

Development of Ice Cream Enriched with Copigmented Maoberry (*Antidesma bunius* (L.) Spreng.) Anthocyanins with Gum Arabic

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Abstract

This study aimed to develop a functional ice cream enriched with copigmented maoberry (*Antidesma bunius* (L.) Spreng.) anthocyanins stabilized with gum arabic and to evaluate its physicochemical and antioxidant properties. Copigmented anthocyanins were added to the ice cream mix at concentrations of 0-4% (w/w). The formulations were evaluated for pH, viscosity, overrun, color, melting rate, total anthocyanin content, and antioxidant activity. Addition at 1-3% enhanced viscosity, overrun, color intensity, and antioxidant activity, indicating improved stability and molecular interactions within the matrix. However, the 4% addition reduced both stability and antioxidant activity due to interactions among the ice cream components. The results show that moderate levels of copigmented anthocyanins improve texture, functionality, and nutritional quality, supporting the development of naturally colored, health-promoting dairy desserts.

Keywords: Anthocyanin, Copigment, Gum arabic, Ice cream, Maoberry

1. Introduction

Maoberry (*Antidesma bunius* (L.) Spreng.) is a native Thai fruit with high potential for application in the food industry, as it contains high levels of polyphenolic compounds, flavonoids, and especially anthocyanins (Ngamlerst et al., 2024). Anthocyanins are natural pigments that exhibit a reddish-purple color and demonstrate antioxidant activity, which helps reduce the risk of various chronic diseases, such as cardiovascular disease and cancer. However, anthocyanins have a major limitation in that they are unstable under environmental conditions such as heat, light, and pH. These factors can lead to color fading and deterioration in quality during food processing, particularly in products with high fat and protein content, such as ice cream.

Copigmentation is a process in which anthocyanins form complexes with copigments, such as phenolic acids or polysaccharides, enhancing the molecular stability of pigments and preventing their degradation during processing (Dara et al., 2024). Gum arabic is a natural polysaccharide that acts as a copigment to enhance the stability of the system and increase the viscosity of the product, thereby improving the texture and physicochemical quality of ice cream. Therefore, the development of anthocyanin-enriched ice cream from maoberry using copigmentation with gum arabic is of considerable significance in the food industry. In addition, this approach adds value to Thai indigenous fruits by creating naturally colored functional food products, reducing the use of synthetic colorants, and supporting the current trend toward sustainable and health-conscious food consumption.

1.1 Research Objective

The objective of this research was to investigate the effects of copigmented maoberry anthocyanins with gum arabic on the physicochemical and chemical properties of ice cream.

2. Methodology

2.1 Preparation of raw materials

Maoberries were obtained from Udon Thani Province, Thailand, during the harvesting period from July to August 2025. The fruits were thoroughly cleaned with tap water, rinsed with distilled water, air-dried at ambient temperature, packed in polyethylene bags, and stored at $-18\text{ }^{\circ}\text{C}$ until further use.

2.2 Anthocyanin extraction from maoberry

Anthocyanin extraction was conducted according to the method of Dara et al. (2023) with slight modifications. Briefly, maoberry fruits were ground and mixed with distilled water at a ratio of 1:1 (w/w). A pectinase enzyme solution (polygalacturonase) was added at a concentration of 0.2% (w/w). The mixture was agitated using a temperature-controlled orbital shaker (BSI Series Shaker, Beijing, China) at 150 rpm and $50\text{ }^{\circ}\text{C}$ for 2 h. The extracted anthocyanin solution was filtered through Whatman No. 1 filter paper to separate the solid residues from the liquid extract.

2.3 Copigmentation of Maoberry Anthocyanin

The extracted anthocyanin solution was mixed with gum arabic at a ratio of 4:1 (w/w) using a high-speed homogenizer (T25 digital ULTRA-TURRAX, IKA, Germany) at 5000 rpm. The resulting mixture was poured into stainless steel trays and pre-cooled at $-70\text{ }^{\circ}\text{C}$ in a freezer. Subsequently, the mixture was freeze-dried for 72 h, or until completely dry. The dried copigmented maoberry anthocyanins powder was then packed in aluminum foil bags and stored in $-18\text{ }^{\circ}\text{C}$.

