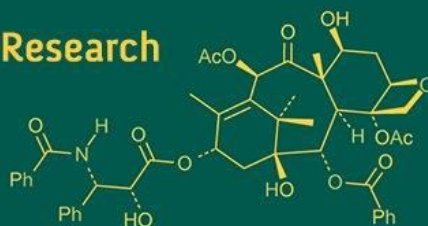


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Development of probiotic enriched chakka whey drink

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Abstract

The present study aimed to develop a probiotic-enriched functional beverage utilizing chakka whey as a base substrate. Chakka whey, a nutrient-dense by-product of traditional dairy processing, was incorporated with *Lactobacillus acidophilus* NCDC-14, with and without the prebiotic inulin, to formulate three treatment variants: T₁ (control), T₂ (chakka whey drink with *L. acidophilus*), and T₃ (chakka whey drink with *L. acidophilus* and inulin). All formulations were stored under refrigerated conditions (4±1 °C) and subjected to analysis at 0, 2, 4, 6, and 8 days of storage. Proximate analysis revealed that total solids, solids-not-fat (SNF), and titratable acidity increased progressively during storage across all treatments, while fat content, protein, and pH exhibited a gradual decline. Microbiological assessment demonstrated that the viable count of *L. acidophilus* in T₂ and T₃ remained above the recommended therapeutic threshold of 10⁶ CFU/mL throughout the storage period. Notably, T₃ exhibited significantly higher probiotic viability compared to T₂, indicating a marked prebiotic-mediated protective effect of inulin on probiotic survival. Yeast and mould counts were absent in all treatments, confirming satisfactory microbiological quality. Sensory evaluation indicated that all formulations were organoleptically acceptable; however, the synbiotic formulation (T₃) attained the highest scores for overall acceptability. These findings suggest that chakka whey represents a viable and nutritionally appropriate substrate for the development of probiotic functional beverages. Furthermore, the incorporation of inulin as a prebiotic was found to significantly enhance both probiotic viability and sensory quality, supporting the potential of synbiotic formulation as a value-added strategy for the utilization of dairy by-products.

Keywords: Chakka whey, *Lactobacillus acidophilus*, inulin, synbiotic, probiotic viability, functional beverage, refrigerated storage

Introduction

Whey, a by-product obtained during the manufacture of cheese, chhana, paneer, and Chakka, has gained considerable attention due to its high nutritional value. But whey is not utilised efficiently and discarded in environment although often underutilized, whey contains lactose, high-quality proteins, minerals, and water-soluble vitamins, retaining nearly half of the total solids of milk. Globally, whey production is estimated at 180-190 million tonnes annually, yet less than 50% is effectively utilized, highlighting the need for its value addition (Borkar, 2020; Madavi *et al.*, 2025; Mirzakulova *et al.*, 2025) [9, 13, 16].

Probiotics and prebiotics have emerged as key components in the development of functional foods. Probiotics such as *Lactobacillus* and *Bifidobacterium* contribute to gastrointestinal health, while prebiotics act as substrates that promote their growth and activity (Al-Habsi *et al.*, 2024) [2]. The combination of both, known as synbiotics, enhances microbial viability, improves gut health, and provides additional metabolic and immunological benefits. Techniques such as encapsulation further improve probiotic stability and survival under adverse conditions, increasing their effectiveness in food applications (Sarita *et al.*, 2025; Pal and Bhowal, 2023; Al-Habsi *et al.*, 2024) [22, 21, 21].

In this context, the development of a probiotic-enriched chakka whey drink represents a sustainable and functional approach to utilize dairy by-products while addressing the growing demand for health-promoting beverages. Incorporation of probiotics into whey enhances its nutritional and therapeutic value, contributing to improved gut health, immunity, and overall well-being. Furthermore, synbiotic formulations offer superior benefits by modulating intestinal microbiota, enhancing nutrient absorption, and preventing various

