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Innovation for the production of healthier edible ice creams: process development, physicochemical and sensory analysis of ice cream with addition of green banana biomass

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Abstract

Bananas are widely consumed fruits globally, known for their nutritional and economic significance. Thus, this study set out to create a green banana biomass ice cream using various proportions, along with physicochemical and sensory analyses. The findings revealed that the ice cream containing 20% green banana biomass closely resembled the characteristics of market-available products. Additionally, it boasted good nutritional quality and lower fat content and received positive sensory feedback. This indicates that ice cream made with green banana biomass holds great potential in both the consumer market and the edible ice cream industry.

Keywords: ice cream; preference; acceptability; analysis.

Practical Application: The inclusion of green banana biomass in the samples had a significant impact on their physicochemical characteristics, especially in terms of reducing total lipid content and increasing ash content. In sensory evaluation, the formulation with 20% biomass yielded positive results. Therefore, given the benefits of green banana biomass and the favorable results of this study regarding the preservation of the sensory and technological properties of ice cream, the use of this ingredient has shown great potential for the ice cream industry and consumers.

1 INTRODUCTION

Ice cream is a popular dessert worldwide, often enjoyed after meals or as a snack. It is made up of a complex mixture of fat, ice crystals, proteins, and air (Statista, 2022b; Tolve et al., 2024). However, the high levels of fat and sugar in ice cream can lead to overconsumption of these nutrients, potentially contributing to an increased risk of obesity and related health issues (Gustavsen et al., 2008; Krystyjan et al., 2015).

Conversely, there is a growing demand for healthier food options with reduced caloric content and minimal synthetic additives (Domínguez Díaz et al., 2020; Durmaz et al., 2020; Samakradhamrongthai et al., 2021). This consumer awareness has prompted the food industry to explore new formulations that align with healthier lifestyles. This is particularly relevant in the lucrative global ice cream market (Statista, 2022a).

Dietary fibers have been recognized not only as fat substitutes in certain food products but also for their functional and nutritional advantages. The nutritional benefits of dietary fibers are contingent upon their physicochemical characteristics, including water-binding capacity, viscosity, interaction with other molecules, and fermentability (Tolve et al., 2024). Soluble fibers function by boosting viscosity and forming gels, which in turn affect the glycemic response and help lower blood cholesterol levels. On the contrary, insoluble fibers increase fecal volume and promote intestinal transit (Bai et al., 2022).

Green banana biomass (GBB), as a food source of dietary fiber, is noteworthy due to its technological and nutritional potential. Green bananas are rich in minerals, vitamins, and resistant starch, making them an important component for promoting good health (Das et al., 2022; Riquette et al., 2019). Given that banana production results in substantial waste, the use of GBB becomes a beneficial and feasible approach, with positive effects on the economy, nutrition, and environment (Falcomer et al., 2019; Gomes et al., 2020; Mohd Zaini et al., 2022). While various studies have utilized green bananas in the form of flour or biomass for creating different products such as cakes, diet cereal bars, wholemeal bread, and symbiotic fermented milk (Andrade et al., 2018; Batista et al., 2017), there has been a lack of research on the application of GBB in ice cream production, particularly in evaluating the physicochemical and acceptability characteristics.

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Consequently, GBB presents itself as a promising technological solution for integration into the ice cream industry, meeting consumer demands and providing economic benefits to producers while creating positive environmental impacts. Therefore, the objective of this study is to develop ice creams with varying proportions of GBB integrated into their formulation, followed by nutritional and sensory analyses.

2 MATERIAL AND METHODS

2.1 Material

The bananas used for the production of biomass and as pulp for the production of ice cream were of the genus Musa (group AAA) "Cavendish anã," dwarf variety, acquired through a donation from a rural producer in the city of Barreiras – Bahia.

