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Sensorially accepted *Mangifera indica* and *Myrciaria dubia* yogurts with high ascorbic acid content

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Ascorbic acid deficiency has been associated with several health conditions. The objective of this study was to evaluate the content of ascorbic acid and the sensorial qualities of *Mangifera indica* and *Myrciaria dubia* yogurts. Four yogurt treatments were elaborated with different concentrations of these fruits (T1: 15% and 5%; T2: 15% and 10%; T3: 20% and 5% and T4: 20% and 10%) respectively, compared with a control treatment (CT: yogurt with 15% of *Fragaria vesca*). The ascorbic acid contents of the different treatments were determined by spectrophotometry, with values in the following order (T1: 63.2 mg/100 g; T2:114.3 mg/100 g; T3: 57.3 mg/100 g; T4: 115.1 and the control treatment CT:11.5 mg/100 g). The sensorial evaluation consisted of the application of a hedonic scale of 5 points (1: I dislike it very much; 2: I dislike it; 3: I neither like it nor dislike it; 4: I like it; 5: I like it a lot), results show evidence that the acidity level had a significant influence during the sensory evaluation. Treatment (T3) showed the greatest preference. The use of *Mangifera indica* and *Myrciaria dubia* in the treatments studied ensured ascorbic acid concentrations compared to the control treatment. This was significantly appreciated by consumers when the percentage of *Myrciaria dubia* was less than 10% of the total mass of the yogurt.

KEYWORDS

yogurt, *Mangifera indica*, *Myrciaria dubia*, ascorbic acid, physicochemical analysis, sensory evaluation

Introduction

Vitamin C or ascorbic acid (AA) is a water-soluble organic compound with high antioxidant power (Toh and Wilson, 2020; Lie and Liu, 2021), which is obtained mainly from fresh fruits or vegetables. Humans cannot produce it themselves, unlike most animals (Griffiths, 2020; Kang et al., 2020). Ascorbic acid is necessary for the production of various important chemical substances for the body. Such as collagen, neurotransmitters, cortisol, l-carnitine, vasopressin and catecholamines among others; it is also necessary for homeostasis and cellular function (Hoang et al., 2020). The nutritional deficiency of ascorbic acid in food diets causes various health problems such as anemia, scurvy, bleeding gums, muscle atrophy, poor wound healing, increased sensitivity to stress and a weakened the immune system (Singh and Prasad, 2018). These conditions can limit the return to normal homeostasis in cases of sepsis, a potentially fatal condition for the individual who suffers from it, whose deregulation of the body's immune response to an infection alters the intestinal barrier and the dysbiosis of the present microbiota (Figure 1), giving as a result the translocation of molecular patterns associated with intestinal pathogens (Haak et al., 2018; Zhang et al., 2022). In this same sense, 40% of the Peruvian child population under 3 years of age suffers from anemia due to iron deficiency (CEPLAN, 2021). Iron deficiency anemia is often caused by poor absorption of non-heme iron due to the presence of inhibitory compounds in the diet (Suri et al., 2020). However, food rich in ascorbic acid can improve the fixation of this mineral in the body (Liberal et al., 2020; Bhatnagar and Padilla-Zakour, 2021).

The recommended doses of ascorbic acid are 90 and 75 mg/day in adult men and women, respectively (Castillo Velarde, 2019), in children, ascorbic acid deficiency is called Moeller-Barlow disease, which delays wound healing (Qureshi et al., 2020). The recommended dose in children 1–3 years is 15 mg/day (Bastías Montes and Cepero, 2016). Ascorbic acid deficiency in pregnant women, often leads to serious problems in the fetus's brain (Tveden-Nyborg et al., 2012), therefore, it is recommended to consume doses of at least 10–20 mg/day of ascorbic acid for pregnant women and 20–60 mg/day for lactating women to compensate their daily requirements (Rowe and Carr, 2020; Carr and Lykkesfeldt, 2021). Child intake is poor in ascorbic acid, and some fruits could offer it (Aghili et al., 2012). Among the main fruits with a high content of ascorbic acid is possible to cite camu camu (*Myrciaria Dubia*) with 5043.51 to 6110 mg/100 g (Santos et al., 2021, 2022), *Citrus* genus fruit from 24.22 to 74.85 mg/100 g (Coelho et al., 2021), strawberry (*Fragaria ananassa*) from 52.82 to 55.66 mg/100 g (Aubert et al., 2021) and mango (*Mangifera indica*) from 9.52 to 52.27 mg/100 g (Qureshi et al., 2020).

M. dubia (camu camu) is a typical Amazonian fruit, known for its high content of ascorbic acid, which is 100 times higher than most citrus fruits, and attracts national and international commercial interest, in food, pharmaceutical and nutraceutical

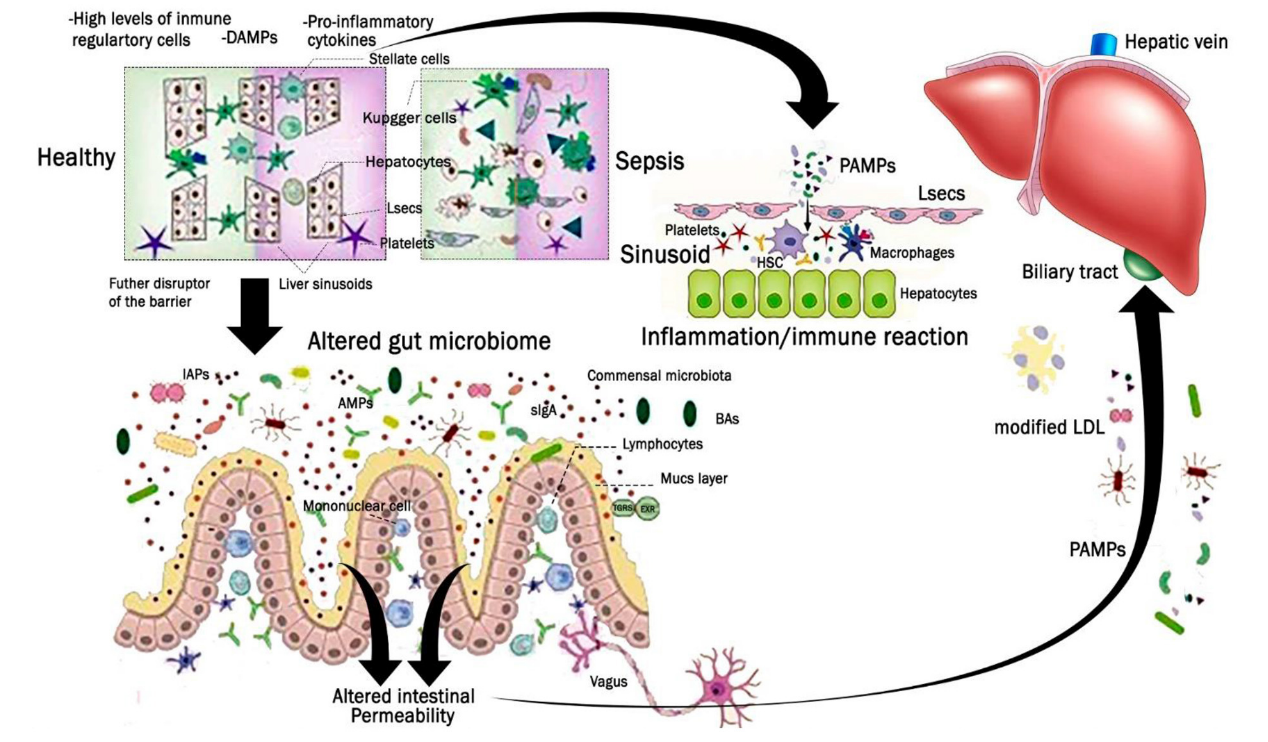

FIGURE 1
Mechanism of sepsis and microbial behavior at the intestinal level. Based on Zhang et al. (2022). DAMPs, damage-associated molecular patterns; LSECs, hepatic sinusoidal endothelium; PAMPs, pathogen-associated molecular patterns. In sepsis several mechanisms disrupt the intestinal barrier, including apoptosis of intestinal epithelial cells; disrupting the mucosal layer and intercellular junctions, generating a translocation of intestinal pathogen-associated molecules into the liver *via* lymphatic vessels or the biliary tract in response to the spread of PAMPs and DAMPs and systematic inflammation.

industries, due to its potential benefits for health (Abreu et al., 2020; Santos et al., 2021). Perú is the main exporter of *M. dubia*, and markets it in the form of flour, capsules, extract and dehydrated (Azevedo et al., 2019). In 2020, the joint export of these products based on *M. dubia* was 327.48 tons, with an FOB value of US$ 4.48 million (PROMPERU, 2021). Similarly, *M. indica* (mango), another fruit that provides significant amounts of ascorbic acid, is also a source of beta-carotene (which the human body can use to synthesize vitamin A), potassium, magnesium and fiber (Table 1); it is also highly demanded in the European market (Fratianni et al., 2020; Mishra et al., 2020). Piura region (Peru) is a reference in this crop, during 2020 around 132,000 tons were produced, representing 10.1% of the national participation (Sisagri et al., 2020).

