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Development of bael powder incorporated functional flavoured milk

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Abstract

Functional flavoured milk was developed by incorporating bael powder in milk. To determine the optimal formulation, levels of bael powder varying from 1-4 and sugar 7-9 percent was employed, using Response Surface Methodology a statistical tool. The optimization process was based on sensory characteristics such as colour and appearance, flavour, consistency/mouthfeel, sedimentation and overall acceptability of the product. RSM optimization yielded ideal proportions of 3.13 percent bael powder and 7.82 percent sugar. The formulation prepared using these optimized values were compared to control flavoured milk containing cocoa in place of bael powder. The experimental formulation had notably higher protein content (3.51%), titratable acidity (0.18%LA), viscosity (25.2 cP), tyrosine values (230.23 µg tyrosine/5 ml), DPPH radical scavenging activity (89.63 percent inhibition) and total phenolic content (1.32 mg GAE/g) compared with control flavoured milk sample. Sensory evaluations revealed that the bael enriched flavoured milk outperformed the control in overall acceptability.

Keywords: Bael, flavoured milk, antioxidant activity, DPPH

Introduction

Flavoured milk prepared by using natural ingredients is gaining popularity as a nutritious and refreshing beverage that combines the health benefits of milk with the therapeutic properties of various natural ingredients. Bael fruit holds significant potential in functional foods, as it can be used and processed into a variety of products such as preserves, murabba, wine, jam, slabs, powder and sherbet, syrup (Singh *et al.*, 2014) [20]. The bael pulp is particularly recognized for its strong laxative effect. It is widely used to treat gastrointestinal issues such as diarrhea, dysentery, and diabetes (Maity *et al.*, 2009) [13]. Additionally, bael has antibacterial, antifungal, anticancer, antipyretic, and analgesic properties and helps to relieve constipation (Patel *et al.*, 2012) [18]. The antioxidant properties of dried bael fruit powder have also been studied by Wijewardana *et al.* (2015) and evaluated its effectiveness in scavenging DPPH free radicals. Human's gastrointestinal infections are treated with the fruit pulp of *Aegle marmelos* (bael). Terpenoids, flavonoids, phenolic compounds, steroids, fat, lignin and oil, proteins, alkaloids, carbohydrates, cardiac glycosides, and flavonoids are all present in this fruit's pulp. Due to the presence of phytochemicals such as flavonoids and other polyphenolic components, it was discovered that the fruit pulp extract of bael had strong antioxidant qualities (Rajan *et al.*, 2011) [19].

The current study was focused on developing a flavoured milk containing bael powder to meet the growing demand for functional foods among health conscious consumers.

The primary objective is to determine the optimal levels of bael powder and sucrose using response surface methodology (RSM) to enhance sensory attributes and also to improve the nutritional content of the flavoured milk. Bael has an untapped prospective for processing because the good aroma of this fruit is not destroyed even during different processing techniques. By incorporating bael (*Aegle marmelos*) powder in flavoured milk, it can utilize the fruit's rich cultural heritage and nutritional potency to offer consumers a unique and health enhancing beverage option. Bael has a potential to address the demand for natural, plant-based ingredient in flavoured milk and it is a healthier alternative to artificial flavoured drinks. The incorporation of bael powder into milk lead to an increase in viscosity, which in turn contributed to improved mouthfeel and a richer sensory experience of the final product.

Materials and Methods

The bael enriched flavoured milk was formulated using toned milk (3.2% fat & 8.7% SNF) obtained from Vidya Dairy, Anand. Non-dairy ingredients included crystalline sugar of Madhur brand was procured from local market of Anand and tri sodium citrate from LOBA chemie was used. The flavoured milk was packed in sterilizable glass bottles (200 mL).

Preparation of flavoured milk: Toned milk was heated to 90°C for 10 minutes to stabilize the milk protein and then cooled to 60°C. Then the bael powder, sugar and tri-sodium citrate solution was added and properly mixed. The mixture was held for 30 minutes with frequent stirring to ensure proper dissolution. After that, homogenization was carried out and filled into 200 mL glass bottles and sealed with crown corks, followed by in-bottle sterilization at 115°C for 21 minutes. Finally, it was cooled and stored at room temperature.

