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Development and quality evaluation of a hybrid dairy-peanut fermented product fortified with pomegranate peel powder

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Abstract

The present study aimed to develop a functional hybrid fermented milk by incorporating peanut milk and pomegranate peel powder (PPP) into cow milk and to evaluate its sensory, physicochemical, functional, microbiological, and storage characteristics. A formulation containing 70% cow milk and 30% peanut milk was selected based on sensory evaluation for further development. Hybrid fermented milk fortified with 0.5, 1.0, and 1.5% PPP showed no significant differences ($p > 0.05$) in sensory attributes, and the formulation containing 1.5% PPP was selected for further evaluation. Compared with control dahi, the optimized product exhibited significantly higher moisture, protein, ash, crude fibre, total phenolic content ($132.49 \pm 6.06 \mu\text{g GAE/g}$), and DPPH radical scavenging activity ($65.16 \pm 1.57\%$), while fat content and titratable acidity remained comparable. Both products were free from detectable coliforms, yeast, and moulds. During refrigerated storage, the optimized hybrid fermented milk showed slower post-acidification and better retention of sensory quality than the control, remaining acceptable for up to 12 days. The incorporation of peanut milk and pomegranate peel powder enhanced the nutritional, functional, and storage characteristics of fermented milk without compromising sensory acceptability, demonstrating its potential as a value-added functional dairy product.

Keywords: Hybrid fermented milk, functional dairy product, peanut milk, pomegranate peel powder, total phenolic content

Introduction

Fermented dairy products are recognized as important components of a healthy diet because of their high nutritional value, desirable sensory characteristics, and probiotic properties. Among these, dahi is one of the most widely consumed fermented milk products in South Asia and serves as an excellent carrier of viable lactic acid bacteria (LAB). The fermentation process enhances nutrient bioavailability, improves protein digestibility, promotes the production of bioactive peptides and organic acids, and contributes to improved gastrointestinal health, immune modulation, and antioxidant potential. Growing consumer awareness regarding the relationship between diet and health has accelerated the demand for functional fermented dairy products enriched with natural bioactive compounds, probiotics, prebiotics, and plant-derived ingredients that provide health benefits beyond basic nutrition [1-3].

The integration of plant-based ingredients with conventional dairy products has emerged as a promising strategy for developing sustainable and nutritionally enhanced functional foods. Hybrid dairy-plant products combine the superior sensory attributes and fermentation characteristics of dairy milk with the nutritional and functional advantages of plant-derived ingredients. Peanut (*Arachis hypogaea* L.) is an economical source of high-quality protein, unsaturated fatty acids, dietary fibre, vitamins, minerals, and several bioactive phytochemicals. Peanut milk has attracted considerable attention as a plant-based ingredient because of its balanced nutritional composition and its potential to improve the protein quality and lipid profile of fermented dairy products. Incorporation of peanut milk into fermented dairy formulations may therefore enhance their nutritional value while meeting the growing consumer demand for diversified and sustainable food products.

In recent years, agro-industrial fruit by-products have gained increasing importance as inexpensive and sustainable sources of functional ingredients. Among these, pomegranate (*Punica granatum* L.) peel, which accounts for nearly one-third of the total fruit weight, is particularly rich in dietary fibre, phenolic compounds, flavonoids, ellagitannins, and other bioactive phytochemicals possessing strong antioxidant and antimicrobial activities. Instead of being discarded as processing waste, pomegranate peel can be valorized as a natural functional ingredient in food products, thereby contributing to waste reduction and sustainable food production. Several studies have demonstrated that incorporation of pomegranate peel or its extracts into fermented milk products significantly improves antioxidant activity, enhances functional properties, and may contribute to better microbial stability during refrigerated storage [4,5].

