DRF-575
[1-11]

RESEARCH ARTICLE Asian Journal of Dairy and Food Research

Development of a Functional Dairy Product: Aloe vera and Kithul (*Caryota urens*) Treacle-enriched Cow Milk Curd

Kalaivizhi Varathanathan[1], Susantha Piratheepan[1],
Weerasingha Diwakarage Isuru Prabhath Jayaweera[1], Thasanthan Loganathan[2]

10.18805/ajdfr.DRF-575

ABSTRACT

Background: This study aimed to develop a functional curd by incorporating aloe vera juice and kithul (*Caryota urens*) treacle into cow milk and to evaluate its physicochemical, sensory and microbial properties.

Methods: Aloe vera juice was first optimized with kithul treacle at concentrations of 8%, 16% and 24%, with 24% treacle identified as optimal based on sensory evaluation. This optimized aloe vera juice was then added to cow milk curd at varying levels (5%, 10%, 15%, 20% and 25%), alongside a control. Sensory evaluation was conducted using a nine-point hedonic scale with 60 semi-trained panelists. Physicochemical parameters, texture, pH, acidity and microbial safety were assessed across treatments.

Result: The 15% aloe vera juice curd (T4) achieved the highest overall sensory preference. Physicochemical analysis revealed increased protein, ash, carbohydrate and fiber contents in aloe vera curds compared to control, while fat content remained consistent. T4 exhibited optimal texture, viscosity and hardness. Aloe vera incorporation led to decreased pH and increased acidity. Microbial analysis confirmed the absence of *E. coli* and coliforms, with higher aloe vera levels contributing to reduced microbial growth and extended shelf life.

Key words: Aloe vera, Cow milk, Curd, Kithul treacle, Physicochemical analysis, Sensory evaluation.

INTRODUCTION

Curd, a fermented dairy product, is highly valued for its nutritional benefits, enhanced digestibility and probiotic content, which support gut health and immunity (Hui *et al*., 2019; Boudreau and Beland, 2006; Kavanagh *et al*., 2019). Cow milk, rich in high-quality proteins, essential amino acids and micronutrients like calcium and riboflavin, is a cornerstone of dairy nutrition, promoting bone health and metabolic functions (Shetty and Shetty, 2018; Huth and DiRienzo, 2006). Aloe vera (*Aloe barbadensis* miller), known for its anti-inflammatory, antioxidant and antimicrobial properties, offers additional digestive and immune benefits (Radha *et al*., 2012; Salehi *et al*., 2018; Minjares-Fuentes and Femenia, 2019; Talukdar *et al*., 2023). Kithul treacle, derived from *Caryota urens* L., complements aloe vera with its antioxidant-rich composition and natural sweetness (Ratnasiri and Seneviratne, 2012). This study aimed to develop a functional curd by incorporating aloe vera juice, optimized with kithul treacle at 24%, into cow milk curd at varying levels (5–25%) alongside a control. These findings underscore the potential of integrating aloe vera juice and kithul treacle into curd production to create a nutritionally enriched, functional dairy product that appeals to health-conscious consumers while preserving traditional flavors.

MATERIALS AND METHODS

Study location and raw material collection

This study took place at the Department of Animal Science, Faculty of Agriculture, University of Jaffna, in partnership with a JICA-supported laboratory and infrastructure from March to August 2023. Cow milk was sourced from the Ariviyal Nagar farm. Curd culture came from the VRI, Peradeniya and kithul treacle from Kalawana. Laboratory equipment included autoclave, Soxhlet, Kjeldahl, muffle furnace, texture analyzer, colorimeter, pH meter, incubator, freezer and laminar-flow hood.

Preparation of mother culture and working culture

Powdered starter culture was stored at 4°C. To prepare the mother culture, 25 g of Anchor non-fat skim milk powder was mixed with 250/ ml of boiling water. Once fully dissolved and cooled to 45°C, the starter culture was added. The mixture was poured into 20 ml bottles and

[1]Department of Animal Science, Faculty of Agriculture, University of Jaffna, Sri Lanka.
[2]Department of Radiography/Radiotherapy, Faculty of Allied Health Sciences, University of Peradeniya, Sri Lanka.

