from producers in the region of Umuarama, Paraná, Brazil (Latitude: 23 ° 45'57 "south and Longitude: 53 ° 19 '30" W - GR and altitude of 442 m), which were harvested when they had reddish peels, indicating the ideal maturity for harvest. To prepare the pulp, the fruits were previously washed, sanitized with sodium hypochlorite solution (100 ppm v/v) for 5 minutes, and manually peeled. The pulp (15.8 °Brix) was processed in a fruit pulper (Silva, model MS-200, Brazil), packed in polyethylene bags and stored at -15 °C until use and analysis.

2.2 PROXIMAL COMPOSITION AND ENERGETIC VALUE

The cassava by-product and the lychee pulp were characterized before their incorporation into ice cream production. The moisture was determined by drying at 105 °C until constant weight, based on the removal of water by heating. The ashes (total crude minerals) were determined using the incineration followed by the calcination of the sample in a muffle oven at 550 °C. The analysis of lipids was conducted using the ether extract method with previous acid hydrolysis in Soxhlet. The determination of dietary fibers was performed according to enzymatic-gravimetric method (IAL 2008). Total carbohydrate content was calculated by difference. The energetic value was obtained by the sum of carbohydrates, lipids and proteins multiplied by their respective conversion factors: 4 kcal, 9 kcal, 4 kcal, 2 kcal (MENEZES *et al.*, 2016).

2.3 PRODUCTION OF ICE CREAM FORMULATIONS

The ice cream formulations, determined after preliminary tests, were produced using different proportions of ingredients such as palm fat (PF) 0 to 5%, lychee pulp (LP), 0 to 8%, and dehydrated cassava bagasse (CB), 0 to 3% (Table 1).

Table 1. Ice cream formulations produced with the addition of cassava bagasse and lychee pulp in replacement of palm fat.

	Ingredients (%)							
Formulation	Water	Milk powder	Sucrose	Stabilizer	Glucose	Palm fat	Cassava bagasse	Lychee pulp
F1	63.5	14.0	13.0	0.5	3.0	5.0	0.0	1.0
F2	63.5	14.0	13.0	0.5	3.0	3.0	2.0	1.0
F3	63.5	14.0	13.0	0.5	3.0	2.0	3.0	1.0
F4	63.5	14.0	13.0	0.5	3.0	0.0	5.0	1.0
F5	63.5	14.0	13.0	0.5	3.0	2.0	2.0	3.0
F6	63.5	14.0	13.0	0.5	3.0	0.0	2.0	6.0
F7	63.5	14.0	13.0	0.5	3.0	0.0	2.0	8.0

The first formulation (F1), named control, has a composition similar to a conventional industrial formulation, including 1% lychee pulp in order to impart a slight flavor to the product. Seven ice cream formulations were produced according to the good manufacturing practices, set out in the Collegiate Board Resolution (CBR) nº 267, of September 25, 2003 (BRASIL, 2003). To prepare the F1 formulation ice cream, the weighed ingredients (except lychee pulp) were mixed in an industrial stainless-steel blender (Skymsen, Brazil) at 75 °C for 10 min. Then, the syrup was transferred to a stainless-steel container and immediately cooled and stored at 5 ºC. In this stage, the syrup was manually stirred every 30 min, aiming the maturation, for a total period of 6 h. The matured syrup was poured into the blender and received the addition of lychee pulp, by stirring until complete homogenization for 3 min. Then, the product was frozen in a batch producer (Central, model C21), with an outlet at -6 ºC, and stored at -25 °C until the moment of the analysis. For the other formulations, due to the addition of CB, there was a change in the beginning of ice cream preparation. CB was added to hot water (75 °C) and then the other ingredients were added, so it was possible to obtain the formulations F2 (3% PF, 1% LP and 2% CB), F3 (2% PF, 1% LP and 3% CB), F4 (0% PF, 1% LP and 5% CB), F5 (2% PF, 3% LP and 2% CB), F6 (0% PF, 6% LP and 2% CB) and F7 (0% PF, 8% LP and 2% CB). The other steps of the preparation were the same as described for F1 (VACONDIO *et al.*, 2013).

2.4 CHEMICAL ANALYSIS

Regarding the proximal composition and energetic values of ice cream formulations, it was used the same methods described in item 2.2.

