RESEARCH PAPER

Development And Caracterization Of Natural Sweetener From *Muntingia Calabura* Berry

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ABSTRACT
Growing concerns about the health risks associated with synthetic sweeteners have increased demand for natural, plant-derived alternatives. This study developed a natural sweetener from *Muntingia calabura* L. (Jamaican cherry) fruits using two distinct methods: solvent extraction (acetone, TCA, ethanol) for analytical characterization and enzymatic clarification (pectinase 0.5% w/w, cellulase 0.3% w/w; pH 4.5–5.0, 45–50 °C) for edible product preparation. Ripe berries underwent mechanical crushing, magnetic stirring, sonication, enzymatic treatment, centrifugation and lyophilization to yield a purified powder. FTIR analysis confirmed the presence of carbohydrate-related functional groups, including O–H, C–H and C–O glycosidic vibrations, supporting the sugar-rich nature of the extract. The total soluble sugar content was 83.25 mg/mL, after correction for dilution, indicating adequate sweetness potential. Functional evaluation revealed strong antioxidant activity (DPPH, IC_{50} = 50.4 µg/mL) and notable anti-inflammatory activity (BSA assay, IC_{50} = 108.3 µg/mL), along with promising anti-diabetic potential. Sensory evaluation showed good acceptability in cookies, with scores for sweetness (7.2 ± 0.8), flavour (7.5 ± 0.7) and overall acceptability (7.3 ± 0.8), approaching sucrose controls (8.0 ± 0.5; $p < 0.05$). Lower acceptability in milk was observed because of colour changes. Overall, the results indicate that enzymatically extracted *Muntingia calabura* berry has strong potential as a functional plant-based natural sweetener. Further optimization and stability studies are recommended.

Key Words: *Muntingia Calabura*, berry, Natural Sweetener, Solvent Extractions, Enzymatic Extraction, Sensory Analysis.

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Introduction

Sweetness is one of the most appealing sensory attributes of food and often determines whether a product is accepted or rejected. Although many people consider natural sweeteners to be safe, excessive consumption of sweet foods remains a nutritional and health concern. In addition to providing sweetness, these compounds can influence the colour, flavour, texture and shelf life of food products. Sugar consumption has increased significantly in recent years(Grembecka 2015).

Sweeteners are generally classified according to their origin as natural or synthetic. Natural sweeteners are obtained from plant, fruit and animal sources. Sucrose is the most widely used table sugar and sweetening agent worldwide and it is a disaccharide (Popescu et al., 2025) (Popescu et al., 2025). Sweeteners can also be divided into nutritive and non-nutritive types. Nutritive or caloric sweeteners, typically derived from fruits, sugarcane and sugar beet, provide about four calories per gram. In contrast, non-nutritive or high-intensity sweeteners provide sweetness with little or no calories and do not produce a significant glycaemic response during metabolism (Varzakas et al., 2012).

Artificial sweeteners are food ingredients that mimic the flavour of sugar and are widely used as sugar substitutes. Consumers often choose products containing low-calorie sweeteners because they provide sweetness without the added calories (Chattopadhyay et al., 2014). However, recent evidence suggests that artificial sweeteners may affect digestion, nutrient absorption and metabolism and they may not produce satiety in the same way as sugar. Establishing clear causality in human studies is also difficult because these sweeteners may be present in non-edible products and are often consumed unknowingly (Pearlman et al., 2017). Although many artificial sweeteners are considered safe because they are not fully metabolized by the body, concerns remain regarding the possible harmful effects of their metabolites in experimental animals (Whitehouse et al., 2008).

Natural sweeteners are derived from sources such as honey, maple syrup, agave nectar, carob syrup, stevia and other plant-based materials. These products provide familiar and natural sources of sweetness and have long been used in many countries. Unlike refined sweeteners, many traditional sweeteners are consumed in their natural matrix with little or no processing. Although they still contain calories, they generally have a lower glycaemic impact than refined sugars (Bogdanov et al. 2008). In addition, natural sweeteners have attracted interest because they may support metabolic health, reduce weight gain and help control blood sugar levels.