Corresponding Author: Kalaivizhi Varathanathan, Department of Animal Science, Faculty of Agriculture, University of Jaffna, Sri Lanka.
Email: angelinakalaivizhi@gmail.com
ORCID: 0009-0006-7477-4334

How to cite this article: Varathanathan, K., Piratheepan, S., Jayaweera, W.D.I.P. and Loganathan, T. (2025). Development of a Functional Dairy Product: Aloe vera and Kithul (*Caryota urens)* Treacle-enriched Cow Milk Curd. *Asian Journal of Dairy and Food Research.* 1-11. doi: 10.18805/ajdfr.DRF-575.

Submitted: 15-07-2025 **Accepted:** 21-11-2025 **Online:** 06-01-2026

incubated at 30°C for 12-16 hours until thickened, then stored frozen until use. The working culture was prepared a day before production. One liter of cow milk was boiled and cooled to 30°C to eliminate unwanted microbes (De, 1986; Tamime and Robinson, 2007). After thawing, 20 ml of mother culture was added and the milk was incubated at 30°C for 12 hours (Bhat and Naik, 2013; Johns, 1960).

Preparation of aloe vera juice

Mature aloe vera leaves (≥3 years) were harvested for optimal gel and juice yield (Uppar *et al*., 2024). After thorough washing, thorns and leaf ends were removed and the leaves were filleted to extract the inner gel. The gel was blended with filtered water (0.5:1 ratio) to form aloe vera gel (Thu *et al*., 2023), then filtered through muslin cloth. The juice was heated at 70-80°C for 10-15 minutes to inactivate spoilage enzymes (Añibarro-Ortega *et al*., 2019; Hingne and Shelke, 2020). Kithul treacle was added at 8%, 16% and 24%, with optional preservatives (0.1% citric acid and 0.1% sodium benzoate) (Uppar *et al*., 2024). The final product was stored in airtight containers at 4°C in a cool, dry place to retain quality.

Sensory evaluation

Sensory acceptability was assessed by 40 semi-trained panelists using a 9-point hedonic scale (Ali *et al*., 2021; Freitas *et al*., 2021; Govindammal and Thangaraj, 2017; Inyang, 2018). Samples (30 mL) with 8%, 16% and 24% kithul treacle were coded and presented under controlled lighting, with palate cleansing between tastings (Magalhães and Cazal, 2021; Tt *et al*., 2020).

Sterilization of earthen pots

Package the final product, earthen pots were utilized. Before filling the samples into the pots, a thorough cleaning process was conducted using heated water. Subsequently, the pots were wholly sterilized by being placed in an oven at a temperature of 100°C for 6-7 hours (Gonzalez, 2007).

Preparation of curd with different levels of aloe vera juice sample

All equipment was sterilized (Ban *et al*., 2023). Milk was heated to 85°C, reduced, cooled, homogenized and inoculated with culture (Tadjine *et al*., 2021; Al-Taif *et al*., 2022; Tank *et al*., 2022). Aloe vera juice (5-25%) was added before incubation at 37°C for 16 hours.

Sensory evaluation 02

Sensory evaluation of aloe vera curd and control samples was conducted with 60 semi trained Agriculture students using a nine point hedonic scale under randomized, controlled conditions. Participants assessed appearance, aroma, texture, flavor and overall acceptability in 15-20 min sessions.

Proximate and microbial analysis

Moisture, fat, protein, total solids, pH and carbohydrates were analyzed. Moisture was measured by oven drying (AOAC 925.23, 2005). Protein was determined via Kjeldahl (AOAC 991.20, 2005). Fat was extracted using Soxhlet (AOAC 989.05, 2000). Fiber was analyzed with ANKOM 200 (AOAC 985.29, 2000). Ash was incinerated at 550°C (AOAC 923.03, 2005). Carbohydrates were calculated by difference (IAL, 2005). Energy was measured by bomb calorimeter (AOAC 935.29, 2000). Microbiological tests ensured hygienic quality (APHA, 2001; Brasil, 2001).

