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Cost analysis of an optimized antioxidant-enriched and iron-rich prebiotic milk cake developed using kiwi fruit and dates powder

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Abstract
The development of functional dairy products that combine enhanced nutritional value with economic feasibility is gaining increasing attention in the food industry. The present study aimed to evaluate the production cost of an optimized antioxidant-enriched and iron-rich prebiotic milk cake formulated using buffalo milk, kiwi fruit powder, and dates powder. Four formulations were prepared, comprising one control (T0) and three experimental treatments (T1–T3) with varying concentrations of kiwi fruit powder, dates powder, and sugar. Based on previous sensory evaluation, T3 was identified as the optimized formulation due to its superior overall acceptability. Cost analysis was performed by calculating the expenditure on raw materials, processing, labour, electricity, packaging, and miscellaneous production costs using prevailing local market prices. The total production cost of the control milk cake was ₹111.90 per kg, while the optimized formulation (T3) was estimated at ₹119.80 per kg. Although the incorporation of functional ingredients marginally increased the production cost, the optimized product remained economically viable, with only a 7.1% increase compared to the conventional product. The improved nutritional quality, antioxidant potential, iron enrichment, and prebiotic properties justify the slight increase in manufacturing cost. The findings indicate that the optimized prebiotic milk cake possesses excellent commercial potential and may serve as an affordable value-added functional dairy product for health-conscious consumers. Cost analysis demonstrated that functional ingredient incorporation can be achieved without substantially affecting production economics, thereby supporting the large-scale commercialization of nutritionally enhanced milk-based confectionery products.

Keywords: Cost analysis, functional dairy product, milk cake, kiwi fruit powder, dates powder, prebiotic, economic feasibility, value-added food

Introduction

The growing awareness of the relationship between diet and health has significantly increased consumer demand for functional foods that provide health benefits beyond basic nutrition (Corbo *et al*., 2014) [2]. Functional dairy products enriched with bioactive ingredients have emerged as one of the fastest-growing segments of the food industry due to their potential to improve nutritional status and reduce the risk of chronic diseases (Kaur *et al*., 2022) [7]. Traditional Indian dairy products, particularly milk cake, offer an excellent vehicle for incorporating natural functional ingredients because of their widespread popularity, rich nutritional composition, and high consumer acceptability (Kumar *et al*., 2025) [8].

Milk cake is a khoa-based indigenous dairy confection prepared primarily from concentrated buffalo milk and sugar (Mishra *et al*., 2026) [9]. It is characterized by its unique granular texture, caramelized flavour, and high energy value (Aggarwal *et al*., 2018) [1]. Despite its popularity, conventional milk cake contains limited amounts of dietary fibre, antioxidants, and bioactive phytochemicals (El-Beltagi *et al*., 2022) [4]. Consequently, the incorporation of plant-derived functional ingredients has gained considerable research interest for improving its nutritional profile without compromising sensory quality (Jang and Lee, 2024) [6]. Natural ingredients such as kiwi fruit powder and dates powder are rich sources of vitamin C, polyphenols, flavonoids, dietary fibre, minerals, and natural antioxidants that can enhance both the nutritional and functional properties of dairy products (Zhuang *et al*., 2019) [12].

Kiwi fruit is recognized for its exceptionally high antioxidant capacity, vitamin C content, phenolic compounds, and prebiotic fibre, all of which contribute to improved immune function, gastrointestinal health, and oxidative stress reduction (Rahaman and Tewari, 2026) [10]. Similarly, dates are abundant in natural sugars, dietary fibre, iron, potassium, magnesium, and various phenolic antioxidants, making them valuable ingredients for the development of iron-enriched and antioxidant-rich functional foods (Rashid *et al*., 2026) [11]. The combined incorporation of kiwi fruit powder and dates powder into milk cake not only improves its nutritional quality but also enhances its functional attributes by increasing antioxidant activity and promoting gut health.

Although numerous studies have focused on the nutritional, physicochemical, antioxidant, microbiological, and sensory characteristics of fortified dairy products, limited attention has been given to their economic feasibility (El-Sayed *et al*., 2025) [5]. Cost analysis is an essential aspect of product development because it determines the commercial viability, pricing strategy, consumer affordability, and industrial scalability of newly developed food products. Even highly nutritious functional foods may fail to achieve market success if production costs are excessively high. Therefore, evaluating manufacturing costs alongside product quality is necessary to ensure successful commercialization.