Yogurt is a fermented dairy food produced by coagulating milk by adding starter cultures such as *Streptococcus salivarius subsp. thermophilus* and *Lactobacillus delbrueckii subsp. Bulgaricus* (Ahmad et al., 2022, 2023). This product is of great sensory acceptability and is considered a functional food due to its contribution in vitamins, minerals, proteins and fats (Ahmad et al., 2021), however, it lacks ascorbic acid, carotenoids and fiber (Salehi, 2021). This product is widely consumed by people of different ages, especially by infants. Its preparation also includes the addition of fruits to achieve a final product of greater acceptability (Mawad et al., 2015; Chandan, 2017; Freitas-Sá et al., 2018). Due to the growing trend of consumption of functional foods, research in the dairy sector has directed its efforts towards improving these functional and sensory properties (Guiné and Lemos, 2020).

Yogurts produced by cow's and goat's milk, supplemented with L-ascorbic acid and powdered fruits, presented a high content of ascorbic acid between 17.44 and 17.14 mg/100 g, respectively. However, the highest sensory acceptability was found in cow's milk yogurts without the addition of ascorbic acid or fruit powder (Sobczak et al., 2022). Yildiz and Ozcan (2019) studied the effect of supplementation of yogurts with vegetable purees; and observed a higher content of ascorbic acid in yogurt with pumpkin puree with a concentration of 21.30 mg/Kg, in addition to a high sensory acceptability, content of polyphenols and total carotenoids. In other hand, Virgen-Ceceña et al. (2019) investigated the sensory and nutritional quality of yogurt with soursop (*Annona muricata* L.) at 15%. They obtained 11.25 mg/100g of ascorbic acid. Regarding general sensorial acceptability on a hedonic scale from 1 to 10, yogurt had a score of 7.8. Similarly, the study carried out by Sigdel et al. (2018) showed the addition of mulberry *(Morus alba)* osmo-dehydrated yogurt, increased ascorbic acid content from 0.77 mg/100 g to 5.96 mg/100 g, compared to conventional yogurt; in addition, the antioxidant capacity was increased due to the presence of phenolics and anthocyanins.

Since yogurt is a versatile dairy product that offers the possibility of substituting different fruits according to nutritional

TABLE 1 Nutritional composition per 100 grams of pulp of *M. dubia* and *M. indica*.

Macronutrients (g)	***Myrciaria dubia***	***Mangifera indica***	**Reference**
Water	94.1–94.4	83.46	Wall-Medrano et al., 2020; Lebaka et al., 2021
Protein	0.4–0.5	0.82	
Fat	0.2–0.3	0.38	
Carbohydrates	3.5–4.7	14.98	
Dietary fiber	0.1–0.6	1.6	
Sugar	1.28–1.48	13.7	
Vitamins			
Vitamin C (mg)	960–2,990	36.4	Wall-Medrano et al., 2020; Lebaka et al., 2021
Thiamin (mg)	10	0.028	
Riboflavin (mg)	40	0.038	
Niacin (mg)	62	0.669	
Pantothenic acid (mg)	N.R.	0.119	
Folate (μg)	N.R.	43	
Vitamin A(μg)	14.2–24.5	54	
Vitamin E (mg)	N.R.	0.9	
Vitamin K (μg)	N.R.	4.2	
Minerals			
Ca (mg)	6.2–15.7	11	Wall-Medrano et al., 2020; Lebaka et al., 2021
Fe (mg)	0.18–0.665	0.16	
Mg (mg)	4.7–12.4	10	
P (mg)	N.R.	14	
K (mg)	60–144.1	168	
Na (mg)	2.7–11.1	1	
Zn (mg)	0.12–0.472	0.09	
Cu (mg)	0.2–0.8	0.04	
Se (mg)	N.R.	0.06	
Polyphenols			
Cyanidin (mg)	306	0.1	Castro et al., 2018; Chang et al., 2019; Rodrigues et al., 2020; Wall-Medrano et al., 2020; Lebaka et al., 2021; Santos et al., 2022
Catechin (mg)	48.2	1.7	
Kaempferol (mg)	2.1	0.1	
Myricetin (mg)	0.201	0.1	
Proanthocyanidins 4-6 mere (mg)	N.R.	7.2	
Gallic acid (mg)	22.72	0.69	

(Continued)

TABLE 1 (Continued)

Macronutrients (g)	*Myrciaria dubia*	*Mangifera indica*	Reference
Quercetin (mg)	42	2.2	
Ellagic acid	490	N.R.	
Rutine	2.44	N.R	
Carotenoids (μg)			
β-carotene	72.8	640	Chang et al., 2019; Lebaka et al., 2021
α-carotene	N.R.	9	
β-cryptoxanthin	9.9	10	
Lycopene	N.R.	3	
Luteoxanthin	21.5	23	

N.R.: not reported.

TABLE 2 Bi-factorial experimental design with control.

Standard conditions	*Mangifera indica*	*Myrciaria dubia*	Treatment
Milk and sugar	15%	5%	T1
	15%	10%	T2
	20%	5%	T3
	20%	10%	T4
Milk, sugar, strawberry (*Fragaria vesca*)	15%		T5: Control (strawberry yogurt)

or sensory preferences (Granato et al., 2018; Guiné and Lemos, 2020), it was proposed to evaluate the ascorbic acid content and sensory qualities of yogurt using *M. indica* and *M. dubia*. With the incorporation of *M. dubia*, the aim was to increase the ascorbic acid content, while with *M. indica*, a pleasant sweet flavor was sought, balancing the acid-sweetness ratio and maintaining the sensory quality of the yogurts produced.

Materials and methods

Sachets of lactic culture of the brand SACCO LYOFAST SAB 446 B (*Lactobacillus acidophilus* and *Bifidobacterium bifidum*) purchased in the local market were used; camu camu (*M. dubia*) red variety originated from the San Martín region (Peru); Edward variety mango pulp was collected from local producers in Tambogrande, Sullana. Fresh whole milk was purchased from a local agricultural technical college. The equipment used was digital handheld pH meter—Hanna Instruments, Model HI991001, serial number B40848; a handheld refractometer—Yhequiomen, Model RHB0-90, Range 0–90%, Accuracy +/-1% Brix, Resolution 1% Brix; a spectrophotometer–Genesys, Model S-150, serial number 6287015.

Analysis of the density and pH of the raw material

Milk density was determined using a lactodensimeter calibrated at 15°C as described by Brousett-Minaya et al. (2015).

Analysis of pH and soluble solids content in the fruits

The determination of pH and soluble solids content of *M. indica* and *M. dubia* were performed with a handheld digital potentiometer—Hanna Instruments, Model HI991001 and a refractometer at 20°C, taking a sample of fruit pulp previously extracted in a 50 mL beaker in each case, according to the methodology of Cosme Silva et al. (2017) with modifications.

Processing of yogurt samples using *Mangifera indica* and *Myrciaria dubia*

Yogurts were made using a completely randomized bi-factorial design at 2^2+1 of 2 variables (*M. indica* and *M. dubia*) with two levels in each case (15% and 20% of *M. indica*, as well as 5% and 10% *of M. dubia*), the control sample was strawberry yogurt (15% fruit), as it is the most offered product in supermarkets (Table 2).

Preparation of the starter culture

One liter of UHT (Ultra High Temperature) milk was purchased in Tetrapak format at Tottus supermarket in the province of Sullana (Peru). The milk was poured into a 1.5-liter jug and the lyophilized culture envelope was dissolved, whose capacity to ferment is 100 liters of milk. The culture was separated into 50 ml fractions to ferment 5 liters of milk in each case, making a total of 20 culture fractions stored at freezing temperature (−22°C) until the moment of being inoculated during the yogurt fermentation process.