The melt analysis was adapted from Granger *et al.* (2005), on a semi-analytical balance, 100 g of each sample was weighed in a 1.0 mm plastic sieve supported on a beaker (500 mL), to collect the sample as the melt occurred. The values of the weight of the melted ice cream were recorded every 10 min, until completing 60 min, maintaining the samples at 23 ° C.

The overrun values were determined by measuring the initial volume (IV) of the syrup as the final volume (FV), after the production of the ice, so, the overrun was calculated using Equation 1 (SEGALL; GOFF, 2002).

$$Overrun = \frac{(FV-IV)}{IV}\ x\ 100 \quad (1)$$

2.5 TOTAL PHENOLIC COMPOUNDS AND ANTIOXIDANT ACTIVITY OF ICE CREAM FORMULATIONS

The extraction of phenolic compounds was conducted with 99.5% ethanol, using 20 mL of solvent for 10 g of sample. The agitation occurred in a shaker-type agitator for 4 h (100 rpm) at 25 ºC. The extract obtained after centrifugation was stored at -25° C until the time of analysis.

The quantification of total phenolic compounds (TPC) was conducted according to Chen, Zhao and Yu (2015) with some modifications. An aliquot of 2.5 mL of 10% Folin-Ciocalteau reagent and 2.0 mL of 7.5% sodium carbonate was added to test tubes containing 0.5 mL of the extracts. The mixture was incubated for 5 min in a water bath at 50 °C and, afterward, the absorbance at 760 nm was read on the spectrophotometer (Femto Plus 700). An analytical curve was prepared with gallic acid and the results were expressed in μg of gallic acid equivalent (GAE) per100 g of sample on a dry basis (d.b.).

The antioxidant determination by the free radical $ABTS^+$ (2,2-azinobis-(3-ethylbenzothiazoline-6-sulfonate) method was carried out according to Thaipong *et al.* (2006), with some modifications. The $ABTS^+$ radical was prepared by reacting 10 mL of the $ABTS^+$ 7 mM with 0.18 mL of 140 mM potassium persulfate. The mixture was stored in an amber flask at room temperature for 16 h, and after, it was diluted with ethanol until 0.70 $\pm$ 0.05 nm at 734 nm. An aliquot (30 μL) of each extract was transferred to 3 mL of $ABTS^+$ solution in a test tube and the reading was realized after 6 min of reaction. The analytical curve was prepared with a Trolox solutions and the results were expressed in μmol of Trolox (6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid) equivalent (TE) per g of sample (d.b.).

2.6. MICROBIOLOGICAL AND SENSORY ANALYSIS

Microbiological analyzes were carried out to verify the product's safety, following the standards established by CBR No. 12, of January 2, 2001, (BRASIL, 2001) and the recommendations of Silva *et al.* (1997). The analyzes realized were: thermotolerant Coliforms, whose results were expressed in Most

Probable Number (MPN/g); enumeration of *Staphylococcus aureus*, which the results were obtained in Colony Forming Units (CFU/g); and analysis of *Salmonella* spp., in which "absence" or "presence" was recorded in 25 g of ice cream.

The sensory analysis (CAAE: 03615118.5.0000.0104/Maringa State University) was applied to 100 untrained tasters, with ages varying from 18 to 56 years old, being 42% male and 48% female. The ice creams were kept in a freezer at –18° C and served as soon as they were removed, in disposable white plastic cups with a capacity of 50 mL and encoded by three random digits.

For the acceptance test, the parameters were evaluated: general acceptability, aroma, flavor, color, texture. For this, a 9-point hedonic scale was used, with the following values being attributed: "I really disliked": 1; "I disliked a lot": 2; "I disliked moderately": 3, "I disliked slightly": 4; "Indifferent": 5, "I liked it slightly": 6, "I liked it moderately": 7, "I liked it a lot": 8 and "I really liked it": 9. For the purchase intention test, a 5-point scale was used, with the values corresponding to: "certainly would buy": 5, "possibly buy": 4, "maybe buy / maybe not buy": 3, "possibly not buy ": 2 and" I certainly wouldn't buy ": 1.

2.7. STATISTICAL ANALYSIS

The microbiological were realized in triplicates and the results were expressed as mean values. Physical-chemical and antioxidant analysis were realized in triplicates, and together with sensorial analysis, the results were expressed as mean and standard deviation, being evaluated by analysis of variance (ANOVA), followed by the Tukey test ($p < 0.05$). The results were also evaluated using Principal Component Analysis. Statistical analyses were performed using the Statistica 7.0 software.