Fruit processing by-products have also been recognized as promising functional ingredients for fermented dairy products because they supply dietary fibre and phenolic compounds that may act synergistically with probiotic microorganisms. Such ingredients can improve antioxidant capacity, enhance nutritional quality, and support the development of value-added dairy products with improved health-promoting properties. Furthermore, the utilization of fruit by-products aligns with the principles of the circular economy by reducing environmental pollution and promoting sustainable utilization of agricultural residues [6]. Although considerable research has been conducted on plant-based fermented beverages and functional dairy products enriched with fruit-derived bioactive compounds, information regarding the combined use of peanut milk and pomegranate peel powder in dahi is limited. The simultaneous incorporation of these ingredients is expected to provide complementary nutritional benefits by supplying dairy proteins, plant proteins, healthy lipids, dietary fibre, and natural antioxidants within a single fermented food matrix. Such a formulation may improve the nutritional quality and functional characteristics of dahi while maintaining desirable sensory properties.

Therefore, the present investigation was undertaken to develop a novel hybrid functional dahi by incorporating peanut milk and pomegranate peel powder into cow milk. The study aimed to standardize the formulation based on sensory evaluation and to evaluate the optimized product for its physicochemical, microbiological, and sensory characteristics. The developed product is expected to offer an innovative functional fermented dairy food with enhanced nutritional value, natural antioxidant potential, and improved sustainability through the utilization of plant-based ingredients and fruit processing by-products.

Materials

Fresh cow milk was procured from the livestock farm, Kerala Veterinary and Animal Sciences University, Wayanad. Whole peanuts (*Arachis hypogaea* L.) and fresh mature pomegranates (*Punica granatum* L.) were purchased from the local market. A commercial freeze-dried direct vat set yoghurt starter culture containing *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* was used for the preparation of the hybrid fermented product. The starter culture was procured from Novonesis, Bengaluru, Karnataka, India. All chemicals and

analytical-grade reagents used in the study were obtained from standard commercial suppliers.

Preparation of peanut milk

Cleaned peanut kernels were soaked overnight in potable water, manually dehulled, and thoroughly washed. The soaked kernels were blended with hot water in 1:10 (w/v) ratio to obtain a homogeneous slurry, which was filtered through a double-layer muslin cloth to separate the peanut milk. The extracted milk was heat-treated at 95 °C for 15 min to improve flavour and microbial safety, cooled to fermentation temperature, and used for formulation of hybrid fermented milk.

Preparation of pomegranate peel powder

Fresh pomegranate peels were separated manually, washed thoroughly with potable water, and cut into small pieces. The peels were dried in a hot air oven until constant weight was achieved and subsequently ground into a fine powder using a laboratory grinder. The powder was sieved through a fine mesh, packed in airtight containers, and stored under refrigerated conditions until further use.

Standardization of hybrid fermented milk

Initially, different proportions of cow milk and peanut milk were evaluated to identify the most acceptable formulation based on sensory quality. The optimized blend consisting of 70% cow milk and 30% peanut milk was selected for further fortification. Pomegranate peel powder was incorporated into the optimized milk blend at three different levels (0.5%, 1.0%, and 1.5%, w/v), while dahi prepared from 100% cow milk served as the control. The formulation exhibiting the highest overall sensory acceptability was selected for detailed physicochemical, microbiological, and storage studies.

Preparation of hybrid fermented milk

The standardized milk blend was heated to 90 °C for 10 min and cooled to 42 ± 1 °C. Pomegranate peel powder was incorporated into the milk before inoculation and mixed thoroughly to ensure uniform distribution. The mixture was inoculated with 2% DVS starter culture and incubated at 42 ± 1 °C until coagulation was achieved. The prepared fermented samples were immediately transferred to refrigerated storage (4 ± 1 °C) for subsequent analyses.

Physicochemical analysis

The developed fermented milk samples were analyzed for moisture, protein, fat, ash, and crude fibre contents following standard AOAC [7] procedures. Moisture content was determined by hot air oven drying, protein by the Kjeldahl method using a conversion factor of 6.38, fat by Soxhlet extraction, ash by dry ashing in a muffle furnace, and crude fibre by acid-alkali digestion.

The titratable acidity was determined by titration with 0.1 N sodium hydroxide and expressed as percentage lactic acid and syneresis was evaluated by the centrifugal method [8] and expressed as whey separation (mL/100 g).

Microbiological analysis

Microbiological quality was assessed by enumerating coliforms, yeasts, and moulds following the procedures specified in the FSSAI Manual of Methods of Analysis of

Foods: Microbiological Testing ^[9]. The results were expressed as log₁₀ colony-forming units per gram.