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Their lower glycaemic potency also makes them suitable for low-glycaemic-index diets (Arshad et al., n.d.).
Muntingia calabura L., commonly known as Jamaican cherry, is an underutilized tropical fruit native to southern Mexico, tropical South America, Central America and the Caribbean. It is widely grown in warm regions of India and Southeast Asia, including Malaysia, Indonesia and the Philippines. The fruit is small, round, soft, juicy and has a sweet, musky, fig-like flavour (Morton 1987); (Mahmood et al. 2014). Its flavour is influenced by sugar content, tannins and phenolic compounds (Lesschaeve and Noble 2005). Fruit sweetness is mainly determined by sugars such as glucose, fructose and sucrose (Eskin 1990). Previous studies have shown that total sugar increases with fruit maturity (Nasution et al. 2022). Only fructose (0.68 g/100 g) was detected in unripe fruit (stage 1), fructose (4.51 g/100 g) and sucrose (3.56 g/100 g) were present in mid-ripe fruit (stage 2), while fructose (6.37 g/100 g), glucose (4.80 g/100 g) and sucrose (2.21 g/100 g) were found in mature fruit (stage 3), with ripe fruits additionally reported to contain high soluble solids and low titratable acidity, indicating strong sweetness potential. (G. A. Pereira et al. 2018).
In addition to its sweet taste, *Muntingia calabura* has been reported to contain bioactive compounds with various biological activities. The fruit and its extracts contain flavonoids, phenols, steroids, triterpenes, tannins, reducing sugars and saponins, while alkaloids are generally absent (Indriati et al. 2020). Traditional use of the plant includes treatment of stomach pain and other ailments. Several pharmacological properties, including anti-inflammatory, antipyretic, anti-ulcer, anti-diabetic, anti-hypertensive, cardioprotective, antibacterial, insecticidal and antioxidant activities, have been reported (Kuchekar et al. 2021) and (Saud et al., 2023).
Consumer demand is also shifting toward healthier, more natural and sustainable food ingredients. This trend has increased interest in natural sweeteners, especially among consumers who prefer simple ingredients and environmentally friendly products (Lloyd and Radeloff 2017). Although global sugar consumption has declined in some regions because of health concerns, demand continues to grow in developing countries and the market for natural sweeteners is expanding rapidly (Food 2019); (Benucci et al., 2025); (Van Laar et al., 2021)). Natural sweeteners also retain nutrients such as proteins, fibres, lipids and phytochemicals that are absent in refined sugars and many artificial sweeteners (Ozcan et al., 2007).
Therefore, the present study aimed to develop a natural sweetener from *Muntingia calabura* berry using solvent extraction and enzymatic extraction approaches and to evaluate its physicochemical, functional and sensory properties for potential food applications.

2. Materials and Methodology

2.1. Raw Materials Preparation

Fully ripened *Muntingia calabura* (Jamaican cherry) berries were collected from Hosur, India. The fruits were selected based on visual inspection for uniform maturity and absence of spoilage, mechanical damage and fungal contamination. Ethanol (99.9%, analytical grade), acetone (99.5%, HPLC grade), trichloroacetic acid (TCA, 20% w/v in acetone), a magnetic stirrer, centrifuge, hot air oven, refrigerator and lyophilizer were provided by Saveetha Dental College, Poonamallee, Chennai, for extraction and drying processes. The enzymes were procured from VJ Biotech, Coimbatore, Tamil Nadu, India.

2.2. Solvent Extraction Method (Trial I)

The extraction of natural sweetener from *Muntingia calabura* berries was carried out using a systematic procedure to isolate bioactive compounds while maintaining their natural stability and sweetness characteristics. Fresh berries were collected and weighed to obtain 50 g of sample material. The berries were washed thoroughly with running water to remove dust, dirt and surface impurities and then rinsed with distilled water. The cleaned berries were air-dried at room temperature to remove excess surface moisture.
The dried berries were transferred into a clean mortar and ground into a uniform slurry using a pestle. This mechanical disruption helped release intracellular contents, including natural sweetening components, phenolics and other soluble compounds. Then, 150 mL of distilled water was added to the slurry and mixed thoroughly to form a homogeneous blend. The slurry was transferred to a conical flask and stirred on a magnetic stirrer at 50°C for 30 min. This mild heating enhanced the extraction of water-soluble compounds without degrading heat-sensitive components.
After stirring, the mixture was cooled to room temperature and subjected to sonication using a digital ultrasonic cleaner at 50°C for 15 min. Sonication improved extraction efficiency by disrupting cell walls and increasing mass transfer between solid and liquid phases. The mixture was then centrifuged at 3000 rpm for 15 min. The supernatant containing soluble natural sweeteners was carefully collected, yielding approximately 140 mL of extract.
To remove proteins and interfering substances, the method of (Salminen and Alfthan 2008) was followed with slight modifications. A 10% TCA solution was prepared by dissolving 10 g of trichloroacetic acid in 50 mL of acetone in a dark glass bottle and the final volume was adjusted to 100 mL with acetone. Then, 50 mL of berry extract was mixed with 50 mL of the freshly prepared 10% TCA solution in a 1:1 ratio and stirred for 10 min without heating. The mixture was centrifuged again at 3000 rpm for 15 min and the supernatant was collected.
To remove residual TCA, acetone was added in a 1:1 ratio to the supernatant, mixed thoroughly and centrifuged again at 3000 rpm for 15 min. This washing step was repeated until all traces of TCA were removed. The purified sample was transferred to sterile tubes or a glass beaker.