Pre-treatment of the fruit

The mangoes (*M. indica*) were cleaned and chopped manually with a knife. The mango is were heated on a stove top (100°C for 10 min) in a stainless-steel pan container, then cooled and stored at 5°C until use. Similarly, camu camu (*M. dubia*) peel and seeds were removed using a strainer, then heated on a stove at 100°C for 10 min, cooled and stored at refrigerated temperature until use.

Preparation of *Mangifera indica* and *Myrciaria dubia* yogurt

Yogurt preparation was carried out according to the procedure described by Moreira et al. (2017) with some modifications. The whole milk was kept at 5°C until processing, starting with a filtering process in a stainless-steel container, followed by pasteurization at 85°C for 5 min, constantly stirring to avoid the formation of crusts on the base of the container. Later it was subjected to cooling until reaching 43°C. The starter culture was inoculated and placed in a fermenter at 43°C for 5 h. The pH control was performed using a digital potentiometer. After the fermentation stage, the yogurt was left to stand at 5°C for 12 h. Then, four yogurt treatments of *M. indica* and *M. dubia* and a control of *F. vesca* were made, taking into account the amount of sugar provided by the different concentrations of fruits, it was considered to standardize the percentage of sugars present in all the formulations so this parameter did not influence significantly the sensorial evaluation. Finally, the product was packed in PET containers with a screw cap and stored at refrigeration temperature until their sensorial evaluation, as well as the development of the different analyses.

Physicochemical analysis of *Mangifera indica* and *Myrciaria dubia* yogurts

The analysis of all the treatments were carried out according to the following methods:

Determination of moisture by weight difference according to FIL-IDF 151:2005 method.

A 10 g sample was weighed in a Petri dish, then placed in a water bath to evaporate as much water as possible, then placed in an oven for 4 h at 105°C. The remaining residue was weighed and the moisture percentage was calculated, according to the following formula:

$$\%\ Humidity = \left[(Wi - Wf)/Wf\right] \times 100$$

Where:

Wi: initial weight of the sample

Wf: final weight of the sample

Determination of ash content following the method of A.O.A.C. 945.46:2002.

A 2 g sample was weighed into a previously conditioned porcelain crucible for analysis. The sample was calcined in a muffle at 550°C for 5 h until completely white ashes were obtained. The crucibles were placed in a desiccator for 15 min and weighed on an analytical scale. The calculation of the ash content in the sample was carried out according to the following formula:

$$\%\ Ashes = \left(W.residue/W.sample\right) \times 100$$

Determination of fat content following the method of FIL-IDF 116A:1996.

Using the Rose-Göttlieb method, 5 g of yogurt were weighed and extracted in ammoniacal solution with diethyl ether and petroleum ether in three proportions. Then, by distillation and evaporation, the solvents were removed, determining the extracted fat content.

Determination of protein by the method of NTP 202.119:2014.

The concentration of nitrogen then converted to protein through a factor (6.38) was determined using the Kjeldahl method consisting of three steps, (1) digestion or mineralization with sulfuric acid, (2) distillation, and (3) titration. The calculations were made according to the following formula:

$$\%Protein = (14 \times N \times V \times 100 \times factor)/(m \times 1000)$$

Where:

V: volume in mL of the acid used

N: normality of the acid used 0.1 N

m: sample mass in grams

Determination of carbohydrates by the method of differences of Collazos et al. (1993).

The carbohydrate content was obtained by difference subtracting 100% from the sum of all the percentages of moisture (H), ash (C), fat (G) and protein (P) using the following formula:

$$\%\ Carbohidratos = 100 - (H + C + G + P)$$

Determination of total energy by method of Collazos et al. (1993).

To calculate the Kilocalorie content, the protein and carbohydrate content (in grams) were multiplied by 4 Kcal/g; the amount of fat (in grams) was multiplied by 9 Kcal/g and finally the results were added to obtain the total energy expressed in Kcal/100 g.

Ascorbic acid analysis

The analysis was carried out following the method reported by Hung and Yen (2002). 200 ul of the aqueous yogurt extract was reacted with 1,800 ul of solution prepared from 2,6 dichlorophenolindophenol, recording the absorbance at 520 nm, obtaining the amounts of ascorbic acid with the following Equation:

$$A_{520} = A_{Control} - A_{sample}$$

In which the control absorbance was obtained by the reaction of 200 µl of 0.4% oxalic acid with 1,800 µl of 2,6 dichlorophenolindophenol.

Sensorial analysis

The sensorial evaluation was carried out under the methodology described Senaka Ranadheera et al. (2012) with some modifications, in which regular consumers of yogurt participated, whose frequency of consumption was at least once a week, an evaluation sheet was given to each panelist in order to assess the different treatments. This sheet includes a 5-point hedonic scale (1: I dislike it very much; 2: I dislike it; 3: I neither like it nor dislike it; 4: I like it; 5: I like it a lot).

Results and discussion

pH analysis and soluble solids (°Brix) of *Mangifera indica* and *Myrciaria dubia*

The values of the soluble solids content for *M. indica* and *M. dubia* were evaluated. Their values have been reported in Table 3.

As observed in Table 3, the fruits pH (*M. indica* and *M. dubia*) ranged between 2.47 and 4.6, while the sugar content was between 4 and 15%. The pH and sugar content of the fruits are parameters to consider during the yogurts production due to their role in the final product stability, as well as their change to the pH due to their own level of acidity (Parvin et al., 2019). The pH value of mango pulp according to studies carried out on six varieties (Tommy, Kent, Keitt, Dodo, Local and Apple mango), is in the range of 3.33–4.75 (Bekele et al., 2020), while for *M. dubia* (5.35–6.8) Brix and (2.51–2.54) pH (Castro et al., 2018).

TABLE 3 pH evaluation and sugar content of fruit.

Fruit	pH	°Brix
Mangifera indica	4.6	15°
Myrciaria dubia	2.47	4°
Fragaria vesca	3.42	7°

Preparation of yogurt samples using *Mangifera indica* and *Myrciaria dubia*

The pH values of the five fruity yogurt preparations ranged from 4.10 to 4.46. These values were slightly lower than those described by Körzendörfer and Hinrichs (2019) who made fermented yogurts with pH values around 4.8 or 5.0 and very close to the values obtained by Lugo-Zarate et al. (2021) with pH between 4.16 and 4.44 by adding cactus pear juice powder (*Opuntia ficus-indica*). The pH range (4.3–4.7) is usually evident after 3–4 h of fermentation. However, a significant decrease in the pH value occurs between the second and third hours of fermentation due to the concentration of lactic acid due to microbial action (Naibaho et al., 2022). The average pH values should range between 4.33 and 4.83, while the average percentage of lactic acid in yogurt is between 0.77 and 0.92 (Rahmatuzzaman Rana et al., 2021). One of the reasons why the pH presented low values in some treatments is due to the low pH of *M. indica* (4.6), *M. dubia* (2.54) and *F. vesca* (3.42).

Proximate composition of *Mangifera indica* and *Myrciaria dubia* yogurts

The proximal composition of the five yogurt treatments is presented in Table 4. Moisture levels were found in the range of 75.3–77.9, total non-dairy solids (22.1–24.6), carbohydrates (17.6–21.0), milk fat (1–2.0), milk protein (2.1–0.2), ash (0.5–0.6) and total energy (95.9–103.9). It can be seen that treatments T3 and T4 have a higher content of total solids (carbohydrates), decreasing their moisture content, and making them a more energetic food (103.9 and 101.4 Kcal/100 g, respectively). A

TABLE 4 Physicochemical characteristics of *Mangifera indica* and *Myrciaria dubia* yogurt.

Characteristics	T1 (15: 5)	T2 (15: 10)	T3 (20: 5)	T4 (20: 10)	T5 (TC)
Humidity (g/100 g)	77.2	77.9	75.9	75.3	76.9
Total Milk Solids (g/100 g)	22.8	22.1	24.1	24.6	23.1
Carbohydrates (g/100g)	18.3	17.6	19.6	21.0	18.4
Milk Fat Matter (g/100 g)	1.8	1.9	1.9	1.0	2.0
Milk protein (g/100 g)	2.2	2.1	2.1	2.1	2.1
Ash (g/100 g)	0.5	0.5	0.5	0.6	0.6
Total, Energy (Kcal/100 g)	98.2	95.9	103.9	101.4	100.0

T1 (15:5): treatment with 15% of *Mangifera indica* and 5% of *Myrciaria dubia*.
T2 (15:5): treatment with 15% de *Mangifera indica* and 5% de *Myrciaria dubia*.
T3 (15:10): treatment with 15% de *Mangifera indica* and 10% de *Myrciaria dubia*.
T4 (20:5): treatment with 20% de *Mangifera indica* and 5% de *Myrciaria dubia*.
T5 (20:10): treatment with 20% de *Mangifera indica* and 10% de *Myrciaria dubia*.
TC: treatment with 15% of *Fragaria vesca* (treatment control).

