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Influence of the pulp of *Mangifera indica* and *Myrciaria dubia* on the bioactive and sensory properties of ice cream

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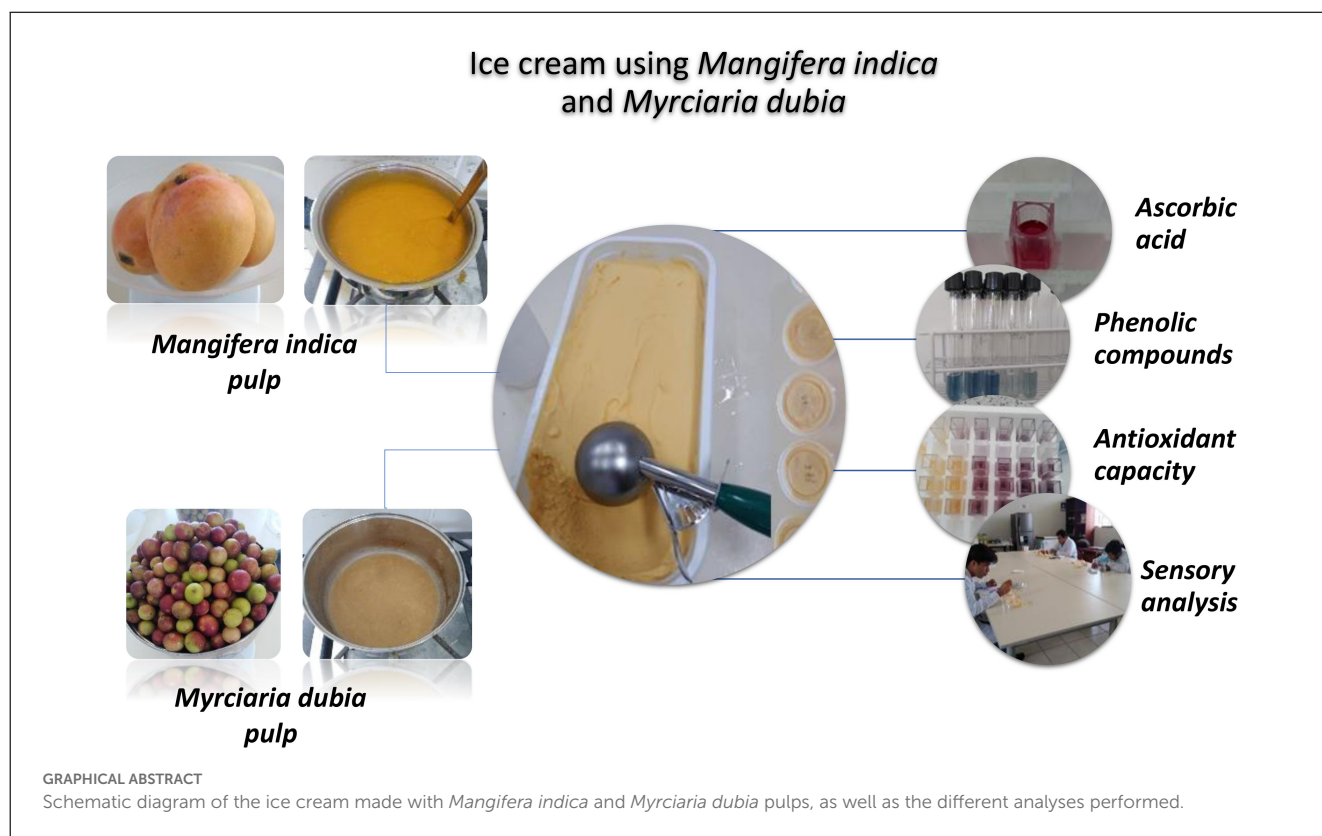
Ice cream is a widely consumed product in the world. Unfortunately, its standard presentation is very poor in nutraceuticals; fruits such as *Mangifera indica* and *Myrciaria dubia* have an important bioactive potential, which can be used to enrich this type of product in phytochemicals. However, maintaining the health and sensory aspects of a functional ice cream is still under investigation. The influence of *Mangifera indica* and *Myrciaria dubia* pulp on the bioactive and sensory properties of ice cream was studied. Four ice cream treatments were prepared with *Mangifera indica* (15% and 20%) and *Myrciaria dubia* (5% and 10%). Ascorbic acid content (reduction of 2,6 dichlorophenolindophenol), total phenolic content (Folin-Ciocalteu reaction) and antioxidant capacity (DPPH radical inhibition) were evaluated in addition to a sensory sorting test. The treatments with 10% *Myrciaria dubia* showed the highest ascorbic acid contents (83.46 and 71.27 mg/100g), total phenolic compounds (80.10 and 79.06 mgGAE/100g) and antioxidant capacity (61.0 and 64.05 mg ice/ml solvent) compared to the 5% treatment and the control; while the influence of *Mangifera indica* on these parameters was relatively minor. However, sensory evaluation showed that T3 (5% *Myrciaria dubia*; 20% *Mangifera indica*) were the most preferred, outperforming the control ice cream. It is evident that *Myrciaria dubia* stands out for its high ascorbic acid content, total phenolic compounds and antioxidant capacity of the ice cream while *Mangifera indica* improves its sensory aspect, allowing an overall balance of sweet-acid taste pleasant to the consumer and maintaining its health properties.

KEYWORDS

camu camu, mango, ascorbic acid, phenolics compounds, sensorial evaluation

1. Introduction

Ice cream is appreciated and consumed by people of different ages and socio-economic groups, due to its sweet taste (Bekiroglu et al., 2022); although consumption is seasonal, demand for ice cream continues to rise, as evidenced by production levels in the EU exceeding 2.9 billion liters, and in the US, almost 5 billion liters by 2020 (Nalbone et al., 2022). In addition, global market sales are expected to be around USD 75 billion in 2024, which would be a 30% increase in comparison to 2017 (Genovese et al., 2022).