Sensory evaluation

Sensory evaluation was conducted using a panel of ten semi-trained members. Samples were coded and presented in random order under refrigerated conditions. Appearance, flavour, body and texture, consistency, and overall acceptability were evaluated using a nine-point hedonic scale, where 9 represented "like extremely" and 1 represented "dislike extremely." The formulation with the highest overall acceptability score was selected as the optimized product.

Preparation of Methanolic Extract

Methanolic extracts of the dahi samples were prepared following the method of Aniljith *et al* ^[10] with slight modifications. Briefly, 2 g of each dahi sample was mixed with 30 mL of aqueous methanol (70:30, v/v) and stirred continuously for 24 h at room temperature under dark conditions to minimize oxidation of phenolic compounds. The mixture was centrifuged at 4000 × g for 20 min, and the resulting supernatant was collected. The residue was re-extracted with a further 30 mL of aqueous methanol (70:30, v/v) under identical conditions. The supernatants from both extraction steps were pooled and used for the determination of total phenolic content and DPPH radical scavenging activity.

Determination of Total Phenolic Content (TPC)

The total phenolic content of the methanolic extracts was determined using the Folin-Ciocalteu colorimetric method as described by Qureshi *et al* ^[11]. Briefly, 0.5 mL of the extract was mixed with 0.5 mL of Folin-Ciocalteu reagent, followed by the addition of 4.0 mL of 1 M sodium carbonate solution. The reaction mixture was incubated in a water bath at 45 °C for 5 min and immediately cooled to room temperature. The absorbance was measured at 765 nm using a UV-Visible spectrophotometer against a reagent blank. Gallic acid was used as the standard for preparing the calibration curve, and the results were expressed as mg gallic acid equivalents (GAE) per g of sample.

Determination of DPPH Radical Scavenging Activity

The DPPH radical scavenging activity of the methanolic extracts was determined according to the method described by Aniljith *et al* ^[10]. Briefly, the DPPH reagent was prepared by dissolving 0.0004 g of DPPH in 100 mL of methanol. An aliquot (250 µL) of the sample extract was diluted with 2.25 mL of methanol, and 1.0 mL of the diluted extract was mixed with 1.0 mL of the freshly prepared DPPH solution. The reaction mixture was vortexed thoroughly and incubated at room temperature in the dark for 30 min. The absorbance was measured at 517 nm against a reagent blank using a UV-Visible spectrophotometer. The DPPH radical scavenging activity was calculated using the following equation:

$$\text{DPPH radical scavenging activity (\%)} = [(A_0 - A_s)/A_0] \times 100$$

where A_0 is the absorbance of the control and A_s is the absorbance of the sample.

Storage study

The optimized hybrid fermented product was stored at 4 ± 1 °C for 21 days. Samples were analyzed at predetermined intervals (0, 4, 8, 12, 16, and 21 days) to evaluate storage stability. Sensory characteristics and titratable acidity were assessed at each sampling interval to determine the shelf life of the product.

Statistical analysis

All experiments were carried out in triplicate unless otherwise stated, and the results were expressed as mean $\pm$ standard error. The experimental data were analyzed using one-way analysis of variance (ANOVA). Significant differences among treatment means were determined using an appropriate post hoc multiple comparison test at a significance level of $p < 0.05$.

Results

Selection of cow milk and peanut milk ratio

The sensory evaluation of dahi prepared using three different cow milk and peanut milk combinations (60:40, 70:30, and 80:20) revealed significant differences in consumer acceptability. The mean sensory scores for colour and appearance, flavour, body and texture, and overall acceptability are presented in Table 1.

Among the three formulations, the 70:30 cow milk:peanut milk ratio (T_2) obtained the highest mean scores for all sensory attributes evaluated. The mean scores for colour and appearance, flavour, body and texture, and overall acceptability were 8.12 ± 0.10 , 7.88 ± 0.18 , 8.25 ± 0.09 , and 8.30 ± 0.10 , respectively. The 60:40 formulation (T_1) recorded the lowest scores for most sensory parameters, whereas the 80:20 formulation (T_3) exhibited intermediate scores.