The purified extract was placed in a desiccator to allow acetone to evaporate slowly under controlled conditions. After complete evaporation, the extract was concentrated and the final volume was approximately 76 mL. To achieve additional purification, 80% ethanol (v/v) was prepared and chilled at 4°C overnight. The chilled ethanol was added to the concentrated extract, mixed thoroughly and centrifuged at 3000–4000 rpm for 15 min. The clear supernatant was collected and heated in a water bath at 60°C to evaporate the ethanol.

After complete evaporation of ethanol, the concentrated extract was cooled to room temperature, then deep-frozen at –15°C to –20°C and lyophilized to obtain a dry powder. The lyophilized material was subsequently dried in a hot air oven at 50°C for 5–7 min to remove residual moisture, yielding a purified natural sweetener from *Muntingia calabura* berries.

2.3. Enzymatic Treated Extraction (Trial II)

The extraction of natural sweetener from *Muntingia calabura* berries was performed using a controlled enzymatic method to maximize the yield of soluble sugars while reducing bitterness and structural polysaccharides. Initially, 300 g of fresh and mature berries were collected and weighed accurately. The berries were selected based on uniform ripeness and absence of physical damage. They were washed under running tap water to remove dust and extraneous materials and then rinsed with distilled water. The washed berries were air-dried at room temperature to remove excess moisture.

To reduce bitterness from the outer layer, the berries were peeled using sterile tools. This step minimized loss of edible portion while removing skin components that could adversely affect sensory quality. After peeling, approximately 250 g of usable berry material remained. The peeled berries were then ground in a clean mortar and pestle to form a uniform slurry. Next, 150 mL of distilled water was added and the mixture was stirred thoroughly to obtain a homogeneous suspension. The slurry was transferred to a conical flask and placed on a magnetic stirrer at 50°C for 30 min. This mild heating improved the extraction of water-soluble compounds, particularly sugars. After cooling to room temperature, the mixture was sonicated at 50°C for 15 min to enhance cell disruption and release intracellular soluble compounds. Enzymatic treatment was then carried out following the method of (Will and Dietrich 1994) with slight modifications. Cellulase and pectinase were added at 1.5 mL each. These enzymes degraded cellulose and pectin in the cell wall and middle lamella, thereby improving the release of trapped sugars. The mixture was stirred to ensure uniform enzyme distribution and then incubated in a water bath at 45°C for 2 h, which was considered optimal for enzyme activity.

After incubation, the enzymes were inactivated by heating the sample at 85°C for 5 min. The sample was then centrifuged at 5000 rpm for 15 min to separate solid residues from the liquid extract. The supernatant, rich in natural sugars and other soluble compounds, was collected carefully using sterile pipettes. To preserve the extract, the supernatant was deep-frozen at –15°C to –20° then lyophilized and subsequently dried in a hot air oven at 50°C for 5–7 min to remove residual moisture, yielding a purified natural sweetener from *Muntingia calabura* berries.

2.4. Physicochemical and Bioactive Analyses

Fourier Transform Infrared (FTIR) spectroscopy, antioxidant activity, anti-inflammatory activity, anti-diabetic activity and total sugar content were determined using standard methods described by(Dhaulaniya et al. 2020), (Baliyan et al. 2022), (Akat 2009), (Madhusudhan and Kirankumar 2018) and (DuBois et al. 1956), respectively. All analyses were conducted at Saveetha Dental College, Chennai, with technical support from the institution.

