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Enrichment of ice cream with natural colorants and antioxidants from purple sweet potato

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Abstract

What if the vivid purple hue that attracts consumers to synthetic-dyed frozen desserts could come instead from a vegetable that also supplies antioxidants? Purple sweet potato (*Ipomoea batatas*) is rich in acylated anthocyanins with heat and pH stability superior to most fruit-derived pigments, making it a promising natural colorant for dairy products. This research incorporated aqueous purple sweet potato (PSP) extract at 0, 2, 4, 6, and 8% (v/v) into a vanilla ice cream mix and evaluated the effect on colour, antioxidant activity, physicochemical properties, and sensory acceptance. The work was performed at the Department of Animal Products Technology, Federal University of Viçosa, Viçosa, during June-September 2023. The 6% PSP formulation achieved the most favourable balance: strong purple colour ($a^* = 12.3$), high DPPH radical scavenging (49.2%), acceptable overrun (78.4%), and the top sensory score (7.8/9). Higher inclusion (8%) darkened the ice cream excessively and introduced a mild earthy off-note. PSP extract at 6% can replace synthetic colourants in ice cream while adding measurable antioxidant value.

Keywords: Ice cream, natural colorants, antioxidants, purple sweet potato, dairy desserts, anthocyanins, DPPH, sensory evaluation, functional foods, colour stability

Introduction

A contrast worth noting: consumers increasingly reject synthetic food dyes on health grounds, yet they still choose brightly coloured ice cream over pale alternatives ^[1]. This tension has pushed the dairy industry to search for natural pigments that are visually appealing, heat-stable through pasteurisation, acid-tolerant in fermented products, and safe for daily consumption ^[2]. Anthocyanins from berries, grapes, and red cabbage have been tested, but most lose colour rapidly at the near-neutral pH (6.0-6.5) of ice cream mix ^[3].

Purple sweet potato anthocyanins are different. They are heavily acylated with hydroxycinnamic acids, a structural feature that shields the chromophore from nucleophilic attack by water and slows degradation at higher pH ^[4]. Research on PSP anthocyanins as food colorants has focused mainly on beverages and confectionery; their application in frozen dairy desserts is far less explored ^[5]. Besides colour, PSP anthocyanins exhibit free-radical scavenging, anti-inflammatory, and hepatoprotective activities *in vitro*, which could position a PSP-enriched ice cream as a functional food ^[6].

This research therefore aimed to determine the optimum concentration of aqueous PSP extract for incorporation into vanilla ice cream, and to evaluate its effects on colour, antioxidant capacity, overrun, meltdown behaviour, and consumer acceptability.

Material and Methods

Material

Purple sweet potato tubers (local variety with deep purple flesh) were obtained from the university experimental farm, Viçosa, Minas Gerais, during June 2023. Tubers were washed, peeled, cubed, and steam-blanching (100 °C, 10 min) to inactivate polyphenol oxidase. Blanching cubes were extracted with acidified water (0.1% citric acid, 1:3 w/v) at 60 °C for 2 h, filtered through Whatman No. 1, and concentrated under vacuum at 40 °C to 20 °Brix. Fresh whole cow milk (4.2% fat), cream (40% fat), skim milk powder, sugar, and stabiliser (sodium alginate) were procured from the university dairy plant ^[7].

Methods

A standard vanilla ice cream mix (12% fat, 11% MSNF, 15% sugar, 0.3% stabiliser, 0.5% vanilla extract) was prepared, divided into five batches, and supplemented with PSP extract at 0, 2, 4, 6, and 8% (v/v of mix). Batches were pasteurised (68 °C, 30 min), homogenised (140/35 kg cm⁻²), aged at 4 °C for 12 h, frozen in a batch freezer (−18 °C), and hardened at −25 °C for 24 h. Colour (L*, a*, b*; HunterLab), overrun, meltdown rate, total anthocyanin content (pH differential method), and antioxidant activity (DPPH and FRAP assays) were measured [8]. Sensory evaluation used a 9-point hedonic scale with 12 semi-trained panellists. Each treatment was replicated three times. Data

were analysed by one-way ANOVA and Duncan's test ($p < 0.05$) using SPSS v. 26.