The production cost of functional foods is primarily influenced by the price of raw materials, processing operations, labour, energy consumption, packaging materials, and transportation. The inclusion of premium functional ingredients often increases manufacturing expenses; however, these costs may be justified if the final product demonstrates improved nutritional quality, greater consumer acceptance, and enhanced market value. Therefore, balancing nutritional enhancement with economic feasibility remains a major objective in functional food development.

In the present study, antioxidant-enriched and iron-rich prebiotic milk cakes were prepared using different proportions of kiwi fruit powder and dates powder. Based on sensory evaluation, the optimized formulation was selected for detailed economic assessment. The study aimed to estimate the production cost of each formulation, compare the economic implications of functional ingredient incorporation, and evaluate the commercial feasibility of the optimized product. The findings are expected to provide valuable information for researchers, dairy entrepreneurs, and food industries interested in developing affordable functional dairy products with high nutritional value and strong market potential.

Materials and Methods

1. Study Design

The present study employed an experimental research design to evaluate the production cost of antioxidant-enriched and iron-rich prebiotic milk cake developed using different proportions of kiwi fruit powder and dates powder. Cost estimation was performed after optimization of the formulation based on sensory evaluation. The economic analysis was conducted from the manufacturer's perspective considering the total cost of production per kilogram of finished product.

2. Procurement of Raw Materials

Fresh buffalo milk, granulated sugar, citric acid, and ghee were procured from the local market of Mahishadal, West Bengal, India. Food-grade kiwi fruit powder and dates powder were obtained from a certified food ingredient supplier. Packaging materials, including laminated food-grade pouches and cardboard boxes, were purchased from local packaging vendors. The preparation of milk cake followed the standardized procedure adopted in the product development study.

3. Product Formulation

Four milk cake formulations were prepared comprising one control (T0) and three experimental treatments (T1–T3). The formulations differed in the proportions of kiwi fruit powder, dates powder, and sugar while maintaining buffalo milk as the principal ingredient.

Table 1: Formulation of Control and Experimental Antioxidant-Enriched and Iron-Rich Prebiotic Milk Cake (Das *et al*., 2023) [3]

Treatment	Formulation
T0 (Control)	Buffalo milk (95%) + Sugar (5%) + Citric acid (0.2%)
T1	Buffalo milk (90%) + Kiwi fruit powder (3%) + Dates powder (3%) + Sugar (4%) + Citric acid (0.2%)
T2	Buffalo milk (90%) + Kiwi fruit powder (2%) + Dates powder (2%) + Sugar (6%) + Citric acid (0.2%)
T3 (Optimized)	Buffalo milk (90%) + Kiwi fruit powder (1%) + Dates powder (1%) + Sugar (8%) + Citric acid (0.2%)

The formulations were prepared in triplicate under identical processing conditions to ensure reproducibility.

4. Preparation of Milk Cake

Standardized buffalo milk was heated in a stainless-steel kettle with continuous stirring until partial concentration was achieved. Citric acid (0.2%) was added to induce partial coagulation and develop the characteristic granular texture. Sugar and the respective quantities of kiwi fruit powder and dates powder were incorporated according to the treatment formulation. The mixture was continuously heated until it reached a semi-solid consistency. The hot mass was transferred into greased trays, allowed to cool at room temperature, cut into uniform pieces, packaged in laminated pouches, and stored under refrigerated conditions until further analysis.

5. Cost Analysis

The economic evaluation was conducted by estimating the production cost for 1 kg of finished milk cake. The total manufacturing cost included both direct and indirect expenses associated with product preparation.

