



Factors influencing the processing of syrup from *Muntingia calabura* L. fruit supplemented with Red dragon fruit

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ABSTRACT

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*This study investigates the processing parameters influencing the quality of a functional syrup developed from *Muntingia calabura* fruit supplemented with red-fleshed dragon fruit (*Hylocereus polyrhizus*). The chemical composition analysis revealed that *M. calabura* is a rich source of Vitamin C (0.136%) , while Red dragon fruit provides significant levels of betacyanin (350 mg/L). Experimental results demonstrated that the mixing ratio of the two juices profoundly affects the product's profile; an increase in *M. calabura* proportion significantly enhanced viscosity and vitamin C content. Furthermore, the juice-to-water dilution ratio and total soluble solids (°Brix) were identified as critical factors for maintaining bioactive stability. A higher juice-to-water ratio (3:1) preserved the highest concentrations of betacyanin (8.36 mg/L) and vitamin C (0.0506%). While increasing the sweetness to 80°Brix resulted in maximum viscosity (4949.3 cP), it slightly reduced vitamin C levels due to processing intensity. These findings provide a technical basis for optimizing the production of a nutrient-dense beverage that leverages the antioxidant properties of tropical fruits.*

1. INTRODUCTION

M. calabura is a tropical species characterized by diverse therapeutic benefits derived from various plant parts, including the leaves, stems, bark, roots, and fruits (Nur et al., 2021a). The fruit of *M. calabura* has been extensively documented for its potent antioxidant (Nur et al.,

2022), antidiabetic, and anti-inflammatory activities (Sowmya and Arul, 2022). Furthermore, it exhibits antimicrobial (Cuadro Mogollón et al., 2018), anti-ulcer (Putri et al., 2021), immunomodulatory (Sujono et al., 2021), and photoprotective properties (Nur et al., 2021b). Recent investigations demonstrated that

the ethanolic extract of *M. calabura* fruit possesses skin-lightening activity through the inhibition of the tyrosinase enzyme. Additionally, it displays anti-aging effects by promoting the proliferation of normal fibroblast cells while simultaneously suppressing elastase and collagenase activities (Nur et al., 2021a, 2020; Nur et al., 2023; Nur et al., 2022). Its capacity to inhibit multiple skin-degrading enzymes positions *M. calabura* extract as a promising candidate for anti-aging skin formulations. These biological activities are attributed to the high antioxidant content, specifically its richness in flavonoids and phenolic compounds. Phytochemical profiling reveals that the ethanolic extract contains key bioactive constituents, including epicatechin, rutin, diosmin, luteolin, and a range of phenolic acids such as gentisic, p-hydroxybenzoic, vanillic, caffeic, p-coumaric, ferulic, sinapic, syringic, p-anisic, rosmarinic, and gallic acids (Lin et al., 2017a). Conventional thermal processing techniques, such as sterilization and concentration, exert profound and adverse impacts on the stability of nutritional compounds in fruit juices, notably in blueberries, strawberries, and blood oranges. To date, there is a paucity of research regarding the processing optimization of *M. calabura* syrup enriched with red dragon fruit. Red-fleshed dragon fruit (*Hylocereus polyrhizus*) is characterized by a rich proximate composition, including proteins, carbohydrates, lipids, and essential vitamins such as B1, B6, and C, alongside various minerals (Jalgaonkar et al., 2020). Beyond its primary nutritional value, this fruit is a significant source of bioactive phytochemicals, particularly phenolic compounds, flavonoids, and betacyanins (Ramli et al., 2014). Dragon fruit in

general, and the red-fleshed variety in particular, are highly regarded for their therapeutic potential in preventing inflammatory diseases and oxidative stress (Nishikito et al., 2023). Previous studies have also indicated that both the pericarp (peel) and the pulp of red dragon fruit are abundant in polyphenols, serving as potent antioxidant sources (Wu et al., 2006). Notably, the betacyanins present in the pulp have been shown to effectively inhibit the proliferation of cancer cells (Zou et al., 2005). Similar to other tropical fruits, red-fleshed dragon fruit contains a myriad of health-promoting compounds, among which natural pigments (such as betacyanins and carotenoids) play a pivotal role in determining both the functional and commercial value of the product. Consequently, this study aims to investigate the critical processing parameters to ensure a high-quality syrup product. The elevated sugar content in the syrup matrix serves to extend the shelf-life and effectively inhibit the degradation of betacyanins. Furthermore, *M. calabura* syrup supplemented with red dragon fruit can be reconstituted and consumed as a nutrient-dense fruit beverage.