Standard ice cream is made from a combination of milk, sugars, fats, non-fat milk solids, stabilizers, emulsifiers, fruits or flavorings and in some cases, colorings (Durmaz et al., 2020; Espinoza et al., 2020). Of these ingredients, non-fat solids and fat are abundant components that directly influence many characteristics such as texture, stability and volume of the ice cream (López-Martínez et al., 2021). Also, these characteristics may be influenced by the addition of carboxymethyl cellulose (Espinoza et al., 2020). In addition, ice cream has highly nutritious components such as protein, some vitamins (A, D, and E) and some minerals (Ca) (Atalar et al., 2021). However, it is a very poor source of bioactive compounds (phenolic compounds, flavonoids, vitamin C, dietary fiber and others) (Virgen-Ceceña et al., 2019; Ismail et al., 2020). Therefore, fruits represent a practical way to increase the bioactive value of ice cream, as they are rich in natural antioxidant compounds, natural colorants and vitamins, and metabolites that have been shown to reduce the development of cancer and decrease risk factors for cardiovascular and degenerative diseases (Bhardwaj et al., 2022; Sharma et al., 2022). Likewise, fruits due to their dietary fiber and polysaccharide content provide increased melt resistance with little noticeable effects on viscosity and texture of ice cream (Sakr et al., 2023).

Myrciaria dubia (*M. dubia*), fruit widely cultivated in the Amazon region of South America, has a high content of vitamin C (Carmo et al., 2019) and other antioxidants such as phenolic compounds (Table 1) (Chirinos et al., 2010; Fidelis et al., 2020). In addition, it is an important source of essential amino acids, fatty acids and minerals (K, Fe, Se, Ca, and Mg) (Santos et al., 2022). Peru is the main exporter of *M. Dubia*. In 2020, 327.48 tons of different substitutes of this fruit were exported, such as

flour, capsules, extract and dried fruit (Barrios Renteria et al., 2022). Similarly, *Mangifera indica* (*M. indica*), is another fruit that possesses various bioactive compounds, particularly phenolic compounds and carotenoids (Yao et al., 2020; Herrera-Cazares et al., 2021). It also contains high concentrations of vitamins (C and A) (Table 1), fiber, minerals, macronutrients and amino acids (Alañón et al., 2019; da Silva Sauthier et al., 2019). *M. indica* is the seventh most produced fruit in the world (Gupta et al., 2022), appreciated for its exquisite taste, nutritional and functional composition (da Silva Sauthier et al., 2019; Lebaka et al., 2021).

In literature, it has been observed that phytochemicals present in *M. dubia* inhibited cell growth in four cancer cell lines (Caco-2, HepG2, A549, and HCT8) without toxicity to normal cells, as well as showing an antimutagenic potential (Carmo et al., 2019). On the other hand, the bioactive compounds present in mango have shown different properties linked to their bioactivity, such as anti-neuroinflammatory (Luo et al., 2021), antioxidant activity (Herrera-Cazares et al., 2021; Marcillo-Parra et al., 2021), immunosuppressants, α -glucosidase inhibition (Gu et al., 2019), antivirals (Umar et al., 2021), anti-modulating (Anaya-Loyola et al., 2020), anti-obesogenic, anti-cancer (Gupta et al., 2022), antidiabetic (Fernández-Ochoa et al., 2020), preventing oxidative stress and consequently the onset of chronic diseases. These attributes indicate that these fruits can be used in the production of functional foods. Barrios Renteria et al. (2022) elaborated yogurt using *M. dubia* (5 and 10%) and *M. indica* (15 and 20%) and showed that the ascorbic acid content increased between 398% and 900% compared to a standard yogurt and the percentages used of *M. dubia* and *M. indica* were sensorially acceptable.

TABLE 1 Main bioactive compounds in *Myrciaria dubia* and *Mangifera indica*.

Bioactive compounds	<i>M. dubia</i>	<i>M. indica</i>	References
Vitamin C (mg/100 g)	1,790–6,110	17.23–80.78	Bekele et al., 2020; Qureshi et al., 2020; Rodrigues et al., 2020; Yao et al., 2020; Lebaka et al., 2021
Phenolic compounds (mg/100 g)	1,120–1,420	258–1,690.2*	Chirinos et al., 2010; da Silva Sauthier et al., 2019; Gentile et al., 2019; Qureshi et al., 2020; Rodrigues et al., 2020; Yao et al., 2020; Lebaka et al., 2021; Santos et al., 2022
Flavonoids (mg EQ/100 g)	6.53	0.9–9.2	
Ellagic acid (mg/100 g)	29.4–31.6	0.71–265.59*	
Gallic acid (mg/100 g)	22.728	9.59–26.87	
Caffeic acid (mg/100 g)	N.E	0.15–0.7	
Anthocyanins (mg/100 g)	12.5	0.85–6.67	
Quercetin (mg/100 g)	42	0.22–11.21*	
Catechin (ug/100 g)	1,300–2,200	535*	
Rutin (ug/100 g)	2,441–3,035	559*	
Kaempferol (mg/100 g)	2.1*	0.13–9.83*	
Cyanidin (mg/100 g)	306*	0.67*	
Mangiferin (mg/100 g)	N.E.	0.78–14.99	Camargo et al., 2015; Gentile et al., 2019; Qureshi et al., 2020; Barrios Renteria et al., 2022; Ndlela et al., 2022
Carotenoids (mg/100 g)	>0.1	1.50–10.4	
B-carotene (mg/100 g)	>0.1	2–8.9	

N.E., value not specified in the study.

*Values expressed on a dry basis.

Ice creams can improve their nutritional, sensory and functional characteristics with the addition of new ingredients. For example, when adding grape by-products (Nascimento et al., 2018), pomegranate peel powder (Ismail et al., 2020), hydrolyzed egg white (López-Martínez et al., 2021), chestnuts (Espinoza et al., 2020), microalgae (Durmaz et al., 2020), olive oil (Sacchi et al., 2019), carrot concentrate (Pandey et al., 2021), herbal extract and fructooligosaccharides (Gremski et al., 2019), prebiotics (da Silva et al., 2020). However, the interaction of these new ingredients can significantly influence the stability and functional characteristics (vitamins, phytochemicals and others) of the ice cream, especially the sensory characteristics of texture and flavor, the latter being a determining factor in the choice of ice cream (Bullock et al., 2020). In this context, the objective of this research is to study the influence of the addition of *M. indica* and *M. dubia* pulp on the total ascorbic acid content, total phenolic content, antioxidant capacity and sensorial properties of ice cream.

