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Development and characterization of green banana-based fondant icing

Desenvolvimento e caracterização de cobertura para bolo do tipo “Pasta americana” à base de banana verde

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ABSTRACT

The insertion of functional foods in the confectionery industry is a growing reality, aiming to meet a growing demand for products that are visually attractive and at the same time healthy. The present study aimed to develop and characterize the physical, physicochemical, microbiological, and sensory properties of fondant icings based on green banana biomass and flour. Two formulations were developed (NFBI - Neutral Flavor Biomass-based Icing, and CFBI - Chocolate Flavor Biomass-based Icing), which were compared with the commercial fondant icings (NFCI – Neutral Flavor Commercial Icing, and CFCI – Chocolate Flavor Commercial Icing). The fondant icings were evaluated for centesimal composition, caloric value, physical, physicochemical (resistant starch, titratable acidity, water activity, texture, and color), and microbiological characteristics, as well as sensory acceptance. The icings based on green banana biomass and flour showed higher levels of ash, fiber, resistant starch, and protein, as well as lower total caloric value, and thus, were healthier. These icings were also softer and had more intense color compared to commercial ones, as well as good sensory acceptance, especially the one with chocolate flavor, which had greater than 72% approval. Microbiological analyses indicated that the icings could be stored under refrigeration (<4 ºC) for 30 days. Given the nutritional quality and health benefits, the icings prepared with green banana biomass and flour proved to be promising and could serve a niche market represented by people who seek a healthier diet or need to control their sugar consumption, such as diabetics.

Index terms: Confectionery; resistant starch; functional food.

RESUMO

A inserção dos alimentos funcionais na indústria da confeitaria é uma realidade em ascensão, visando atender uma crescente demanda por produtos, visualmente, atraentes e ao mesmo tempo saudáveis. O presente estudo teve como objetivo desenvolver e caracterizar as propriedades físicas, físico-químicas, microbiológicas e sensoriais de coberturas de cobertura à base de biomassa de banana verde e farinha. Duas formulações foram desenvolvidas (CBBN = Cobertura para Bolo com Biomassa Sabor Neutro, CBBC = Cobertura para Bolo com Biomassa Sabor Chocolate), as quais foram comparadas com as coberturas de fondant comerciais (CBCN = Cobertura para Bolo Comercial Sabor Neutro, CBCC = Cobertura para Bolo Comercial Sabor Chocolate). As coberturas de fondant foram avaliadas quanto à composição centesimal, valor calórico, características físicas, físico-químicas (amido resistente, acidez titulável, atividade de água, textura e cor) e microbiológica, bem como aceitação sensorial. As coberturas à base de biomassa e farinha de banana verde apresentaram maiores teores de cinzas, fibra, amido resistente e proteína, além de menor valor calórico total e, portanto, foram mais saudáveis. Essas coberturas também foram mais macias e apresentaram cor mais intensa em relação às comerciais, além de boa aceitação sensorial, principalmente a com sabor chocolate, que teve aprovação superior a 72%. As análises microbiológicas indicaram que as coberturas podem ser armazenadas sob refrigeração (<4 ºC) por 30 dias. Pela qualidade nutricional e pelos benefícios à saúde, as coberturas preparadas com biomassa de banana verde e farinha mostraram-se promissoras e poderiam atender a um nicho de mercado representado por pessoas que buscam uma alimentação mais saudável ou precisam controlar o consumo de açúcar, como os diabéticos.

Termos para indexação: Confeitaria; amido resistente; alimento funcional.

INTRODUCTION

The confectionery industry has become increasingly sophisticated over the years, seeking to insert functional ingredients in traditional formulations. Such components have been used in the production of cakes, biscuits, candies, and edible packaging and toppings, which make the cakes more attractive to the consumer, thus playing a key role in their sensory acceptance. (Costa et al., 2017; Korkach; Krusir, 2017; Zumbe; Lee; Storey, 2001).

In Brazil, data from the Technological Institute of Bakery and Confectionery (*Instituto Tecnológico de Panificação e Confeitaria*-ITPC) indicated that, in 2019, the bakery and confectionery sector grew around 2.65%, which would be equivalent to a profit of R$ 95.08 billion/year (Associação Brasileira da Indústria de Panificação e Confeitaria - ABIP, 2019).

Historically, confectionery products predominantly included ingredients containing sugars such as sucrose, dextrose, fructose, or lactose. However, changes have occurred in the confectionery market, influenced by the increased consumer demand for healthy foods, especially with low sugar content or no sugar, lower caloric value, high nutritional value, and with sensory characteristics similar or superior to those of traditional products available in the market (Belščak-Cvitanović et al., 2015).