TABLE 5 Ascorbic acid analysis of the yogurts.

Treatments	% added fruit pulp	Ascorbic acid content (mg/100 g)
T1	15% *M. indica*, 5% *M. dubia*	63.2
T2	15% *M. indica*, 10% *M. dubia*	114.3
T3	20% *M. indica*, 5% *M. dubia*	57.3
T4	20% *M. indica*, 10% *M. dubia*	115.1
T5	15% *F. vesca*	11.5

M. dubia: *Myrciaria dubia* (camu camu).
M. indica: *Mangifera indica* (mango).
F. vesca: *Fragaria vesca* (strawberry).

similar case was observed by Diep et al. (2022), that by adding tamarillo powder (*Solanum betaceum* Cav) at 5, 10 and 15% in yogurts, the moisture content was significantly reduced (78.78–85.79%), compared to the control yogurt (89.72%).

Ascorbic acid in different samples of yogurt

Table 5 shows the results of the ascorbic acid content of the five yogurt samples produced (four study samples and a control sample).

The content of ascorbic acid (AA) in the yogurt samples was significantly different between the different samples evaluated (T1: 63.2 mg/100 g; T2: 114.3 mg/100 g; T3: 57.3 mg/100 g; T4: 115.1 and T5: 11.5 mg/100 g). Basically, those samples with content in *M. dubia* (camu camu) was higher, presented a significant increase in the content of ascorbic acid (treatments 2 and 4), while the variation in the percentage of mango added to the samples did not significantly modify the content of ascorbic acid. The AA content was higher than that found by Khalil et al. (2022) in white sapote pulp (28.25 mg/100 g), the same pulp that was used to make a functional probiotic yogurt. It has been shown that pasteurization in mango juice (90°C for 1 min) reduces 65% of AA (Santhirasegaram et al., 2015). However, a different reaction was observed in *M. dubia* nectar, heat treatment at 85°C for 60 s, only reduced AA approximately 11.44% (do Amaral Souza et al., 2019). This would explain the little significance of the addition of *M. indica* pulp in the AA content of the yogurt. For Fernández (2016), one of the most frequent causes for the destruction of ascorbic acid is high temperatures. Also, studies have shown that in citrus fruits, prolonged contact of food with oxygen causes the degradation of AA by oxidation (Agudelo et al., 2020). Fracassetti et al. (2013) showed that *M. dubia* flour presented interesting values of ascorbic acid from 3.51 g/100 g to 9.04 g/100 g. It was also observed that the highest content of polyphenols was found in the peel. Moreover, Fidelis et al. (2020) reported an increase in phenolic compounds and antioxidant capacity by increasing the concentration of freeze-dried *M. dubia* seed extract in yogurt. The by-products of this fruit produced yogurt enriched with these bioactive compounds.

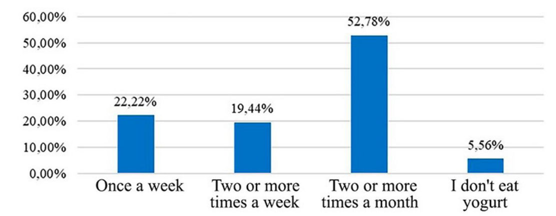

FIGURE 2
Frequency of yogurt consumption.

Sensory qualities of yogurt samples from *Mangifera indica* and *Myrciaria dubia*

The results showed the low consumption of yogurt in the city of Sullana, data shown in Figure 2.

It is evident that large proportion of evaluators consume yogurt between one and two times during the month (52.78%), 22.22% consume it once during the week; while 19.44% consumed 2 to more times during the week. Those who do not consume yogurt represent 5.56% of the total number. From the above, one can infer the need to increase the consumption of yogurt. This data reflects the difficulty of accessing the product due to its high costs, the limited local supply and other barriers. Toapanta and Arroyo (2020) found that 39% of the surveyed people consume yogurt 3 times a week in the Sierra de Ecuador, because they consider it to be a healthy product. The perception of yogurt influences its consumption Allen Ellen (2012). A study showed that, out of 75 evaluators, 97.33% considered yogurt as a beneficial food for health, and also 98.67% of the evaluators valued the consumption of yogurts with added natural antioxidants of paramount importance Fidelis et al. (2020). In addition, other investigations have revealed that organic and functional yogurts have a higher value and acceptance than conventional yogurt; a trend that increases in the consumer sector with greater knowledge related to diet/health, as well as to aging (Ares et al., 2010; Van Loo et al., 2013; Bimbo et al., 2017). The majority of the evaluators considers yogurt as a snack, that would explain the low consumption of this product found in this investigation.

Organoleptic characteristics of yogurt from *Mangifera indica* and *Myrciaria dubia*

The evaluation of sensorial preferences describes the quality that will finally determine the acceptability and the consumption of a certain food (Flores-Mancha et al., 2021), hence the

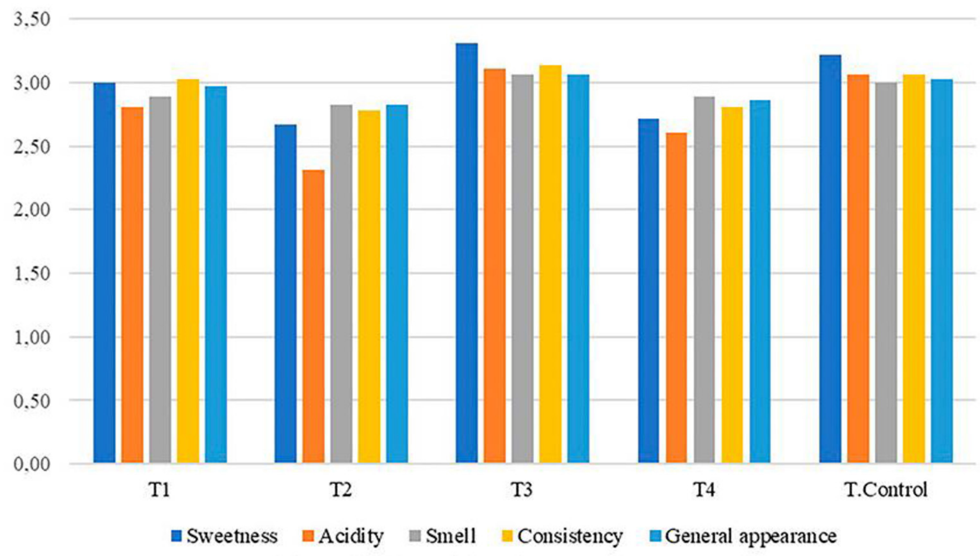

FIGURE 3
Sensorial preferences of yogurt samples.

importance of carrying out this study. According to Figure 3, the organoleptic characteristics for the different attributes such as sweetness, acidity, odor, consistency and general appearance show significant differences between the different samples. For the sweetness, the treatment 3 and control were more pleasant while the treatments 2 and 4 were the least pleasant. During the preparations, an attempt was made to standardize the content of the sugars in all cases, however, these results demonstrate that the intense acid taste interferes significantly, masking the sweet flavor in those treatments with greater content in *M. dubia* (T2 and T4), evidenced by the lowest scores in the sensorial evaluation. This indicates a greater preference for sweeter, less acidic products.

Regarding the attributes of smell, consistency and appearance in general, no significant differences were found, resulting in the samples being very similar, even with the control treatment.

The perception of consumers regarding the different yogurt treatments can be seen in Figure 3.

Treatment 1: 15% *M. indica* and 5% *M. dubia*; Treatment 2: 15% *M. indica* and 10% *M. dubia*; Treatment 3: 20% *M. indica* and 5% *M. dubia*; Treatment 4: 20% *M. indica* and 10% *M. dubia*; Treatment control: 15% *F. vesca*.