2.4 Ice cream formulation and preparation

The formulation consisted of milk (78%), skimmed milk powder (7.5%), sucrose (14%), and stabilizer (0.5%). Copigmented maoberry anthocyanins were added into the ice cream formulations at concentrations of 1, 2, 3, and 4% (w/w), while the control sample was prepared

without (0%) their addition. All ingredients were pasteurized at 85 °C for 1 min, followed by immediate cooling in an ice-water bath at 40 °C. The yogurt starter culture (3.5% w/w) was then added, and the mixture was incubated in an incubator (HettCube 400R – IVDR, Hettich, Germany) at 43 °C for 14 h. After incubation, the mixture was homogenized using a food processor for 1 min. Ice cream was produced using a batch ice cream maker (Gelato Pro 2500, Nemox, Italy) for 12 min and subsequently stored in a freezer at –18 °C for 24 h.

2.5 Physicochemical properties of ice cream

2.5.1 pH

A digital pH meter (inoLab pH 7110, WTW, Germany) was used to measure the pH of the ice cream mixture at room temperature.

2.5.2 Color

The color of the ice cream samples was measured using a spectrophotometer (ColorQuest XE, HunterLab, USA) based on the CIELAB color systems. The color parameters L* (lightness), a* (redness/greenness), and b* (yellowness/blueness) were recorded.

2.5.3 Viscosity

The viscosity of the samples was measured using a viscometer (DV2T, AMETEK Brookfield, USA) equipped with a spindle no. of 21 at a temperature of 8°C. Each sample (10 mL) was placed in the measurement small sample adapter and tested at speeds of 120, 140, 160, 180, and 200 rpm for 1 min.

2.5.4 Overrun

The overrun was measured using a standard container by comparing the weights of the ice cream mix before freezing and the frozen ice cream (Moolwong et al., 2023). The overrun (%) was calculated using the Eq. 1:

$$\text{Overrun (\%)} = \left[\frac{\text{Weight of ice cream mix} - \text{Weight of ice cream}}{\text{Weight of ice cream}} \right] \times 100 \quad (1)$$

2.5.5 Melting rate

The melting rate of the ice cream samples was measured according to the method of BahramParvar & Goff (2013); Goh et al. (2008), with slight modifications. A 40 g ice cream sample stored at –20 °C was removed from its container and weighed. The sample was placed on a funnel and allowed to melt into an Erlenmeyer flask at 25 °C. The weight of the melted portion was recorded every 5 min for a total of 60 min. The relationship between melted portion weight and time was plotted, and the melting rate was determined from the slope of each melting curve.

2.6 Chemical properties of ice cream

2.6.1 Extraction of anthocyanin content

The anthocyanins were extracted from the dried copigmented maoberry by soaking 0.2 g in a 20 mL solution of 70% ethanol (v/v) and anthocyanins from ice cream with copigmented maoberry anthocyanins samples were used to take a sample of 10 grams of ice cream and soak in a 70% ethanol in a volume of 10 mL. The extractions were then performed with a bath ultrasonicator (Elmasonic P, Elma Schmidbauer GmbH, Singen, Germany) at 40 °C for 10 min. The resultant extract was filtered through Whatman No. 1 filter paper and stored at -18°C until further analysis.

2.6.2 Anthocyanin content

Total anthocyanin content was determined using a pH differential modified by Lee et al. (2005) with potassium chloride buffer (pH 1.0) and sodium acetate buffer (pH 4.5). The sample was diluted and analyzed in buffers with pH 1.0 and pH 4.5, respectively. Absorption values were recorded at wavelengths of 510 nm and 700 nm. Anthocyanin content was calculated in terms of cyanidin 3-glucoside equivalent, with a molar extinction coefficient of 26,000 and a molecular weight of 449.2. The results were reported in terms of micrograms per 100 grams of sample dry weight.