The inclusion of functional foods in the confectionery business represents an alternative since they include foods or beverages that, when consumed daily, have the ability to provide beneficial effects, in addition to the basic nutritional ones, owing to the presence of healthy ingredients (Herrera-Cazares et al., 2017; Maxim et al., 2019).

Among the ingredients rich in functional compounds, green banana stands out for containing phenolic compounds, such as flavonoids and resistant starch (Campuzano; Rosell; Cornejo, 2018; Saravanan; Aradhya, 2011). Resistant starch is defined as the part of starch that resists digestion when passing through the gastrointestinal tract, thus behaving as dietary fiber. Therefore, resistant starch is fermented in the large intestine, mainly by bifidobacteria, making it a prebiotic food (Pereira, 2007; Segundo et al., 2017; Silveira et al., 2017).

Studies have indicated that the intake of resistant starch positively influences the intestinal microbiota and promotes protection against colon cancer, diarrhea, and intestinal disorders, besides regulating blood glucose and cholesterol levels. Among the prebiotic properties associated with the ingestion of resistant starch, studies have highlighted an increase in the removal of bowel and stimulation of the production of short-chain fatty acids, such as butyrates, which promote good colon health. Additionally, regular consumption of resistant starch contributes to the production of progressive diffuse energy (EDP), which is the energy of food released over time due to slow digestion, thus prolonging the feeling of satiety (Pereira, 2007; Yuan et al., 2017).

Brazil is one of the world's largest producers of bananas and, in 2019, produced approximately 7 million tons of this fruit (Food and Agriculture Organization of the United Nations Statistics - FAOSTAT, 2020). However, it is also one of the countries that waste bananas the most (Empresa Brasileira de Pesquisa Agropecuária - EMBRAPA, 2020). It is estimated that losses can reach up to 40%, mainly due to inadequate harvesting and post-harvesting techniques and precarious transport and storage systems. The use of green bananas, in the form of either biomass or flour, is an alternative to reduce wastage (Nobre et al., 2018; Riquette et al., 2019).

The neutral flavor of green banana biomass and flour allows its use in numerous preparations without interfering with the final taste of the products such as bread (Viana et al., 2018), pasta, snacks (Castelo-Branco et al., 2017), cakes, and *brigadeiro* (Marques et al., 2017), among others.

In general, the development of a new food product requires, besides innovation, the selection of raw materials with specific properties to develop the intended final product, sensory analysis to determine the consumers' opinions about their acceptance or preference relative to existing products in the market, and microbiological investigation to prove that the new product is safe (Halagarda; Suwała, 2018).

Hence, this study aimed to develop and characterize the physical, chemical, microbiological, and sensory properties of two types of fondant based on green banana biomass and flour.

MATERIAL AND METHODS

Location

The experiments were conducted in the Laboratories of Research and Analysis of Food and Contaminants and Bromatological Analyses of the Faculty of Pharmacy, Federal University of Bahia, and in the Laboratory of Food Science and Technology of Embrapa Cassava and Fruits.

Production of green banana flour

The banana variety used was BRS SCS Belluna, provided by Embrapa Cassava and Fruits, located in the city of Cruz das Almas/Bahia, Brazil.

The green banana flour (GBF) was produced following the procedure described by (Reis et al., 2019). Briefly, bananas in stage 1 of maturation (completely green exterior) were washed with drinking water, sanitized in a hypochlorite solution (10 ml of hypochlorite in 1 L of water) for 15 min, peeled and cut into 4 to 5 mm slices, and immersed in an aqueous citric acid solution (100 mg L^{-1}) and ascorbic acid (300 mg L^{-1}) for 10 to 15 min to prevent browning of the pulp. Then, the fruits were dried in a convection dryer at 50 °C and an air velocity of 1.5 m s^{-1} until the moisture content was between 5 and 10% of the wet weight. The dehydrated slices were ground using a knife mill with 30 mesh sieves to obtain the green banana flour, which was stored at room temperature in vacuum-sealed polyethylene bags until further use.

Preparation of green banana biomass

Bananas in stage 1 of maturation (completely green exterior) were washed with water, sanitized in a hypochlorite solution (10 mL of hypochlorite in 1 L of water) for 15 min, rinsed in running water, and cooked in a pressure cooker for 5 min after boiling in water at a ratio of 1:1.3 (w/v). Then, the bananas were peeled while still hot and crushed in a blender for 4 min without adding water until completely homogenized; the homogenized substance was the green banana biomass, which was used immediately.