Statistical analysis indicated significant differences ($p < 0.05$) among the treatments for colour and appearance, flavour, body and texture, and overall acceptability. The T_2 formulation was significantly superior in colour and appearance, body and texture, and overall acceptability compared with T_1 and T_3 . For flavour, T_2 recorded a significantly higher score than T_1 , while T_3 did not differ significantly from either T_1 or T_2 .

Based on the sensory evaluation, the formulation containing 70% cow milk and 30% peanut milk (T_2) was selected for further development of the functional hybrid fermented milk.

Effect of pomegranate peel powder on sensory characteristics

The sensory characteristics of hybrid fermented milk fortified with different concentrations of pomegranate peel powder (PPP) are presented in Table 2. The incorporation of PPP at concentrations of 0.5%, 1.0%, and 1.5% did not significantly influence ($p > 0.05$) the sensory attributes of the product, including colour and appearance, flavour, body and texture, and overall acceptability. All formulations received high sensory scores, indicating good consumer acceptability irrespective of the level of PPP incorporation.

Among the fortified samples, the formulation containing 1.5% PPP (T_3) recorded sensory scores comparable to those of the control and other treatment groups, demonstrating that the addition of PPP up to this level did not adversely affect the organoleptic quality of the hybrid fermented milk. Since no significant reduction in sensory acceptability was

observed with increasing PPP concentration, the formulation containing 1.5% PPP was selected for subsequent physicochemical, antioxidant, microbiological, and storage studies owing to its higher level of functional fortification while maintaining desirable sensory characteristics.

Physicochemical, antioxidant and microbial characteristics of optimized hybrid fermented milk

The physicochemical, antioxidant and microbial characteristics of the optimized hybrid fermented milk and control dahi are presented in Table 3. Significant differences ($p < 0.05$) were observed between the optimized product and the control for several quality attributes.

The optimized hybrid fermented milk exhibited a significantly higher moisture content ($84.67 \pm 0.33\%$) than the control dahi ($83.90 \pm 0.12\%$). Similarly, the protein content of the optimized product ($3.34 \pm 0.07\%$) was significantly higher than that of the control ($2.41 \pm 0.08\%$). Ash content also increased significantly from $2.36 \pm 0.12\%$ in the control to $4.17 \pm 0.03\%$ in the optimized product ($p < 0.001$). Crude fibre was detected at a significantly higher level in the optimized hybrid fermented milk ($0.89 \pm 0.03\%$) compared to the control ($0.04 \pm 0.02\%$).

No significant differences were observed between the optimized product and the control with respect to fat content and titratable acidity. The fat content was $0.56 \pm 0.03\%$ in the optimized product and $0.48 \pm 0.03\%$ in the control, while the titratable acidity was $0.68 \pm 0.03\%$ and $0.64 \pm 0.03\%$ lactic acid, respectively.

The optimized hybrid fermented milk exhibited significantly higher syneresis (12.16 ± 0.03 mL/100 g) than the control dahi (11.91 ± 0.03 mL/100 g) ($p < 0.01$). A marked improvement in antioxidant properties was also observed, with the optimized product recording significantly higher total phenolic content (132.49 ± 6.06 µg GAE/g) and DPPH radical scavenging activity ($65.16 \pm 1.57\%$) compared with the control dahi, which showed values of 10.78 ± 0.56 µg GAE/g and $12.35 \pm 1.18\%$, respectively.

Microbiological analysis revealed that both the optimized hybrid fermented milk and the control dahi were free from detectable yeast and moulds and coliform bacteria, indicating satisfactory microbiological quality.

Storage stability of optimized hybrid fermented milk

The storage stability of the optimized hybrid fermented milk and control dahi was evaluated by monitoring changes in sensory characteristics and titratable acidity during refrigerated storage. The sensory scores for colour and appearance, flavour, body and texture, and overall acceptability gradually declined in both products with increasing storage duration (Figure 1). However, the optimized hybrid fermented milk consistently retained better sensory quality than the control during storage.