2.6.3 Antioxidant activity

Antioxidant activity measurements were performed using the DPPH (2,2-diphenyl-1-picrylhydrazyl) assay according to the method of Sayar et al. (2022) to evaluate the ability of samples to eliminate DPPH free radicals by measuring the absorption of sample solutions at a wavelength of 517 nm. The dried copigmented maoberry 0.01 g/mL and ice cream with copigmented maoberry anthocyanins 1 g/mL volume of 1 mL were mixed with a 1 mL solution of DPPH. The mixture is incubated at room temperature in a dark place for 30 minutes and the absorption value is measured, and then the % inhibition is calculated as shown in Eq 2.

$$\%Inhibition = \frac{A_{control} - A_{sample}}{A_{control}} \times 100 \quad (2)$$

where $A_{control}$ is the absorbance of the DPPH solution without extract, and A_{sample} is the absorbance of the reaction mixture with extract.

2.7 Statistical analysis

Statistical analysis was performed using a completely randomized design (CRD). Data were subjected to analysis of variance (ANOVA), and all measurements were conducted in triplicate. The results were expressed as mean \pm standard deviation (SD). Significant differences among the means were determined using Duncan's multiple range test at a 95% confidence level.

3. Results and Discussion

3.1 Physicochemical properties of ice cream

3.1.1 pH

The pH, viscosity, and overrun values of ice cream containing copigmented maoberry anthocyanins at different concentration levels are shown in Table 1. The results indicate that the pH values differed significantly among the formulations ($p \leq 0.05$). The control sample exhibited the highest pH value (4.53), while the 4% copigmented sample showed the lowest (4.23). There was no significant difference ($p > 0.05$) in pH between the formulations containing 1% and 2% copigmented maoberry anthocyanins. The pH value tended to decline with increasing concentrations of copigmented maoberry anthocyanins, suggesting that higher levels of these compounds contributed to greater acidity in the ice cream. This effect can be attributed to the natural sourness of maoberry, a berry-type fruit characterized by its acidity, which consequently led to a significant reduction in pH.

Table 1: pH, viscosity, overrun and melting rate of ice cream with copigmented maoberry anthocyanins

Formulation	pH	Viscosity (cP)	Overrun (%)	Melting rate (g/min)
0% (Control)	4.53 ± 0.02 ^a	134.17 ± 14.25 ^c	12.77 ± 0.02 ^d	1.38 ± 0.04 ^b
1%	4.45 ± 0.00 ^b	194.5 ± 3.46 ^b	20.89 ± 0.10 ^b	1.37 ± 0.09 ^b
2%	4.44 ± 0.00 ^b	183.93 ± 1.01 ^b	29.92 ± 1.06 ^a	1.38 ± 0.06 ^b
3%	4.36 ± 0.05 ^c	230.70 ± 7.49 ^a	11.69 ± 0.83 ^d	1.41 ± 0.11 ^b
4%	4.23 ± 0.00 ^d	125.2 ± 14.05 ^c	15.78 ± 0.87 ^c	1.56 ± 0.09 ^a

^{a-d} Different letters in the same column indicate significant differences ($p \leq 0.05$)

3.1.2 Viscosity

An increase in anthocyanin concentration from 1% to 3% resulted in an enhancement of viscosity, with the 3% formulation exhibiting the highest value. The addition of copigmented maoberry anthocyanins effectively enhanced the viscosity of the ice cream mix. The increase in viscosity may be attributed to the ability of polyphenolic compounds in anthocyanins to form hydrogen bonds and intermolecular interactions with proteins and polysaccharides within the system, which contribute to the structural integrity of the matrix. Dara et al. (2024) reported that the incorporation of barberry anthocyanins into ice cream formulations enhanced the mix viscosity, as polyphenolic compounds function as natural stabilizers that promote viscosity and stability. Nevertheless, excessive concentrations (e.g., 4%) were found to induce particle precipitation and weaken intermolecular interactions within the matrix, leading to a reduction in viscosity. This result corresponds to the study of Shamshad et al. (2023), who reported that the addition of purple carrot anthocyanins to ice cream reduced mix viscosity at higher concentrations (>2%) due to phase separation within the colloidal system.