Preparation of icings based on green banana biomass and flour

Icings with green banana biomass and flour were developed after considering the composition of commercial fondants of neutral and chocolate flavors, which were used as the control treatments (Table 1). The components of the commercial formulations were replaced to obtain formulations based on green banana biomass and flour, with texture and applicability like those of commercial icings.

The manufacturing process is not described here, as the icing developed is in the process of being patented by the National Institute of Intellectual Property (INPI), which can be verified through the process number: BR 10 2019 018826 0.

Table 1: Formulations of the commercial and green banana biomass and flour-based icings.

Ingredients	Commercial icings (Controls)		Developed icings	
	NFCI (%)	CFCI (%)	NFBI (%)	CFBI (%)
Citric acid	-	-	0.31	-
Impalpable sugar	73.28	48.89	-	-
Water	9.10	7.25	10.19	9.14
Green banana biomass	-	-	30.86	27.70
100% alkalinized cocoa powder	-	8.13	-	10.25
Carboxymethylcellulose (CMC)	0.18	0.44	0.62	0.55
85% chocolate bar	-	10.99	-	13.85
Inorganic dye	-	-	3.70	-
White vanilla essence	-	-	7.41	-
Green banana flour	-	-	18.52	10.80
Flavorless and colorless powdered gelatine	0.88	1.32	1.85	1.66
Xanthan gum	-	-	0.93	-
Glucose	7.33	-	-	-
Vegetal fat	9.10	-	2.78	-
Condensed milk	-	21.98	-	-
Xylitol	-	-	22.84	26.32

NFCI = Neutral Flavor Commercial Icing, CFCI = Chocolate Flavor Commercial Icing, NFBI = Neutral Flavor Biomass-based Icing, CFBI = Chocolate Flavor Biomass-based Icing. (-) = Does not contain.

Physical and physicochemical evaluations of the icings

The analyses were conducted with 100 g of the products, on the day of manufacture, for the developed icings and on the day the packages were opened for the commercial icings.

The levels of moisture, ash, lipids, dietary fibers, and titratable acidity were determined according to the methodology described by (Instituto Adolfo Lutz, 2008) and the protein content according to Brasil (Brasil, 2018).

The carbohydrate fraction was calculated by the difference between 100 and the sum of the values (in percentage) of moisture, ash, lipids, and crude protein (Instituto Adolfo Lutz, 2008). The energy values were determined by summing the energy value of carbohydrates, proteins, and lipids, using Atwater conversion factors: 4 kcal g^{-1} carbohydrates, 4 kcal g^{-1} proteins, and 9 kcal g^{-1} lipids, according to Brasil (Brasil, 2008).

Resistant starch content was determined according to the methodology described in Goñi et al. (1996).

Water activity was measured by the direct method at 25 °C using the Aqualab Lite analyzer (Decagon, Pullman, USA).

The texture profile was instrumentally determined by the double compression test of the samples with constant weight within the plastic packages, using a 6-mm-diameter probe in a TA-XTPlus texture analyzer (Stable Micro Systems, Haslemere, United Kingdom). The primary attributes comprising hardness, adhesiveness, and elasticity were analyzed using the following parameters: pre-test: 2 mm s^{-1}; quick test: 2 mm s^{-1}; post-test: 2 mm s^{-1}; force: 5 g; distance: 10 mm; time: 5 s.

The color was evaluated using the Minolta® CR5 colorimeter (Konica Minolta, Osaka, Japan) by determining the values of the parameters L*, a*, b*, and C*, respectively indicating lightness, which ranged from 0 to 100 (black/white), red/green intensity (+/-), yellow/blue intensity (+/-), and color saturation. The device was calibrated using a white ceramic plate with the standard illuminant D65.

Microbiological analyses

Microbiological analyses were performed on the day the product was manufactured and after 15 and 30 days of refrigeration. To comply with the requirements of the Collegiate Board Resolution (*Resolução da Diretoria Colegiada*-RDC 12) (Brasil, 2019), the presence of coliforms (at 45 °C), *Salmonella*, and coagulase-positive staphylococci count were evaluated. Additionally, the numbers of mesophilic aerobic bacteria, as well as molds and yeasts, were counted. The methodology applied for microbiological analyses was as described by (American Public Health Association - APHA, 2001).