Consumers scored yogurt based on sweetness, acidity, odor, consistency and appearance in general. Treatment 3 was the most balanced sample control and obtained values around 3 points on a scale between 0 and 5 points. Treatment 2 and 4 were the least valued, with the sweetness and the acidity parameters showing the differences between the evaluated treatments.

The differences with respect to sweetness and acidity are related to the addition of fruit pulp, which has an effect on the other attributes evaluated. For Pereira et al. (2021) the texture of the yogurt is influenced by the type of sweetener used, notably the addition of *M. indica* pulp and phospholigosaccharides. Karnopp et al. (2017) demonstrated that the incorporation of grape juice positively affects the viscosity and consistency of yogurt, while yogurt with grape flour had greater hardness and consistency, having a greater influence on the texture of the comparison of the oligofructose. Sucrose is usually more valued for yogurt making over other sweeteners (Parra Huertas et al., 2016), being able to reduce up to 25% without significantly affecting sweetness (Oliveira et al., 2021).

On the other hand, regarding acidity, in a smooth yogurt, a decrease in this parameter was evidenced as the concentration of aggregates such as chia and raisin puree increased, resulting with 0.5% chia and 15% raisin puree the best score affecting to a lesser extent the acidity, viscosity, firmness and general acceptability of the yogurt (Gonzales and Zevallos, 2015). Similarly, it was shown that *M. indica* in yogurt formulations substantially improves the flavor during sensory evaluation despite containing stevia (Parra Huertas et al., 2016). In another study, it was shown that the enrichment of fermented milk with fig puree in different proportions (5, 10 and 15%) was sensorially acceptable, despite the fact that the pH decreased (5.34 to 4.43) and the acidity increased (0.48 to 0.77%), in this sense; the addition of fruit at an optimal level improves the sensory quality, physical-chemical and rheological properties of the yogurt (Abd-Eltawab, 2019).

Other parameters are evaluated in sensory studies of yogurt, such as using polymerized whey protein (PWP) was shown to be a potential thickening agent of protein origin that improves the consistency of goat's milk yogurt and other products (Wang et al., 2012). On the other hand, a study by Pingo et al. (2019) showed that some fruits such as aguaymanto (golden berry) or pear subtract value in some cases, concluding in the importance of not exceeding percentages of added fruits.

With this study it was shown that *M. dubia* has a high amount of ascorbic acid and maintains these properties in the final product (yogurt), being beneficial for health in the prevention of respiratory infections, skin lesions, bleeding gums (Potter and Hotchkiss, 1998; Scott et al., 2001) and especially in wound healing (Levine et al., 1996; Lee et al., 2003). For this reason, future research is recommended to evaluate the incorporation of *M. dubia* yogurt as a functional product in restaurants and mainly in dairy product businesses.

Amazonian countries like Peru, have an important production of fruits such as *M. dubia* or *Moringa oleifera*, their importance has been demonstrated in restructuring the intestinal microbiota, controlling infectious processes and improving immunity (Mehwish et al., 2020, 2021a,b), improvement of inflammations and antiviral qualities (Xiong et al., 2021, 2022) which encourages the development of new research to elucidate the presence of micronutrients and the mechanism of action of these compounds of medical interest. On the other hand, the food industry is interested in knowing the presence of volatile aromatic compounds, the level of biodigestibility and the study of the shelf life for their introduction to the market. Research groups from universities and companies are encouraged to work on new lines of research that value *M. indica* for its significant sugar content and *M. dubia* for its high content of ascorbic acid.

Additionally, it is necessary to carry out randomized clinical trials to determine the effectiveness of yogurt using these fruits in the dietary treatment of postoperative patients at the intestinal level (Jia et al., 2018). Recent studies report the importance of the intestinal microbiota in the regulation of the production and signaling of bile acids. According to Halloran and Underwood (2019) several probiotics inhibit the Toll-like receptor 2.4 (TLR2 and TLR4) and stimulate the action of inflammatory mediators, improving intestinal function by strengthening the mucus and the union of enterocytes in the layer of the intestine, therefore the consumption of yogurt is recommended in postoperative patients.

Conclusions

The ascorbic acid content of the different *M. indica* and *M. dubia* yogurt treatments remained with significantly high values (T1: 63.2 mg/100 g; T2: 114.3 mg/100 g; T3: 57.3 mg/100 g; T4: 115.1) unlike the control treatment (TC: 11.5 mg/100 g). However, the sensorial evaluation showed a significant influence in those treatments with 10% of *M. dubia*, decreasing its level of acceptance due to its acid taste, being better valued those treatments that contained 5% of this fruit with respect to the total mass of the yogurt, while the addition of *M. indica* did not significantly influence organoleptic parameters, having used up to 20% of the total mass of yogurt.

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.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

Author contributions

JB contributed to the conception and design of the study, reviewed the scientific literature, participated in the laboratory experiments, analyzed the data, and wrote the manuscript. JV-M contributed to the laboratory experiments and field work during the sensory analysis, analyzed the data, reviewed the scientific literature, and wrote the manuscript. LM-Q contributed in the review of the scientific literature, collaborated during the sensory analysis, supervised the data analysis, wrote and corrected the manuscript, and sought funds to finance the study. LE-E contributed to the conception, design and planning of the study, supervised the field and laboratory work and analyzed the data, wrote and revised the manuscript, and sought funds to finance the study. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Abd-Eltawab, S. (2019). Production and evaluation of stirred synbiotic fermented milk fortified with fig fruit (Ficus carica L.). *Egyptian J. Food Sci.* 47, 201–212. doi: 10.21608/ejfs.2019.18646.1026

Abreu, J., De Andrade, M., Henrique, P., Maria, A., Lago, T., Pereira, T., et al. (2020). Encapsulation of camu-camu extracts using prebiotic biopolymers : controlled release of bioactive compounds and e ff ect on their physicochemical and thermal properties. *Food Res. Int.* 137, 109563. doi: 10.1016/j.foodres.2020.109563

Aghili, F., Khoshgoftarmanesh, A. H., Afyuni, M., and Mobli, M. (2012). Mineral and ascorbic acid concentrations of greenhouse- and field-grown vegetables: implications for human health. *Int. J. Vegetable Sci.* 18, 64–77. doi: 10.1080/19315260.2011.572147

Agudelo, P., Ramirez, J., and Quintero, V. (2020). Formulación y evaluación fisicoquímica de jugo de mora (Rubus glaucus Benth) enriquecido con calcio y vitamina C. *Biotecnología en el Sector Agropecuario y Agroindustrial* 18, 56–63. doi: 10.18684/bsaa.v18n1.1411

Ahmad, I., Xiong, Z., Hanguo, X., Khalid, N., and Khan, R. S. (2022). Formulation and characterization of yogurt prepared with enzymatically hydrolyzed potato powder and whole milk powder. *J. Food Sci. Technol.* 59, 1087–1096. doi: 10.1007/s13197-021-05112-6

Ahmad, I., Xiong, Z., Hanguo, X., Khalid, N., and Rasul Suleria, H. A. (2021). Effect of enzymatically hydrolyzed potato powder on quality characteristics of stirred yogurt during cold storage. *J. Food Process. Preserv.* 45, e15690. doi: 10.1111/jfpp.15690

Ahmad, I., Xiong, Z., Xiong, H., Aadil, R. M., Khalid, N., Lakhoo, A. B. J., et al. (2023). Physicochemical, rheological and antioxidant profiling of yogurt prepared from non- enzymatically and enzymatically hydrolyzed potato powder under refrigeration. *Food Sci. Hum. Well.* 12, 69–78. doi: 10.1016/j.fshw.2022.07.024

Allen Ellen, S. G. (2012). *Consumer Preferences for Milk and Yogurt Attributes: How Health Beliefs and Attitudes Affect Choices.* Agricultural and Applied Economics Association's 2012 Annual Meeting, 1–45.