At the beginning of storage, both products received high sensory scores, indicating good initial acceptability. A gradual reduction in all sensory attributes was observed during refrigerated storage, which became more pronounced after the 12th day. The optimized hybrid fermented milk maintained overall acceptability scores of 8.0, 7.5, 7.5 and 7.5 on days 0, 4, 8 and 12, respectively, whereas the control recorded corresponding scores of 8.5, 8.0, 8.0 and 6.5. After the 12th day, a marked decline in sensory quality was observed in both products. On the 16th day, the overall acceptability of the optimized product decreased to 5.0,

while the control declined to 3.0, indicating deterioration in sensory quality. By the 21st day, both products exhibited poor sensory scores and were considered unacceptable for consumption.

The changes in titratable acidity during storage are presented in Figure 2. Titratable acidity increased progressively in both the optimized hybrid fermented milk and the control dahi throughout refrigerated storage. The acidity of the optimized product increased from 0.62% lactic acid on day 0 to 0.98% on day 21, whereas the control exhibited a greater increase from 0.64% to 1.18% during the same period. The slower increase in acidity observed in the optimized hybrid fermented milk indicates reduced post-acidification during storage compared with the control.

Based on the sensory evaluation, the optimized hybrid fermented milk remained acceptable for up to 12 days under refrigerated storage, after which a substantial decline in sensory quality was observed. The lower rate of acid development together with the retention of desirable sensory attributes suggests that the incorporation of peanut milk and pomegranate peel powder contributed to improved storage stability of the hybrid fermented milk.

Discussion

The superior sensory performance of the 70:30 cow milk:peanut milk formulation indicates that partial replacement of cow milk with peanut milk at an optimum level effectively preserves the characteristic sensory attributes of dahi while enhancing its overall acceptability. The balanced proportion of dairy and peanut milk likely contributed to a desirable appearance, pleasant flavour, and improved body and texture through favourable interactions between dairy and peanut proteins during fermentation. In contrast, increasing the proportion of peanut milk adversely affected sensory quality, possibly due to the more pronounced nutty flavour and changes in gel structure associated with plant proteins. Similar findings have been reported in recent studies on peanut-based and hybrid fermented milk products, where optimized levels of peanut milk incorporation improved sensory quality, whereas higher substitution levels reduced consumer acceptability [12].

The incorporation of pomegranate peel powder (PPP) up to 1.5% did not significantly influence the sensory characteristics of the hybrid fermented milk, indicating that functional fortification could be achieved without compromising consumer acceptability. The comparable scores obtained for colour and appearance, flavour, body and texture, and overall acceptability suggest that the level of PPP incorporated was well tolerated by the sensory panel. The mild colour and flavour imparted by PPP did not adversely affect the organoleptic properties of the product, demonstrating its suitability as a functional ingredient in fermented milk.

The findings of the present study are in agreement with those of Ibrahim *et al* [13], who reported that supplementation of bio-yoghurt with pomegranate peel at an appropriate level maintained high sensory acceptability while improving the functional and rheological properties of the product. Their study also demonstrated that low levels of pomegranate peel could be incorporated into fermented dairy products without negatively affecting consumer preference. Similarly, Chan *et al* [14] reported that fortification of *Lactobacillus acidophilus*-fermented milk

with pomegranate peel extracts enhanced the antioxidant potential of the product while maintaining acceptable sensory characteristics, indicating that pomegranate peel-derived bioactive compounds can be successfully incorporated into fermented milk without adversely affecting product quality.

The optimized hybrid fermented milk exhibited significantly higher protein, ash, crude fibre, total phenolic content, and antioxidant activity than the control dahi, demonstrating the nutritional and functional advantages of incorporating peanut milk and pomegranate peel powder into the formulation. The increase in protein content can be attributed to the complementary contribution of dairy and peanut proteins, while the higher ash and crude fibre contents reflect the mineral and dietary fibre content of peanut milk and pomegranate peel powder. Similar improvements in the nutritional composition of fermented dairy products fortified with dietary fibre and phenolic-rich ingredients have been reported by Mohamed *et al* [15] who observed enhanced physicochemical quality in yoghurt enriched with dietary fibre and phenolic compounds.