3.1.3 Overrun

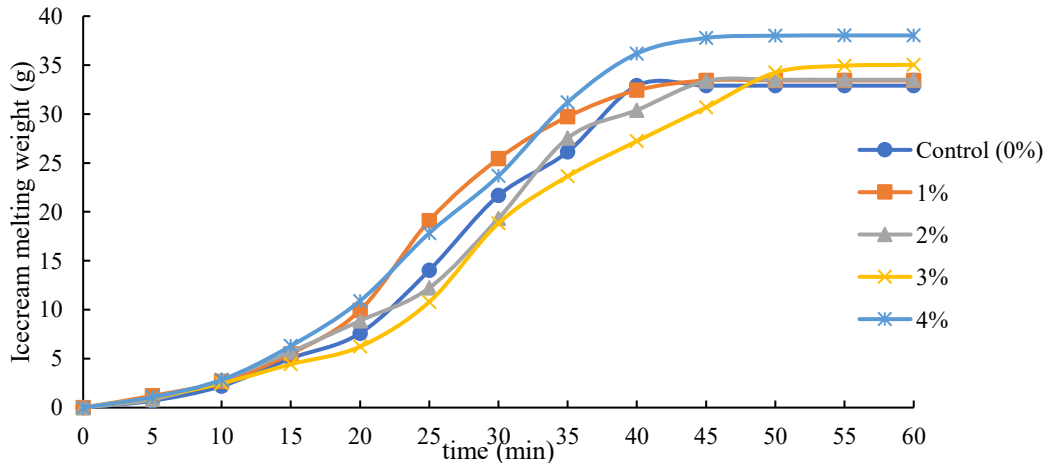
The addition of copigmented maoberry anthocyanins to ice cream increased overrun at concentrations of 1-2%; however, at higher concentrations (3-4%), pigment aggregation

occurred, reducing the foam stability of the system. Strekalova et al. (2022) reported that the incorporation of natural antioxidants into dairy products can influence the system's physical properties, including viscosity and air retention, which in turn are closely related to foam stability.

3.1.4 Melting rate

The changes in ice cream weight during melting are presented in Figure 1. The results indicated that the ice cream sample containing 4% copigmented maoberry anthocyanins exhibited a significantly different melting rate compared with the other formulations (0–3%). This finding suggests that the highest concentration of copigmented anthocyanins influenced the physical structure and shape-retention ability of the ice cream. This effect resulted from compositional and structural changes within the ice cream matrix, including alterations in fat destabilization, variations in overrun (air incorporation within the matrix), and differences in ice crystal size. These changes may also interfere with the functionality of stabilizers and emulsifiers, which are critical factors in determining melting behavior (Muse & Hartel, 2004). Moreover, the addition of concentrated phytochemicals may induce interactions between anthocyanins and proteins or carbohydrates in the formulation. These interactions can alter the water-binding capacity and mix viscosity, thereby influencing the melting characteristics of the final product (Shamshad et al., 2023; Markowska et al., 2023).

Figure 1: Changes in ice cream weight during melting



3.1.5 Color

The color of ice cream with copigmented maoberry anthocyanins is shown in Table 2. The results showed that the addition of copigmented maoberry anthocyanins significantly affected the color of the ice cream samples ($p \leq 0.05$) compared with the control sample. The lightness value (L^*) decreased significantly, indicating that the product became darker as the anthocyanin concentration increased. The redness value (a^*) increased with the addition of copigmented maoberry anthocyanins, demonstrating that anthocyanin addition enhanced the red color of the product. On the other hand, the yellowness value (b^*) decreased compared with the control, which altered the overall color tone of the ice cream from light yellow to reddish-purple.

Therefore, the addition of copigmented maoberry anthocyanins contributed to a darker and redder appearance of the product, while the lightness and yellowness decreased significantly. Anthocyanins are natural pigments classified within the flavonoid group, exhibiting colors that range from red to purple depending on the pH level (Castañeda-Ovando et al., 2009). The decrease in L* and b* values, together with an increase in a*, indicates a color transition toward a reddish-purple tone, which represents a distinctive characteristic of anthocyanins under the acidic conditions commonly found in fermented dairy products.