2. Materials and methods

2.1. Material and reagents

Ripe *M. indica* var. Edward was provided by Agromar S.A.C (Sullana, Perú), *M. dubia* fruits were purchased in a local market from the Cooperativa Agroindustrial Yarinacocha (Coopay), Pucallpa, Ucayali, Perú. The fresh whole milk was purchased from the livestock establishment in the agricultural technical college, located in Sullana. The powdered milk, sugar,

carboxymethylcellulose (CMC), were also purchased in the local market of Sullana (Perú).

DPPH (2,2-diphenyl-1-picrylhydrazyl), gallic acid, Folin-Ciocalteu, sodium carbonate, oxalic acid, ascorbic acid, 2,6-dichlorophenolindophenol, ethanol (99.9% purity) and methanol (99.5% purity) were obtained from Sigma-Aldrich (ACS, Lima, Perú).

2.2. Preparation of *Mangifera indica* and *Myrciaria dubia* pulp

The selected fruits, *M. dubia* (intermediate ripening) and *M. indica* (mature), were washed, disinfected by immersion in water with sodium hypochlorite at 50 ppm and manually, with the help of a knife, the peel and seed were removed. Then independently chopped pulps were homogenized with a blender for 2 min, and subjected to heat treatment boiling temperature for 10 min, then cooled until 5°C, using ice water. The pulps were stored at 5°C until they were used for ice cream preparation.

2.3. Analysis of milk and fruit pulp

In milk, the pH was analyzed using a potentiometer (Hanna Instruments, HI991001, serial N° B40848) and the density using a lactodensimeter calibrated at 15 °C, according to the methodology described by Rodrigues et al. (2020). Likewise, the methodology described by da Silva et al. (2020) to analyze pH using a

TABLE 2 The ingredients used in the ice cream preparation.

Treatments	<i>M. indica</i>	<i>M. dubia</i>	Other ingredients
T1	15%	5%	Milk (4 000 mL), milk powder (2%), sugar (23%), CMC (0.28%)
T2	15%	10%	
T3	20%	5%	
T4	20%	10%	

potentiometer (Hanna Instruments, HI991001, #B40848) and total soluble solids through a refractometer (Yhequiomen, RHB0-90) at 20°C in *Myrciaria dubia* and *Mangifera indica* pulps.

2.4. Ice cream preparation

The four ice cream treatments were prepared using the ingredients indicated in Table 2 and the percentages considered for each pulp (15% and 20% of *M. indica*, as well as 5% and 10% of *M. dubia*) were based on the study carried out by Barrios Renteria et al. (2022). The ice cream preparation was carried out according to Espinoza et al. (2020). First, the milk powder (2%) was dissolved in fresh milk, it was heated up to 75°C and the premixed dry ingredients (sugar and CMC) were added to it with constant stirring to avoid agglutination until the mixture reached 80°C. After constant stirring, the mixture was pasteurized at 80°C for 45 seconds, cooled until 5°C using ice water and kept refrigerated (at 5°C) for 24 h. Later, the corresponding *M. indica* and *M. dubia* pulps were added for each treatment. The churning process was carried out in an ice cream machine at -8°C for 20 min. The soft ice cream was packed in polystyrene containers (100 g capacity) and stored at -22°C for hardening (Figure 1) and subsequent determination of the ascorbic acid content, total phenolic content, antioxidant capacity and sensorial analysis was completed.

2.5. Determination of ascorbic acid in ice cream

The determination of the ascorbic acid content was carried out by reduction of 2,6-dichlorophenolindophenol according to the method described by Hung and Yen (2002). Approximately 2 g of ice cream was mixed with 4 mL of 0.4% oxalic acid, the mixture was filtered through Whatman No. 2 paper and a solution was obtained. Then 200 µL of the solution were reacted with 1,800 µL 2,6-dichlorophenolindophenol and the absorbance values were recorded in a UV-Visible spectrophotometer (Genesys, S-150, 6287015), at 520 nm wavelength. For AA quantification, Equation (1) was used

$$Abs_{520} = Abs_{Control} - Abs_{sample} \quad (1)$$

The control absorbance was obtained by the reaction of 200 µL of 0.4% oxalic acid, with 1,800 µL of 2,6-dichlorophenolindophenol.

2.6. Determination of total phenolic content (TPC) in ice cream

The total phenolic content was determined according to the method reported by Cornelio-Santiago et al. (2019). To obtain the extracts, approximately 2 g of ice cream were weighed, 2 mL of methanol were added in a 10 mL capacity tube, and then they were homogenized in a Vortex mixer at 2,500 rpm for 20 min. Additionally, it was centrifuged at 4,500 rpm for 20 min and the supernatant was removed. With the residue obtained, the aforementioned steps were repeated, obtaining a second supernatant. The two supernatants were mixed, and 1 mL of distilled water was added, finally centrifuged at 2,500 rpm for 2 min, the methanolic extract (ME) was refrigerated until use.

Later, 1.364 mL of distilled water were mixed in a test tube with 0.3 mL of methanolic extract, which reacted with 136 µL of Folin-Ciocalteu reagent, the resulting solution was left to stand at room temperature for 8 min in a dark room. Then, 1.2 mL of 7.5% Na₂CO₃ were added, the reaction was completed after standing for 2 h in the dark at room temperature, observing a dark blue color. Absorbance was recorded on a UV-Visible spectrophotometer (Genesys, S-150, 6287015) at 760 nm. The blank was prepared in the same way, replacing the methanolic extract with 0.3 mL of methanol and water (80:20, v/v). The TPC was calculated using the gallic acid calibration curve at the concentrations of 10, 20, 30, 40, 50 and 60 mg/L.