3 RESULTS AND DISCUSSION

3.1 PROXIMAL COMPOSITION

Table 2 shows the values of the composition of lychee pulp, cassava bagasse and ice cream formulations. Lychee pulp had higher moisture content (81.27 g/100g) than cassava bagasse (9.34 g/100g), due to the previous dehydration of the by-product. The higher ash content in cassava bagasse compared to lychee pulp may be associated with the presence of minerals such as potassium, calcium, phosphorus, sodium and iron (FIORDA, 2011). For lychee pulp, according to the cultivars, main minerals found are potassium, magnesium, iron, calcium and phosphorus, even in smaller proportions (CABRAL; CARDOSO; PINHEIRO-SANT´ANA; 2019).

Table 2. Proximal composition (g/100g) and energetic value (kcal/100g) of cassava bagasse, lychee pulp and the ice cream formulations.

(Continua)

	Moisture	Ashes	Proteins	Dietary fibers	Lipids	TC[2]	EV[3]
CB	$9.34^b \pm 0.08$	$2.19^a \pm 0.09$	2.05^a 0.05	$35.75^a \pm 1.55$	$0.55^b \pm 0.04$	$50.52^a \pm 0.05$	$215.23^a \pm 1.05$
LP	$81.27^a \pm 0.56$	$1.53^b \pm 0.16$	$0.53^b \pm 0.04$	$0.75^b \pm 0.05$	$0.97^a \pm 0.07$	$14.65^b \pm 0.01$	$69.45^b \pm 0.55$
Ice cream formulations[1]							
F1	$63.77^a \pm 0.67$	$0.82^a \pm 0.01$	$3.48^b \pm 0.05$	$0.18^e \pm 0.008$	$6.31^a \pm 0.06$	$25.41^d \pm 0.11$	$172.83^a \pm 0.04$
F2	$63.51^a \pm 0.10$	$0.96^a \pm 0.02$	$3.89^a \pm 0.02$	$0.98^d \pm 0.04$	$4.38^b \pm 0.03$	$26.29^c \pm 0.04$	$162.06^b \pm 0.05$
F3	$64.73^a \pm 0.25$	$0.88^a \pm 0.01$	$3.79^a \pm 0.03$	$2.42^a \pm 0.04$	$3.64^d \pm 0.03$	$24.55^e \pm 0.04$	$150.92^c \pm 0.05$

(Conclusão)

	Moisture	Ashes	Proteins	Dietary fibers	Lipids	TC[2]	EV[3]
F4	64.36[a]±0.15	0.91[a]±0.01	3.72[a]±0.03	2.65[a]±0.13	2.67[e]±0.01	25.69[d]±0.10	146.97[d]±0.07
F5	67.70[a]±0.51	0.79[a]±0.11	3.78[a]±0.02	1.87[c]±0.03	3.49[d]±0.08	22.32[d]±0.05	139.75[e]±0.04
F6	66.67[a]±0.57	0.57[b]±0.04	2.26[c]±0.04	2.26[b]±0.08	4.30[bc]±0.32	23.90[b]±0.04	148.02[d]±0.09
F7	66.43[a]±0.70	0.46[b]±0.02	2.00[c]±0.04	2.45[a]±0.14	3.78[cd]±0.20	24.92[a]±0.07	146.44[d]±0.06

Equal letters in the same column indicate that there was no significant difference among the values (p>0.05). CB: cassava bagasse; LP: Lychee Pulp; PF: Palm fat. [1]F1 - 5% PF, 1% LP, 0% CB. F2 - 3% PF, 1% LP, 2% CB. F3 - 2% PF, 1% LP, 3% CB. F4 - 0% PF, 1% LP, 5% CB, F5 - 2% PF, 3% LP, 2% CB. F6 - 0% PF, 6% LP, 2% CB, F7 - 0% PF, 8% LP, 2% CB. [2]CT – total carbohydrates. [3]EV – energetic value.

According to Queiroz, Abreu and Oliveira (2012) and Cabral *et al.* (2019), the values found for proteins in fresh lychee pulp vary between 0.70 and 1.20 g/100g, which were similar than that determined in the lychee pulp characterized in this study (0.53 g/100g). The cassava bagasse also had a higher protein content than the lychee pulp ~2g/100g. The lipid content was similar in both raw materials.