Analysis of physiochemical parameters and shelf-life evaluation

pH was measured using a pH meter. Titratable acidity was determined by acid-base titration (AOAC 947.05, 2019) and CIE color coordinates (Akalın *et al*., 2008). Texture was analyzed with an IMADA texture analyzer (model FRTS). Shelf-life was evaluated via microbial analysis, pH and titratable acidity, measured on production day and day 14. Sensory panelists assessed visual acceptability, mouth feel (juiciness), color, aroma, flavor/taste and overall impression.

Evaluation of cost of production

Production cost was assessed for each of the six treatments individually by using the following components; Cow milk, aloe vera juice, starter culture, earthen pot and Unit price (80 ml pot).

Experimental design and statistical analysis

Physicochemical data were analyzed using the General Linear Model in SAS software, following a completely randomized design. Mean scores for storage periods and formulations were compared *via* Duncan's Multiple Range Test at $p \leq 0.05$. Statistical analyses used SAS version 6.0.10. Sensory acceptance data, based on a 9-point hedonic scale, were analyzed using SPSS version 20.

RESULTS AND DISCUSSION

Proximate analysis of aloe vera juice

Results for the proximate composition of each parameter of aloe vera juice are represented Table 1.

Proximate analysis of aloe vera juice revealed 55.97% moisture, lower than typical 98% in aloe gel (Raza *et al*., 2024), enhancing stability. Protein (0.322%) supported

Table 1: Proximate composition of aloe vera juice, including moisture, protein, carbohydrate, fat, fiber and ash content.

Parameters%	Aloe vera juice
Moisture	55.97±0.05
Protein	0.322±0.002
Carbohydrate	19.69±0.04
Fat	2.096±0.01
Fiber	0.989±0.003
Ash	0.728±0.003

Results are expressed as percentages (%), representing mean values ± standard deviation.

cellular functions (Zhang *et al*., 2018), while low fat (2.096%) suited health-oriented beverages. Carbohydrates (19.69%) provided energy and fiber (0.989%) aided gut health (Khan *et al*., 2015). Ash (0.728%) indicated mineral content. Bioactive compounds offered antioxidant and anti-inflammatory benefits (Tariq *et al*., 2023; Patel and Gupta, 2019; Mamdouh and Youssef, 2022). High moisture requires preservation to extend shelf life (Khan *et al*., 2015).

Physicochemical properties of aloe vera juice (Table 2)

Aloe vera juice exhibited a pH of 6.0±0.2, slightly acidic, enhancing stability and taste, consistent with (Soltanizadeh and Mousavinejad, 2015); (pH 4.98±0.64). Its smooth, slightly dense texture and 17.25% Brix indicate balanced viscosity for consumer appeal. Kithul treacle can enhance sweetness and texture (Monteiro-Alfredo *et al*., 2021; Sharma *et al*., 2015). Energy content was 125 kJ±0.2 kJ, higher than Singh's (2022; 62.76 ±0.65 kJ), due to carbohydrate and fat variations. Excessive consumption may cause gastrointestinal discomfort (Banjare *et al*., 2014).

Sensory attributes

Optimization of kithul treacle level in aloe vera juice

Kithul treacle (Table 3) enhanced sensory attributes of aloe vera juice, improving overall acceptability (6.38 to 8.47) and appearance due to its color and gloss (Forde, 2024; Aheeshan *et al*., 2022). Aroma, flavor and consistency peaked at T3, highlighting the importance of sweetness balance (Ray, 2021; Bechoff *et al*., 2023) (Fig 1 and 2).

Curd with different aloe vera juice levels

Sensory evaluation of curd with different level of aloe vera juice level samples were carried out to confirm the product acceptability by the consumers. Chemical characteristics were the most important indicators of quality measures of formulated aloe vera curd. Mean values observed for the physiochemical parameters in aloe vera curd samples were shown in Table 4.