Sensory evaluation

The study was approved by the Research Ethics Committee of the Maria Milza College, located in Governador Mangabeira – BA, Brazil (authorization registered under the number CAAE: 17106213.1.0000.0053). Sensory tests were performed with 98 untrained tasters of both genders and older than 15 years after they had read and accepted the Free and Informed Consent Form.

Sensory analysis was performed for pairs of samples by comparing the neutral flavor commercial icing (NFCI) to the neutral flavor biomass-based icing (NFBI) and the chocolate flavor commercial icing (CFCI) to the chocolate flavor biomass-based icing (CFBI).

The tasters were provided the pairs of samples randomly, and four samples were provided to each participant. The icings were served to the participants at isolated booths on mini cakes (vanilla flavor), placed on plastic plates that were encoded with random three-digit numbers.

The attributes of overall acceptance, appearance, aroma, flavor, and texture of the icings were evaluated by a structured 9-point scale, ranging from 1: “disliked extremely” to 9: “liked extremely”.

Experimental design and statistical analysis

The experimental design was completely randomized with three experimental replicates. Data on centesimal composition, physical, physicochemical, microbiological, and sensory characteristics were analyzed by performing analysis of variance, and the means were compared by the Tukey test, using the Sisvar program. Differences among/between treatments and groups were considered to be statistically significant at $p < 0.05$.

RESULTS AND DISCUSSION

Centesimal composition and physicochemical characteristics of the icings

There was a significant difference ($p < 0.05$) among the formulations for all the variables evaluated (Table 2).

Icings based on green banana biomass and flour had higher moisture than commercial icings (Table 2). This was due to the presence of green banana biomass in the formulations and the nature of the fibers present in green banana flour, predominantly soluble fibers, which retained water in the food products. Additionally, the absence of sugar in the developed formulations might have also contributed to higher moisture (Ng; Ismail; Ishak, 2020).

The highest ash contents were found in the icings based on the green banana biomass and flour (Table 2), indicating that the addition of these two ingredients promoted the increase in the mineral content of the product, considering the two variables were correlated. According to Carmo (Ng; Ismail; Ishak, 2020), banana in the green stage has a higher concentration of mineral salts, which explains the high values of ash observed in the icings. Minerals are important for the metabolic and physicochemical processes in the body, such as the maintenance of pH and osmotic pressure, muscle contraction, and gas transport. They also act as important components of enzymes and hormones essential for bone formation and vitamin synthesis (Mergedus et al., 2015).

Proteins are crucial for various functions in the body, as they provide materials for the construction and maintenance of all organs and tissues and participate in the formation of hormones, enzymes, and antibodies (Farfan, 1990). The highest crude protein contents were found in chocolate flavor icings (CFBI and CFCI) (Table 2). This was due to the presence of bitter chocolate in the products. Previous studies have shown that, on average, bitter chocolate contains 9.96% of crude protein (Torres-Moreno et al., 2015). When the two neutral flavor icings were compared, it was observed that the icing based on green banana biomass and flour (NFBI) had 13 times more protein than the commercial icing (NFCI).

The Brazilian Legislation considers a food product as a protein source when it has at least 6% of protein for every 100 g or ml of the product (Brasil, 2012), and therefore, the two chocolate flavor icings (CFBI and CFCI) could be considered as sources of protein, provided 100 g of the product is consumed.

The highest lipid contents were found in the chocolate icings (Table 2), as the chocolate contains 42.62% of lipids on average (Torres-Moreno et al., 2015). Furthermore, the higher lipid fraction observed in the CFCI was due to the presence of condensed milk, which was produced from whole milk and had 8% lipids on average (Renhe et al., 2018).

Icings with the addition of green banana biomass and flour, especially the neutral flavor icing (NFBI) (Table 2), showed the highest dietary fiber content and could be considered as a source of fiber according to the Brazilian Legislation (Brasil, 2012).

Dietary fiber aids in the proper functioning of the intestine, besides reducing the risk of cardiovascular diseases, diabetes, hypertension, obesity, and some gastrointestinal pathologies; the intake of dietary fiber recommended by the Ministry of Health for adults is 25 g/day (Brasil, 2008).

Table 2: The means and standard deviations of the centesimal composition and physicochemical characteristics of the four icings.