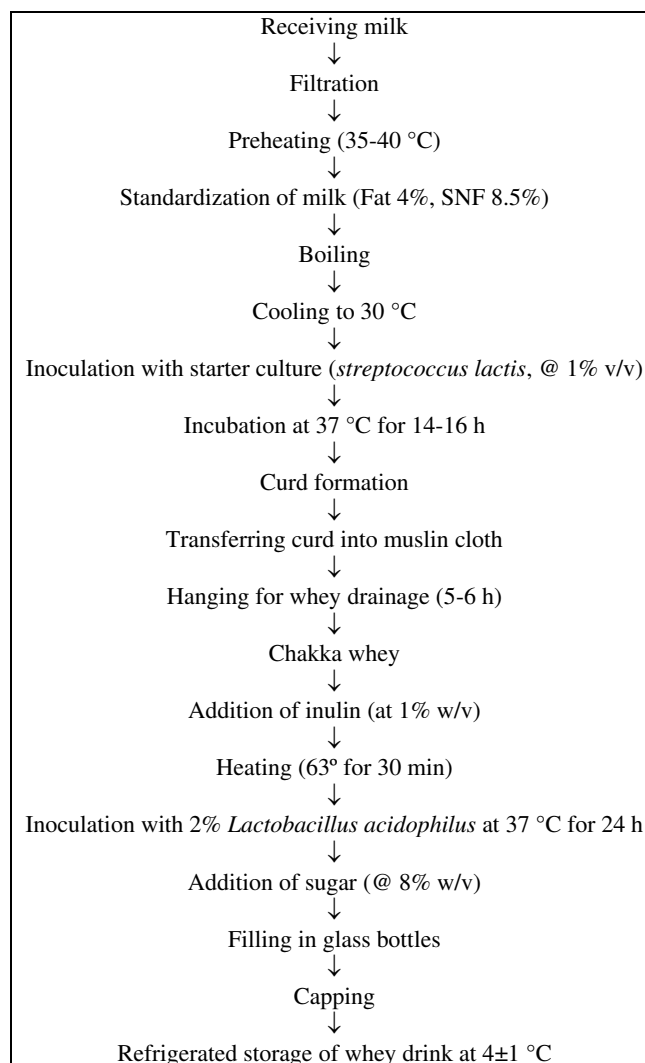
gastrointestinal disorders. Therefore, the present study focuses on the development and evaluation of a probiotic-enriched chakka whey drink as an innovative functional beverage.

Materials and Methods

The present investigation was undertaken to develop a functional dairy beverage, namely a probiotic-enriched chakka whey drink, and to evaluate the growth pattern of probiotic microorganisms in the developed product. The study included preparation of whey drink, incorporation of probiotic and prebiotic components, and subsequent evaluation through physicochemical, microbiological, and sensory analyses.

The experiment was designed in two parts. The first experiment aimed to optimize the process for the development of probiotic chakka whey drink using three treatments, namely (T₁) control (without probiotic and prebiotic), (T₂) probiotic-added, and (T₃) synbiotic (probiotic with prebiotic inulin), each replicated six times. The whey drink was prepared following the method

described by Drgalic *et al.*, (2005) ^[11] with suitable modifications. Fresh buffalo milk procured from the cattle breeding farm was filtered and standardized to 4% fat and 8.5% solids-not-fat using Pearson's square method. The standardized milk was heated, cooled to incubation temperature (37±1 °C), and inoculated with *Streptococcus lactis* culture at 1% (v/v), followed by incubation for 14-16 hours to obtain curd. The curd was transferred into muslin cloth and allowed to drain under gravity to obtain whey. The extracted whey was incorporated with prebiotic inulin at 1% (w/v) as per treatment requirements and subjected to heat treatment at 63 °C for 30 minutes. After cooling to 37±1 °C, the whey was inoculated with *Lactobacillus acidophilus* NCDC 14 at 2% (v/v) and incubated at 37±1 °C for 24 hours under anaerobic conditions. The fermented whey was subsequently cooled to 4±1 °C to arrest microbial activity. Sugar was added at 8% (w/v), and the final product was filled into sterilized glass bottles, capped, and stored under refrigerated conditions (4±1 °C) until further analysis. The flowchart for the preparation of chakka whey drink is as follows:



Flowchart for the preparation of probiotic enriched chakka whey drink.

In the second experiment, the developed whey drink samples were analysed to study the growth pattern of probiotic microorganisms along with quality attributes. Proximate composition, including fat, solids-not-fat, total solids, and protein, was determined using standard methods

of AOAC, 2016 ^[3] and AOAC, 2019 ^[4]. Physico-chemical properties such as pH and titratable acidity were evaluated following AOAC, (2016) ^[3] procedures. Microbiological quality, including, psychrophilic count, yeast and mould count, and *Lactobacillus acidophilus* count, was determined

as per standard methods described by APHA (1984) [5], and results were expressed as log₁₀ CFU/mL. Sensory evaluation of the product was carried out by a semi-trained panel using a 9-point hedonic scale as described by Nelson and Trout (1964) [19] to assess appearance, flavour, taste, and overall acceptability. The experimental data were statistically analysed using Completely Randomized Design (CRD) as described by Snedecor and Cochran (1989) [25].