The cassava bagasse showed the highest fiber content, due to the processing conditions of the by-product as starch extraction and drying. The bagasse also had the highest content of total carbohydrates, associated to residual starch that was not completely extracted in the industry, in addition to the fact that cassava is a rich carbohydrate root (94%) (MARTINEZ *et al.,* 2018). In the lychee pulp, total carbohydrates are mainly related to the presence of soluble sugars.

In relation to ice cream formulations, the highest moisture contents were found in the formulations F5, F6 and F7, due to the LP addition. For ashes contents, formulations F1 to F5 did not differ statistically (p> 0.05), which showed higher values when compared to formulations F6 (0.57 g/100g) and F7 (0.46 g/100g) (p>0.05). These results can be associated to higher level of LP addition (6% and 8%) in the formulations F6 and F7, which had high moisture content and may have diluted the mineral salts present in the samples. The ashes contents in low-fat ice creams found by McGhee, Jones and Park (2015) ranged from 1.54 to 1.58%, values higher than those observed in this study.

The content of protein ranged from 2.00 g/100g to 3.89 g/100g in the ice cream formulations. The results obtained from formulations F2 to F5 did not differ (p> 0.05), being higher than those observed in the control formulation (F1). The addition of higher levels of LP (6% and 8%), reduced the protein content in formulations F6 and F7, which is due to the low protein content of lychee pulp and its high moisture content. Silva *et al.* (2020), in the production of passion fruit ice cream processed with water-soluble rice extract, found protein content ranging from 0.60 to 0.76 g/100g, lower values than those achieved in this study.

Dietary fiber contents ranged from 0.18 to 2.65 g/100g, being the results similar (p>0.05) among F3, F4 and F7 formulations and higher than those found in the other formulations. This is due to the addition of high content of CB in the formulations F3 (3%) and F4 (5%), as well as the addition of high content of LP in F7 (8%). Thus, it was possible to increase the dietary fiber content from 5 to 14 times, when compared to the conventional formulation (F1). Boff *et al.* (2013) produced chocolate ice creams with addition of 0.74 and 1.10% of orange peel and found 0.70 and 1.03 g/100 g of dietary fibers, respectively, which are within the values observed in this study.

The incorporation of dietary fibers in traditional products is a challenge for food industries, and, it is interesting that the source of this nutrient had low cost and absence of off flavors (FIGUEROA and GENOVESE, 2019). Dietary fiber intake can provide many health benefits, reducing the risk of developing diabetes, hypertension, obesity, coronary heart disease and some types of gastrointestinal disorders (LI and KOMAREK, 2017).

F1 had the highest fat content, since this formulation has similar composition to a conventional product, produced with palm vegetable fat (5%). The formulations with substitution of vegetable fat by CB and LP, showed a reduction between 31 and 58% of the lipid content in relation to the control (F1), being the highest percentage obtained in the formulation F4, produced with the highest level of CB (5%) in replacement of vegetable fat (0%). The fat content of F4 sample (2.67 g/100g) was lower when compared to ice cream with the addition of 5% yacon extract (5.2 g/100g) (VACONDIO *et al.*, 2013) and lower than those found in reduced fat ice creams with different levels of inulin addition (8.27 to 15.20 g/100 g) (SAMAKRADHAMRONGTHAI *et al.*, 2021).

Formulation F4 could be characterized as a low-fat ice cream, according to Brazil (2012) - Complementary Nutritional Information (CNI) – that allow such declaration in labeling, when the fat value is below 3 g/100g in a 30 g serving. Ice cream formulations F2 to F7 can be classified as light (BRASIL, 2012), as they have a reduction of more than 25% in their lipid content compared to the conventional product (F1). These results are important due to the market demand for reduced-fat and low-energetic products, since its consumption can be associated to health benefits, such as, decreasing the risk of obesity and cardiovascular diseases (PINTOR; ESCALONA-BUENDÍA; TOTOSAUS, 2017; SAMAKRADHAMRONGTHAI *et al.*, 2021).

The values of total carbohydrates ranged from 22.54 to 27.88 g/100g, for the ice cream formulations produced, with the highest value found in formulation 7, as it contains the highest level of lychee pulp (8%) and it also contains CB (2%). Czaikoski *et al.* (2016) produced ice cream with 40% mango pulp and found 17.03 g/100g of carbohydrates, a lower value when compared to ice cream formulations produced in this study.

Regarding the energetic value, the formulations F1 and F7 had the highest values, due to the highest value for lipids and total carbohydrates, respectively. The formulations produced in this study showed higher energetic value, ranging from 134.97 to 160.83 kcal/100g, when compared to the ice cream produced with 40% mango pulp, 113.84 kcal/100g (CZAIKOSKI *et al.,*2016).