Evaluation	Commercial icing (Control)		Green banana-based icing	
	NFCI	CFCI	NFBI	CFBI
Moisture (%)	6.11 ± 0.36 d	16.48 ± 0.21c	40.31 ± 0.51a	32. 21 ± 0.16 b
Ash (g)	0.44 ± 0.01 d	1.47 ± 0.10 c	1.81 ± 0.03 b	1.99 ± 0.05 a
Crude protein (g)	0.29 ± 0.22 c	7.37 ± 0.95 a	3.81 ± 0.77 b	8.35 ± 0.73 a
Lipids (g)	2.19 ± 0.06 d	53.00 ± 0.47 a	8.30 ± 0.37 c	28.69 ± 0.97 b
Dietary fibre (g)	1.49 ± 0.07 c	2.63 ± 0.27 b	3.98 ± 0.08 a	2.50 ± 0.15 b
Carbohydrate fraction (g)	89.35 ± 0.39 a	19.06 ± 1.62 d	42.39 ± 0.52 b	25.85 ± 0.59 c
Resistant starch (g)	0.68 ± 0.02 c	0.45 ± 0.03 d	6.53 ± 0.04 a	6.20 ± 0.03 b
Caloric value (kcal)	378.21 ± 0.56 c	582. 69 ± 1.17 a	257.13 ± 1.62 d	398.36 ± 1.73 b
Titratable acidity (%)	4.07 ± 0.13 c	5.17 ± 0.49 b	8.57 ± 0.39 a	9.03 ± 0.34 a
Water activity (%)	0.57 ± 0.01 c	0.63 ± 0.01 b	0.67 ± 0.01 a	0.64 ± 0.01 b

NFCI = Neutral Flavor Commercial Icing, CFCI = Chocolate Flavor Commercial Icing, NFBI = Neutral Flavor Biomass-based Icing, CFBI = Chocolate Flavor Biomass-based Icing. Values correspond to the mean ±standard deviation of three repetitions. Different lowercase letters, in the same row, indicate significant difference by Tukey test ($p<0.05$).

The carbohydrate fraction of a food product corresponds to the carbohydrates present in its composition, and the NFCI samples had the highest mean carbohydrate fraction (Table 2). Carbohydrates are essential for supplying the energy necessary for metabolic processes; however, the carbohydrate fraction present in NFCI was primarily from white sugar, which is considered to be a simple carbohydrate with a high glycemic index due to its rapid digestion, absorption, and lack of nutrients. The neutral flavor icing, with the addition of green banana biomass and flour (NFBI), showed a reduction of approximately 53% carbohydrates when compared to the commercial icing (NFCI), and hence, had lesser calories and was healthier.

The highest levels of resistant starch were found in the icings with green banana biomass and flour (Table 2). These results agreed with previous information reported in the literature that green banana is rich in resistant starch (Wuang et al., 2014). Thus, resistant starch can enrich icings developed using functional ingredients. According to the literature, there are four types of resistant starch, and green bananas contain type 2 resistant starch, which acts as prebiotics, stimulating the growth of beneficial bacteria in the intestine, which increases the production of short-chain fatty acids that, in turn, improves the immunological function and modulation of the intestinal microbiota (Wuang et al., 2014).

The icings prepared with green banana biomass and flour had lower caloric values than their respective controls (Table 2). This result was similar to that found by Santos (Oliveira et al., 2015), who developed a bread with green banana biomass and also obtained a formulation with a lower caloric value than the commercial wholegrain bread. When comparing the four icings, NFBI was the one with the lowest caloric value, while CFCI had the highest value (Table 2). This was due to the different composition of the products, especially due to the presence of additional lipids and carbohydrates in the CFCI treatment, which contributed 9 and 4 kcal per gram, respectively.

There was no significant difference between NFBI and CFBI for titratable acidity, and both had higher values when compared to commercial icings (Table 2). This was due to the presence of green bananas in the formulations since green fruits contain higher levels of organic acids than ripe fruits (Maduwanthi; Marapana, 2019), which imparted higher acidity in the icings based on green banana biomass and flour.

It was found that the mean values of water activity of chocolate flavor icings were statistically similar. Only NFCI showed low water activity (< 0.60), and therefore, was considered to be a product with a low risk of microbial growth (Reolon et al., 2012). Hence, the icings based on green banana biomass and flour could be considered perishable foods and should be refrigerated to prevent microbial development.

The instrumental texture is the response of a product to the application of a force, i.e., it represents the objective evaluation of the deformation and can be presented using different parameters, such as hardness, adhesiveness, and elasticity (Tang et al., 2017).