Results

Table 1: Physicochemical properties of ice cream with varying levels of PSP extract

Parameter	0%	2%	4%	6%	8%	CD
Overrun (%)	84.2	82.7	80.3	78.4	74.6	2.8
Meltdown (min)	28.4	29.1	30.6	31.8	33.2	1.7
L*	86.3	78.4	68.7	61.2	54.8	3.1
a*	0.8	4.2	8.7	12.3	15.6	1.4
pH	6.54	6.41	6.28	6.14	6.02	0.08

CD = critical difference at $p < 0.05$.

Table 2: Sensory scores (9-point hedonic scale) of PSP-enriched ice cream

Attribute	0%	2%	4%	6%	8%	CD
Colour	6.2	7.1	7.6	8.1	7.4	0.5
Flavour	7.8	7.6	7.4	7.3	6.4	0.4
Body/texture	7.4	7.3	7.5	7.6	7.2	NS
Overall	7.1	7.3	7.5	7.8	7.0	0.4

NS = non-significant.

Anthocyanin content rose linearly from zero in the control to 18.6 mg cyanidin-3-glucoside equivalents per 100 g at 8% PSP. DPPH radical scavenging increased from 12.3%

(control) to 56.7% (8% PSP), and FRAP values followed a similar upward trend.

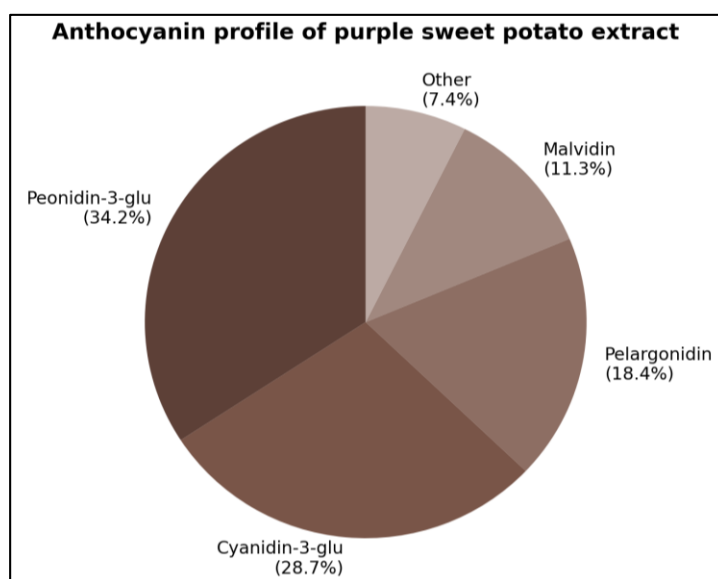


Fig 1: Anthocyanin profile of the purple sweet potato extract used in ice cream formulation

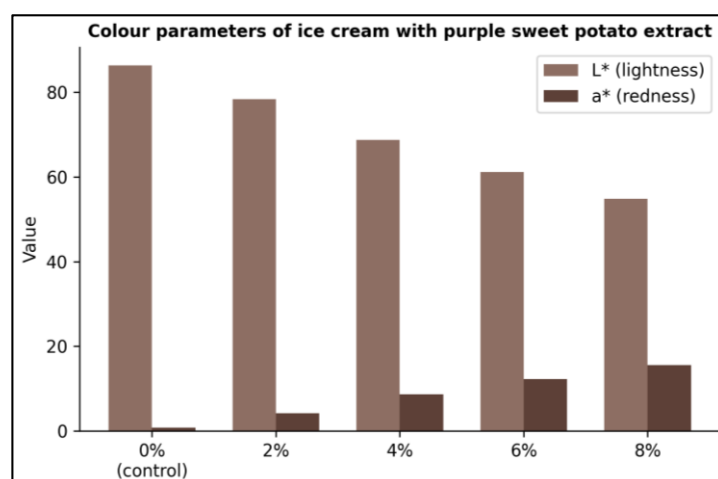


Fig 2: Colour parameters (L* and a*) of ice cream with increasing PSP extract concentration