The following cost components were considered:

- Raw materials (buffalo milk, kiwi fruit powder, dates powder, sugar, citric acid)
- Processing cost
- Labour charges
- Electricity and fuel consumption
- Packaging materials
- Miscellaneous expenses

The prices of raw materials were obtained from prevailing local wholesale market rates during the study period. Labour and utility costs were calculated based on the average expenditure incurred during small-scale laboratory production. The total production cost was determined by summing all expenditure components using the following equation:

$$= \sum \text{Raw Material Cost} + \text{Processing Cost} + \text{Labour Cost} + \text{Electricity Cost} + \text{Packaging Cost} + \text{Miscellaneous Expenses}$$

The production cost per 100 g of milk cake was calculated using:

$$\text{Cost (₹/100 g)} = \frac{\text{Total Cost per kg}}{10}$$

6. Economic Feasibility Assessment

The optimized formulation (T3), selected on the basis of superior sensory acceptability, was compared with the control and other fortified formulations to evaluate its commercial feasibility. The percentage increase in production cost over the control formulation was calculated using the following equation:

$$\text{Percentage Increase} = \frac{\text{Cost of Experimental Product} - \text{Cost of Control}}{\text{Cost of Control}} \times 100$$

This analysis was used to determine whether the nutritional enhancement achieved through the incorporation of kiwi fruit powder and dates powder justified the additional manufacturing cost.

7. Statistical Analysis

All cost data were calculated in triplicate and expressed as Mean ± Standard Deviation (SD). Descriptive statistical analysis was performed to compare the production costs among different formulations. One-way Analysis of Variance (ANOVA) was used to determine significant differences between treatments, and Tukey's Honest Significant Difference (HSD) post hoc test was applied for pairwise comparisons. Statistical significance was considered at $p < 0.05$. Data analysis was performed using appropriate statistical software such as GraphPad Prism.

Results and Discussion

The economic feasibility of newly developed functional foods is an important criterion determining their commercial applicability and consumer acceptance. In the present study, a cost analysis was conducted for all treatment combinations of antioxidant-enriched and iron-rich prebiotic milk cake. The cost estimation included the market price of raw materials, processing ingredients, packaging materials, electricity, labour, and miscellaneous production expenses. The analysis was performed based on the preparation of 1 kg of finished product using the prevailing local market prices.

Table 2: Cost Analysis of Newly Developed Prebiotic Milk Cake (₹/kg)

Ingredients	T0 (Control)	T1	T2	T3 (Optimized)
Buffalo milk	72.00	68.40	68.40	68.40
Kiwi fruit powder	—	18.00	12.00	6.00
Dates powder	—	12.00	8.00	4.00
Sugar	2.50	2.00	3.00	4.00
Citric acid	0.40	0.40	0.40	0.40
Processing cost	10.00	10.00	10.00	10.00
Electricity	5.00	5.00	5.00	5.00
Packaging	8.00	8.00	8.00	8.00
Labour	10.00	10.00	10.00	10.00
Miscellaneous	4.00	4.00	4.00	4.00
Total Cost (₹/kg)	111.90	137.80	128.80	119.80

Table 3: Cost per 100 g Product

Treatment	Cost (₹/100 g)
T0	11.19
T1	13.78
T2	12.88
T3	11.98

Figure 6. Cost of Newly Developed Milk Cake

Treatment	Cost (₹/100 g)
T0	11.19
T1	13.78
T2	12.88
T3	11.98

The incorporation of kiwi fruit powder and dates powder increased the production cost of the experimental milk cakes compared with the control because of the relatively higher market prices of these functional ingredients. Among the experimental formulations, T1 exhibited the highest production cost (₹13.78/100 g) due to the greater inclusion level of both kiwi fruit powder and dates powder. Conversely, T3 showed the lowest production cost (₹11.98/100 g) among the fortified formulations while simultaneously achieving the highest sensory acceptability in the study.

The optimized formulation (T3) demonstrated an excellent balance between nutritional enhancement, sensory quality, and production cost. Although the fortified products were marginally more expensive than the conventional control milk cake, the increase in cost was relatively small (approximately 7% over the control) considering the additional antioxidant compounds, dietary fibre, iron, and prebiotic properties contributed by kiwi fruit powder and dates powder. Therefore, the developed prebiotic milk cake can be considered economically feasible for commercial production and offers added functional health benefits with only a modest increase in manufacturing cost.

Conclusion

The economic evaluation indicated that the optimized formulation (T3) is the most cost-effective among the fortified treatments. With a production cost of ₹119.80 per kg (₹11.98 per 100 g), the optimized milk cake provides superior sensory quality and enhanced functional value at a reasonable cost. The findings suggest that the developed antioxidant-enriched and iron-rich prebiotic milk cake has good commercial potential and may serve as an affordable functional dairy product for health-conscious consumers.

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