2. MATERIALS AND METHODS

2.1 Materials

M. calabura fruits were collected from My Tho ward, Dong Thap province from September 2024 to January 2025. They were cleaned and stored at -5°C in the freezers until use for experiments in Food Technology Department, Tien Giang University. Red dragon fruits were purchased at CO.OPMART My Tho.

2.2 Preparation of yogurt samples

M. calabura fruit → Cleaning and washing → Freezing (-5°C) → Grinding with and peeled red

dragon fruit → Filtering → *M. calabura* fruit solution (A)

Red dragon fruit → Cleaning and washing → Grinding → Filtering → red dragon fruit solution (B)

Blending solutions (A) and (B) in the ratios 3:1, 2:1, 1:1, 1:2, and 1:3 → Adding water according to the ratio of fruit juice:water: 3:1, 2:1, 1:1, 1:2, and 1:3 with sugar (65, 70, 75, and 80°Brix) and citric acid (pH 4.0) → Filling in glass bottle → Sealing → Pasteurizing → Syrup

2.3 Determining the physicochemical properties

The moisture content (%) was determined using an infrared moisture analyzer (Model MX-50, A&D Company Ltd., Japan) with a weighing resolution of 0.001 g and a moisture precision of 0.1% for sample weights exceeding 1 g. The titratable acidity, expressed as the percentage of citric acid, was determined via acid-base titration using 0.1 N NaOH as the titrant. The calculations were performed using a conversion factor (K) of 0.0064, corresponding to the milliequivalent weight of citric acid. The pH measured directly in the yogurt curd using a digital pH meter (HI2210, Hanna, Romania) at room temperature. Total sugar and reducing sugar content (mg/100 g) was determined by the potassium ferricyanide method. The viscosity (expressed in cP) was determined using a Brookfield viscometer (DV1, Brookfield Ametek, USA) equipped with an s64 spindle at a rotational speed of 20 rpm. The total soluble solids content (°Brix) was measured using a handheld refractometer (Master Refractometer, Atago, Japan). The vitamin C (ascorbic acid) content (%) was quantified via titration with a 0.01 N iodine (I₂) solution. The titration process was performed until a persistent faint blue color

appeared, using starch as an internal indicator. The betacyanin content (mg/L) was determined according to the method described by Wong and Siow (2015) with minor modifications. The samples were diluted in a buffer solution consisting of 30 mL of 0.1 M citric acid and 70 mL of 0.2 M sodium phosphate (pH 6.5). Subsequently, the absorbance of the mixture was measured at a wavelength of 537 nm using a UV-Vis spectrophotometer (UH5300, Hitachi, Japan). The color parameters of the samples were measured using a Chroma Meter (CR-410, Konica Minolta, Japan).

2.4 Statistical analysis

All experimental data were subjected to statistical analysis using Statgraphics Centurion (version 19.2) and Microsoft Excel. One-way analysis of variance (ANOVA) followed by the Least Significant Difference (LSD) post-hoc test was employed to determine significant differences between treatment means. Statistical significance was evaluated at a 95% confidence level ($p < 0.05$).

3. RESULTS AND DISCUSSION

3.1 Chemical composition of raw materials

The primary physicochemical characteristics of the raw materials are fundamental in determining the nutritional profile and organoleptic properties of the final syrup. According to the data in Table 1, *M. calabura* fruit exhibits a relatively high vitamin C content (0.136%) and a total sugar concentration of 7.94 mg/100 g. Its pH of 5.2 suggests a low-acid profile, which necessitates acidification during processing to ensure microbial stability and flavor balance. The total sugar content in *M. calabura* fruit (7.52 g/100 g fresh weight, FW) was comparable to that of cherries (7.26 g/100 g