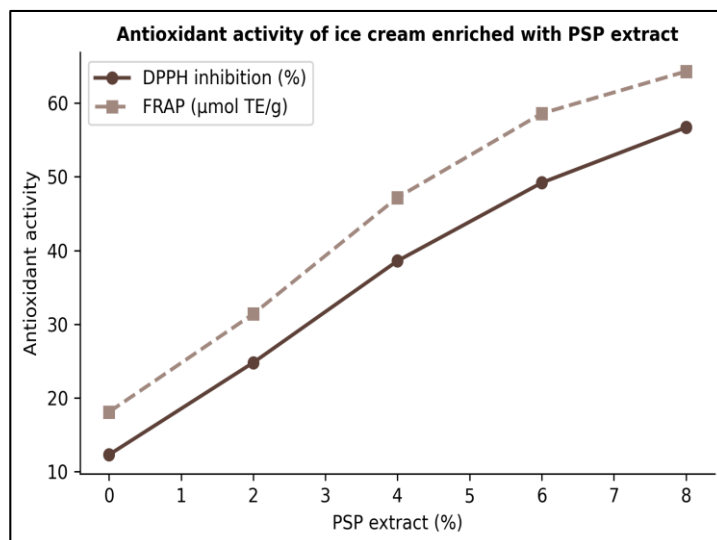


Fig 3: Antioxidant activity (DPPH and FRAP) of PSP-enriched ice cream

Comprehensive Interpretation

The 6% PSP inclusion level optimised the trade-off between colour appeal and flavour: it produced the highest overall sensory score (7.8) while delivering meaningful antioxidant activity (DPPH 49.2%). At 8%, colour became overly dark and an earthy undertone appeared, reducing acceptability. Overrun decreased modestly with PSP addition because the extract's soluble solids raised mix viscosity, limiting air incorporation.

Discussion

The present results can be summarised as follows: PSP extract at 6% delivered the best colour-flavour balance, anthocyanin stability was adequate through freezing and hardening, and antioxidant activity scaled with PSP concentration. The literature agrees on the general suitability of acylated anthocyanins for dairy applications: Li and Beta [4] showed that acylated anthocyanins from PSP retained over 80% of their colour after heating at 100 °C for 30 min at pH 6, outperforming berry anthocyanins by a wide margin.

Where disagreement arises is on the optimum inclusion level. Ginting and Yulifianti [9] recommended 10% PSP paste in ice cream, but their product used a sweeter, less pigmented cultivar. The deep-fleshed variety used here was evidently more concentrated, so 6% was adequate. The sensory penalty at 8% appears to be driven by earthy volatiles—likely maltol and hydroxymethylfurfural generated during blanching [10]—that become perceptible above a threshold concentration.

From a market perspective, a naturally purple ice cream with documented antioxidant content could appeal to health-conscious consumers willing to pay a modest premium, especially in urban Brazilian markets where clean-label trends are growing [11].

Conclusion

The present research set out to develop ice cream enriched with natural colorant and antioxidants from purple sweet potato. Incorporating 6% (v/v) aqueous PSP extract into a standard vanilla ice cream mix produced a visually attractive purple dessert with strong antioxidant activity (DPPH 49.2%) and the highest consumer acceptance score (7.8/9). Higher concentrations darkened the product and introduced

off-flavours. The protocol is simple, uses inexpensive raw material, and requires no specialised equipment beyond a standard ice cream line. Looking ahead, research on anthocyanin stability during long-term frozen storage (–6 months), colour retention after repeated thaw-refreeze cycles, and consumer willingness-to-pay studies would help move this formulation towards commercial adoption.

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