Ares, G., Giménez, A., and Deliza, R. (2010). Influence of three non-sensory factors on consumer choice of functional yogurts over regular ones. *Food Qual. Prefer.* 21, 361–367. doi: 10.1016/j.foodqual.2009.09.002

Aubert, C., Bruaut, M., Chalot, G., and Cottet, V. (2021). Impact of maturity stage at harvest on the main physicochemical characteristics, the levels of vitamin C, polyphenols and volatiles and the sensory quality of Gariguette strawberry. *Eur. Food Res. Technol.* 247, 37–49. doi: 10.1007/s00217-020-03605-w

Azevedo, L., de Araujo Ribeiro, P. F., de Carvalho Oliveira, J. A., Correia, M. G., Ramos, F. M., de Oliveira, E. B., et al. (2019). Camu-camu (Myrciaria dubia) from commercial cultivation has higher levels of bioactive compounds than native cultivation (Amazon Forest) and presents antimutagenic effects in vivo. *J. Sci. Food Agric.* 99, 624–631. doi: 10.1002/jsfa.9224

Bastías Montes, J. M., and Cepero, B. Y. (2016). La vitamina C como un eficaz micronutriente en la fortificación de alimentos. *Revista Chilena de Nutricion* 43, 81–86. doi: 10.4067/S0717-75182016000100012

Bekele, M., Satheesh, N., and, Sadik, J. A. (2020). Screening of Ethiopian mango cultivars for suitability for preparing jam and determination of pectin, sugar, and acid effects on physico-chemical and sensory properties of mango jam. *Sci. Afr.* 7, e00277. doi: 10.1016/j.sciaf.2020.e00277

Bhatnagar, R. S., and Padilla-Zakour, O. I. (2021). Plant-based dietary practices and socioeconomic factors that influence anemia in india. *Nutrients* 13, 1–19. doi: 10.3390/nu13103538

Bimbo, F., Bonanno, A., Nocella, G., Viscecchia, R., Nardone, G., De Devitiis, B., et al. (2017). Consumers' acceptance and preferences for nutrition-modified and functional dairy products: a systematic review. *Appetite* 113, 141–154. doi: 10.1016/j.appet.2017.02.031

Brousett-Minaya, M., Torres Jiménez, A., Chambi Rodríguez, A., Mamani Villalba, B., and Gutiérrez Samata, H. (2015). Physicochemical, microbiological and toxicological quality of raw milk in cattle basins of the region Puno-Peru. *Scientia agropecuaria* 6, 165–176. doi: 10.17268/sci.agropecu.2015.03.03

Carr, A. C., and Lykkesfeldt, J. (2021). Discrepancies in global vitamin C recommendations: a review of RDA criteria and underlying health perspectives. *Crit. Rev. Food Sci. Nutr.* 61, 742–755. doi: 10.1080/10408398.2020.1744513

Castillo Velarde, E. R. (2019). Vitamina C En La Salud Y En La Enfermedad. *Revista de la Facultad de Medicina Humana* 19, 95–100. doi: 10.25176/RFMH.v19i4.2351

Castro, J. C., Maddox, J. D., and Imán, S. A. (2018). "Camu-camu— Myrciaria dubia (Kunth) McVaugh," in *Exotic Fruits* (London: Elsevier Inc), 97–105. doi: 10.1016/B978-0-12-803138-4.00014-9

CEPLAN (2021). *Perú: datos para el planeamiento estratégico, regional.* Available online at: https://www.ceplan.gob.pe/informacion-sobre-zonas-y-departamentos-del-peru/ (accessed August 20, 2022).

Chandan, R. C. (2017). "An overview of yogurt production and composition," in *Yogurt in Health and Disease Prevention* (London: Elsevier Inc), 31–47. doi: 10.1016/B978-0-12-805134-4.00002-X

Chang, S. K., Alasalvar, C., and Shahidi, F. (2019). Superfruits: phytochemicals, antioxidant efficacies, and health effects–a comprehensive review. *Crit. Rev. Food Sci. Nutr.* 59, 1580–1604. doi: 10.1080/10408398.2017.1422111

Coelho, E. M., da Silva Haas, I. C., de Azevedo, L. C., Bastos, D. C., Fedrigo, I. M. T., dos Santos Lima, M., et al. (2021). Multivariate chemometric analysis for the evaluation of 22 Citrus fruits growing in Brazil's semi-arid region. J. Food Compos. Anal. 101. doi: 10.1016/j.jfca.2021.103964

Collazos, C., White, P. L., White, H. S., Viñas, E., and Alvestur, E. (1993). *La composición de alimentos de mayor consumo en el Perú* (No. Q04 C6–R). Lima: Ministerio de Salud; Instituto Nacional de Nutrición.

Cosme Silva, G. M., Silva, W. B., Medeiros, D. B., Salvador, A. R., Cordeiro, M. H. M., da Silva, N. M., et al. (2017). The chitosan affects severely the carbon metabolism in mango (*Mangifera indica* L. *cv. Palmer) fruit during storage. Food Chem.* 237, 372–378. doi: 10.1016/j.foodchem.2017.05.123

Diep, T. T., Ji, M., and Yoo, Y. (2022). Effect of tamarillo fortification and fermentation process on physicochemical properties and nutrient and volatiles content of yoghurt. *Foods* 11, 79. doi: 10.3390/foods11010079

do Amaral Souza, F. das C., Gomes Sanders Moura, L., de Oliveira Bezerra, K., Paiva Lopes Aguiar, J., Moreira Mar, J., Sanches, E. A., et al. (2019). Thermosonication applied on camu–camu nectars processing: effect on bioactive compounds and quality parameters. *Food Bioprod. Process.* 116, 212–218. doi: 10.1016/j.fbp.2019.06.003

Fernández, L. (2016). *Evaluación de la concentración de ácido ascorbico en cocona (Solanum Sessiliflorum* dunnal), por fotometría.

Fidelis, M., de Oliveira, S. M., Sousa Santos, J., Bragueto Escher, G., Silva Rocha, R., Gomes Cruz, A., et al. (2020). From byproduct to a functional ingredient: camu-camu (Myrciaria dubia) seed extract as an antioxidant agent in a yogurt model. *J. Dairy Sci.* 103, 1131–1140. doi: 10.3168/jds.2019-17173

Flores-Mancha, M. A., Ruíz-Gutiérrez, M. G., Rentería-Monterrubio, A. L., Sánchez-Vega, R., Juárez-Moya, J., Santellano-Estrada, E., et al. (2021). Stirred yogurt added with beetroot extracts as an antioxidant source: Rheological, sensory, and physicochemical characteristics. *J. Food Process. Preserv.* 45, e15628. doi: 10.1111/jfpp.15628

Fracassetti, D., Costa, C., Moulay, L., and Barberán, F. A. (2013). Derivados del ácido elágico, elagitaninos, proantocianidinas y otros fenoles, vitamina C y capacidad antioxidante de dos productos en polvo del fruto del camu-camu (Myrciaria dubia). *Food Chem.* 139, 578–588. doi: 10.1016/j.foodchem.2013.01.121

Fratianni, A., Adiletta, G., Matteo, M. D., Panfili, G., Niro, S., Gentile, C., et al. (2020). Evolution of carotenoid content, antioxidant. *Foods* 9, 1424.

Freitas-Sá, D. D. G. C., de Souza, R. C., de Araujo, M. C. P., Borguini, R. G., de Mattos, L. da S., Pacheco, S., et al. (2018). Effect of jabuticaba (Myrciaria jaboticaba (Vell) O. Berg) and jamelão (Syzygium cumini (L.) Skeels) peel powders as colorants on color-flavor congruence and acceptability of yogurts. *Lwt* 96, 215–221. doi: 10.1016/j.lwt.2018.05.024

Gonzales, A. R., and Zevallos, A. R. (2015). Efecto de la adición de chía (Salvia hispanica L.) y pasas sobre la sinéresis, acidez, firmeza, viscosidad aparente y aceptabilidad general del yogur aflanado frutado. *Pueblo continente* 26, 467–475. Available online at: http://journal.upao.edu.pe/PuebloContinente/article/view/319

Granato, D., Santos, J. S., Salem, R. D., Mortazavian, A. M., Rocha, R. S., and Cruz, A. G. (2018). Effects of herbal extracts on quality traits of yogurts, cheeses, fermented milks, and ice creams: a technological perspective. *Curr. Opin. Food Sci.* 19, 1–7. doi: 10.1016/j.cofs.2017.11.013

Griffiths, J. K. (2020). "Vitamin deficiencies," in *Hunter's Tropical Medicine and Emerging Infectious Disease* (London: Elsevier Inc), 1042–1047. doi: 10.1016/B978-0-323-55512-8.00144-7

Guiné, R. P. F., and Lemos, E. T. De (2020). Development of new dairy products with functional ingredients. *J. Culinary Sci. Technol.* 18, 159–176. doi: 10.1080/15428052.2018.1552901