Table 1: Formulation of the chakka whey drink under different treatment

Treatment	Formulation
T ₁	Chakka whey + Sugar @ 8%w/v
T ₂	Chakka whey + <i>L. acidophilus</i> @ 2% v/v + Sugar @ 8%w/v
T ₃	Chakka whey + <i>L. acidophilus</i> @ 2% v/v + Inulin @ 1%w/v + Sugar @ 8%w/v

Proximate Composition

Fat

Fat content of chakka whey drink decreased significantly ($p < 0.01$) during refrigerated storage (Table 2). The control

treatment (T₁) showed a decline from 0.22 to 0.19%, while T₂ and T₃ decreased from 0.21 to 0.14% and 0.19 to 0.14%, respectively. Among treatments, T₁ consistently exhibited higher fat content compared to T₂ and T₃.

Table 2: Changes in proximate analysis of chakka whey drink during refrigerated storage (4±1 °C)

Treatment	Storage period (Days)				
	0	2	4	6	8
Fat					
T ₁ Control	a0.22±0.006 ^a	a0.21±0.006 ^a	ab0.20±0.010 ^a	b0.19±0.012 ^a	c0.19±0.021 ^a
T ₂ With probiotic	a0.21±0.006 ^b	a0.21±0.005 ^b	ab0.21±0.014 ^b	b0.16±0.009 ^b	c0.14±0.016 ^b
T ₃ With probiotic and prebiotic	a0.19±0.020 ^b	a0.21±0.006 ^b	ab0.17±0.002 ^b	b0.17±0.011 ^b	c0.14±0.004 ^b
Solid not fat					
T ₁ Control	d5.77±0.006 ^c	c5.82±0.015 ^c	c5.87±0.018 ^c	b5.92±0.007 ^c	a5.97±0.036 ^c
T ₂ With probiotic	d6.02±0.012 ^b	c6.07±0.012 ^b	c6.11±0.010 ^b	b6.21±0.029 ^b	a6.28±0.019 ^b
T ₃ With probiotic and prebiotic	d6.08±0.021 ^a	c6.15±0.042 ^a	c6.19±0.035 ^a	b6.22±0.031 ^a	a6.31±0.023 ^a
Total solids					
T ₁ Control	d6.03±0.050 ^c	c6.03±0.008 ^c	bc6.07±0.014 ^c	ab6.11±0.012 ^c	a6.15±0.028 ^c
T ₂ With probiotic	d6.24±0.010 ^b	c6.28±0.012 ^b	bc6.32±0.010 ^b	ab6.37±0.030 ^b	a6.4±0.014 ^b
T ₃ With probiotic and prebiotic	d6.27±0.003 ^a	c6.35±0.040 ^a	bc6.36±0.035 ^a	ab6.39±0.033 ^a	a6.4±0.022 ^a
Protein					
T ₁ Control	a0.73±0.027 ^b	a0.70±0.015 ^b	ab0.68±0.038 ^b	bc0.66±0.039 ^b	c0.59±0.004 ^b
T ₂ With probiotic	a0.72±0.026 ^b	a0.72±0.006 ^b	ab0.71±0.012 ^b	bc0.59±0.036 ^b	c0.60±0.034 ^b
T ₃ With probiotic and prebiotic	a0.82±0.011 ^a	a0.80±0.016 ^a	ab0.77±0.009 ^a	bc0.75±0.023 ^a	c0.74±0.032 ^a

Mean ± SE with different superscripts in a row and subscripts in a column differ significantly at 1% ($p < 0.01$) and 5% ($p < 0.05$) levels of significance.

Solids-Not-Fat (SNF)

SNF content increased significantly ($p < 0.01$) during storage (Table 2). Values increased from 5.77 to 5.97% in T₁, 6.02 to 6.28% in T₂, and 6.08 to 6.31% in T₃. The highest SNF content was recorded in T₃, followed by T₂ and T₁.