3.2 ANTIOXIDANT PROPERTIES OF ICE CREAM FORMULATIONS

Fruits have been considered as a good source of antioxidants compounds, that can help in the prevention of several chronic diseases in the human body (MUNIR *et al.*, 2018). The results obtained for the analysis of total phenolic compounds (TPC) and antioxidant activity (AA) in the ice cream formulations (Table 3) demonstrated that the addition of lychee pulp had higher effect than the incorporation of cassava bagasse in these parameters. This was expected, as the lychee pulp is known to have a high content of these antioxidant compounds, when compared to other commonly consumed fruits. The total phenolic content of 13 lychee varieties tested ranged from 101.51 to 259.18 mg EAG/100g (ZHANG *et al.,* 2013).

The higher level of CB addition (5%) in F4 allowed to obtain higher content of TPC and higher AA, in relation to samples F1, F2 and F3. When considered all formulations produced, the higher the content of LP added to ice cream, higher is the TPC content, and the highest AA was observed in the samples with 6 and 8% of LP addition (F6 and F7). Lima *et al.* (2017) produced a functional ice cream added with kinkan orange (*Fortunella margarita*) and achieved favorable results, due to the high levels of antioxidant compounds present in the fruit.

Table 3. Total phenolic compounds and antioxidant activity of ice cream formulations produced with the addition of cassava bagasse and lychee pulp in replacement of palm fat.

Formulations[1]	Total phenolic compounds (GAE/100g[2])	Antioxidant activity (μmol Trolox/100g)
F1	$13.19^{f}\pm0.93$	$8.19^{c}\pm0.50$
F2	$17.10^{e}\pm1.27$	$8.29^{c}\pm0.42$
F3	$20.35^{e}\pm1.21$	$8.39^{c}\pm0.58$
F4	$30.92^{d}\pm0.62$	$9.45^{b}\pm0.13$
F5	$74.90^{c}\pm4.35$	$9.59^{b}\pm0.72$
F6	$106.05^{b}\pm3.46$	$11.34^{a}\pm0.65$
F7	$134.52^{a}\pm2.86$	$12.52^{a}\pm0.73$

Equal letters in the same column indicate that there was no significant difference among the values ($p>0.05$). [1]CB: cassava bagasse; LP: Lychee Pulp; PF: Palm fat. F1 - 5% PF, 1% LP, 0% CB. F2 - 3% PF, 1% LP, 2% CB. F3 - 2% PF, 1% LP, 3% CB. F4 - 0% PF, 1% LP, 5% CB, F5 - 2% PF, 3% LP, 2% CB. F6 - 0% PF, 6% LP, 2% CB, F7 - 0% PF, 8% LP, 2% CB. [2]GAE – gallic acid equivalent.

3.3 MELTING RATE, OVERRUN AND COLOR PROPERTIES OF ICE CREAM FORMULATIONS

The results for melting rate, overrun and color properties obtained for the ice cream formulations produced are shown in Table 4. F1 had the highest overrun value ($p<0.05$), and a reduction of ~12% in the values was observed in the formulations F2, F3, F4 and F5, and of ~20% in F6 and F7. According to Aime *et al.* (2001), fat substitutes from carbohydrates are associated with increased viscosity in ice cream, which consequently reduces the incorporation of air. Santos and Silva (2012) studied fat and sugar substitutes in ice cream, and they also observed a reduction in overrun values when compared to the control.

The overrun values found in this study ranged from 27.30 to 34.30%, which are in accordance with the values reported by Goff and Hartel (2013), in which the volume of air incorporated can vary from at least 10% to 15%, up to more than 50%. According to CBR No. 266, of September 22, 2005, ice creams can contain a maximum of 110% of air incorporated in the product, with no minimum value required (BRASIL, 2005), indicating that the formulations produced showed results within the legal limits.

Table 4. Overrun (%), melting rate (g/min) and color properties of ice cream formulations produced with the addition of cassava bagasse and lychee pulp in replacement of palm fat.