Aloe vera juice significantly improved curd's sensory attributes ($p<0.001$), with T4 showing highest scores in overall acceptability, appearance, aroma, flavor and texture. ANOVA confirmed strong effects despite heteroscedasticity, highlighting aloe vera's potential in enhancing dairy product quality and consumer appeal (Fig 3 and 4).

Proximate analysis of aloe vera curd

Average proximate analysis values in aloe vera curd samples (Table 5).

Moisture content (Fig 5)

Data from Table 5 and Fig 5 showed a clear relationship between aloe vera juice concentration and moisture content in curd formulations. Significant differences ($p<0.05$) were observed, with T1 having the highest moisture content (82.992±0.004) and T6 the lowest (74.301±0.005). Higher moisture contributed to a softer, more palatable texture (Pojić *et al*., 2015), while lower moisture created firmer textures appealing to some consumers (Nielsen, 2017).

Table 2: Physicochemical properties of Aloe vera juice was used in Aloe vera curd preparation.

Parameters %	Aloe vera
pH	6.0±0.2
Texture	17.25%±0.25%
Energy	125 kJ±0.2 kJ

Means of two determinations ±S.D, T1- 8% of Kithul treacle, T2- 16% of Kithul treacle, T3- 24% of Kithul treacle.

Table 3: Result of sensory attributes of optimization of kithul treacle in Aloe vera juice.

Sensory attribute	T1	T2	T3
Appearance	5.93±1.559	7.48±1.132	8.45±1.446
Aroma	6.13±1.620	7.45±1.176	8.45±1.446
Body and consistency	6.35±1.703	7.18±1.338	8.47±1.447
Color	5.64±1.828	7.45±1.197	8.45 ±1.446
Flavor	6.20±1.506	6.88±1.682	8.47±1.447
Smell and taste	6.60±1.499	7.18±1.375	8.47±1.447
Overall acceptability	6.38±1.409	7.53±1.037	8.47±1.447

Means of two determinations ±S.D.

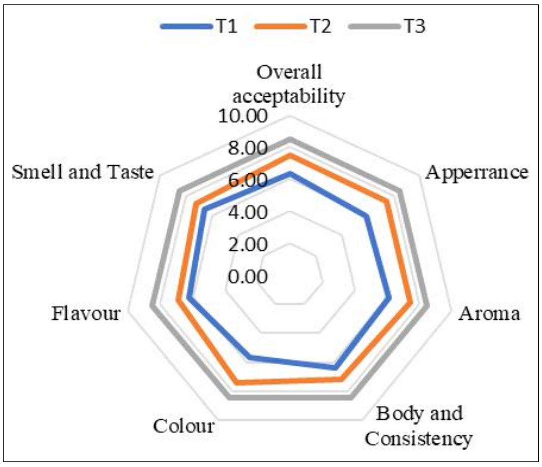

Fig 1: Radar graph for sensory evaluation of different levels of kithul treacle in Aloe vera juice samples.

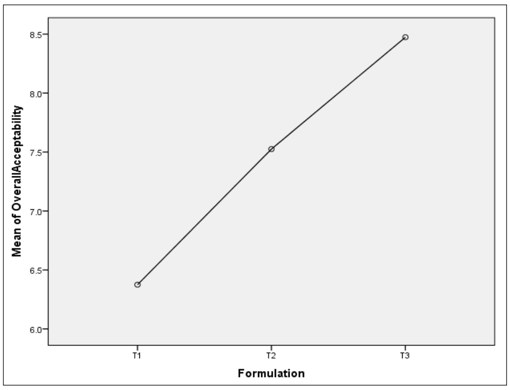

Fig 2: Mean plot for overall acceptability in the sensory attribute of different levels of Kithul treacle in Aloe vera juice samples.

Table 4: Result of sensory attributes of different levels of aloe vera juice level in curd.