2.5. Sensory Evaluation

The enzymatically extracted Trial II sample was used as *Muntingia calabura* (MC) Sweetener for sensory evaluation. The solvent-extracted sample was not used for sensory analysis because residual chemicals may remain after extraction, making it unsuitable for direct human consumption. Therefore, it was used only for analytical purposes.

The extract was incorporated into food matrices as a topping for freshly baked cookies (10 g sugar per 100 g cookie) and as an additive in standardized cow milk (10 g per 200 mL). Sensory evaluation was conducted by 75 semi-trained panelists, including students and staff from the Department of Food Technology, Mahendra Engineering College, Namakkal, Tamil Nadu, India. Panelists evaluated sweetness intensity, aroma, taste, colour acceptability, mouthfeel and overall liking using a 9-point hedonic scale, where 1 = dislike extremely and 9 = like extremely. The evaluations were carried out under controlled conditions at 25°C using red lighting and coded samples in triplicate(Triandini et al., 2024; Fenga et al. 2026). The sensory data were analyzed using one-way ANOVA followed by Duncan's multiple range test at $p < 0.05$ using SPSS version 26.0.

3. Results

The enzymatic extraction method (Trial II) from *Muntingia calabura* berries outperformed the chemical solvent approach (Trial I), achieving a lyophilized yield of 8% compared with 5%, representing a 60% improvement. This increase was mainly due to cellulase and pectinase hydrolysis of the cell wall, which enhanced the release of soluble compounds. Processing time was also reduced from 10 days in Trial I to 3 days in Trial II because the enzymatic method required fewer purification steps. In addition, the enzymatic method was more cost-effective, with moderate cost compared with the high cost of the solvent-based method. Supernatant recovery after centrifugation was approximately 140 mL in Trial I, while a higher recovery was obtained in Trial II. Overall, the enzymatic process produced stable lyophilized powder and showed better suitability for scalable natural sweetener production (Table 1).

Table 1. Comparison Of Extraction Methods

Parameter	**Trial I (Solvent Extractions)**	**Trial II (Enzyme)**
Yield (%)	5	8
Processing Time	10 days	3 days
Cost	High	Moderate
Overall Efficiency	Low	Moderate

3.1. Sensory Performance in Cookies and Milk

Sensory evaluation of the MC sweetener showed good consumer acceptability in both food applications. In cookies containing 10 g/100 g dough, panelists scored sweetness intensity as 7.2 ± 0.8, aroma/flavour as 7.5 ± 0.7 and overall acceptability as 7.3 ± 0.8 on the 9-point hedonic scale. These scores indicate that the cookies were generally liked. When the extract was added to cow milk at 10 g/200 mL, the scores were slightly lower, with sweetness intensity at 6.9 ± 0.9, aroma/flavour at 6.8 ± 1.0 and overall acceptability at 6.9 ± 0.9. The lower score in milk was mainly due to colour changes caused by the extract. Sucrose controls received the highest scores, with overall acceptability of 8.0 ± 0.5. These results suggest that the MC sweetener was more acceptable in cookies than in milk (Table 2).

Table 2. Sensory evaluation scores (9-point hedonic scale) for enzymatic extract Muntingia calabura sweetener in food applications (n=75).

Attribute	**Cookies (topping)**	**Cow Milk (additive)**	**Sucrose Control**
Sweetness Intensity	7.2 ± 0.8a	6.9 ± 0.9b	8.1 ± 0.5a
Aroma/Flavor	7.5 ± 0.7a	6.8 ± 1.0b	7.8 ± 0.6a
Overall Acceptability	7.3 ± 0.8a	6.9 ± 0.9b	8.0 ± 0.5a
Colour Acceptability	7.1 ± 1.0a	6.5 ± 1.1c	7.9 ± 0.7a