Formulations[1]	Overrun	Melting rate	L*	a*	b*
F1	$34.32^{a}\pm0.59$	$0.23^{c}\pm0.02$	$94.31^{a}\pm1.38$	$-3.66^{d}\pm0.64$	$9.07^{c}\pm0.16$
F2	$30.31^{b}\pm0.62$	$0.26^{c}\pm0.01$	$90.54^{b}\pm0.48$	$-2.70^{c}\pm0.12$	$9.32^{bc}\pm0.15$
F3	$30.35^{b}\pm0.58$	$0.15^{e}\pm0.005$	$90.98^{b}\pm0.46$	$-2.96^{cd}\pm0.06$	$10.66^{a}\pm0.43$
F4	$30.29^{b}\pm0.61$	$0.09^{f}\pm0.01$	$85.17^{c}\pm0.46$	$-1.36^{a}\pm0.20$	$10.62^{a}\pm0.26$
F5	$30.27^{b}\pm0.55$	$0.19^{d}\pm0.005$	$90.24^{b}\pm1.08$	$-1.74^{ab}\pm0.12$	$9.88^{b}\pm0.62$
F6	$27.28^{c}\pm0.66$	$0.34^{b}\pm0.01$	$89.99^{b}\pm0.87$	$-2.84^{c}\pm0.15$	$9.71^{bc}\pm1.54$
F7	$27.35^{c}\pm0.50$	$0.38^{a}\pm0.005$	$89.13^{b}\pm0.42$	$-2.47^{bc}\pm0.09$	$9.88^{b}\pm0.24$

Equal letters in the same column indicate that there was no significant difference among the values ($p>0.05$). [1]CB: cassava bagasse; LP: Lychee Pulp; PF: Palm fat. F1 - 5% PF, 1% LP, 0% CB. F2 - 3% PF, 1% LP, 2% CB. F3 - 2% PF, 1% LP, 3% CB. F4 - 0% PF, 1% LP, 5% CB, F5 - 2% PF, 3% LP, 2% CB. F6 - 0% PF, 6% LP, 2% CB, F7 - 0% PF, 8% LP, 2% CB.

Melting results ranged from 0.09 (F4) to 0.38 g/min (F7), only F1 and F2 did not differing from each other ($p>0.05$). The reduction in melting rate in formulations F3 and F4 is related to the higher addition of CB, 3% and 5%, respectively, due to the ability of the fibers to absorb water, increasing viscosity, reducing molecular mobility and the time for the water present in the middle flows from the inside to the outside (SOUKOULISET; LEBESI; TZIA, 2009).

The opposite tendency between the values of overrun and melting rate was also observed by Samakradhamrongthai *et al.* (2021) in ice cream formulations with inulin addition. According to these authors it can be attributed to the fact that the melting rate was lower when more air (higher overrun) is incorporated into the ice cream, moreover, the higher viscosities can cause the formation of smaller air cells and improve air incorporation.

Color is one of the most important attributes, which directly influences consumers' purchasing decisions (DUTCOSKY, 2007). For luminosity (L*), the highest value was found in F1 (94.31), and the addition of CB and LP in formulations F2, F3, F5, F6 and F7 caused a reduction in this value (89.13 – 90.54), thus, there was a slight darkening of these formulations, whose values did not differ from each other ($p > 0.05$). F4 with the highest addition of CB (5%), had the lowest L* value ($p < 0.05$) among the formulations produced.

Negative values of a* and positive values of b* indicate greenish and yellowish color, respectively. The addition of CB and LP increased a* values (-2.96 to -1.36) when compared to the control (-3.66), being the highest value found in F4. F3 and F4 formulations containing higher CB levels, showed higher values of b* ($p > 0.05$), while the other formulations showed similar values. Similarly, Crizel *et al.* (2014) and Akalin *et al.* (2018) reported an increase in the b* values and decrease of L* values, with the addition of orange fiber and apple fiber to ice cream, becoming the products less bright and more yellow than those without fiber addition.

3.3 MICROBIOLOGICAL AND SENSORY PARAMETERS OF ICE CREAM FORMULATIONS

According to the microbiological analyzes conducted, the results obtained for all ice cream formulations were: < 3 NMP/mL for Coliforms at 45°C, < 3 CFU/mL for *Staphylococcus coagulase* positive and absence for *Salmonella* sp/25g. These results were satisfactory, as the formulations were within the standards established by Brazilian legislation, according to CBR No. 12, of January 2, 2001 (BRASIL, 2001). Moreover, the data indicate that all formulations were produced following the protocols of good manufacturing and storage practices.