FW), blackberries (6.8 g/100 g FW), and raspberries (6.58g/100 g FW). However, this value was lower than the sugar levels found in grapes (22.71g/100 g FW), blueberries (17.29g/100 g FW), mulberries (11.61g/100g FW), and blackcurrants (9.85 g/100 g FW), while remaining higher than that of strawberries (3.62 g/100 g FW). Nevertheless, *M. calabura* exhibited a lower total fructooligosaccharide content (0.01 g/100 g FW) compared to the aforementioned fruits (Jovanovic-Malinovska et al., 2014). These ripe berries exhibit a distinct sweetness, attributed to their high total soluble solids content (10.24°Brix) and low titratable acidity (0.11 g citric acid per 100 g fruit; pH 5.64). In addition to their desirable flavor and color profiles, these fruits have been reported to provide essential nutrients, including carbohydrates (14.64%), proteins (2.64%), lipids (2.34%), dietary fibers (1.75%), and minerals (1.28%), with a relatively low overall caloric value (Pereira et al., 2016). Furthermore, they contain high levels of soluble phenolic compounds, predominantly phenolic acids and flavonoids (Lin et al., 2017a; Rotta et al., 2017). Phenolic-rich extracts from *M. calabura* fruit have demonstrated significant biological activities, such as antimicrobial activity against

foodborne pathogens (Sibi et al., 2013), antioxidant properties that inhibit human low-density lipoprotein (LDL) oxidation (Lin et al., 2017a), and anti-inflammatory effects in carrageenan-induced rat paw edema models (Gomathi et al., 2013) as well as against lipopolysaccharide-induced inflammatory mediators in macrophages (Lin et al., 2017a). Although *M. calabura* fruit is typically consumed fresh or processed at a domestic scale, it holds immense potential for industrial food applications and functional foods due to its favorable physicochemical properties and high antioxidant content (Lin et al., 2017b; Pereira et al., 2016). Nevertheless, literature regarding the comprehensive chemical composition of this berry remains scarce, whereas the scientific and industrial utilization of the fruit is fundamentally dependent on its compositional profile. In contrast, while red-fleshed dragon fruit contains significantly lower vitamin C (0.012%) and sugars (6.30 mg/100 g), it serves as a critical source of betacyanins, yielding a concentration of 350 mg/L. This high betacyanin content is essential for providing the natural vibrant red pigmentation and antioxidant functionality to the syrup, compensating for the lack of such pigments in the *M. calabura* fruit.

Table 1. Chemical composition of *M. calabura* fruit and red-fleshed dragon fruit

	Moisture (%)	Vitamin C (%)	pH	Brix	Total sugar content (mg/100g)	Reducing sugar (mg/100 g)	Betac- yanin (mg/L)
<i>M. calabura</i> fruit	81	0.136	5.2	11.3	7.94	7.40	-

Red-fleshed dragon fruit	85	0.012	4.5	10.2	6.30	6.05	50
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(Note: "-" "Not detected")

3.2 Effect of the mixing ratio of red dragon fruit and *M. calabura* fruit juices

The interaction between the two fruit juices significantly modulates the rheological and phytochemical properties of the syrup. As shown in Table 2, shifting the ratio from 3:1 (dragon fruit dominant) to 1:3 (*M. calabura* dominant) resulted in a substantial increase in viscosity from 279.68 cP to 762.33 cP. This trend is accompanied by a linear rise in vitamin C levels, peaking at 0.1459% in the 1:3 ratio, confirming

that *M. calabura* is the primary contributor of ascorbic acid in this matrix. Conversely, the betacyanin concentration plummeted from 7.97 mg/L to 2.30 mg/L as the proportion of dragon fruit decreased. Interestingly, despite the lower betacyanin levels, the 1:3 ratio exhibited the highest redness value ($a^*=1.83$), suggesting that the higher acidity or specific phytochemicals from the *M. calabura* extract may enhance the color expression or stability of the remaining pigments.

Table 2. Effect of the mixing ratio of red dragon fruit juice and *M. calabura* fruit juice on the quality of syrup product

Ratio (red-fleshed dragon fruit: <i>M. calabura</i> fruit)	Viscosity (cP)	Vitamin C (%)	Betacyanin (mg/L)	Color	
				L [*]	a [*]
3:1	279.68 ^a	0.0381 ^a	7.97 ^e	27.28 ^{ab}	1.21 ^a
2:1	404.33 ^b	0.0557 ^b	4.80 ^d	26.62 ^a	1.23 ^a
1:1	463.33 ^b	0.1019 ^c	4.42 ^c	27.17 ^{ab}	1.72 ^b
1:2	560.33 ^c	0.1166 ^d	3.41 ^b	26.45 ^a	1.41 ^{ab}
1:3	762.33 ^d	0.1459 ^e	2.30 ^a	27.80 ^b	1.83 ^b

3.3 Effect of the juice-to-water dilution ratio

The degree of dilution with water exerts a profound impact on the density of bioactive

compounds and the physical consistency of the product.