Total Solids

Total solids showed a significant increase ($p < 0.05$) during storage (Table 2). T₁ increased from 6.03 to 6.15%, while T₂ and T₃ increased from 6.24 to 6.40% and 6.27 to 6.40%, respectively. Synbiotic treatment (T₃) consistently showed higher total solids.

Protein

Protein content decreased significantly ($p < 0.01$) in all treatments during storage (Table 2). T₁ decreased from 0.73 to 0.59%, T₂ from 0.72 to 0.60%, and T₃ from 0.82 to

Results

Formulation of Chakka Whey Drink

Three formulations of chakka whey drink were developed under different treatment combinations, namely control (T₁), probiotic (T₂), and synbiotic (T₃). The control sample (T₁) consisted of chakka whey with sugar, while T₂ included *Lactobacillus acidophilus* and sugar. The synbiotic treatment (T₃) comprised *Lactobacillus acidophilus*, inulin and sugar. The detailed formulation is presented in Table 1.

treatment (T₁) showed a decline from 0.22 to 0.19%, while T₂ and T₃ decreased from 0.21 to 0.14% and 0.19 to 0.14%, respectively. Among treatments, T₁ consistently exhibited higher fat content compared to T₂ and T₃.

0.74%. Among treatments, T₃ maintained the highest protein content throughout storage.

Physico-Chemical Properties

pH

The pH of chakka whey drink decreased significantly ($p < 0.01$) during storage (Table 3). The values declined from 4.84 to 4.69 in T₁, 4.78 to 4.68 in T₂, and 4.78 to 4.66 in T₃. The lowest pH values were observed in T₃.

Titrateable Acidity

Titrateable acidity increased significantly ($p < 0.01$) during storage (Table 4). Acidity values increased from 0.78 to 0.89% in T₁, 0.81 to 0.96% in T₂, and 0.84 to 0.99% in T₃. The highest acidity was recorded in T₃, followed by T₂ and T₁.

Table 3: Changes in physico-chemical analysis (pH) of chakka whey drink during refrigerated storage (4±1 °C)

Treatment	Storage period (Days)				
	0	2	4	6	8
	pH				
T ₁ Control	^a 4.84±0.029 ^a	^{ab} 4.81±0.034 ^a	^{ab} 4.80±0.045 ^a	^{bc} 4.74±0.033 ^a	^c 4.69±0.013 ^a
T ₂ With probiotic	^a 4.78±0.007 ^{ab}	^{ab} 4.76±0.008 ^{ab}	^{ab} 4.76±0.045 ^{ab}	^{bc} 4.72±0.05 ^{ab}	^c 4.68±0.060 ^{ab}
T ₃ With probiotic and prebiotic	^a 4.78±0.007 ^b	^{ab} 4.70±0.031 ^b	^{ab} 4.72±0.030 ^b	^{bc} 4.72±0.055 ^b	^c 4.66±0.026 ^b

Mean ± SE with different superscripts in a row differ significantly at 5% ($p \leq 0.05$) levels of significance and subscripts in a column differ significantly at 1% ($p \leq 0.05$) and 5% ($p \leq 0.05$) levels of significance.

Table 4: Changes in physico-chemical analysis (Titratable acidity) of chakka whey drink during refrigerated storage (4±1 °C)

Treatment	Storage period (Days)				
	0	2	4	6	8
	Titratable acidity				
T ₁ Control	^d 0.78±0.008 ^c	^d 0.77±0.008 ^c	^c 0.83±0.007 ^c	^b 0.86±0.007 ^c	^a 0.89±0.007 ^c
T ₂ With probiotic	^d 0.81±0.004 ^b	^a 0.81±0.004 ^b	^c 0.88±0.007 ^b	^b 0.93±0.004 ^b	^a 0.96±0.008 ^b
T ₃ With probiotic and prebiotic	^d 0.84±0.004 ^a	^a 0.84±0.004 ^a	^c 0.91±0.006 ^a	^b 0.96±0.004 ^a	^a 0.99±0.008 ^a

Mean ± SE with different superscripts in a row and subscripts in a column differ significantly at 1% ($p \leq 0.01$) and 5% ($p \leq 0.05$) levels of significance.

Microbial Analysis

Psychrophilic Count

Psychrophilic count was not detected up to day 6 but

showed a significant increase ($p < 0.01$) by day 8 (Table 5).