The comparable fat content and titratable acidity between the optimized product and the control indicate that partial substitution of cow milk with peanut milk and fortification with pomegranate peel powder did not adversely influence the fermentation process. Likewise, Ibrahim *et al* [13] reported that the incorporation of pomegranate peel into bio-yoghurt maintained normal acid development while improving the functional characteristics of the product. The slightly higher syneresis observed in the optimized product may be attributed to modifications in the gel network caused by the incorporation of plant-derived proteins and fibre, which can influence water retention in fermented milk systems. Similar observations have been reported for peanut milk yoghurt analogues, where plant proteins affected the structural characteristics of the fermented gel [12].

A substantial increase in total phenolic content and DPPH radical scavenging activity was observed in the optimized hybrid fermented milk, confirming the effectiveness of pomegranate peel powder as a natural source of bioactive compounds. Pomegranate peel is rich in ellagitannins, flavonoids, phenolic acids and other antioxidant phytochemicals, which contribute significantly to the antioxidant potential of functional foods. Fermentation may further enhance the availability of these compounds through microbial enzymatic activity. Similar increases in phenolic content and antioxidant activity have been reported in yoghurt fortified with pomegranate peel extracts [14,16], bio-yoghurt containing pomegranate peel [13], and functional yoghurt enriched with pomegranate peel powder, which also exhibited improved antimicrobial activity [17].

The findings of the present study are also consistent with recent investigations demonstrating that the incorporation of fruit peel-derived ingredients into fermented dairy products

enhances their functional value without compromising product quality. Zahid *et al* [18] reviewed the application of fruit peel powders in probiotic yoghurts and concluded that these by-products effectively improve antioxidant capacity and nutritional quality while maintaining acceptable sensory and physicochemical characteristics. Similarly, Ahmad *et al* [19] reported that apple peel polyphenol extract significantly enhanced the antioxidant properties of probiotic yoghurt, whereas a recent study on plant-based fermented yoghurt fortified with peach pomace also demonstrated improvements in phenolic content and antioxidant activity following fruit by-product incorporation.

The absence of detectable coliforms and yeasts and moulds in both the optimized hybrid fermented milk and the control dahi indicates satisfactory microbiological quality and hygienic processing conditions. The acidic environment created during fermentation, together with good manufacturing practices, likely inhibited the growth of spoilage and indicator microorganisms, ensuring the microbiological safety of the products.

The gradual decline in sensory attributes and the concurrent increase in titratable acidity observed during refrigerated storage are characteristic of fermented milk products and can be attributed to the continued metabolic activity of starter cultures, resulting in post-acidification, accumulation of organic acids, and subsequent deterioration of flavour, texture, and overall acceptability [20]. The optimized hybrid fermented milk exhibited better retention of sensory quality and a slower increase in acidity than the control throughout storage, indicating improved storage stability. This enhanced stability may be attributed to the incorporation of peanut milk and pomegranate peel powder, which altered the composition of the fermented matrix while enriching it with dietary fibre and phenolic compounds. Phenolic constituents from pomegranate are well recognized for their antioxidant properties, which help minimize oxidative changes associated with flavour deterioration, whereas dietary fibre can improve water-holding capacity and contribute to the maintenance of gel structure during storage. Similar improvements in the physicochemical, functional, and sensory properties of yoghurt enriched with pomegranate-derived ingredients have been reported by Golmakani *et al* [21]. Furthermore, recent reviews have highlighted that fortification of yoghurt with plant-derived bioactive ingredients can enhance antioxidant potential and storage stability when appropriately optimized [22]. Therefore, the slower post-acidification and better preservation of sensory attributes observed in the optimized hybrid fermented milk suggest that the combined incorporation of peanut milk and pomegranate peel powder effectively improved product stability, enabling acceptable sensory quality to be maintained for up to 12 days under refrigerated storage.

Table 1: Sensory evaluation of hybrid fermented milk prepared with different cow milk and peanut milk ratios.

Treatment (Cow milk :Peanut milk)	Colour & Appearance	Flavour	Body & Texture	Overall Acceptability
T ₁ (60:40)	7.36 ± 0.09 ^c	6.98 ± 0.14 ^b	7.35 ± 0.13 ^b	7.10 ± 0.10 ^b
T ₂ (70:30)	8.12 ± 0.10 ^a	7.88 ± 0.18 ^a	8.25 ± 0.09 ^a	8.30 ± 0.10 ^a
T ₃ (80:20)	7.75 ± 0.08 ^b	7.37 ± 0.14 ^{ab}	7.13 ± 0.10 ^b	7.37 ± 0.14 ^b

Values are expressed as mean ± SE (n = 6)

Different superscripts within a column indicate significant differences ($p < 0.05$).