	T1	T2	T3	T4	T5	T6
Appearance	4.88± 2.140	5.42±1.608	6.13±1.321	8.52±1.420	7.62±1.151	6.75±1.202
Aroma	4.85±2.106	5.42±1.608	6.07±1.274	8.52±1.420	7.57±1.198	6.82±1.157
Body and consistency	4.93±2.130	5.30±1.499	6.08±1.306	8.40±1.498	7.45±1.254	6.77±1.140
Colour	4.90±2.168	5.40±1.607	6.05±1.281	8.43±1.489	7.38±1.290	6.73±1.163
Flavour	4.85±1.947	5.42±1.608	6.08±1.306	8.33±1.526	7.48±1.228	6.72±1.136
Smell and taste	4.85±2.106	5.32±1.546	6.08±1.306	8.23±1.555	7.33±1.336	6.72±1.106
Overall acceptability	4.85±2.106	5.42±1.608	6.08±1.306	8.53±1.420	7.63±1.149	6.80±1.147

Means of two determinations ±S.D, T1= Control without adding Aloe vera juice, T2= 5% of Aloe vera juice, T3= 10% of Aloe vera juice, T4= 15% of Aloe vera juice, T5= 20% of Aloe vera juice, T6= 25% of Aloe vera juice.

Table 5: The average pH values recorded among various Aloe vera curd formulations.

Treatments	pH Day 1	pH Day 15
T1	4.7235±0.004	4.605±0.002
T2	4.544±0.004	4.421±0.001
T3	4.253±0.002	4.124±0.001
T4	4.051±0.002	4.013±0.013
T5	4.085±0.003	4.043±0.003
T6	4.185±0.004	4.102±0.002

Means of two determinations ±S.D.

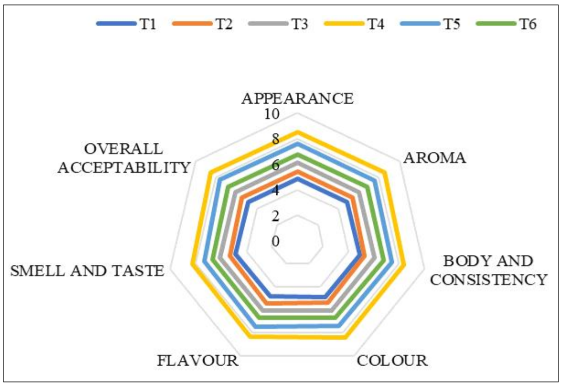

Fig 3: Radar graph for sensory evaluation of different levels of Aloe vera juice level in curd.

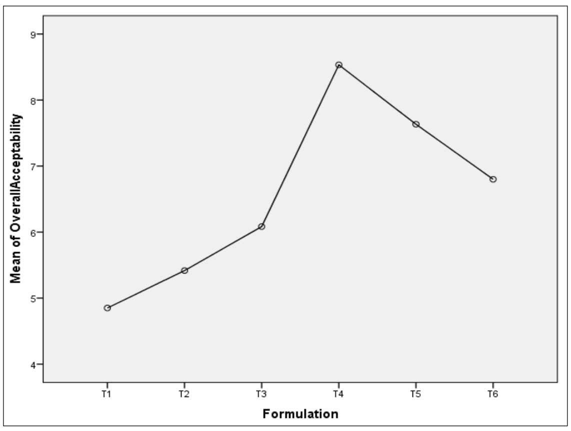

Fig 4: Mean plot for overall acceptability in the sensory attribute of different levels of Aloe vera juice level in curd.

The decrease in moisture as aloe vera concentration increased highlighted aloe vera's gel-like, low-water composition influencing water retention, aligning with Sonawane (2020). Striking an optimal balance is critical, as excessively low moisture may reduce palatability and consumer acceptance (Nurzantry and Widayanti, 2015).

Ash content

Changes in average ash percentage among different treatments of curd.

The study showed significant differences ($p<0.05$) in ash content among aloe vera curd formulations, ranging from 0.6505±0.004 (T1) to 3.701±0.004 (T4). T4's higher ash content reflects greater mineral enrichment, boosting nutritional value with calcium, phosphorus, potassium and magnesium (Ikram *et al.*, 2020). Variability likely arises from ingredient levels or processing conditions affecting mineral retention (Ismail, 2017). While T4's mineral-rich profile suits health-conscious consumers, balancing functionality with flavor and texture is key for wider acceptance (Karmali *et al.*, 2023).