Counts ranged from 1.13 to 1.47 log₁₀ CFU/mL, with higher values in T₂ and T₃ compared to T₁.

Table 5: Changes in microbiological analysis (Total plate count and psychrophilic count) of chakka whey drink during refrigerated storage (4±1 °C)

Treatment	Storage period (Days)				
	0	2	4	6	8
	Total plate count				
T ₁ Control	^e 3.20±0.008 ^b	^d 3.30±0.008 ^b	^c 3.42±0.008 ^b	^b 3.54±0.008 ^b	^a 3.66±0.006 ^b
T ₂ With probiotic	^e 3.38±0.008 ^a	^d 3.49±0.029 ^a	^c 3.64±0.006 ^a	^b 3.74±0.008 ^a	^a 3.87±0.008 ^a
T ₃ With probiotic and prebiotic	^e 3.48±0.042 ^a	^d 3.58±0.011 ^a	^c 3.61±0.058 ^a	^b 3.76±0.038 ^a	^a 3.89±0.025 ^a
Psychrophilic count					
T ₁ Control	ND	ND	ND	^b 1.13±0.017 ^b	^a 1.31±0.012 ^b
T ₂ With probiotic	ND	ND	ND	^b 1.21±0.013 ^a	^a 1.41±0.015 ^a
T ₃ With probiotic and prebiotic	ND	ND	ND	^b 1.23±0.043 ^a	^a 1.47±0.019 ^a

Mean ± SE with different superscripts in row and subscripts in a column differ significantly at 1% ($p \leq 0.01$) and 5% ($p \leq 0.05$) Tlevels of significance.

Yeast and Mould Count: Yeast and mould were not detected in any treatment throughout the storage period.

decreased significantly ($p < 0.01$) during storage (Table 6). In T₂, counts decreased from 8.41 to 7.62 log₁₀ CFU/mL, while in T₃ they decreased from 8.78 to 7.94 log₁₀ CFU/mL. Higher counts were maintained in T₃ compared to T₂.

Lactobacillus acidophilus Count: Probiotic counts

Table 6: Changes in microbiological analysis (*Lactobacillus acidophilus* count) of chakka whey drink during refrigerated storage (4±1 °C)

Treatment	Storage period (Days)				
	0	2	4	6	8
	<i>Lactobacillus acidophilus</i> count				
T ₂ With probiotic	^a 8.41±0.008 ^b	^b 8.21±0.008 ^b	^c 8.00±0.009 ^b	^d 7.81±0.012 ^b	^e 7.62±0.010 ^b
T ₃ With probiotic and prebiotic	^a 8.78±0.008 ^a	^b 8.57±0.015 ^a	^c 8.38±0.010 ^a	^d 8.16±0.010 ^a	^e 7.94±0.033 ^a

Mean ± SE with different superscripts in a row and subscripts in a column differ significantly at 1% ($p \leq 0.01$) and 5% ($p \leq 0.05$) levels of significance.

Sensory Evaluation

Appearance

Appearance scores differed significantly among treatments ($p < 0.01$) (Table 7). T₃ recorded the highest mean score (8.70), followed by T₂ (8.20) and T₁. Storage had no significant effect.

Flavour

Flavour scores were significantly influenced by treatments ($p < 0.01$). T₃ showed the highest mean score (8.80), followed by T₂ (8.12) and T₁ (7.88).

Taste

Taste scores differed significantly among treatments ($p < 0.01$), with T₃ recording the highest score (8.80), followed by T₂ (8.27) and T₁ (7.68). Storage effect was non-significant.

Overall Acceptability

Overall acceptability was significantly affected by both treatment and storage ($p < 0.01$). T₃ recorded the highest score (8.98), followed by T₂ (8.23) and T₁ (7.77). Scores decreased slightly during storage but remained within acceptable limits.