Analysis of bael enriched flavoured milk: Toned milk and flavoured milk were analyzed for its titratable acidity (IS: SP-18, Part XI, 1981), fat, protein, total solids (FSSAI, 2022) [3], ash (IS 1479, Part-II-1961) and carbohydrate was calculated by difference. For flavoured milk, water activity, pH, viscosity (Jelena *et al.*, 2002) [9], total phenolic content (Beatrix *et al.*, 2023) [1], protein breakdown, in terms of tyrosine content (Park *et al.*, 2019) [17] and DPPH radical scavenging activity (McCune and Johns, 2002) [14] were also

analyzed. Aerobic plate count, coliform count, yeast and mold count (FSSAI, 2024) [4] and spore count (IS: 4238, 1967) was analyzed for microbial quality.

Sensory evaluation of bael enriched flavoured milk: The sensory evaluation of bael enriched flavoured milk was done by trained panel of 10 judges using a 9-point hedonic scale (Meilgaard *et al.*, 1999) [15].

Statistical analysis: Design Expert software was used for all statistical work including the selection of the number of trials and final analysis of the data generated. An advanced statistical software programme named RSM Design Expert 13.0.1.0 was employed in the study. RSM with central composite rotatable design (CCRD) for two variables was adopted to optimize the quantity of bael powder and sucrose in flavoured milk with respect to selected sensory responses. The optimized level of ingredients was then replicated seven times and actual values of sensory analysis was compared with predicated value.

Results and Discussion

Optimization of variables, bael powder and sucrose level using RSM thirteen experimental trials were conducted using a central composite rotatable design (CCRD) as delineated in Table 1. The responses in terms of sensory evaluation is recorded and presented in Table 1 and is discussed herein.

Table 1: Experimental design matrix and sensory attributes of bael enriched flavoured milk

Run	Ingredient		Sensory scores				
	Bael powder (%)	Sucrose (%)	Colour & Appearance	Flavour	Consistency/Mouthfeel	Sedimentation	Overall Acceptability
1	2.5	8	8.5	8.42	8.28	8.42	8.28
2	0.38	8	7.21	7.5	7.57	8.07	7.57
3	2.5	6.58	8.57	8.42	8.24	8.14	8.07
4	2.5	8	8.42	8.42	8.35	8.35	8.35
5	2.5	9.41	8.5	8.35	8.14	8.14	8.1
6	4	7	8.35	8.14	8.14	8.14	7.85
7	2.5	8	8.42	8.21	8.28	8.5	8.57
8	4	9	8.35	8.07	8	8.14	7.92
9	1	7	7.78	7.85	7.78	8	7.57
10	2.5	8	8.5	8.42	8.42	8.35	8.5
11	1	9	7.64	7.78	7.71	8.14	7.5
12	4.62	8	8.07	7.92	8	8.21	7.92
13	2.5	8	8.5	8.42	8.35	8.35	8.57

Effects on sensory parameters

The colour and appearance scores of flavoured milk, ranged from 7.21 to 8.57 (Table 1). The formulation with 2.50% bael powder and 6.58% sucrose received the highest score, while the one with 0.38% bael powder and 8.00% sucrose scored the lowest. The colour and appearance of the product were positively influenced by bael powder (A) ($p < 0.05$) and it had a non-significant negative influence of sucrose (B). The interactive effect of bael powder and sucrose (AB) had non-significant positive impact on colour and appearance. At quadratic level, bael powder (A^2) had negatively significant impact while sucrose (B^2) had non-significant negative impact on colour and appearance score (Table 2). Similar effect was found by Begum *et al.* (2024) [2] who developed functional ice cream by incorporating bael fruit (*Aegle marmelos*) pulp and found that increase in fruit pulp concentration (0-50%) had a positive effect on colour & appearance score. Similarly Navdeep *et al.* (2023) [16]

developed protein enriched whey-bael beverage and found that the increase in bael pulp concentration (6.0 to 14.0%) positively affected the colour & appearance score.