2.7. Determination of antioxidant capacity in ice cream

The antioxidant capacity was determined by the method of 1,1-diphenyl-2-picrylhydrazyl picrilhidrazil (Tian et al., 2018). The array comprised the combination of 100 µL of ME obtained with 2 mL of DPPH solution (0.8 mmol/L, solution in absolute ethanol), the reaction was completed after 10 min of rest at room temperature, the absorbance was read at 517 nm using a UV-Visible spectrophotometer (Genesys 150, 6287015). The percentage of inhibition was calculated using Equation (2).

To express in IC₅₀, the same test is carried out working with different concentrations of the extract (120, 100, 50, 25, 12, 6 mg/ml). The standard reaction required the combination of 100 µL of 80% methanol with 2 mL of absolute ethanol.

$$\% \text{ Inhibition} = \left(1 - \frac{abs \text{ sample}}{abs \text{ control}} \right) \times 100 \quad (2)$$

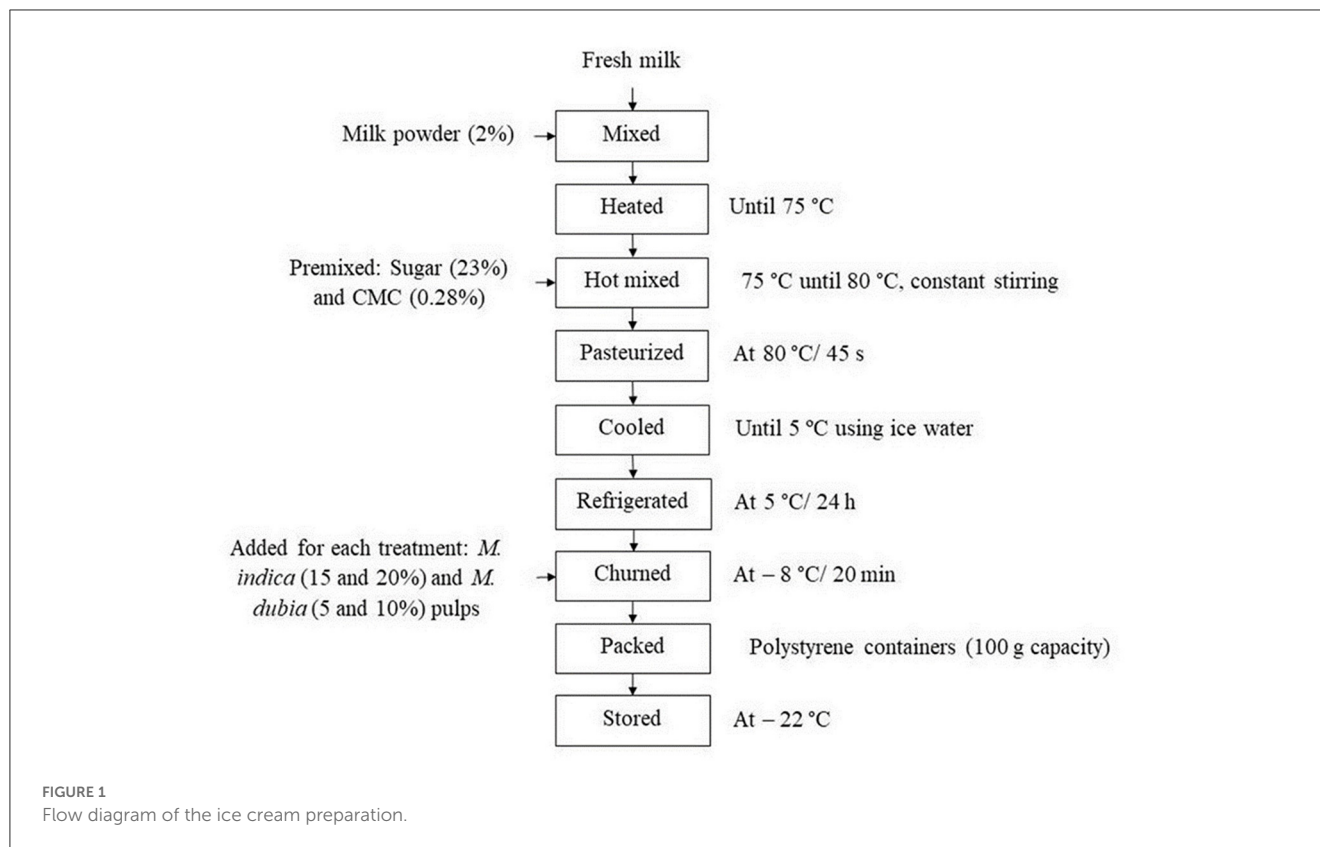
Where:

Abs control: absorbance of the DPPH solution at 0.8 mmol/L.

Abs sample: sample absorbance after 10 min.

2.8. Sensorial analysis

The sensorial evaluation was carried out by 40 semi-trained panelists (10 women and 30 men) whose ages ranged from 18 to 73 years. The evaluation took place between 10:00 a.m. and 12:30 p.m. inside the Functional Foods and Bioprocesses laboratory at



the Universidad Nacional de Frontera. Ice cream samples between 80 and 100 g were delivered in disposable plastic containers at -5°C , previously coded with 3-digit random numbers. The four ice cream treatments and commercial mango ice cream were subjected to a 4-attribute preference or ranking test (flavor, texture, color and general preference) using a scale between 1 and 5 (1 = least preferred and 5 = most preferred) (Rogers, 2010; Espinoza et al., 2020).

2.9. Experimental design and statistical analysis

The four ice cream treatments were prepared using a 2^2 completely randomized two-factorial design with two variables (*M. indica* and *M. dubia*) and with two levels in each case (15% and 20% of *M. indica*, as well as 5% and 10% of *M. dubia*) and as control, a commercial mango ice cream was used. The statistical model proposed according to Montgomery and Runger (2010) is the following:

$$Y_{ij} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \epsilon_{ij}$$

Where, Y_{ij} denotes any of the observations, μ is the Population mean, α_i is the Effect of the i -th α (different *M. indica* ice cream formulations), β_j is the Effect of the j -th β (different *M. dubia* ice cream formulations), $(\alpha\beta)_{ij}$ is the interaction effect of factor α and factor β (different formulations of *M. indica* and *M. dubia* ice cream), ϵ_{ij} is the Error effect.