2.2 Obtaining green banana biomass

The fruits were harvested the same day the biomass was obtained and did not undergo the ripening process. They were then sorted and cleaned under running water to remove any dirt. After that, they were submerged in a solution containing 10 mL of 2.5% sodium hypochlorite for every liter of water for 15 min, followed by rinsing with drinking water.

The bananas were submerged in water and pressure-cooked for 10 min after reaching pressure. Following the cooking process, the peels were removed, and the pulp was blended in an industrial blender until a smooth paste with a puree consistency was obtained. This paste was then placed in plastic containers that had been washed with soap, sterilized with 70% alcohol, and stored at a temperature of approximately -20°C.

2.3 Ice cream formulations

The ice cream formulations were produced at an industrial ice cream shop in Barreiras, Bahia. Using a batch process in 15-L batches, the formulations outlined in Table 1 were meticulously prepared according to the specified proportions. In an industrial blender, the base syrup (comprising pasteurized milk, cream, powdered milk, and sugar), along with GBB, ripe banana pulp, and stabilizer, was homogenized. The mixture was then transferred to a horizontal producer for a 20-min air incorporation process at -3°C. Subsequently, the product was packaged in 10-L plastic-coated cardboard boxes and stored in a hardening chamber at -18°C until analysis.

2.4 Chemical physical analysis

The analyses were carried out in triplicates, in order to obtain precision of the results obtained. Proximate composition analyses were evaluated according to the methodologies described by the Instituto Adolfo Lutz (2008).

2.4.1 Moisture

The moisture content was determined by drying the sample in an oven at 105°C until a constant weight was achieved. The lost mass was then calculated and expressed as a percentage of the total mass (% m/m).

2.4.2 Ash

To assess the mineral content, the sample was incinerated in a muffle furnace at 550°C until a constant weight was obtained. The result was expressed as a percentage of ash (% m/m).

2.4.3 Lipids

The lipid content was determined using the Soxhlet method, with petroleum ether used to extract lipids. The quantified mass was then expressed as a percentage of the total mass (% m/m).

2.4.4 Proteins

For protein content determination, the sample was digested in sulfuric acid with a catalytic mixture (composed of copper sulfate and potassium sulfate 1:9) and then subjected to nitrogen distillation in a Kjeldahl distiller. The distilled ammonia was collected in a boric acid solution and quantified using a standard hydrochloric acid solution. A correction factor of 6.38 specific to milk and dairy products was used to calculate the protein content, expressed as a percentage of the total mass (% m/m).

2.4.5 Carbohydrates

The carbohydrate content was determined by difference, that is, it was obtained by subtracting the moisture, ash, lipid, protein, and fiber contents from 100%, being expressed as % (m/m) of carbohydrates.

Table 1. Formulations of control banana ice creams and formulations with different concentrations of green banana biomass (GBB).

Ingredients	Control ice cream 0% biomass	Ice cream 10% biomass	Ice cream 20% biomass	Ice cream 30% biomass
Whole milk (L)	6.78	6.78	6.78	6.78
Powdered milk (kg)	0.65	0.65	0.65	0.65
Milk cream (kg)	1.02	1.02	1.02	1.02
Refined sugar (kg)	1.22	1.22	1.22	1.22
Green banana biomass (kg)	-	1.3	3	5
Banana pulp (kg)	1.5	1.5	1.5	1.5
Stabilizer (kg)	0.23	0.23	0.23	0.23
Emulsifier (kg)	0.1	0.1	0.1	0.1
Total mass (kg)	11.5	12.8	14.5	16.5

2.4.6 Overrun rate

To determine the overrun, the equation described by Soler and Veiga (2001) was used as follows (Equation 1):

Overrun (%) = [(Ice cream volume - Base syrup volume) / Base syrup volume] × 100 (1)

2.4.7 pH

A solution was prepared by diluting 10 g of samples in 100 mL of water and then shaking the mixture. A digital pH meter, calibrated and following the instructions in the manufacturer's manual, was used to take three measurements.