The flavour score of flavoured milk samples were observed in the range of 7.5 to 8.42 (Table 1). The formulation with 2.50% bael powder and 8.00% sucrose scored highest, while the one with 0.38% bael powder and 8.00% sucrose scored lowest among panellists. The flavour of the product were positively influenced by bael powder (A) ($p < 0.05$) and sucrose (B) had minimal non-significant negative influence. The interactive effect of bael powder and sucrose (AB) had a minor non-significant positive impacts on flavour score. At quadratic level, bael powder (A^2) had a significant negative impact and sucrose (B^2) had a non-significant negative impact on flavour score (Table 2). A similar trend was found by Begum *et al.* (2024) [2] who incorporated bael fruit (*Aegle Marmelos*) pulp into functional ice cream and observed that increasing in fruit pulp concentration (till 25

percent) had a positive effect on taste & smell score. Similarly Vipul *et al.* (2023) [21] developed value added products from bael powder such as bread, soup and sharbat and found that as increasing in bael powder (10 - 20%) concentration positively affected the flavour score.

The mouthfeel/consistency score of flavoured milk samples were observed in the range of 7.57 to 8.42 (Table 1). The formulation with 2.50% bael powder and 8.00% sucrose received the highest panelist score, while the one with 0.38% bael powder and 8.00% sucrose received the lowest. Mouthfeel/consistency were significantly ($p < 0.05$) enhanced by bael powder (A), highlighting its role in improving the thickness/viscosity of the product and it had non-significant negative influence of sucrose (B). The interactive effect of bael powder and sucrose (AB) had non-significant positive effect on this response. At quadratic level, bael powder (A^2) had a significant negative impact and sucrose (B^2) had a non-significant negative impact on consistency/mouthfeel score. Similar trend was reported by Begum *et al.* (2024) [2] who developed a functional ice cream by incorporating bael fruit (*Aegele Marmelos*) pulp and found that increase in fruit pulp concentration (till 25 percent) positively affected on texture score. Similarly Hitendra *et al.* (2016) developed basundi from admixture of whole milk and *Aegle marmelos* pulp and found that increase in bael pulp concentration (0-15%) positively affected the body and texture score.

The sedimentation score of flavoured milk samples were observed in the range of 8.00 to 8.42 (Table 1). The formulation with 2.50% bael powder and 8.00% sucrose received the highest panelist score, while the one with 1.00% bael powder and 7.00% sucrose received the lowest. Bael powder (A) affected the sedimentation score in a non-significant positive manner and sucrose (B) affected in a non-significant negative manner. While the interaction term (AB) contributed negatively to the sedimentation score. At quadratic level, both bael powder (A^2) and sucrose (B^2) had significant negative impact on sedimentation score (Table

2). The overall acceptability score of flavoured milk samples were observed in the range of 7.5 to 8.57 (Table 1). The formulation with 2.50% bael powder and 8.00% sucrose received the highest score from the panelists, while the one with 1.00% bael powder and 9.00% sucrose scored the lowest. Bael powder (A) affected the overall acceptability score in a non-significant positive way and sucrose (B) affected in a non-significant negative way. While interaction term (AB) showed a non-significant positive effect. At quadratic level, both bael powder (A^2) and sucrose (B^2) had significant negative impact on overall acceptability score (Table 2). Similar observations were reported by Begum *et al.* (2024) [2] for functional ice cream incorporating bael fruit (*Aegele Marmelos*) pulp and found that increase in fruit pulp concentration (till 25 percent) had a positive effect on overall acceptability score. Similarly Kaur *et al.* (2019) [11] developed burfi with carrot and bael pulp and found that increase in bael pulp concentration (40%) positively affected the overall acceptability score.

Regression analysis resulted in quadratic models for all sensory parameters: colour and appearance ($R^2=0.83$), flavour (0.93), consistency/mouthfeel (0.86), sedimentation (0.88), and overall acceptability (0.90). The high R^2 values indicate a strong correlation between the model and experimental data, reflecting good model predictability. The model F-values such as 6.87, 19.03, 8.76, 10.40 and 13.51 for colour and appearance, flavour, consistency/mouthfeel, sedimentation and overall acceptability respectively, were found to be significant, indicating that the model terms are statistically meaningful with a non-significant lack of fit, thus validating the model reliability. Adequate precision values, 9.53, 13.76, 9.67, 7.56 and 10.36 for colour and appearance, flavour, consistency/mouthfeel, sedimentation and overall acceptability respectively. Since AP values greater than 4 are considered desirable, the obtained values confirm that the model has an adequate signal-to-noise ratio and can be used to navigate the design space effectively.