The values were collected in triplicate and the data obtained from each the experiment were subjected to an analysis of variance (ANOVA), and Tukey's multiple comparison test, at a confidence level of 95%. The effects of the addition of *M. indica* pulp and *M. dubia* on the response variables studied were also identified. Statistical analyses were performed with STATGRAPHICS software (StatPoint, Inc. v.16.1.03). The curves were drawn by Microsoft Excel MSO (version 2019; 16.0.10390.20024; Microsoft Office Standard 2019).

3. Results and discussion

3.1. Milk and *Mangifera indica* and *Myrciaria dubia* pulp analysis

Table 3 shows the results of the routine analyses carried out on the fruit pulp and the milk used to make the ice cream. The density and pH values of the milk complied with the quality limits for fresh milk established by Peruvian regulations (Instituto Nacional de Calidad, 2016).

The pH and the content of sugars in the fruits are important factors to take into account when carrying out the treatments, since they directly influence the sweet and acid taste of the product. It is observed that the pH of *M. indica* was higher than that reported by previous studies, which were between 3.8 to 4.7 (Musyimi, 2013). The content was between 10 to 20% higher for ripe *M. indica* (Lawson et al., 2019). Regarding *M. dubia*, higher values of pH (3.24) and soluble solids (7.20 °Brix) have been reported (Rodriguez et al., 2020) to those obtained in this study. These variations are

TABLE 3 Analysis of milk, *M. indica* pulp, *M. dubia* pulp and ice creams.

Description	pH	Soluble solids (°Brix)	Density (g/cm ³)
Milk + Powder milk (2%)	6.77	8.5	1.030
<i>M. dubia</i> pulp	2.64	4	-
<i>M. indica</i> pulpa	4.67	15	-
T1: 15% <i>M. indica</i> and 5% <i>M. dubia</i>	4.53	17	-
T2: 5% <i>M. indica</i> and 10% <i>M. dubia</i>	4.4	18	-
T3: 20% <i>M. indica</i> and 5% <i>M. dubia</i>	4.33	16	-
T4: 20% <i>M. indica</i> and 10% <i>M. dubia</i>	4.24	18	-
Control: commercial mango ice cream	4.11	25	-

attributed to the variety of the fruit, the weather conditions and agricultural practices (Bekele et al., 2020).

3.2. pH and soluble solids of ice creams using *Mangifera indica* and *Myrciaria dubia*

Table 3 shows the results of pH and soluble solids of the formulated ice creams. The pH values ranged between 4.24 and 4.53, while the soluble solids were between 16 and 18 °Brix. The control ice cream had a very close pH value (4.11); however, the soluble solids content was much higher (25 °Brix). The pH values were close to those reported in similar studies on ice cream with the addition of grape by-product powder (pH = 4.52–4.54) (Nascimento et al., 2018). In ice creams with the addition of 20 to 61% of *M. dubia* pulp, the soluble solids were around 24 to 51.30%, while the pH values ranged from 3.71 to 4.42; the higher the % of *M. dubia*, the lower the pH (Grigio et al., 2019). In the same way, an ice cream made with 50% soursop pulp, presented a soluble solids content of 22.70 °Brix (Virgen-Ceceña et al., 2019). It is important to consider that the high acidity and consequently a low pH value, generates higher viscosity, makes it difficult to shake, affects the stability of the mixture and generates protein denaturation, which affects the texture of the ice cream (Ismail et al., 2020).

3.3. Ascorbic acid in ice cream

Table 4 shows the results of the ascorbic acid content of the four ice cream treatments and the control. Ascorbic acid (AA) content was found in the range of 42.33–83.46 mg/100 g of ice cream; values well above the control (1.61 mg/100 g of ice cream). In the main effects analysis for AA content in ice cream treatments (Figure 2), it was evidenced that *M. dubia* pulp (PMd, %), *M. indica* pulp (PMi, %) and the interaction PMi x PMd significantly influence the AA content. Basically, those samples whose content in *M. dubia* was

higher (T2 and T4), presented an increase of 98% and 69% in the content of ascorbic acid, respectively. This behavior was attributed to the high AA content of *M. dubia* between 1.7 to 6.11g/100 g of fresh pulp (Santos et al., 2022), higher content than that shown by *M. indica* (4.10–92.8 mg/100 g) (Gentile et al., 2019; Qureshi et al., 2020; Gupta et al., 2022). In addition, the AA present in the pulp of *M. indica* could be degraded by the pasteurization treatment. It has been reported that high temperature conditions favor the oxidation of ascorbic acid to dehydroascorbic acid, followed by hydrolysis to 2,3-diketogulonic acid and, finally, polymerization to other nutritionally inactive components (Bekele et al., 2020), which would explain the little significance of the addition of *M. indica* on AA in the different ice cream formulations. In a study carried out on frozen popsicles, 27% of *M. dubia* pulp was added, finding 84 mg of AA per 100 g of sample. However, in the present study, 17% less pulp was used to achieve a similar concentration of AA (T2), attributable to the origin of the fruits and possibly AA degradation by various factors (temperature, pH, enzymes, light and oxygen) (Grigio et al., 2019). Similarly, the content of ascorbic acid in yogurt and frozen dessert using 15% and 50% soursop pulp was between 11.25 and 9.84 mg/100g. In each case, a content of AA below our findings, the consumption of 100 g of frozen dessert would only provide between 10 and 13% of the Dietary Reference Intake (DRI) of AA for men and women. However, the T2 treatment of the present study would provide between 93.3% and 100% of the DRI, respectively (Virgen-Ceceña et al., 2019).

3.4. Total phenolic content (TPC) in ice cream

The TPC is shown in Table 4. The TPC for all treatments ranged from 41.23 to 80.10 mg GAE/100 g of ice cream, values higher than those found in the control (3.64 mg/100 g of ice cream). All treatments were statistically different. T2 and T4 were the treatments with the highest phenolic content. The low TPC of the control may be due to the low mango incorporation and the few phenolic compounds present in the milk from the cows' diet. However, the heat treatment leading to the Maillard reaction could favor the increase in TPC (Pandey et al., 2021).