Regarding the texture profiles, there was a significant difference in the hardness and adhesiveness parameters among the four icings (Table 3). Hardness is the force required to compress a material, while adhesiveness is the effort required to remove the material from a surface (Szczesniak, 2002). For hardness, it was found that NFBI had the lowest value, thus producing the softest icing, while the two chocolate flavor icings (CFCI and CFBI) showed the highest values. Regarding adhesiveness, NFCI had a lower value, indicating that it required lesser effort to be removed from a surface and was less sticky. Icings based on green banana biomass and flour (CFBI and NFBI) had the highest values of adhesiveness. This characteristic could cause the icing to firmly adhere to the consumer’s mouth, which would be undesirable. However, the values obtained in the study were favorable, as they allowed an adequate adherence of the icing only to the cake.

There was no significant difference in elasticity among the four icings (Table 3), indicating that all of them had a similar ability to return to their original form after being subjected to a deforming force (Szczesniak, 2002). Obtaining icings with characteristics similar to those of commercial ones is important when the goal is to replace ingredients without compromising their effectiveness.

There was a significant difference in the color among the icings for all parameters evaluated (Table 3). NFBI showed a darker color than NFCI, which was due to the presence of green banana biomass and flour. Andrade et al. (2018), while developing bread with green banana flour, also identified a reduction in the lightness of the final product compared to that in the bread without green banana flour. The icings containing chocolate (CFBI and CFCI) had the lowest values of lightness since chocolate imparts a dark brown color to the products.

For the parameter a*, the negative value found in the NFCI samples indicated distancing from the red color, while the higher values observed in the chocolate flavor icings indicated a color closer to red. The highest values of the parameter b* were found in the NFBI samples, which indicated that their color tended to yellow, influenced by the color of green banana biomass and flour. The saturation or chromaticity (C) of the color represented its vividness or paleness. A lesser grey color implied greater saturation, and hence, greater purity of the color. The icings prepared with green banana biomass and flour (CFBI and NFBI) showed higher saturation, i.e., a more vivid, and consequently, purer color.

Microbiological analysis

The results of microbiological analyses of developed and commercial icings are presented in Table 4.

The microbiological analyses of the four icings followed the microbiological standards recommended by the current legislation (Brasil, 2019).

Although the legislation did not include the analysis of mesophilic aerobic bacteria as mandatory, the number of these microorganisms found in foods represents one of the most used microbiological quality indicators, indicating whether cleaning, disinfection, and temperature control during manufacturing and storage were performed appropriately (Fazzioni; Gelinski; Roza-Gomes, 2013).

From the results of the microbiological analysis (Table 4), it was found that the number of colony-forming units per gram (CFU/g) of mesophilic aerobic bacteria reduced over time, while the number of molds and yeasts remained constant in all the treatments analyzed, except in the NFBI treatment. The coagulase-positive *Staphylococcus* was present in all the treatments for all three replicates analyzed.

Molds and yeasts are often identified as food contaminants since they multiply easily, as they are more tolerant to extreme factors that limit bacterial development, such as low values of water activity (aw), pH, and temperature. Fungi grow slower than bacteria in foods with low acidity and high water activity, whereas they grow faster in foods that are acidic and have low water activity, causing deterioration and contamination (Oliveira; Lyra; Esteves, 2013).

Thus, the results of the microbiological evaluation of the samples of the four treatments indicated that good manufacturing practices were followed during the preparation and handling of these products and that the conservation and storage methods used (packaging in sanitized plastic package and storage under refrigeration) were adequate to avoid contamination by pathogens and preserve the microbiological quality for at least 30 days.

Sensory evaluation

For aroma, there was no significant difference between NFCI and NFBI, indicating that this attribute was not responsible for any difference between the samples (Table 5).

Table 3: The means and standard deviations of the texture and color profiles of the four icings on the day when the package was opened (for NFCI and CFCI) or the day of production (for NFBI and CFBI).