Table 2: Regression coefficients for sensory scores

Terms	Sensory scores				
	Colour & appearance	Flavour	Consistency/ Mouthfeel	Sedimentation	Overall Acceptability
Intercept	8.42*	8.37*	8.31*	8.39*	8.43*
A: Bael Powder	0.361	0.147	0.221	0.0549*	0.106*
B: Sucrose	-0.123*	-0.041*	-0.107#	-0.003*	-0.012*
AB	0.133*	0.0001*	0.054*	-0.009*	0.041*
A^2	-0.411	-0.345	-0.318	-0.135	-0.370
B^2	-0.019 *	-0.022*	-0.109#	-0.144	-0.212
R^2	0.83	0.93	0.86	0.88	0.90
Model F-Value	6.87	19.03	8.76	10.40	13.51
APV	9.53	13.76	9.67	7.56	10.36
Suggested Model	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic

$p < 0.05$; $0.05 \leq p < 0.1$ -# ; $p \geq 0.1$ - *

APV= Adequate Precision Value, R^2 = Coefficient of determination

The regression equation for various responses like colour and appearance, flavour, consistency/mothfeel,

sedimentation and overall acceptability is presented in Table 3.

Table 3: Regression equations for predicting sensory

Property	Equation
Colour & appearance	$8.18122+0.444724A-0.030465B+0.088608AB-0.182602A^2-0.019633B^2$
Flavour	$6.09246+0.864966A+0.308865B+0.000074AB-0.153556A^2-0.021886B^2$
Consistency/mouthfeel	$1.62509+0.565217A+1.55517B+0.036245AB-0.141519A^2-0.109536B^2$
Sedimentation	$-1.41009+0.387917A+2.31971B-0.006289AB-0.060191A^2-0.144198B^2$
Overall acceptability	$-5.68760+0.674381A+3.30796B+0.027368AB-0.164504A^2-0.211794B^2$

The relationship of variables on sensory responses is also vividly demonstrated in the three-dimensional response surface plots (Figure1, a - e), which depicts the effect of

varying levels of levels of bael powder and sugar level on various responses under study.