Table 5 shows the results obtained in the sensory analysis of the ice cream formulations. The values ranged from 6.23 to 7.85 for overall acceptance, aroma, color, flavor and texture, being within the range of 6 "I liked it slightly" and 8 "I liked it a lot".

Table 5. Sensorial parameters of ice cream formulations produced with the addition of cassava bagasse and lychee pulp in replacement of palm fat.

Formulations[1]	OA[2]	Aroma	Color	Flavor	Texture	PI[3]
F1	$6.66^{abc} \pm 1.56$	$6.46^{bc} \pm 1.59$	$7.25^{b} \pm 1.34$	$6.62^{bc} \pm 1.54$	$6.86^{bcd} \pm 1.35$	$3.52^{ab} \pm 1.17$
F2	$7.23^{a} \pm 1.33$	$6.92^{ab} \pm 1.47$	$7.82^{a} \pm 1.02$	$7.26^{a} \pm 1.47$	$7.61^{a} \pm 1.21$	$3.76^{a} \pm 0.92$
F3	$6.98^{abc} \pm 1.38$	$6.72^{abc} \pm 1.46$	$7.85^{a} \pm 1.01$	$6.95^{abc} \pm 1.55$	$7.36^{ab} \pm 1.69$	$3.64^{a} \pm 1.06$
F4	$7.09^{ab} \pm 1.43$	$6.93^{ab} \pm 1.47$	$7.83^{a} \pm 1.02$	$6.86^{abc} \pm 1.54$	$7.04^{abc} \pm 1.75$	$3.39^{ab} \pm 1.11$
F5	$7.11^{ab} \pm 1.40$	$7.00^{a} \pm 1.46$	$7.82^{a} \pm 1.11$	$7.22^{ab} \pm 1.39$	$7.59^{a} \pm 1.33$	$3.74^{a} \pm 1.00$
F6	$6.61^{abc} \pm 1.63$	$6.50^{abc} \pm 1.52$	$7.19^{b} \pm 1.42$	$6.55^{c} \pm 1.53$	$6.59^{cd} \pm 1.59$	$3.42^{ab} \pm 1.04$
F7	$6.42^{bc} \pm 1.59$	$6.23^{c} \pm 1.55$	$6.98^{b} \pm 1.54$	$6.41^{c} \pm 1.60$	6.42d ± 1.62	$3.19^{b} \pm 0.98$

Equal letters in the same column indicate that there was no significant difference among the values ($p > 0.05$). [1]CB: cassava bagasse; LP: Lychee Pulp; PF: Palm fat. F1 - 5% PF, 1% LP, 0% CB. F2 - 3% PF, 1% LP, 2% CB. F3 - 2% PF, 1% LP, 3% CB. F4 - 0% PF, 1% LP, 5% CB, F5 - 2% PF, 3% LP, 2% CB. F6 - 0% PF, 6% LP, 2% CB, F7 - 0% PF, 8% LP, 2% CB.[2]OA: overall acceptance. [3]PI: purchase intention.

Eiki *et al.* (2015) produced ice cream using soy milk and with addition of chia or psyllium (*Plantago ovata*) and they noted similar results to those found in this work, indicating a good acceptance of the product. For overall acceptance and aroma attributes, formulations F1 to F6 showed the highest averages, not differing from each other ($p>0.05$). F7, containing the highest LP level (8%), had the lowest average ($p<0.05$), but without differences in relation to the formulations F3 and F6.

Regarding color, flavor and texture it was noted that formulations F2, F3, F4 and F5 showed the highest averages. Thus, it is possible to infer that formulations F1 (control) and those containing 2% of CB and the addition of 6% of LP (F6) or 8% of LP (F7) caused a decrease in acceptance in relation to these parameters, the latter two being attributes were also negatively affected by the addition of 5% CB (F4).

For the purchase intention (Table 5) it was noted that formulations 1 to 6 did not differ from each other ($p> 0.05$), presenting the highest averages, while F7 showed lower values than those found in F2, F3 and F5 ($p <0.05$). The values obtained in this evaluation ranged from 3.19 to 3.76, that corresponds to maybe bought/maybe not bought (3) and possibly would buy (4). Similar results were reported by Czaikoski *et al.* (2016), in ice creams with mango pulp addition, with values for purchase intention ranging from 3.10 to 4.03.

3.4 PRINCIPAL COMPONENT ANALYSIS

Principal Component Analysis (PCA), showed in Figure 1, was used to assess the importance of the variables studied in the discrimination of ice cream formulations.