2.4.8 Melting rate

The analysis of the melting rate of the ice cream was conducted by adapting the methodology proposed by Goff and Hartel (2012). In this method, a 50 g sample of each ice cream was placed on a stainless-steel sieve attached to the analytical balance support. The drained sample was collected in a watch glass, and its mass was recorded at 10-min intervals. The analysis was conducted at a laboratory temperature of 20 ± 1°C.

2.5 Sensory analysis

For the sensory acceptance test, the overall acceptance of the product and the attributes of color, flavor, aroma, and texture were evaluated using the 9-point hedonic scale. The scale ranges from point 1 for "I really disliked it" to point 9 for "I really liked it." Additionally, the intention to purchase the product was assessed. The test was carried out at the Universidade Federal do Oeste da Bahia with 112 untrained testers. Each taster received a 50 g sample of each product in a coded plastic cup, along with the evaluation form (Dutcosky, 2013; Hough et al., 2006).

2.6 Statistical analysis

The results were statistically evaluated by analysis of variance and Tukey's test, both at a 5% significance level using the statistical software Sisvar version 5.6 (Ferreira, 2019).

3 RESULTS AND DISCUSSION

3.1 Proximate composition of the different formulations

Tables 2 and 3 present the proximate composition and overrun of the different formulations. Noticeable differences between the parameters in the four formulations are evident.

The control sample demonstrated a statistically significant difference from the other formulations, with the lowest value among the four preparations evaluated. The addition of GBB led to an increase in moisture. Consequently, the formulation containing 30% GBB presented the highest moisture value. This rise in moisture in the samples can be attributed to the moisture present in the GBB. Previous studies conducted with GBB reported moisture levels ranging from 67.4 to 89.05% (Costa et al., 2017; Dinon et al., 2014; Izidoro et al., 2008).

The values of crude protein and total lipids decrease with the higher concentration of biomass in the ice cream. Similar findings were reported by Aragão et al. (2018), where physicochemical analyses showed lower levels of lipids and soluble solids in samples with GBB. This could be attributed to the fact that as biomass is added, the other components tend to become more diluted, resulting in reduced amounts of protein and lipids.

The ash values recorded were 1.6% for the control ice cream, 2.8% for the ice cream with 10% GBB, 3.3% for the ice cream with 20% GBB, and 4.1% for the ice cream with 30% GBB, all showing statistically significant differences ($p < 0.05$). In simple terms, the higher the concentration of GBB, the greater the ash content. GBB is known for containing resistant starch and a high presence of minerals such as potassium, phosphorus, calcium, and sodium, which can enhance the mineral content of various foods, including ice cream (Auriema et al., 2021).

The incorporation of air into ice cream is assessed using overrun. Air bubbles influence the perceived softness of the product (Goff, 2002). This study assessed the overrun of the four formulations, with the sample containing 10% GBB showing the highest value at 95.3%. While the addition of GBB affected the total lipids and soluble solids, it did not impact the overrun. Similar findings were reported by Aragão et al. (2018), where lower levels of lipids and soluble solids were observed in samples with added GBB, with no impact on overrun or texture-related parameters.

The pH increased with the addition of GBB. Consequently, the formulation containing 30% biomass exhibited the highest pH at 6.78. This outcome can be attributed to the neutralizing effect of the starch present in bananas on this indicator, resulting in minimal impact on the texture of the ice cream (Munir et al., 2024).

Table 2. Proximate composition of control banana ice creams and formulations with different concentrations of green banana biomass (GBB).