Table 2: Color of ice cream with copigmented maoberry anthocyanins

Formulation	L*	a*	b*
0% (Control)	87.99 ± 0.09 ^a	-1.43 ± 0.06 ^c	10.79 ± 0.06 ^a
1%	82.19 ± 0.03 ^b	1.62 ± 0.04 ^d	5.88 ± 0.09 ^b
2%	77.45 ± 0.04 ^c	3.5 ± 0.06 ^c	4.19 ± 0.07 ^c
3%	75.34 ± 0.10 ^d	4.15 ± 0.01 ^b	3.48 ± 0.01 ^d
4%	71.77 ± 0.08 ^e	4.84 ± 0.12 ^a	3.39 ± 0.18 ^d

^{a-e} Different letters in the same column indicate significant differences ($p \leq 0.05$)

3.2 Chemical properties of ice cream

3.2.1 Total anthocyanin content (TAC)

TAC and antioxidant activity ice cream with copigmented maoberry anthocyanins are presented in Table 4. The results revealed that when dried copigmented maoberry anthocyanins was added to the ice cream formulations, the formulations containing 3% and 4% showed the highest total phenolic content (TPC), at 56.59 ± 27.31 and 58.45 ± 5.57 $\mu\text{g}/100$ g, respectively, whereas the control sample exhibited no detectable TAC. These results indicate that the addition of anthocyanins from maoberry can effectively increase the amount of natural pigments in the product. This effect may be attributed to the copigmentation process, which helps prevent the degradation of anthocyanins under ice cream storage conditions. These findings are consistent with the results reported by Dara et al. (2024), who investigated the incorporation of copigmented barberry anthocyanins in ice cream formulations. Their study revealed that copigmentation improved the stability of anthocyanins and phenolic compounds.

3.2.2 Antioxidant activity

The addition of copigmented maoberry anthocyanins at concentrations of 1–3% resulted in an increase in % inhibition, whereas the formulation containing 4% exhibited a significant decrease ($p \leq 0.05$). These results suggest that the higher anthocyanin concentration (4%) may have induced chemical interactions with other components within the ice cream matrix. Markowska et al. (2023) reported that in ice cream systems, excessive incorporation of plant-derived antioxidants can alter the structure of the fat and protein matrix, promoting the retention of active compounds in the aqueous phase and consequently reducing their accessibility to the DPPH radical assay. Therefore, incorporating copigmented maoberry anthocyanins at low to moderate levels (approximately 1–3%) appears to represent the optimal range for enhancing the

nutritional and antioxidant properties of ice cream without compromising its structural integrity or physicochemical characteristics.

Table 4: Total anthocyanin content (TAC) and antioxidant activity ice cream with copigmented maoberry anthocyanins

Formulation	TAC ($\mu\text{g}/100\text{ g}$)	%Inhibition
0% (Control)	$0.00 \pm 0.00^{\text{d}}$	$76.63 \pm 1.41^{\text{b}}$
1%	$19.48 \pm 2.78^{\text{c}}$	$81.41 \pm 0.98^{\text{a}}$
2%	$44.53 \pm 7.36^{\text{b}}$	$80.21 \pm 1.33^{\text{a}}$
3%	$56.59 \pm 27.31^{\text{a}}$	$78.15 \pm 2.09^{\text{ab}}$
4%	$58.45 \pm 5.57^{\text{a}}$	$76.63 \pm 2.54^{\text{b}}$

^{a,d} Different letters in the same column indicate significant differences ($p \leq 0.05$)

5. Conclusion

This study demonstrates that copigmentation of maoberry anthocyanins with gum arabic effectively enhances both the stability and functionality of ice cream. The incorporation of copigmented maoberry anthocyanins at concentrations of 1–3% resulted in improved physicochemical and chemical properties, including increased viscosity, enhanced color intensity, and higher antioxidant activity, without compromising structural integrity. However, excessive addition at 4% resulted in reduced stability and lower antioxidant activity due to chemical interactions within the ice cream matrix. Overall, the results suggest that moderate levels of copigmented anthocyanins not only contribute to product quality and consumer acceptability but also support the development of functional ice cream with natural coloring and health-promoting properties.