3.2. FTIR Analysis

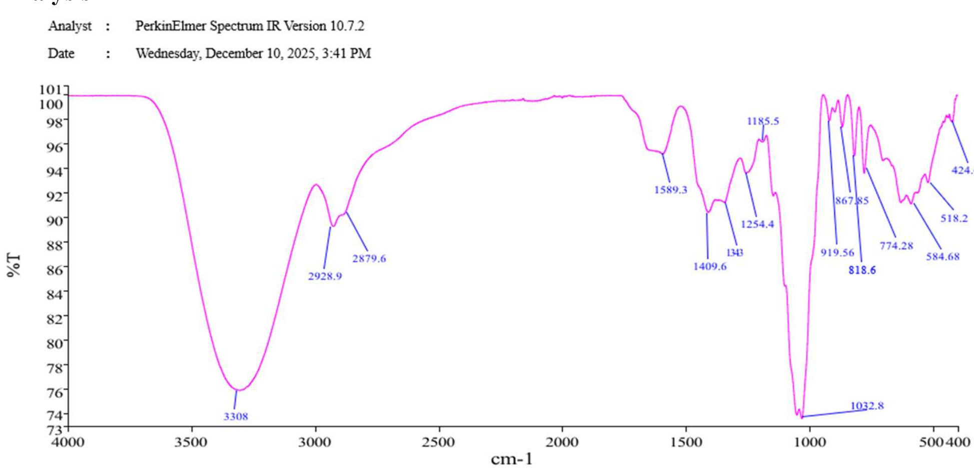

Fig 1. FTIR (Fourier-transform infrared) spectrum showing functional-group regions of the MC sweetener sample.

The FTIR spectrum of the MC sweetener showed clear evidence of carbohydrate-related functional groups (Fig 1). A broad peak at 3308 cm^{-1} indicated O–H stretching, while peaks at 2928 and 2879 cm^{-1} confirmed C–H stretching in carbohydrate-related compounds. The peaks at 1409 and 1343 cm^{-1} supported carbohydrate structure and the region between 1185 and 1032 cm^{-1} indicated C–O–C and C–O stretching, which are characteristic of glycosidic bonds. Additional peaks at 919, 867, 818 and 774 cm^{-1} corresponded to ring vibrations of cyclic sugar structures. The bands at 584, 518 and 424 cm^{-1} reflected the overall organic molecular framework. These results confirmed that the sample was rich in sugar-like compounds.

3.3. DPPH Radical Scavenging Activity

The DPPH radical scavenging activity of the MC sweetener increased in a concentration-dependent manner (Fig 2.A). At 50 µg/mL, the extract showed 49.75% inhibition, which increased to 52.7%, 55.17%, 58.62% and 68.47% at 100, 150, 200 and 250 µg/mL, respectively. The IC_{50} value was 50.4 µg/mL, indicating moderate to strong antioxidant activity. These findings suggest that the extract contains phenolic and/or flavonoid compounds capable of donating hydrogen or electrons to stabilize free radicals.

3.4. Anti-Inflammatory Activity

The MC sweetener showed a clear concentration-dependent anti-inflammatory effect in the BSA protein denaturation assay (Fig 2.B). Inhibition increased from 20.0% at 50 µg/mL to 37.5% at 100 µg/mL, 72.5% at 150 µg/mL, 85.0% at 200 µg/mL and 90.0% at 250 µg/mL. The IC_{50} value was 108.3 µg/mL, indicating appreciable anti-inflammatory potential. These results suggest that the extract can effectively protect against heat-induced protein denaturation.

3.5. Anti-Diabetic Activity

The α-amylase inhibitory activity of both acarbose and the MC sweetener increased with concentration, showing a dose-dependent response (Fig 2.C). At 10 µg, the MC sweetener showed 22.41% inhibition, which was higher than acarbose at 15.60%. However, at higher concentrations, acarbose showed stronger inhibition, reaching 90.26% at 50 µg, while the MC sweetener reached 67.81% at the same concentration. These results indicate that the extract has significant α-amylase inhibitory potential, although it remains lower than the standard drug at the highest dose.

3.6. Total Soluble Sugar Content

The total soluble sugar content of the MC sweetener was estimated using a glucose standard curve and spectrophotometric absorbance measurements (Fig 2.D). The blank showed an absorbance of 0.148, while glucose standards from 10 to 100 µg showed a gradual increase in absorbance from 0.171 to 0.352, indicating a suitable linear response. The sample absorbance was 0.341, which fell between the 80 µg standard (0.328) and the 90 µg standard (0.368). By linear interpolation, the sugar content of the sample was calculated as 83.25 µg in the diluted aliquot. After correcting for the 1000-fold dilution, the original sample concentration was 83.25 mg/mL. This result confirms that the MC sweetener extract contains a substantial amount of soluble sugars and has potential as a natural sweetening material.