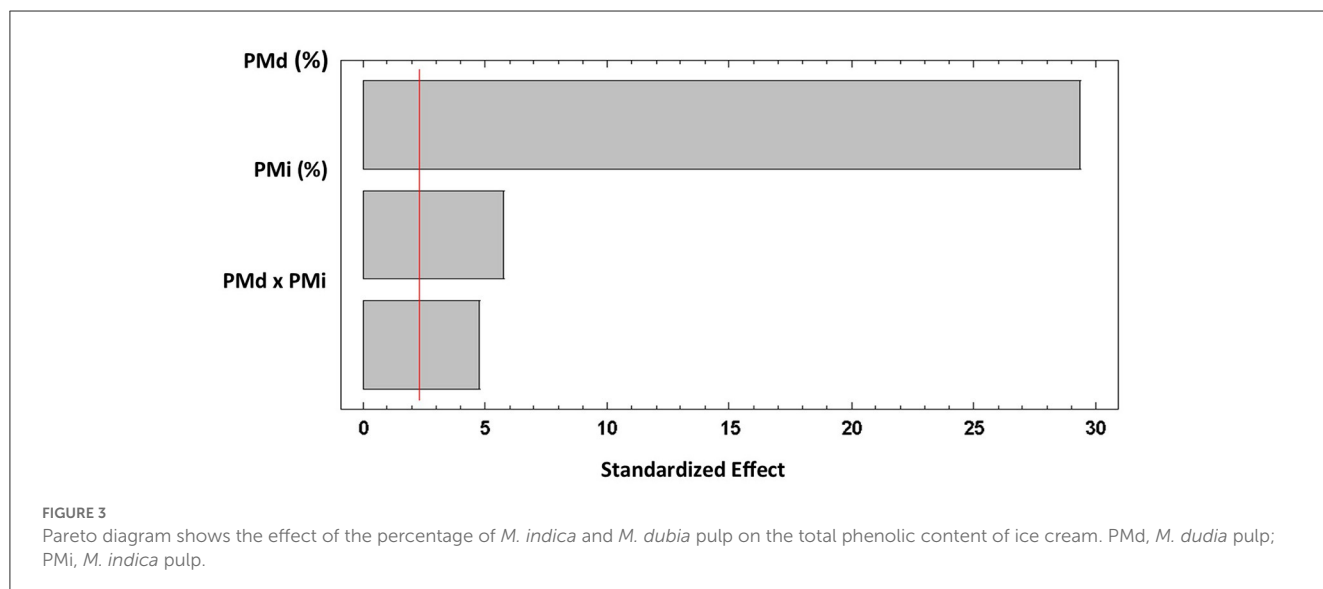
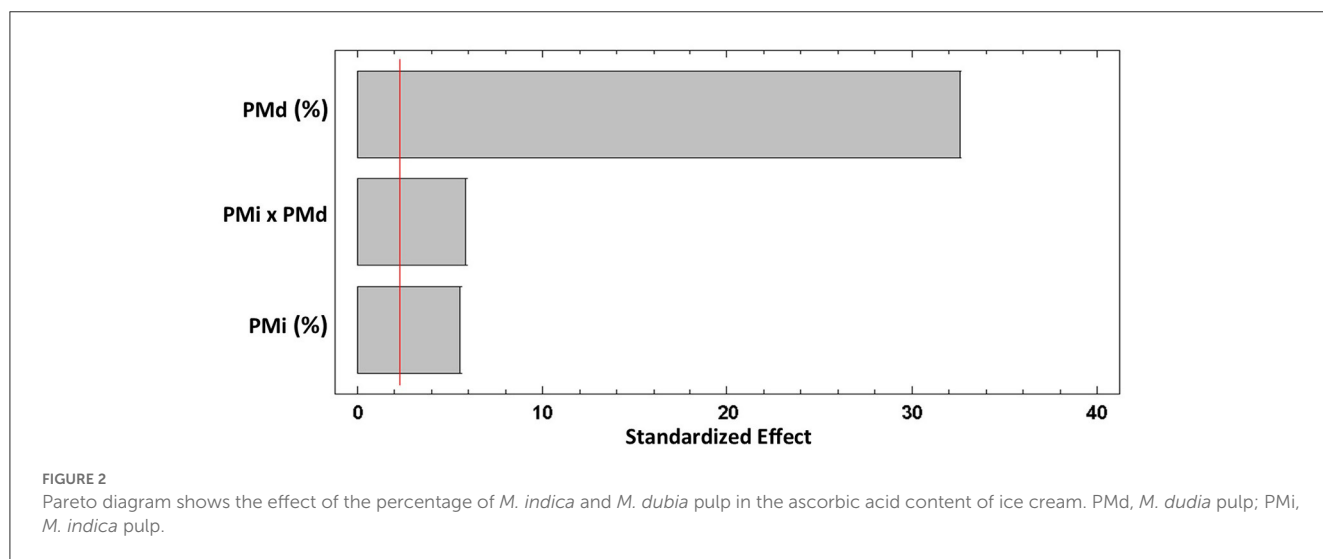
According to the analysis of the main effects in Figure 3, the PMd (%), PMi (%) and PMd x PMi, affect the TPC of the different treatments, the addition of PMd exerts the greatest influence on the TPC in the treatments of ice cream depending on the added doses. Studies reported an increase in TPC (0.7 to 4.4 mg GAE/g) as the percentage of substitution of wheat flour by powder of by-products of *M. dubia* increased (0 to 20%) in cookie production (das Chagas et al., 2021). Similar behavior was found in yogurt enriched with *M. dubia* seed extract, where the sensorially accepted sample (0.25 g/100 g of extract) with respect to the TPC, showed about 20 mgGAE/100g, values exceeded by all treatments of the present study (Fidelis et al., 2020). In the same way, the incorporation of black carrot concentrate (7.5%), produced ice creams with TPC of 513.67 mgGAE/100g. It is highlighted that the carrot concentrate presented 30 times more TPC than the fresh roots, which supports the high TPC values shown in the ice cream (Pandey et al., 2021). In the literature, the degradation

TABLE 4 Ascorbic acid content, total phenolics and antioxidant capacity in ice creams with *Mangifera indica* and *Myrciaria dubia* pulps.