	Icing			
Parameter	NFCI	CFCI	NFBI	CFBI
		Texture		
Hardness (g)	297.77 ±1.10 c	593.8 ±1.14 b	234.10 ±1.87 d	746.8 ±1.18 a
Adhesiveness (g s)	1.73 ±1.27 d	3.98 ±1.20 c	18.8 ±1.27 b	29.63 ±1.13 a
Elasticity (mm)	0.95 ±0.06 a	0.94 ±0.02 a	0.91 ±0.03 a	0.91 ±0.04 a
		Colour		
L*	87.23 ±0.09 a	21.22 ±0.04 d	68.02 ±0.04 b	23.14 ±0.05 c
a*	-3.28 ±0.04 c	9.30 ±0.02 b	2.52 ±0.04 d	10.16 ±0.21 a
b*	5.34 ±0.03 d	8.12 ±0.03 c	12.68 ±0.03 a	9.94 ±0.04 b
C*	6.32 ±0.02 d	12.31 ±0.04 c	12.93 ±0.02 b	14.08 ±0.02 a

NFCI = Neutral Flavor Commercial Icing, NFBI = Neutral Flavor Biomass-based Icing, CFCI = Chocolate Flavor Commercial Icing, CFBI = Chocolate Flavor Biomass-based Icing. Values correspond to the mean ±standard deviation of three repetitions. Different lowercase letters in the same row indicate that there is a statistical difference by Tukey's test ($p<0.05$). L*-lightness (ranges from 0 to 100-pure black to pure white); a*-intensity of green (-) and red (+); b*-intensity of blue (-) and yellow (+); C*-chromaticity/saturation.

Table 4: The mean values of mesophilic aerobic bacteria, molds and yeasts, coliforms (at 45°C), coagulase-positive *Staphylococcus*, and *Salmonella* sp. in the four icings.

Microorganism	Icing												ANVISA standards*
	NFCI			NFBI			CFCI			CFBI			
	Time (days)												
	0	15	30	0	15	30	0	15	30	0	15	30	
Mesophilic aerobic bacteria	9.0×10^2 CFU g^{-1}	< 1.0×10 CFU g^{-1}	< 1.0×10 CFU g^{-1}	1.2×10^3 CFU g^{-1}	8.0×10 CFU g^{-1}	>6.5×10^4 CFU g^{-1}	4.0×10^2 CFU g^{-1}	2.5×10^2 CFU g^{-1}	1.1×10^2 CFU g^{-1}	4.0×10 CFU g^{-1}	1.5×10^2 CFU g^{-1}	1.2×10^2 CFU g^{-1}	---
Molds and yeasts	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU/g	4.0×10 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	< 1.0×10 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	1.0×10 CFU g^{-1}	1.0×10 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	---
Coliforms at 45 °C	< 3.0 MPN g^{-1}	< 3.0 MPN g^{-1}	< 3.0 MPN g^{-1}	2.3×10 MPN g^{-1}	< 3.0 MPN g^{-1}	2.3×10 MPN g^{-1}	< 3.0 MPN g^{-1}	< 3.0 MPN g^{-1}	< 3.0 MPN g^{-1}	9.3×10 MPN g^{-1}	< 3.0 MPN g^{-1}	< 3.0 MPN g^{-1}	1.0×10^2 MPN g^{-1}
Coagulase-positive *Staphylococci*	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	<1.0×10^2 CFU g^{-1}	1.0×10^3 CFU g^{-1}
Salmonella sp.	Absence in 25 g	Absence in 25 g	Absence in 25 g	Absence in 25 g	Absence in 25 g	Absence in 25 g	Absence in 25 g	Absence in 25 g	Absence in 25 g	Absence in 25 g	Absence in 25 g	Absence in 25 g	Absence in 25 g

NFCI = Neutral Flavor Commercial Icing, NFBI = Neutral Flavor Biomass-based Icing, CFCI = Chocolate Flavor Commercial Icing, CFBI = Chocolate Flavor Biomass-based Icing. CFU g^{-1} = Colony Forming Unit per gram, MPN g^{-1} = Most Probable Number per gram.
*RDC No. 331, of December 23, 2019-Ministry of Health.

Table 5: The means of the scores and acceptance percentage of the four icings.

Attribute	Neutral flavor icing			
	NFCI		NFBI	
	Mean[1]	Approval[2]	Mean[1]	Approval[2]
Overall Acceptance	6.9 ±1.40 [a]	87.6	6.0 ±1.66 [b]	70.1
Appearance	7.5 ±1.09 [a]	93.9	5.4 ±1.70 [b]	52.0
Aroma	6.5 ±1.66 [a]	75.5	6.1 ±1.62 [a]	62.2
Flavor	6.8 ±1.71 [a]	85.7	6.0 ±1.72 [b]	57.1
Texture	6.9 ±1.63 [a]	87.6	5.7 ±1.73 [b]	70.1
	Chocolate flavor icing			
Attribute	CFCI		CFBI	
	Mean[1]	Approval[2]	Mean[1]	Approval[2]
Overall Acceptance	7.8 ±0.95 [a]	99.0	6.6 ±1.47 [b]	80.6
Appearance	7.4 ±0.99 [a]	96.9	6.6 ±1.53 [b]	83.7
Aroma	7.4 ±1.31 [a]	90.8	6.9 ±1.42 [b]	83.7
Flavor	7.8 ±1.47 [a]	94.9	6.2 ±1.92 [b]	72.4
Texture	7.5 ±1.36 [a]	99.0	6.3 ±1.81 [b]	80.6