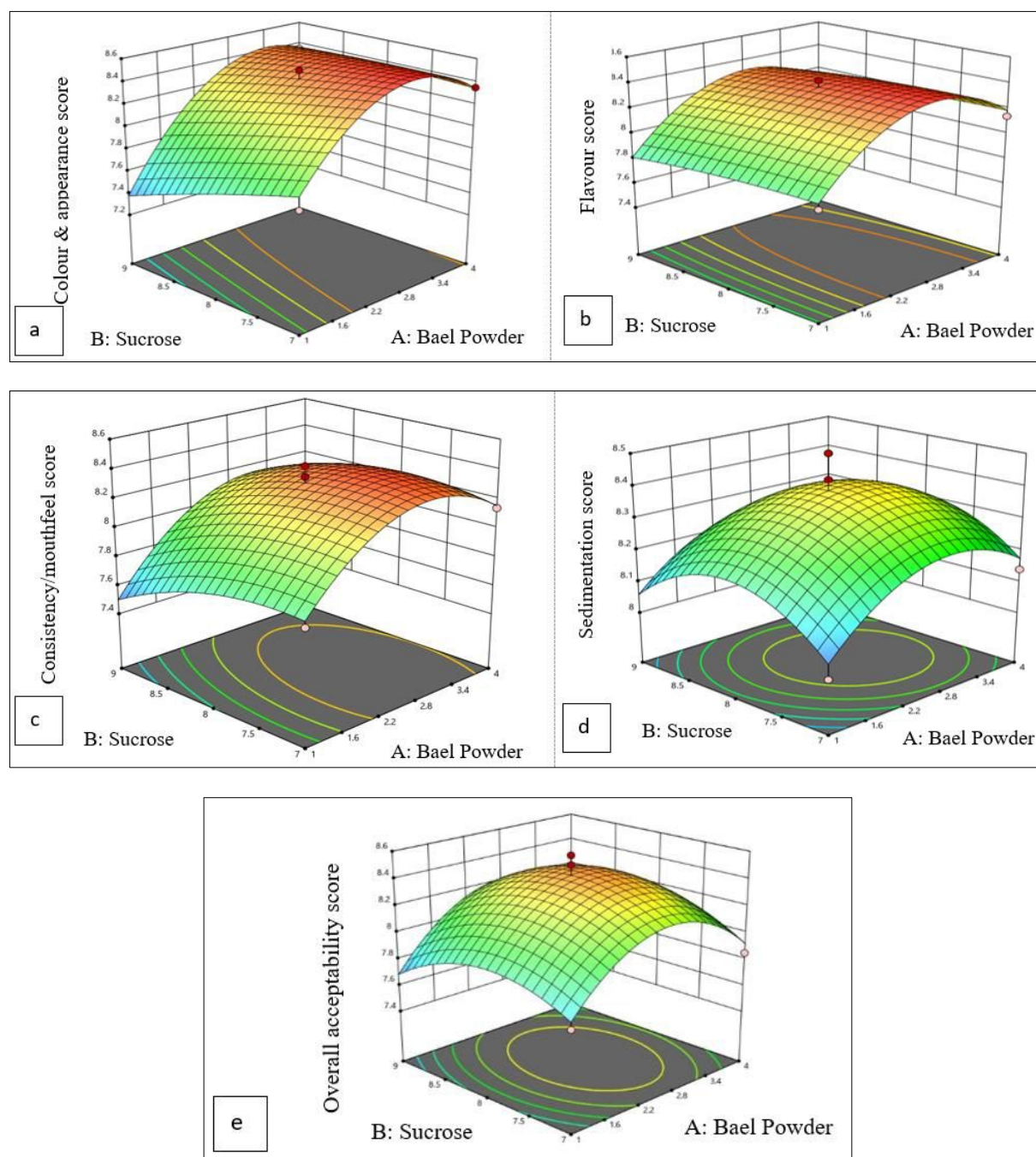


Fig 1: a: colour & appearance, b: flavour, c: consistency/mouthfeel, d: sedimentation, e: overall acceptability

Optimization of flavoured milk

The optimization of bael enriched flavoured milk was performed using numerical optimization techniques. For optimization, bael powder was set to be maximized, while sucrose was kept within the range, both having a level of importance of 3. Sensory attributes such as colour & appearance, flavour, consistency/mouthfeel, sedimentation and overall acceptability were also evaluated. Among these, flavour was given the highest importance level of 5, followed by consistency and overall acceptability (importance level 4) and then colour & appearance and sedimentation (importance level 3) (Table 4). The RSM suggested optimal levels of 3.13 percent bael powder and

7.82 percent sucrose, achieving a desirability of 0.86. Bael enriched flavoured milk was prepared by adding optimized level of bael powder and sucrose as suggested by RSM. The predicted values and actual values for colour and appearance, flavour, mouthfeel/consistency, sedimentation and overall acceptability were 8.51 & 8.55, 8.37 & 8.42, 8.36 & 8.38, 8.38 & 8.51 and 8.39 & 8.49 respectively. The observed values for these parameters were not significantly different from the predicted values, confirming that the suggested levels of bael powder and sucrose are optimal for achieving desirable sensory properties in the bael enriched flavoured milk.

Table 4: Criteria/responses chosen for optimization of bael enriched flavoured milk

Sr. No.	Parameter	Units	Goal	Lower Limit	Upper Limit	Level of Importance
1	A:Bael powder	percent	Maximize	1	4	3
2	B:Sucrose	percent	in range	7	9	3
3	Colour & Appearance	Out of 9	in range	7.21	8.57	3
4	Flavour	Out of 9	Maximize	7.5	8.42	5
5	Consistency/Mouthfeel	Out of 9	Maximize	7.41	8.42	4
6	Sedimentation	Out of 9	in range	8	8.5	3
7	Overall Acceptability	Out of 9	Maximize	7.57	8.57	4