Table 2: Effect of pomegranate peel powder (PPP) incorporation on the sensory characteristics of hybrid fermented milk

Treatment	Colour & appearance	Flavour	Body & texture	Overall acceptability
T ₀ (Control)	8.12 ± 0.10 ^a	7.88 ± 0.18 ^a	8.25 ± 0.09 ^a	8.30 ± 0.10 ^a
T ₁ (0.5% PPP)	8.08 ± 0.12 ^a	7.85 ± 0.25 ^a	8.12 ± 0.09 ^a	8.25 ± 0.10 ^a
T ₂ (1.0% PPP)	7.97 ± 0.14 ^a	7.99 ± 0.15 ^a	8.17 ± 0.15 ^a	8.17 ± 0.15 ^a
T ₃ (1.5% PPP)	8.17 ± 0.10 ^a	7.95 ± 0.17 ^a	8.28 ± 0.08 ^a	8.22 ± 0.16 ^a

Values are expressed as mean ± SE (n = 6).

Means bearing the same superscript within a column do not differ significantly ($p > 0.05$).

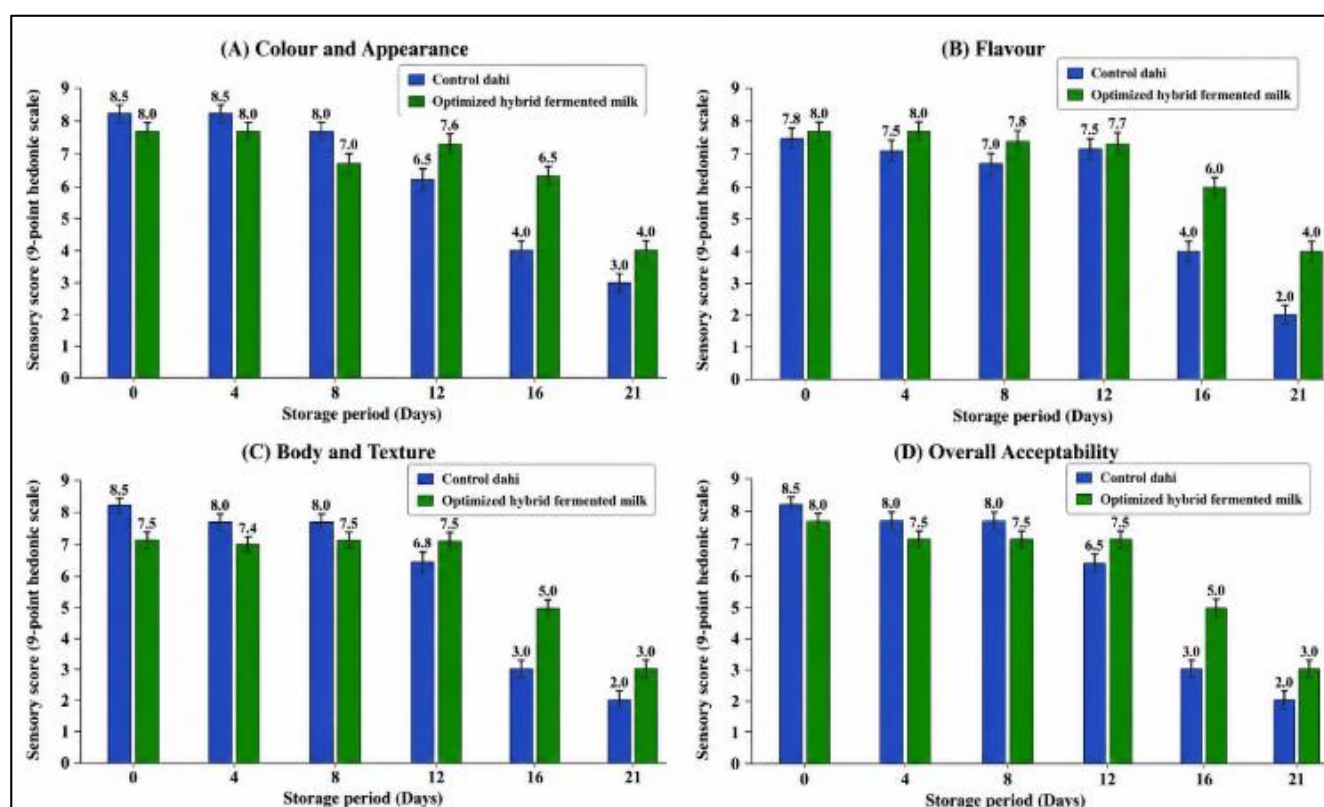
Table 3: Physicochemical, antioxidant and microbial characteristics of optimized hybrid fermented milk and control dahi