NFCI = Neutral Flavor Commercial Icing, NFBI = Neutral Flavor Biomass-based Icing, CFCI = Chocolate Flavor Commercial Icing, CFBI = Chocolate Flavor Biomass-based Icing
[1]Means ±standard deviation of the scores of the attributes (n = 98), according to 9-point scale, with the terms "disliked extremely" (1) and "liked extremely" (9) at the extremes; [2]results expressed in percentage of scores ≥ 6
Different lowercase letters, in the same row, indicate that there is the statistical difference by F test (p<0.05)

The NFCI samples showed higher acceptance, with a score of 6.5 and an approval percentage higher than 75% for all attributes (Table 5). More importantly, there was no rejection of the NFBI samples since, on average, the lowest scores received were higher than 5 (score indicative of indifference). Importantly, the appearance of the NFBI samples received the lowest score (5.4), possibly due to the darker color of the formulation. Moreover, the absence of sugar in the NFBI formulation might have influenced the reduction in its brightness, thus affecting the appearance. It should be emphasized that fiber-rich whole foods might have a different appearance compared to their traditional counterparts (Bagdi et al., 2016).

Although the NFBI formulation had lower acceptance than the commercial icing, it could meet the demands of a niche market, consisting of people interested in consuming healthier foods and/or those who have restrictions on sugar consumption. It can be inferred that comparing sucrose-rich foods to sucrose-free foods might lead to results like the one found here, as confectionery consumers are habituated to products with higher sugar and fat contents (Peters et al., 2018).

Overall, the mean scores and approval percentages were higher for the chocolate flavor icings. It was found that CFCI was accepted more than CFBI for all attributes (Table 5). However, the scores attributed to the CFBI samples indicated that they were not rejected by consumers, and the icing was associated with positive terms such as "liked slightly" and "liked moderately". The percentage of approval was high for the two chocolate flavor icings, being higher than 80% for most attributes, except for the flavor of CFBI. This was because the CFBI formulation did not have sucrose in its composition, and xylitol was used as a sweetener, which might have been insufficient to reduce the bitterness of the chocolate that had a high content of cocoa. Additionally, the sweetness imparted by xylitol had a different characteristic from that imparted by sucrose, which might also have influenced the lower percentage of acceptance for the flavor attribute of CFBI. Different results were observed by Fernandes et al. (2017), where the authors found greater acceptance for chocolate flavor ice cream, with the addition of biomass, for the attributes of flavor, texture, and appearance, compared to commercial chocolate ice cream.

As found in the present study, sensory evaluations of other products developed with green banana biomass, such as *brigadeiro* (Marques et al., 2017) and yogurt (Silveira et al., 2017), showed good acceptance, indicating that the investment in the improvement of products prepared with green banana biomass and flour represents an opportunity to improve the eating habits of the population.

The comparison of icings based on green banana biomass and flour with sugary commercial icings might have impaired sensory results since the participants who evaluated the samples did not have sugar restrictions, and hence, were probably accustomed to sweeter preparations.

CONCLUSIONS

Icings based on green banana biomass and flour had higher levels of minerals, fibers, resistant starch, and protein than commercial icings and were healthier options. Icings developed with green banana biomass and flour could be stored for up to 30 days under refrigeration, without significant changes in their microbiological characteristics. The chocolate flavor was more suitable for the preparation of icing based on green banana biomass and flour as it had greater sensory acceptance compared to the neutral flavor icing. The icings based on green banana flour and biomass developed in this study are innovative products that deserve the attention and investment of the industries to further improve them and eventually offer them to the public.

AUTHOR CONTRIBUTIONS

Conceptual idea: Silva, ISO.; Methodology design: Silva, ISO.; Viana, ES.; Soares, SE.; Reis, RC.; Data collect: Silva, ISO.; Data analysis and interpretation: Silva, ISO.; Chaves, RS.; Soares, SE.; Viana, ES.; Reis, RC.; Writing and editing: Silva, ISO.; Viana, ES.; Soares, SE.; Reis, RC.

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