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References

- BahramParvar, M., & Goff, H. D. (2013). Basil seed gum as a novel stabilizer for structure formation and reduction of ice recrystallization in ice cream, *Dairy Science & Technology*, 93, 273-285.
- Castañeda-Ovando, A., Pacheco-Hernández, M. de L., Páez-Hernández, M. E., Rodríguez, J. A., & Galán-Vidal, C. A. (2009). Chemical studies of anthocyanins: A review, *Food Chemistry*, 113(4), 859-871.
- Dara, A., Naji-Tabasi, S., Feizy, J., Fooladi, E., & Rafe, A. (2024). Exploring the potential utilization of copigmented barberry anthocyanins in ice cream: Focusing on foaming aspects and melting attributes, *Current Research in Food Science*, 9, 100811.
- Dara, K., Hosseini, S. F., & Khalesi, M. (2024). Exploring the potential utilization of copigmented barberry anthocyanins in ice cream: Focusing on foaming aspects and melting attributes, *Food Hydrocolloids*, 158, 110992.

- Goh, K. K., Nair, R. S., & Matia-Merino, L. (2008). Exploiting the functionality of lactic acid bacteria in ice cream, *Food Biophysics*, 3, 295-304.
- Lee, J., Durst, R. W., & Wrolstad, R. E. (2005). Determination of total monomeric anthocyanin pigment content of fruit juices, beverages, natural colorants, and wines by the pH differential method: collaborative study, *Journal of AOAC international*, 88 (5), 1269-1278.
- Markowska, J., Tyfa, A., Drabent, A., & Stepniak, A. (2023). The physicochemical properties and melting behavior of ice cream fortified with multiminerall preparation from red algae, *Foods*, 12(24), 4481.
- Moolwong, J., Klinthong, W., & Chuacharoen, T. (2023). Physicochemical properties, antioxidant Capacity, and consumer acceptability of ice cream incorporated with avocado (*Persea Americana* Mill.) Pulp, *Polish Journal of Food and Nutrition Sciences*, 73(3), 289-296.
- Muse, M. R., & Hartel, R. W. (2004). Ice Cream Structural Elements That Affect Melting Rate and Hardness. *Journal of Dairy Science*, 87 (1), 1-10.
- Ngamlerst, C., Kosum, S., Chomshome, N., Aukkanit, N., Kaewyai, K., Promyos, N. & Masavang, S. (2024). Development of Thai-taste maoberry (*Antidesma bunius* (L.) Spreng.) vegan sorbet from fruit of different maturities with added inulin: Physicochemical and antioxidant properties, *International Food Research Journal*, 31(2), 433 -442
- Sayar, E., Sengül, M., Ürkek, B. (2022). Antioxidant capacity and rheological, textural properties of ice cream produced from camel's milk with blueberry. *Journal of Food Processing and Preservation*, 46(3), e16346.
- Shamshad, A., Iathisham-Ul-Haq, Butt, M. S., Nayik, G. A., Al Obaid, S., Ansari, M. J., Karabagias, I. K., Sarwar, N., & Ramniwas, S. (2023). Effect of storage on physicochemical attributes of ice cream enriched with microencapsulated anthocyanins from black carrot, *Food Science & Nutrition*, 11, 3976-3988.
- Strekalova, T., Pavlov, D., Trofimov, A., Anthony, D. C., Svistunov, A., Proshin, A., Umriukhin, A., Lyundup, A., Lesch, K.-P., & Cespuglio, R. (2022). Hippocampal over-expression of cyclooxygenase-2 (COX-2) is associated with susceptibility to stress-induced anhedonia in mice, *International Journal of Molecular Sciences*, 23(4), 2061.