Analysis*	Control ice cream 0% Biomass	Ice cream 10% Biomass	Ice cream 20% Biomass	Ice cream 30% Biomass
Moisture (%)	67.5 ± 0.3[a]	70.3 ± 0.3[b]	69.1 ± 0.5[b]	71.5 ± 0.2[c]
Crude protein (%)	5.3 ± 0.3[a]	4.5 ± 0.5[b]	4.2 ± 0.6[b]	3.8 ± 0.3[c]
Total lipids (%)	10.2 ± 0.3[a]	8.6 ± 0.4[b]	9.2 ± 0.3[c]	7.4 ± 0.6[d]
Ash (%)	1.6 ± 0.1[a]	2.8 ± 0.2[b]	3.3 ± 0.4[c]	4.1 ± 0.2[d]
Carbohydrates(%)	15.40**	13.80**	14.20**	13.22**
Total solids (%)	32.5 ± 0.2***	29.7 ± 0.1***	30.9 ± 0.1 ***	28.5 ± 0.2***

*Mean ± standard deviation. Means followed by the same letter in the same line do not differ from each other at the 5% significance level; **carbohydrate average was calculated by difference after results obtained from macronutrients; ***average performed by difference after moisture results.

Table 3. Physicochemical characteristics of ice cream with the addition of green banana biomass (GBB).

Parameter	Control ice cream 0% biomass	Ice cream 10% biomass	Ice cream 20% biomass	Ice cream 30% biomass
pH	6.50	6.65	6.77	6.78
Overrun (%)	91.30	95.30	93.10	94.93

3.2 Melt test

It should be noted that the inclusion of banana biomass has proven to be effective in reducing the melting rate of the product, as illustrated in Figure 1. When prepared with 30% GBB, the product exhibited a lower melting rate. Similar findings were reported by Aragão et al. (2018), indicating that ice cream samples with higher GBB concentration experienced lower melting rates, albeit with reduced viscosity and uniformity due to lower fat content. It is worth noting, however, that the melting rate can be influenced by various factors, including fat globules, cluster size, crystallization, air incorporation, stabilizers, and total solids content (Goff & Hartel, 2012). With ice cream being a complex colloidal system, these findings present interesting trends. Additionally, it is important to emphasize that the impact of starch on melting rates remains a topic of debate, warranting further research in specific cases (Oliveira et al., 2024).

3.3 Sensory evaluation

In the sensory evaluation, it was utilized a 9-point hedonic scale to assess attributes such as aroma, appearance, color, and texture (Table 4). The ratings for the different formulations fell within the range of 6–8, denoting varying degrees of liking from "I liked it slightly" to "I liked it a lot."

The formulations that received the most favorable evaluations were the control and the 20% biomass. On the contrary, the formulation containing 30% biomass performed poorly across all attributes. As a result, this study focused on evaluating the two formulations with the highest ratings: the control and the 20% biomass. It is important to note that a preferred sample may not always be universally accepted by a given audience (Cardoso et al., 2023).

The average scores obtained in the acceptance tests for attributes such as aroma, color, texture, flavor, and overall acceptability ranged from 7 to 8 on the hedonic scale, encompassing a significant portion of participants. These evaluations yielded positive results. Notably, Fernandes et al. (2017) achieved a 26% approval rate for its yogurt ice cream formulation with the addition of GBB and red fruits, based on the 9-point hedonic scale. By applying the same scale, we found that our product garnered more than double the maximum acceptance of the aforementioned work, indicating a favorable acceptability for the GBB-formulated ice cream in our study.

In the study, Figure 2 illustrates the purchase intentions of the 112 participants who took part in the sensory analysis. Analysis shows that 87.64% of participants expressed a purchase intention for the ice cream formulated with 10% biomass, while 94.87% indicated a purchase intention for the ice cream formulated with 20% biomass. However, for the ice cream formulated with 30% biomass, only 36.59% of participants expressed a purchase intention. This suggests that the 20% biomass formulation had the highest purchase intention among the participants, likely due to its similarity to the control ice cream in terms of color and flavor. On the contrary, the 30% biomass