Haak, B. W., Prescott, H. C., and Wiersinga, W. J. (2018). Therapeutic potential of the gut microbiota in the prevention and treatment of sepsis. *Front. Immunol.* 9, 1–8. doi: 10.3389/fimmu.2018.02042

Halloran, K., and Underwood, M. A. (2019). Probiotic mechanisms of action. *Early Hum. Dev.* 135, 58–65. doi: 10.1016/j.earlhumdev.2019.05.010

Hoang, X., Shaw, G., Fang, W., and Han, B. (2020). Possible application of high-dose vitamin C in the prevention and therapy of coronavirus infection. *J. Glob. Antimicrob. Resist.* 23, 256–262. doi: 10.1016/j.jgar.2020.09.025

Hung, C. Y., and Yen, G. C. (2002). Antioxidant activity of phenolic compounds isolated from Mesona procumbens Hemsl. *J. Agric. Food Chem.* 50, 2993–2997. doi: 10.1021/jf011454y

Jia, W., Xie, G., and Jia, W. (2018). Bile acid–microbiota crosstalk in gastrointestinal inflammation and carcinogenesis. *Nat. Rev. Gastroenterol. Hepatol.* 15, 111–128. doi: 10.1038/nrgastro.2017.119

Kang, C. H., Yoon, E. K., Muthusamy, M., Kim, J. A., Jeong, M. J., and Lee, S. I. (2020). Blue LED light irradiation enhances L-ascorbic acid content while reducing reactive oxygen species accumulation in Chinese cabbage seedlings. *Sci. Hortic.* 261, 108924. doi: 10.1016/j.scienta.2019.108924

Karnopp, A. R., Oliveira, K. G., de Andrade, E. F., Postingher, B. M., and Granato, D. (2017). Optimization of an organic yogurt based on sensorial, nutritional, and functional perspectives. *Food Chem.* 233, 401–411. doi: 10.1016/j.foodchem.2017.04.112

Khalil, O. S. F., Ismail, H. A., and Elkot, W. F. (2022). Physicochemical, functional and sensory properties of probiotic yoghurt flavored with white sapote fruit (Casimiroa edulis). *J. Food Sci. Technol.* 59, 3700–3710. doi: 10.1007/s13197-022-05393-5

Körzendörfer, A., and Hinrichs, J. (2019). Manufacture of high-protein yogurt without generating acid whey – impact of the final pH and the application of power ultrasound on texture properties. *Int. Dairy J.* 99, 104541. doi: 10.1016/j.idairyj.2019.104541

Lebaka, V. R., Wee, Y. J., Ye, W., and Korivi, M. (2021). Nutritional composition and bioactive compounds in three different parts of mango fruit. *Int. J. Environ. Res. Public Health* 18, 1–20. doi: 10.3390/ijerph18020741

Lee, J., Chang, M., Park, C., Kim, H., and Kim, J. (2003). Diferenciación inducida por ascorbato de precursores corticales embrionarios en neuronas y astrocitos. *J. Neurosci. Res.* 73, 156–165. doi: 10.1002/jnr.10647

Levine, M., Conry-cantilenat, C., Wang, Y., Welch, R. W., Washko, P. W., Dhariwal, K. R., et al. (1996). Pharmacokinetics healthy dietary. *Proc. Natl. Acad. Sci. USA*. 93, 3704–3709. doi: 10.1073/pnas.93.8.3704

Liberal, Â., Pinela, J., Vívar-Quintana, A. M., Ferreira, I. C. F. R., and Barros, L. (2020). Fighting iron-deficiency anemia: innovations in food fortificants and biofortification strategies. *Foods* 9, 1–19. doi: 10.3390/foods9121871

Lie, J., and Liu, J. C. (2021). Closed-vessel microwave leaching of valuable metals from spent lithium-ion batteries (LIBs) using dual-function leaching agent: ascorbic acid. *Sep. Purif. Technol.* 266, 118458. doi: 10.1016/j.seppur.2021.118458

Lugo-Zarate, L., Cruz-Cansino, N. del S., Ramírez-Moreno, E., Zafra-Rojas, Q. Y., Calderón-Ramos, Z. G., Delgado-Olivares, L., et al. (2021). Evaluation of physicochemical, microbiological, and antioxidant properties of a drinkable yogurt added with ultrasonicated purple cactus pear (Opuntia ficus-indica) juice powder. *J. Food Process. Preserv.* 45, 1–13. doi: 10.1111/jfpp.15720

Mawad, F., Trías, M., Giménez, A., Maiche, A., and Ares, G. (2015). Influence of cognitive style on information processing and selection of yogurt labels: Insights from an eye-tracking study. *Food Res. Int.* 74, 1–9. doi: 10.1016/j.foodres.2015.04.023

Mehwish, H. M., Liu, G., Rajoka, M. S. R., Cai, H., Zhong, J., Song, X., et al. (2021a). Therapeutic potential of Moringa oleifera seed polysaccharide embedded silver nanoparticles in wound healing. *Int. J. Biol. Macromol.* 184, 144–158. doi: 10.1016/j.ijbiomac.2021.05.202

Mehwish, H. M., Rajoka, M. S. R., Xiong, Y., Cai, H., Aadil, R. M., Mahmood, Q., et al. (2021b). Green synthesis of a silver nanoparticle using Moringa oleifera seed and its applications for antimicrobial and sun-light mediated photocatalytic water detoxification. *J. Environ. Chem. Eng.* 9, 105290. doi: 10.1016/j.jece.2021.105290

Mehwish, H. M., Riaz Rajoka, M. S., Xiong, Y., Zheng, K., Xiao, H., Anjin, T., et al. (2020). Moringa oleifera–a functional food and its potential immunomodulatory effects. *Food Rev. Int.* 00, 1–20. doi: 10.1080/87559129.2020.1825479

Mishra, P., Woltering, E., and El Harchioui, N. (2020). Improved prediction of 'Kent' mango firmness during ripening by near-infrared spectroscopy supported by interval partial least square regression. *Infrared Phys. Technol.* 110, 103459. doi: 10.1016/j.infrared.2020.103459

Moreira, T. C., Transfeld da Silva, Á., Fagundes, C., Ferreira, S. M. R., Cândido, L. M. B., Passos, M., et al. (2017). Elaboration of yogurt with reduced level of lactose added of carob (Ceratonia siliqua L.). *LWT - Food Sci. Technol.* 76, 326–329. doi: 10.1016/j.lwt.2016.08.033

Naibaho, J., Butula, N., Jonuzi, E., Korzeniowska, M., Laaksonen, O., Föste, M., et al. (2022). Potential of brewers' spent grain in yogurt fermentation and evaluation of its impact in rheological behaviour, consistency, microstructural properties and acidity profile during the refrigerated storage. *Food Hydrocoll.* 125, 107412. doi: 10.1016/j.foodhyd.2021.107412

Oliveira, A. A. A., Andrade, A. C., Bastos, S. C., Condino, J. P. F., Curzi Júnior, A., and Pinheiro, A. C. M. (2021). Use of strawberry and vanilla natural flavors for sugar reduction: a dynamic sensory study with yogurt. *Food Res. Int.* 139, 109972. doi: 10.1016/j.foodres.2020.109972

Parra Huertas, R. A., Barrera Rojas, L. J., and Rojas Parada, D. C. (2016). Evaluación de la adición de avena, mango y estevia en un yogur elaborado a partir de una mezcla de leche semidescremada de cabra y de vaca. *Ciencia and Tecnología Agropecuaria* 16, 167–179. doi: 10.21930/rcta.vol16_num2_art:365

Parvin, I., Haque, M. A., Akter, F., Zakaria, M., and Baqui, M. A. (2019). Preparation of low calorie and shelf-life extended yogurt by mixing wood apple powder in the formulation. *J. Food Process. Preserv.* 43, 1–12. doi: 10.1111/jfpp.14267

Pereira, C. T. M., Pereira, D. M., de Medeiros, A. C., Hiramatsu, E. Y., Ventura, M. B., and Bolini, H. M. A. (2021). Yogur Skyr con pulpa de mango, fructooligosacáridos y edulcorantes naturales: Aspectos físicos e impulsores del gusto. *Lwt* 150, 1–9. doi: 10.1016/j.lwt.2021.112054

Pingo, A., Maza, G., and Nuñez, L. (2019). *Elaboración y Caracterización de Yogurt a base de pera (Pyrus communis) y aguaymanto (Physalis peruviana L.) Edulcorado con Stevia (Stevia rebaudiana Bertoni)*. Agroindustria y Seguridad Alimentaria.