Table 7: Changes in sensory analysis of chakka whey drink during refrigerated storage (4 ±1 °C)

Treatment	Storage period (Days)				
	0	2	4	6	8
Appearance					
T ₁ Control	8.28±0.192 ^b	8.17±0.174 ^b	8.28±0.207 ^b	7.48±0.172 ^b	7.57±0.239 ^b
T ₂ With probiotic	8.20±0.283 ^{ab}	8.45±0.330 ^{ab}	7.98±0.266 ^{ab}	8.07±0.286 ^{ab}	7.93±0.225 ^{ab}
T ₃ With probiotic and prebiotic	8.70±0.191 ^a	8.77±0.150 ^a	8.55±0.161 ^a	8.25±0.324 ^a	8.47±0.353 ^a
Flavour					
T ₁ Control	7.53±0.437 ^c	7.25±0.310 ^c	7.87±0.191 ^c	7.60±0.301 ^c	7.88±0.210 ^c
T ₂ With probiotic	8.07±0.042 ^b	7.92±0.054 ^b	7.93±0.095 ^b	8.25±0.177 ^b	8.12±0.266 ^b
T ₃ With probiotic and prebiotic	8.48±0.183 ^a	8.73±0.176 ^a	8.37±0.316 ^a	7.77±0.345 ^a	8.80±0.181 ^a
Taste					
T ₁ Control	7.68±0.337 ^b	7.87±0.406 ^b	7.88±0.310 ^b	7.62±0.197 ^b	7.45±0.270 ^b
T ₂ With probiotic	8.10±0.379 ^a	8.23±0.307 ^a	8.07±0.136 ^a	8.22±0.111 ^a	8.27±0.141 ^a
T ₃ With probiotic and prebiotic	8.67±0.211 ^a	8.40±0.200 ^a	8.62±0.172 ^a	8.70±0.167 ^a	8.80±0.179 ^a
Overall palatability					
T ₁ Control	^a 7.77±0.293 ^c	^b 7.20±0.118 ^c	^b 7.05±0.165 ^c	^b 7.33±0.120 ^c	^b 7.23±0.105 ^c
T ₂ With probiotic	^a 8.23±0.131 ^b	^b 7.72±0.271 ^b	^b 7.77±0.105 ^b	^b 7.55±0.081 ^b	^b 7.23±0.061 ^b
T ₃ With probiotic and prebiotic	^a 8.98±0.017 ^a	^b 8.68±0.145 ^a	^b 8.53±0.186 ^a	^b 8.52±0.182 ^a	^b 8.90±0.000 ^a

Mean ± SE with different superscripts in a row and subscripts in a column differ significantly at 1 % ($p \leq 0.01$) and 5% ($p \leq 0.05$) levels of significance.

Cost Structure

The cost of production per litre of chakka whey drink was Rs. 142.61, Rs. 152.61, and Rs. 172.51 for T₁, T₂, and T₃,

respectively (Table 8). The synbiotic treatment (T₃) showed the highest production cost.

Table 8: Cost of production of 1 litre of chakka whey drink

Particulars	Treatments					
	T ₁		T ₂		T ₃	
	Qty	Value (Rs)	Qty	Value (Rs)	Qty	Value (Rs)
Quantity of milk to obtain 1 litre Chakka whey @ Rs.57/lit.	1.4	79.8	1.4	79.8	1.4	79.8
Sugar used in 8% (g) in all treatment @ Rs. 42.50/-kg.	80	3.40	80	3.40	80	3.40
Fuel Charges LPG (gm) Rs. 904.50/14.2 kg	25.20	1.61	25.20	1.61	25.20	1.61
Electricity charges @ Rs. 5/Unit	0.56	2.80	0.56	2.80	0.56	2.80
Labour charge @ Rs.400/8 hrs. (1 min-0.50 Rs.)	60 (min)	50	60 (min)	50	60(min)	50
Prebiotic (gm) inulin cost @ Rs 497.50/250 gm	-	-	-	-	10	19.90
Overhead expenses (including cultures) (Rs)	-	5	-	10	-	10
Total cost of production (Rs.)		142.61		152.61		172.51

Discussion

The present investigation on the development of probiotic-enriched chakka whey drink revealed significant changes in proximate composition, physico-chemical properties, microbiological quality, and sensory attributes during refrigerated storage. The observed variations among treatments and storage periods indicate the influence of probiotic and prebiotic incorporation on product quality and stability.

A significant decrease in fat content was observed during storage in all treatments, with a more pronounced reduction in probiotic (T₂) and synbiotic (T₃) samples. This decline may be attributed to physicochemical instability and possible oxidative changes in fat fractions during storage. Similar findings have been reported by Madhavi (2009) [14] and Naik *et al.*, (2023) [17], who observed a gradual reduction in fat content in whey-based beverages during refrigerated storage. The comparatively lower fat content in T₂ and T₃ suggests the influence of microbial activity on fat destabilization.