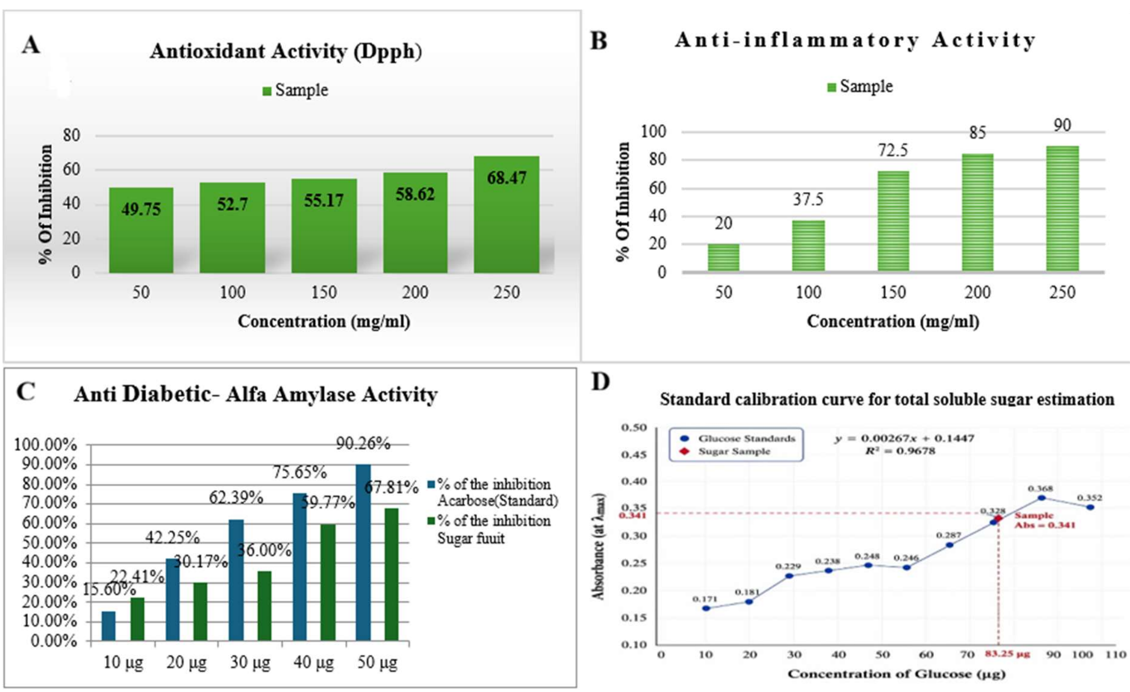

Fig 2. In vitro antioxidant, anti-inflammatory, antidiabetic activities and total sugar content of MC sweetener is shown as panels (A-D), respectively.

Eq. (1.A) Calculated sugar concentration in the sample (by linear interpolation between 80 µg and 90 µg) Using

$$C_{\text{sample}} = C_1 + \frac{A_{\text{sample}} - A_1}{A_2 - A_1} \times (C_2 - C_1)$$

with $C_1 = 80$, $A_1 = 0.328$, $C_2 = 90$, $A_2 = 0.368$ and $A_{\text{sample}} = 0.341$:

$$C_{\text{sample}} = 80 + \frac{0.341 - 0.328}{0.368 - 0.328} \times (90 - 80) = 80 + \frac{0.013}{0.040} \times 10 = 80 + 3.25 = 83.25\ \mu g$$

$$C_{\text{original}} = 83.25 \times 1000 = 83250\ \mu g/mL = 83.25\ mg/mL$$

Thus, the total soluble sugar content of the *Muntingia calabura* sweetener was 83.25 mg/mL after correction for a 1000-fold dilution.

4. Discussion

Muntingia calabura berries were selected for sweetener development because they are an underutilized fruit with a naturally sweet taste and reported health-promoting properties. In this study, the fruit was investigated as a potential source of natural sweetener with the aim of adding value to an inexpensive raw material while also developing a product with possible functional benefits. The compositional and biological results suggest that the berry extract contributes sweetness and may also exhibit antioxidant, anti-inflammatory and antidiabetic activities, making it a promising candidate for natural sweetener formulation.

The comparison of the two extraction trials highlights the different purposes of each method in the development of the *Muntingia calabura* sweetener. Trial I, based on solvent extraction, was mainly suitable for analytical characterization because it required multiple purification steps and involved greater time and solvent use. In contrast, Trial II was designed as a greener and more food-grade approach, using an enzyme-assisted method without chemical solvent influence to produce an edible sweetener. The higher yield and shorter processing time observed in Trial II suggest that cellulase and pectinase improved the release of soluble constituents from the fruit matrix, making this method more suitable for sustainable product development.