Potter, N. N., and Hotchkiss, J. H. (1998). *La Ciencia de los alimentos*, ed S. Acribibia Zaragoza-España. Aspen Publ.

PROMPERU (2021). *Informe anual: Desenvolvimiento del Comercio Exterior Agroexportador 2020. Camu Camu en polvo, deshidratado, cápsulas y extracto*, 1–131. Available online at: https://recursos.exportemos.pe/Desenvolvimiento-comercio-exterior-agroexportador-2020.pdf (accessed August 20, 2022).

Qureshi, T. M., Nadeem, M., Maken, F., Tayyaba, A., Majeed, H., and Munir, M. (2020). Influence of ultrasound on the functional characteristics of indigenous varieties of mango (Mangifera indica L.). *Ultrason. Sonochem.* 64, 104987. doi: 10.1016/j.ultsonch.2020.104987

Rahmatuzzaman Rana, M., Babor, M., and Sabuz, A. A. (2021). Traceability of sweeteners in soy yogurt using linear discriminant analysis of physicochemical and sensory parameters. *J. Agric. Food Res.* 5, 1–7. doi: 10.1016/j.jafr.2021.100155

Rodrigues, L. M., Romanini, E. B., Silva, E., Pilau, E. J., da Costa, S. C., and Madrona, G. S. (2020). Camu-camu bioactive compounds extraction by ecofriendly sequential processes (ultrasound assisted extraction and reverse osmosis). *Ultrason. Sonochem.* 64, 105017. doi: 10.1016/j.ultsonch.2020.105017

Rowe, S., and Carr, A. C. (2020). Factors affecting Vitamin C status and prevalence of deficiency taa global health perspective. *Nutrients* 1, 1–19. doi: 10.3390/nu12071963

Salehi, F. (2021). Quality, physicochemical, and textural properties of dairy products containing fruits and vegetables : a review. *Food Sci. Nutr.* 9, 4666–4686. doi: 10.1002/fsn3.2430

Santhirasegaram, V., Razali, Z., George, D. S., and Somasundram, C. (2015). Comparison of UV-C treatment and thermal pasteurization on quality of Chokanan mango (Mangifera indica L.) juice. *Food Bioprod. Process.* 94, 313–321. doi: 10.1016/j.fbp.2014.03.011

Santos, I. L., Miranda, L. C. F., da Cruz Rodrigues, A. M., da Silva, L. H. M., and Amante, E. R. (2022). Camu-camu [Myrciaria dubia (HBK) McVaugh]: a review of properties and proposals of products for integral valorization of raw material. *Food Chem.* 372, 131290. doi: 10.1016/j.foodchem.2021.131290

Santos, R. L., Brandão, R. J., Nunes, G., Duarte, C. R., and Barrozo, M. A. S. (2021). Analysis of particles collisions in a newly designed rotating dryer and its impact on the Camu-Camu (Myrciaria dubia) pulp drying. *Drying Technol.* 40, 2034–2045. doi: 10.1080/07373937.2021.1915795

Scott, D., Miller W., Jr, and Griffin, C. (2001). "Dermatoses of pet rodents, rabbits, and ferrets," in *Muller & Kirk's Small Animal Dermatology*, 1415–1458. doi: 10.1016/B978-0-7216-7618-0.50025-0

Senaka Ranadheera, C., Evans, C. A., Adams, M. C., and Baines, S. K. (2012). Probiotic viability and physico-chemical and sensory properties of plain and stirred fruit yogurts made from goat's milk. *Food Chem.* 135, 1411–1418. doi: 10.1016/j.foodchem.2012.06.025

Sigdel, A., Ojha, P., and Karki, T. B. (2018). Phytochemicals and syneresis of osmo- - dried mulberry incorporated yoghurt. *Food Sci. Nutr.* 6, 1045–1052. doi: 10.1002/fsn3.645

Singh, P., and Prasad, S. (2018). Determination of ascorbic acid and its influence on the bioavailability of iron, zinc and calcium in Fijian food samples. *Microchem. J.* 139, 119–124. doi: 10.1016/j.microc.2018.02.019

Sisagri, S., Cenagro, S., and Agrarias, D. R. (2020). Perfil productivo y competitivo de los principales cultivo del sector. *in Perfil productivo regional (Perú),* 1–2.

Sobczak, A., Marzena, D.-, Zabek, K., Micińsk, J., and Narwojsz, A. (2022). Effect of vitamin C fortification on the quality of cow's and goat's yoghurt. *Food Sci. Nutr.* 1–6. doi: 10.1002/fsn3.2959

Suri, S., Dutta, A., Chandra Shahi, N., Raghuvanshi, R. S., Singh, A., and Chopra, C. S. (2020). Numerical optimization of process parameters of ready-to-eat (RTE) iron rich extruded snacks for anemic population. *Lwt* 134, 110164. doi: 10.1016/j.lwt.2020.110164

Toapanta, J., and Arroyo, P. (2020). *Modelo canvas para empresa Yogurt-Za, en el sector de San Rafael-Cantón Rumiñahui* [Tesis de título, Instituto Superior Tecnológico Honorable Consejo Provincial de Pichincha].

Toh, J. W. T., and Wilson, R. B. (2020). Pathways of gastric carcinogenesis, helicobacter pylori virulence and interactions with antioxidant systems, Vitamin C and phytochemicals. *Int. J. Mol. Sci.* 21, 6451. doi: 10.3390/ijms21176451

Tveden-Nyborg, P., Vogt, L., Schjoldager, J. G., Jeannet, N., Hasselholt, S., Paidi, M. D., et al. (2012). Maternal vitamin C deficiency during pregnancy persistently impairs hippocampal neurogenesis in offspring of Guinea pigs. *PLoS ONE* 7, e48488. doi: 10.1371/journal.pone.0048488

Van Loo, E. J., Diem, M. N. H., Pieniak, Z., and Verbeke, W. (2013). Consumer attitudes, knowledge, and consumption of organic yogurt. *J. Dairy Sci.* 96, 2118–2129. doi: 10.3168/jds.2012-6262

Virgen-Ceceña, L. J., Anaya-Esparza, L. M., Coria-Téllez, A. V., García-Magaña, M. D. L., García-Galindo, H. S., Yahia, E., et al. (2019). Evaluation of nutritional characteristics and bioactive compounds of soursop-yoghurt and soursop-frozen dessert. *Food Sci. Biotechnol.* 28, 1337–1347. doi: 10.1007/s10068-019-00584-x

Wall-Medrano, A., Olivas-Aguirre, F. J., Ayala-Zavala, J. F., Domínguez-Avila, J. A., Gonzalez-Aguilar, G. A., Herrera-Cazares, L. A., et al. (2020). "Health benefits of mango by-products," in *Food Wastes and By-products: Nutraceutical and Health Potential* (John Wiley & Sons), 159–191. doi: 10.1002/9781119534167.ch6

Wang, W., Bao, Y., Hendricks, G. M., and Guo, M. (2012). Consistency, microstructure and probiotic survivability of goats' milk yoghurt using polymerized whey protein as a co-thickening agent. *Int. Dairy J.* 24, 113–119. doi: 10.1016/j.idairyj.2011.09.007

Xiong, Y., Rajoka, M. S. R., Mehwish, H. M., Zhang, M. X., Liang, N., Li, C., et al. (2021). Virucidal activity of Moringa A from Moringa oleifera seeds against Influenza A Viruses by regulating TFEB. *Int. Immunopharmacol.* 95, 107561. doi: 10.1016/j.intimp.2021.107561

Xiong, Y., Riaz Rajoka, M. S., Zhang, M. X., and He, Z. (2022). Isolation and identification of two new compounds from the seeds of Moringa oleifera and their antiviral and anti-inflammatory activities. *Nat. Prod. Res.* 36, 974–983. doi: 10.1080/14786419.2020.1851218

Yildiz, E., and Ozcan, T. (2019). Functional and textural properties of vegetable - fi bre enriched yoghurt. *Int. J. Dairy Technol.* 72, 199–207. doi: 10.1111/1471-0307.12566

Zhang, X., Liu, H., Hashimoto, K., Yuan, S., and Zhang, J. (2022). The gut – liver axis in sepsis: interaction mechanisms and therapeutic potential. *Crit. Care* 26, 1–14. doi: 10.1186/s13054-022-04090-1