Treatments	Ascorbic acid content (mg/100 g of ice cream)	Total Phenolic Content (mg GAE/100 g of ice cream)	Antioxidant capacity expressed in IC ₅₀ (mg ice cream/mL solvent)
T1	42.33 ± 2.31 ^c	41.23 ± 0.24 ^c	67.24 ± 0.10 ^c
T2	83.46 ± 1.45 ^a	79.06 ± 2.37 ^a	61.00 ± 0.17 ^a
T3	42.65 ± 1.57 ^c	52.88 ± 1.41 ^b	65.93 ± 0.40 ^b
T4	71.27 ± 1.47 ^b	80.10 ± 2.65 ^a	64.05 ± 0.69 ^b
Control	1.61 ± 0.13 ^d	3.64 ± 0.24 ^d	149.56 ± 0.58 ^d

T1 (15 % *M. indica* and 5% *M. dubia*), T2 (15 % *M. indica* and 10% *M. dubia*), T3 (20 % *M. indica* and 5% *M. dubia*), T4 (20 % *M. indica* and 10% *M. dubia*) y Control (commercial mango ice cream).

^{a-d}Mean values in the same column (corresponding to the same component) not followed by a common superscript differ significantly ($P < 0.05$).



of TPC is observed during storage at $-22\text{ }^{\circ}\text{C}$, after 30 and 72 days, reducing between 10 and 80% of TPC in samples of ice cream enriched with herbal extracts (mate and lemon balm), which suggests a short life span for this type of product (Gremski et al., 2019).

3.5. Antioxidant capacity in ice cream

The antioxidant capacity (AC), is an important parameter that determines the potential to sequester and extinguish free radicals. The AC values found for the different ice cream treatments,

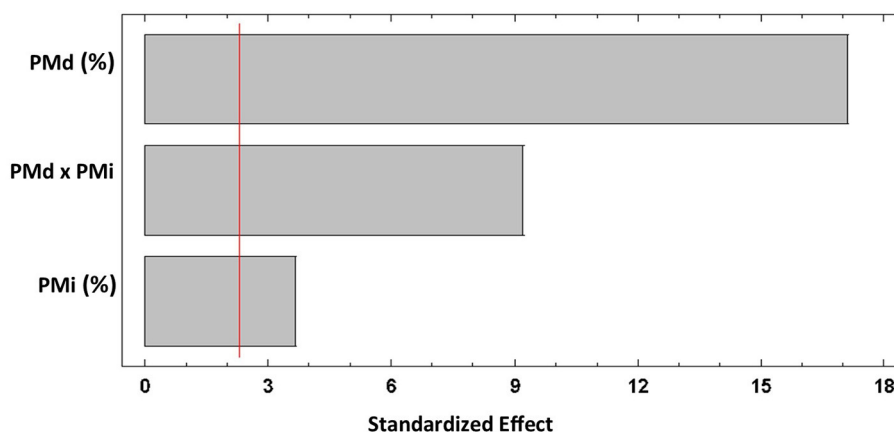


FIGURE 4 Pareto diagram shows the effect of the percentage of pulp *M. indica* and *M. dubia* on the antioxidant capacity of ice cream. PMd, *M. dudia* pulp; PMi, *M. indica* pulp.

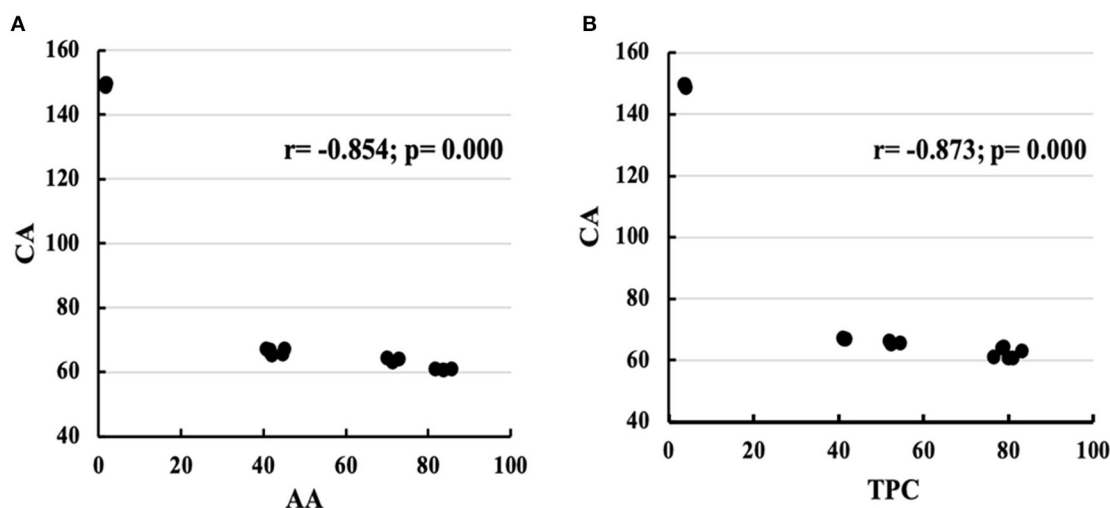
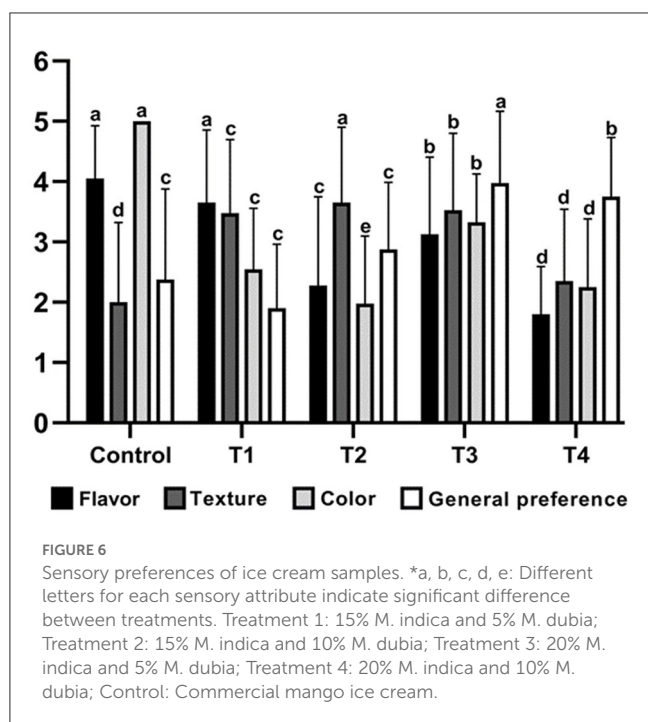