The enzymatically extracted MC sweetener showed moderate acceptability in cookies, with scores for sweetness, flavour and overall acceptability approaching those of sucrose controls. This may be attributed to the pleasant incorporation of the extract into the baked matrix, where heat-induced flavour development likely helped mask any undesirable notes. In milk, acceptability was lower, mainly because the extract caused visible colour changes that reduced consumer preference. These findings suggest that the sweetener is better suited for bakery applications than for clear dairy formulations, although further optimization of concentration and colour could improve its performance in beverages or milk-based products.

The FTIR spectrum confirmed the presence of sugar-related functional groups in the sweetener, as indicated by characteristic O–H, C–H and C–O/glycosidic vibrations typical of carbohydrates. These features support the sugar-based nature of the product and its potential as a natural sweetener. In addition, the DPPH assay showed strong antioxidant activity with concentration-dependent inhibition and an IC_{50} of 50.4 µg/mL, indicating good free-radical scavenging capacity. This is important because natural sweeteners with antioxidant properties may offer added health benefits beyond sweetness alone.

The BSA protein denaturation assay also showed increasing inhibition with concentration and an IC_{50} of 108.3 µg/mL, suggesting appreciable anti-inflammatory activity. The extract further displayed promising antidiabetic effects, indicating possible value in formulations intended to support glucose-related metabolic health. Together, these findings suggest that the *Muntingia calabura* extract may function not only as a sweetener but also as a bioactive ingredient with additional functional properties.

The total soluble sugar analysis confirmed substantial sugar content in the extract, supporting its suitability as a sweetening agent in beverages, syrups and other formulations requiring sweetness and acceptable mouthfeel. The corrected value should be stated as 83.25 mg/mL after correction for a 1000-fold dilution. The fruit also has potential for use in healthy beverage formulations, such as mocktails prepared with coconut water as a base and *Muntingia calabura* as a natural sweetener and flavour modifier. More broadly, the use of natural sweeteners in desserts, confectionery(Sahin et al. 2019; Campostrini et al. 2022), bakery products, beverages(Chen et al. 2022) and dairy foods(McCain et al., 2018) is contributing to market growth. Compared with refined sugars, many natural sweeteners offer lower glycaemic potency and retain additional nutrients and phytochemicals, which increases their appeal in health-oriented food products(Edwards et al. 2016).

Overall, the sensory and functional properties of *Muntingia calabura* fruit extract indicate strong potential as a natural sweetener. It is derived from an underused, low-cost fruit source and shows acceptable sweetness, flavour and bioactivity. Its antioxidant and anti-inflammatory properties further support its use as a health-oriented alternative to conventional sweeteners.

5. Conclusion

This study demonstrates the potential of Jamaican cherry as a novel source of plant-based natural sweetener with functional health benefits. Among the two extraction methods evaluated, enzymatic extraction using pectinase and cellulase proved more effective, yielding a higher recovery than the solvent-based method and making it more suitable for edible applications. The extracted sweetener showed significant in vitro biological activities, including antioxidant, anti-inflammatory and antidiabetic properties, indicating the presence of bioactive compounds with health-promoting potential.

Sensory evaluation confirmed acceptable organoleptic properties, including taste, colour and overall palatability, supporting its use as a sugar alternative. These findings suggest that the developed sweetener is suitable for partial sucrose replacement in thermally processed foods, with further optimization required for beverage applications. Importantly, the use of an underexploited fruit resource highlights the sustainability of this approach by contributing to biomass valorization and waste reduction.

Overall, *Muntingia calabura* extract shows strong promise as a functional and eco-friendly natural sweetener. Future studies should focus on detailed compound characterization, product optimization and in vivo validation to support industrial application.

CRediT authorship contribution statement

Subriya S: Writing –review & editing, Supervision, Conceptualization, Visualization, Formal analysis, Project administration. **Gugan A:** Writing – original draft, Investigation, Data curation, Formal analysis, Visualization, Writing – review & editing. **Saritha N:** Resources, Writing – original draft, Methodology, Writing – review & editing. **Elakiya M:** Investigation, Writing – review & editing. **Kavinesh M:** Investigation, Writing – review & editing. **Vasunthara E:** Writing – review & editing, Conceptualization, Supervision.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the author(s) used Chat GPT in order to edit and refine grammar and sentence structure. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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