Table 3. Effect of the mixing ratio of juice and water on the quality of syrup product

Ratio of juice and water	Viscosity (cP)	Vitamin C (%)	Betacyanin (mg/L)	Color	
				L [*]	a [*]
3:1	3957.4 ^c	0.0506 ^c	8.36 ^d	27.18 ^{bc}	1.48 ^c
2:1	2563.1 ^d	0.0432 ^d	4.71 ^c	28.02 ^c	1.02 ^b

1:1	1604.6 ^c	0.0388 ^c	3.24 ^b	25.09 ^a	0.71 ^a
1:2	1257.9 ^b	0.022 ^b	1.15 ^a	26.09 ^{ab}	0.62 ^a
1:3	214.4 ^a	0.0095 ^a	1.12 ^a	26.12 ^{ab}	0.48 ^a

Data from Table 3 indicates that the highest concentration of juice (3:1 juice-to-water ratio) yields superior quality across all parameters, including the highest viscosity (3957.4 cP), vitamin C (0.0506%), and betacyanin content (8.36 mg/L). Increasing the water proportion led to a drastic decline in viscosity, dropping to 214.4 cP at a 1:3 ratio, which may negatively affect the "mouthfeel" expected of a syrup. Furthermore, the color intensity was significantly compromised at higher dilutions, with the redness (a^*) value falling from 1.48 to 0.48. These results demonstrate that a higher juice-to-water ratio is imperative to maintain the functional integrity and aesthetic appeal of the syrup.

3.4 Influence of total soluble solids (°Brix) on syrup quality

The adjustment of total soluble solids (°Brix) is a critical processing step for achieving the

desired shelf-life and structural stability. As the syrup concentration increased from 65 to 80 °Brix, there was a dramatic exponential rise in viscosity, reaching 4949.3 cP. This increase in sugar concentration appears to provide a protective effect for the betacyanin pigments, which showed a slight but statistically significant upward trend from 3.04 mg/L to 3.15 mg/L. This phenomenon is likely due to the reduction in water activity (a_w), which inhibits the degradative pathways of betacyanins. However, the vitamin C content decreased from 0.0601% to 0.0484% as Brix increased, possibly due to the prolonged thermal exposure required to achieve higher sugar concentrations. Despite the stability of the pigments, the a^* value decreased at 80°Brix, indicating that extremely high sugar concentrations might induce slight browning or alter the light reflectance of the syrup.

Table 4. The influence of Brix in blending on syrup product quality

Brix	Viscosity (cP)	Vitamin C (%)	Betacyanin (mg/L)	Color	
				L^*	a^*
65	1008.7 ^a	0.0601 ^c	3.04 ^a	27.95 ^b	0.82 ^b
70	1230.6 ^a	0.0564 ^b	3.08 ^b	25.22 ^a	0.64 ^b
75	2346.8 ^b	0.0542 ^b	3.11 ^c	26.05 ^a	0.36 ^a
80	4949.3 ^c	0.0484 ^a	3.15 ^d	26.16 ^a	0.31 ^a

4. CONCLUSION

The research successfully characterized the influence of formulation and processing variables on the quality of *M. calabura* syrup enriched with

red dragon fruit. The study established that the combination of these two fruits creates a complementary nutritional profile, effectively balancing the high vitamin C content found in *M.*

calabura (0.136%) with the potent betacyanin pigments (350 mg/L) and antioxidant properties of red dragon fruit. Specifically, a 1:3 mixing ratio of red dragon fruit to *M. calabura* juice was found to maximize vitamin C retention (0.1459%) and provide a robust viscosity (762.33 cP), though it yielded lower betacyanin levels compared to dragon fruit-dominant blends. Furthermore, the investigation into dilution effects revealed that a 3:1 juice-to-water ratio is essential for maintaining the functional integrity of the syrup, as higher dilution levels significantly degraded both color intensity and bioactive concentrations. Finally, adjusting the total soluble solids to higher levels, particularly 80°Brix, was shown to maximize product viscosity (4949.3 cP) and stabilize betacyanin pigments, although it resulted in a slight reduction in vitamin C content. In summary, by precisely controlling the blending ratios and concentration levels, it is possible to produce a high-quality, stable fruit syrup that serves as a nutrient-dense beverage.

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