FIGURE 5 Analysis of correlation, (A) CFT vs. CA and (B) AA vs. CA.

expressed in IC_{50} (mg/mL), were higher than 60 mg/mL, as seen in Table 4. The control sample exhibited the lowest DPPH radical scavenging power, requiring 2.5 times more samples compared to ice cream formulations with *M. indica* and *M. dubia* pulps.

Consequently, all the treatments were statistically different. According to the Pareto diagram for the main effects in Figure 4, both PMd, PMi, PMd x PMi showed a significant effect at 95% confidence, in which the greatest influence was exerted by the addition of PMd, and to a lesser extent the PMd x PMi interaction, *M. indica* by itself, showed a minor influence. Similar results have been observed in ice cream made with the addition of black carrot concentrate (CZ), in which the higher the CZ, the CA increased (Pandey et al., 2021). In the same way, the addition of *M. dubia* seed extract in a dairy product (Fidelis et al., 2020). The values of the correlation analysis between TPC vs CA and AA vs CA are shown in Figure 5. As can be seen, the P -value is $0.000 < 0.05$; demonstrating

that there is a relationship between TPC and AA with the CA of the ice cream. The correlation for both variables (TPC vs. CA and AA vs. CA) was negative; because a higher content of these compounds led to a lower antioxidant capacity value (expressed as IC_{50}). These findings are consistent with the results of ice cream made with hazelnut milk, which showed a positive correlation between TPC and CA (Atalar et al., 2021). Study shows antioxidant effects of an ice cream using cocoa, hazelnut extract and green tea. After the consumption of the ice cream, a reduction in oxidative stress and a greater availability of nitric oxide were observed, which improves the vascular function, due to the influence on arterial dilation and increased physical performance of healthy subjects. From this approach it is proposed that the synergy of different ingredients improves the antioxidant capacity of the final product, unlike using a single source of antioxidants. Another aspect to consider is that the bioavailability of phenolic compounds and



other bioactive compounds from natural sources is greater than that of supplements (Sanguigni et al., 2017).

3.6. Sensorial analysis

Figure 6 shows the results of the sensory evaluation of the ice cream. The organoleptic characteristics for the different attributes such as taste, texture, color and overall preference show significant differences between the different treatments. Two of the ice creams (T3 and T4) were the most preferred by the panelists. On the other hand, T1 and T2 showed no differences with respect to the control ice cream. In terms of taste, T1 and T2 ice creams were comparable to the control; however, T2 and T4 ice creams were perceived as less sweet than the others. On the other hand, three of the ice creams (T1, T2, and T3) were significantly milder than the control and T4. And as for the predominant color in the four ice creams developed, it corresponded to the natural color provided by the fruits. Therefore, the control ice cream received a better assessment by showing greater intensity of the yellow-orange color.

It was observed that the appreciation of the sweet taste of ice cream tends to decrease when the amount of *M. dubia* pulp is increased from 5 to 10%. This effect may be due to the increase of the characteristic sour taste of the fruit. A similar effect was demonstrated by Grigio et al. (2019); however, higher sweetness scores were also linked to higher sugar addition.

Ice creams containing 20% (T1 and T2) to 25% (T3) of added fruit showed a softer texture. Despite the fact that no milk fat is added in the development of the ice creams, the creaminess of the ice creams (T1, T2, and T3) was superior to the control ice cream. The fruit pulp contributes to improving the texture of the ice cream. Moreover, it intensifies the flavor and expands the smell of the ice cream, even during storage (Kowalczyk et al., 2021). On

the other hand, the addition of CMC played an important role in the stabilization of the ice cream texture, as it simulates the physical properties of fat provided by its water retention capacity, gel formation and thickener function (Regand and Goff, 2002). The use of hydrocolloids in ice cream has improved the inhibition of recrystallisation, reduced the melting speed, improved the stability of the ingredients in the mixture, increased the viscosity and the overrun rate (Kamińska-Dwórznička et al., 2022).

Probably the presence of yellow-orange coloring in the control ice cream led to better evaluations by the panelists. However, there was a greater preference for the ice creams with a higher percentage of added *M. indica*. Consequently, the ice cream with 20% *M. indica* and 5% *M. dubia* (T3), was the best rated against the other ice creams. The interaction of sweet-acid taste in this ice cream was very pleasant, which even surpassed the control in some organoleptic characteristics.

4. Conclusion

This study has shown that the addition of *Myrciaria dubia* (5% and 10%) and *Mangifera indica* (20%) pulp could be used as a valid ingredient in the production of sensorially acceptable, functional ice creams. *M. dubia* pulp significantly influenced ascorbic acid content (42.33–83.46 mg/100 g), total phenolic content (41.23–80.10 mg GAE/100 g) and antioxidant capacity (61–67 mg ice cream/ml solvent), and *M. indica* pulp positively influenced sensory characteristics. For a possible commercialization, a study of shelf life, microbiological analysis and nutritional value would be necessary. Also, it is interesting to study the profile of volatile compounds and the level of bio-digestibility.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

EM-S: conceptualization, investigation, and preparation of the original draft. LE-E: conceptualization, funding acquisition, supervision, and revision. LR-F: investigation, writing, and formal analysis. JV-M: investigation and visualization. LM-Q: data curation, review, and visualization. HC-S: methodology, data curation, and review. All authors contributed to the article and approved the version submitted.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships

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that could be construed as a potential conflict of interest.

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