Parameter	Control dahi	Optimized hybrid fermented milk
Moisture (%)	83.90 ± 0.12 ^b	84.67 ± 0.33 ^a
Protein (%)	2.41 ± 0.08 ^b	3.34 ± 0.07 ^a
Fat (%)	0.48 ± 0.03 ^a	0.56 ± 0.03 ^a
Ash (%)	2.36 ± 0.12 ^b	4.17 ± 0.03 ^a
Crude fibre (%)	0.04 ± 0.02 ^b	0.89 ± 0.03 ^a
Titrateable acidity (% LA)	0.64 ± 0.03 ^a	0.68 ± 0.03 ^a
Syneresis (mL/100 g)	11.91 ± 0.03 ^a	12.16 ± 0.03 ^b
Total phenolic content (µg GAE/g)	10.78 ± 0.56 ^b	132.49 ± 6.06 ^a
DPPH radical scavenging activity (%)	12.35 ± 1.18 ^b	65.16 ± 1.57 ^a
Yeast and mould count	ND	ND
Coliform count	ND	ND

Values are expressed as mean ± SE (n = 3).

Means bearing different superscripts within a row differ significantly ($p < 0.05$).

ND = Not detected.

**Fig 1:** Changes in sensory scores of fermented milk during storage

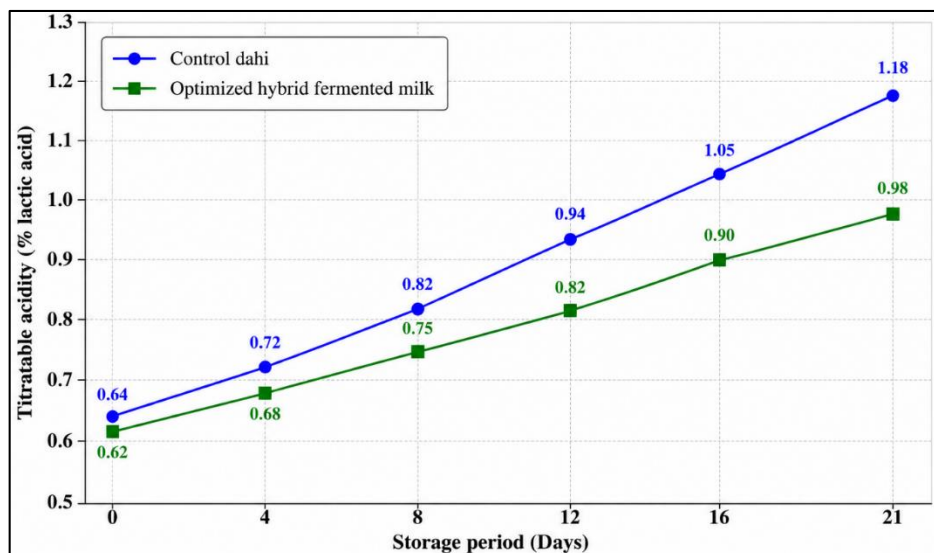


Fig 2: Changes in titratable acidity (% lactic acid) of fermented milk during storage.

Conclusion

The optimized hybrid fermented milk containing peanut milk and pomegranate peel powder demonstrated improved functional properties, good sensory acceptability, and satisfactory storage stability for up to 12 days under refrigerated conditions. The product has potential as a novel functional fermented dairy food with enhanced nutritional value and commercial applicability.

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