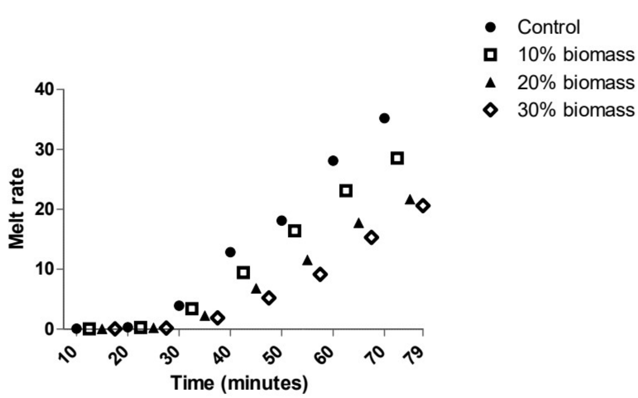

Figure 1. Melting rate of formulations of control banana ice creams and formulations with different concentrations of green banana biomass (GBB).

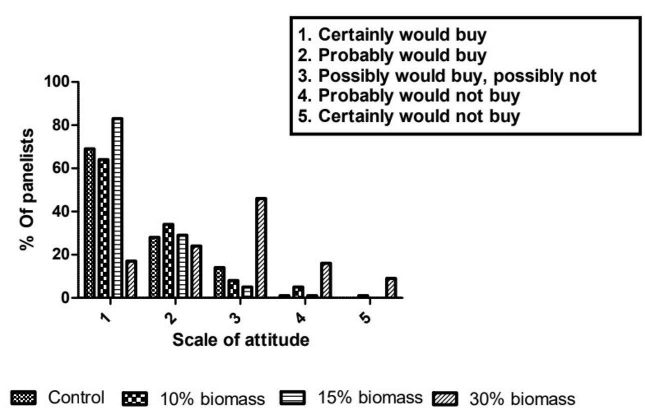

Figure 2. Purchase intention for formulations of control banana ice creams and formulations with different concentrations of green banana biomass (GBB).

Table 4. Evaluation of the different attributes of ice cream with the addition of green banana biomass (GBB).

Samples	Attributes*				
	Aroma	Color	Texture	Flavor	Global acceptability
Control ice cream 0% biomass	7.33 ± 1.58$^{a, b}$	7.91 ± 1.23^{a}	8.06 ± 1.13^{a}	8.41 ± 1.02^{a}	8.28 ± 1.02^{a}
Ice cream 10% biomass	7.21 ± 1.62$^{b, c}$	7.44 ± 1.46 $^{a, b}$	7.92 ± 1.27^{a}	8.21 ± 1.06^{a}	8.13 ± 0.98^{a}
Ice cream 20% biomass	7.81 ± 1.19^{a}	7.59 ± 1.30^{a}	8.30 ± 0.90^{a}	8.40 ± 0.93^{a}	8.35 ± 0.96^{a}
Ice cream 30% biomass	6.71 ± 1.83^{c}	7.05 ± 1.65^{b}	6.20 ± 2.02^{b}	6.72 ± 1.80^{b}	6.79 ± 1.55^{b}

*Mean ± standard deviation. Means followed by the same letter in the same column do not differ from each other at the 5% significance level.

formulation had the lowest purchase intention, possibly due to changes in protein content, total lipids, and texture compared to the control formulation.

4 CONCLUSIONS

The inclusion of GBB in the samples had a significant impact on their physicochemical characteristics, especially in terms of reducing total lipid content and increasing ash content. Among the samples, the one with 30% biomass had the highest ash content and the lowest total lipid content, followed by the samples with 20 and 10% biomass, respectively. However, in sensory evaluation, the formulation with 30% biomass performed the worst. Conversely, the formulation with 20% biomass yielded positive results, comparable to the control formulation, followed by the formulation with 10% biomass. Therefore, given the benefits of GBB and the favorable results of this study regarding the preservation of the sensory and technological properties of ice cream, particularly in formulations with 10 and 20% biomass, the use of this ingredient has shown great potential for the ice cream industry and consumers.

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