In contrast, solids-not-fat (SNF) and total solids content increased significantly during storage, with the highest values observed in synbiotic treatment (T₃). The increase in SNF and total solids may be due to slight moisture loss and improved solubilization of whey constituents over time.

These results are in agreement with studies conducted by Ahmed *et al.*, (2023) [1] and Nedanovska *et al.*, (2022) [18], who reported similar increasing trends in whey-based functional beverages. The higher values recorded in T₃ may be attributed to the addition of inulin, which contributes additional solids to the formulation.

Protein content showed a significant decline during storage; however, synbiotic treatment (T₃) exhibited better protein retention compared to other treatments. The decrease in protein content may be due to denaturation and aggregation of whey proteins during storage. Similar observations have been reported by Zheng (2023) [26] and Singh *et al.*, (2022) [23]. The improved protein stability in T₃ may be attributed to the protective effect of prebiotics, which help in maintaining protein integrity by stabilizing the matrix system.

The pH of all samples decreased significantly, while titratable acidity increased during storage, indicating progressive acidification of the whey drink. This trend is primarily due to the metabolic activity of probiotic microorganisms producing organic acids. Similar results have been reported by Madhavi (2009) [14] and Ahmed *et al.*, (2023) [1] in fermented whey beverages. The greater reduction in pH and higher acidity observed in synbiotic treatment (T₃) confirms the synergistic effect of probiotics and prebiotics in enhancing fermentation activity.

Microbiological analysis revealed a significant increase in total plate count during storage, with higher counts observed in probiotic and synbiotic treatments. This indicates active microbial growth and survival in the whey matrix. Similar findings were reported by Dharani *et al.*, (2021) ^[10] and Atallah and Gemiel (2020) ^[7]. Psychrophilic counts remained low and appeared only during later stages of storage, indicating good initial microbiological quality and effectiveness of refrigeration. The absence of yeast and mould throughout the storage period further confirms the microbiological safety of the product.

The viability of *Lactobacillus acidophilus* decreased during storage but remained within the recommended therapeutic level, particularly in synbiotic treatment (T₃). The higher survival rate in T₃ may be attributed to the presence of inulin, which acts as a protective and nutritive substrate for probiotic bacteria. These findings are consistent with reports by Drgalic *et al.*, (2005) ^[11] and Skryplonek and Jasińska (2015) ^[24], who observed enhanced probiotic survival in synbiotic formulations.

Sensory evaluation indicated that synbiotic treatment (T₃) received significantly higher scores for appearance, flavour, taste, and overall acceptability compared to other treatments. The improved sensory attributes may be attributed to the presence of inulin, which enhances mouthfeel and flavour profile. Similar improvements in sensory quality of synbiotic dairy products have been reported by Aryana *et al.*, (2007) ^[6] and Minj and Vij (2017) ^[15]. Although sensory scores decreased slightly during storage, all treatments remained within acceptable limits throughout the study period.

The cost analysis indicated that synbiotic treatment (T₃) had the highest production cost, followed by probiotic (T₂) and control (T₁). The increased cost is mainly due to the addition of probiotic cultures and prebiotic inulin. However, the enhanced nutritional, functional, and sensory qualities of the synbiotic product justify the higher cost of production.

Overall, the findings of the present study demonstrate that incorporation of probiotics and prebiotics significantly improves the functional, microbiological, and sensory quality of chakka whey drink. The synbiotic formulation (T₃) showed superior performance in terms of nutritional value, probiotic viability, and consumer acceptability, making it a promising functional dairy beverage.

Conclusion

The present study demonstrates that chakka whey, a nutrient-rich dairy by-product, can be effectively utilized for the development of a probiotic and synbiotic functional beverage with desirable quality attributes. Incorporation of *Lactobacillus acidophilus* and inulin significantly influenced physicochemical properties, microbial viability, and sensory characteristics during refrigerated storage. The synbiotic formulation exhibited improved probiotic survivability, acceptable microbial quality, and superior sensory scores compared to the control and probiotic-only treatments.

Among the treatments evaluated, the synbiotic chakka whey drink (T₃) showed the most favourable results in terms of probiotic viability, product stability, and overall acceptability, indicating its potential as a functional dairy beverage. These findings support the utilization of chakka whey as a sustainable raw material for the development of

value-added, health-promoting drinks with good shelf life and consumer acceptability.

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