Comparative analysis of bael enriched flavoured milk with control flavoured milk

The bael enriched flavoured milk (T₂) was analysed and compared with the control flavoured milk containing cocoa (1.5% cocoa powder, T₁) for its proximate composition, physico-chemical properties, sensory attributes and bio-functional properties. Results were statistically analysed using a completely randomized design (CRD) as shown in Table 5. Non-significant variation was observed in fat content, ash content and water activity between experimental (T₂) and control (T₁) sample. Higher protein content was observed in T₂ sample compared to T₁. It was obvious as bael powder contributed to protein content (10.85%). An increase in total solids and carbohydrate content was also recorded in T₂ and such effect was due to higher addition of bael powder (3.13%) compared to cocoa (1.5%). Viscosity was also higher in T₂ compared to T₁, contributed to improved mouthfeel which might be due to contribution of fiber from bael powder (11.36% crude fiber

in powder). A slight reduction in pH was observed in T₂ relative to T₁, while titratable acidity was marginally higher in T₂ than in T₁ which is due to contribution of acidic component of bael powder that had a lowered pH.

Bael incorporated flavoured milk (T₂) exhibited significantly higher DPPH radical scavenging activity compared to control sample (T₁), indicating enhanced antioxidant potential of bael powder. Additionally, total phenolic content was higher in T₂ than in T₁, reflecting improved functional quality. Tyrosine value, an indicator of proteolytic activity, was also elevated in T₂ relative to T₁ that could be due to higher phenolic content of bael compared to cocoa. Sensory evaluation revealed higher scores for T₂ in colour and appearance, flavour, consistency/mouthfeel, sedimentation, and overall acceptability, compared to T₁. Microbiologically, both the experimental and control samples showed no detectable aerobic plate count, coliform count, yeast and mold count and spore count.

Table 5: Proximate composition, physico-chemical, biofunctional, and sensory attributes of bael enriched flavoured milk and control flavoured milk

Parameters	Bael enriched flavoured milk	Control flavoured milk
Proximate composition		
Fat (percent)	3.2±0.05	3.25±0.06
Protein (percent)	3.51±0.06	3.2±0.03
Ash (percent)	0.87±0.05	0.81±0.08
Total solids (percent)	22.82±0.02	21.25±0.01
Carbohydrate (percent)	15.24±0.26	13.99±0.07
Physico-chemical properties		
Viscosity (cP)	25.2±0.03	15.2±0.05
Water activity	0.993±0.001	0.995±0.001
pH	6.39±0.02	6.45±0.03
Acidity (percent LA)	0.18±0.007	0.16±0.008
Biofunctional properties		
DPPH radical scavenging activity (percent inhibition)	89.63±0.45	75.15±0.48
Tyrosine value (µg tyrosine/5 ml)	230.23±0.72	55.36±0.85
Total phenolic content (mg GAE/g)	1.32±0.02	0.24±0.01
Sensory attributes (9 point hedonic scale)		
Colour & Appearance	8.65±0.29	8.15±0.30
Flavour	8.5±0.51	8.2±0.23
Consistency/Mouthfeel	8.63±0.21	8.39±0.20
Sedimentation	8.6±0.30	7.29±0.35
Overall acceptability	8.5±0.10	8.3±0.30

Values are mean±SD; n=7

Conclusion

A bael enriched flavoured milk was developed using response surface methodology (RSM), for the optimization of proportions of bael powder and sucrose to achieve a sensorially acceptable product. Bael powder showed a significant ($p<0.05$) positive effect on colour and appearance, flavour and consistency/mouthfeel score and non-significant positive effect on sedimentation and overall acceptability score. Based on these outcomes, software

suggested preparation of the bael enriched flavoured milk using 3.13 percent bael powder and 7.82 percent sugar. Developed flavoured milk incorporated with bael powder was having fat (3.20%), higher protein (3.51%) compared to regular flavoured milk, ash (0.87%), carbohydrate (15.24%) and total solids (22.82%) and had shelf life of 63 days when stored at room temperature. Bael enriched flavoured milk exhibited 19.26 percent higher DPPH radical scavenging activity and about 450 percent increase in total phenolic

content compared to control flavoured milk which indicates its superior antioxidant potential. This suggest that bael enriched flavoured milk can offer additional health benefits such as reducing oxidative stress and supporting overall wellness which can make it a functional dairy beverage with enhanced nutraceutical properties.

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