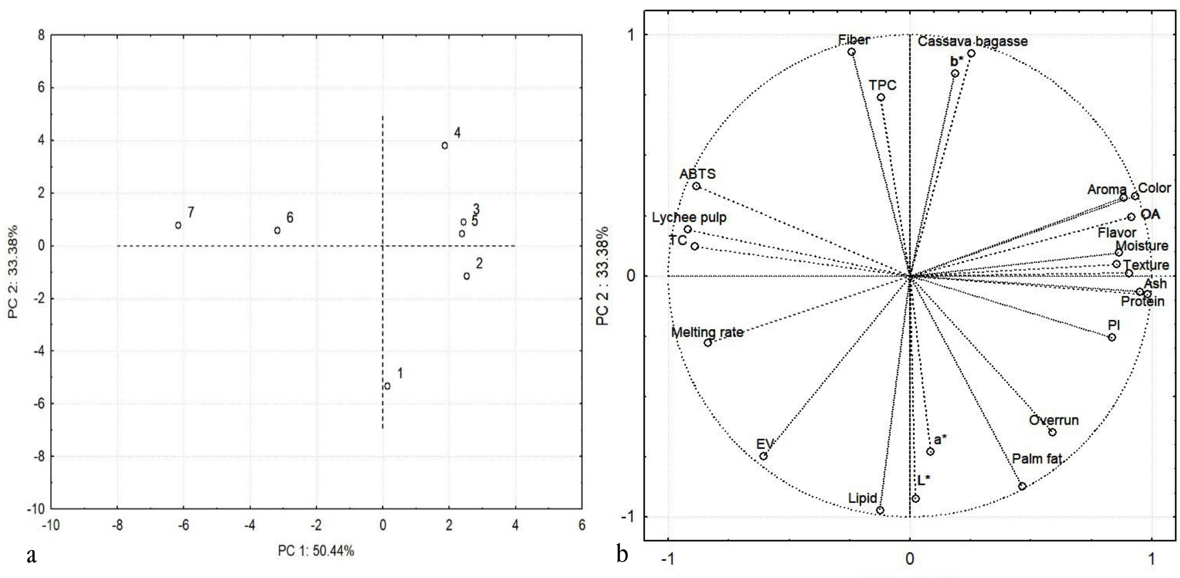

Figure 1. Principal component analysis: ice cream formulations (a) and characterization parameters (b).
PC: Principal component. TPC: total phenolic compounds. EV: energetic value. TC: total carbohydrates. PI: purchase intention. OA: overall acceptance.

The two principal components (PC) accounted for 84% of data, with a 50 and 34% for the first and second component, respectively. The ice cream formulations that were similar in one or more characteristics were close together (Figure 1a).

PC1 was positively correlated with proteins, ashes and moisture contents, overrun and sensorial parameters, and this quadrant also included the formulations F2, F3, F4 and F5. Otherwise, the negative quadrant of PC1 distinguished F6 and F7 from the other formulations, and it was associated with lychee proportion, melting rate, total carbohydrates, energetic value, and antioxidant activity. It also can be observed that higher addition (>3%) of lychee pulp (F6 and F7) did not contribute to sensory acceptance.

The negative quadrant of PC2 separated F1 (control) from the other formulations, and it was correlated with the contents of palm fat and lipids, demonstrating its low nutritional value. Although F1 was correlated with instrumental color (L*, a*), this parameter was not associated with sensory acceptance regarding color. PC2 was positively correlated with cassava bagasse, TPC and dietary fiber contents, and these parameters were more associated to the F4 characteristics. It can be inferred that besides the nutritional enrichment, F4 reached a satisfactory sensory acceptability (PC1 positive quadrant), being the most recommended formulation among those produced in this work.

4 CONCLUSION

The use of cassava bagasse and lychee pulp in replacement to vegetable fat contributed to increase the dietary fiber content and to reduce the lipid values, in the ice cream formulations produced. The antioxidant properties were improved with LP addition, while the inclusion of CB contributed to high overrun and low melting rate. PCA distinguished F1 (control) from the other formulations, especially due to its high fat content. Although color parameters were changed with CB and LP addition to the formulations, the products showed adequate sensory acceptance, with emphasis on the formulations F2, F3, F4 and F5. Therefore, the combination of CB and LP, specially in the proportion of 1% and 5% (F4), is an interesting alternative to improve the nutritional value of ice cream formulations, with positive results regarding quality and sensory parameters.

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