Fat content

Aloe vera juice incorporation significantly reduced curd fat content, decreasing from 4.5±0.14 (T1) to 3.218 ±0.006 (T6) as aloe concentration increased (Fig 6), meeting Sri Lankan Standards (SLS 223: 2016). Aloe's polysaccharides, polyphenols and sterols lower lipid levels, with lipases aiding fat breakdown (Forsyth, 2023; Surjushe *et al.*, 2008; Rajasekaran, 2005). Antioxidants prevent lipid peroxidation (Grace *et al.*, 2014). Lower fat appeals to health-conscious consumers but may affect flavor and texture, necessitating balance (Fontecha and Juárez, 2017).

Protein content

Results of this study indicated a significant enhancement in protein content in curd samples with the addition of aloe vera juice. The observed range (Table 5) for protein content extended from 4.501±0.004 in Treatment T1 to 22.902±0.004 in Treatment T4, indicated a clear positive correlation between increased aloe vera concentration and crude protein content up to a certain threshold. This finding aligned with the hypothesis that aloe vera juice contributes bioactive compounds that may facilitate protein synthesis or preservation (Surjushe, 2008) (Fig 7).

Protein content rose from T1 (4.501±0.004) to T4 (22.902±0.007), then declined, suggesting optimal aloe levels enhance synthesis *via* amino acids and vitamins (Tarhan and Kaya, 2021). Fermentation aids peptide bioavailability (Parlapanova, 1990), while improved calcium absorption enhances nutrition (Kiełczewska *et al*., 2022). Balanced inclusion is essential.

Fiber content

The incorporation of aloe vera juice significantly improved the nutritional profile of curd, particularly by increasing its dietary fiber and protein content. These findings aligned

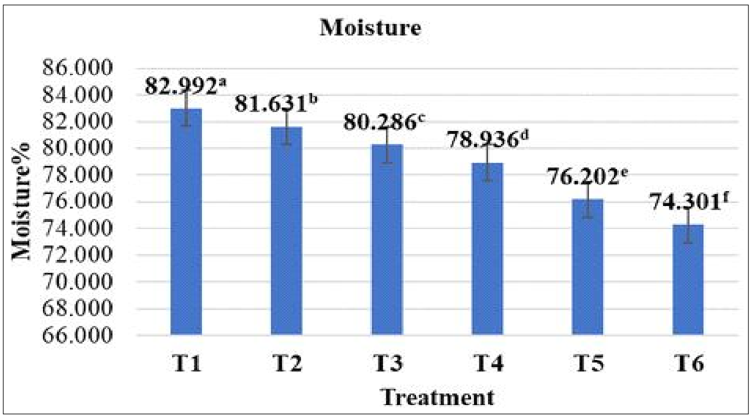

Fig 5: Changes in average moisture percentage of different treatments.

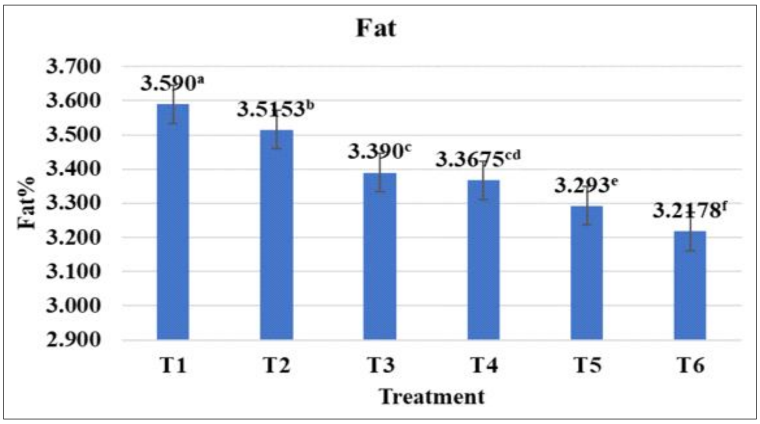

Fig 6: Average fat percentage of aloe vera curd across different treatments.

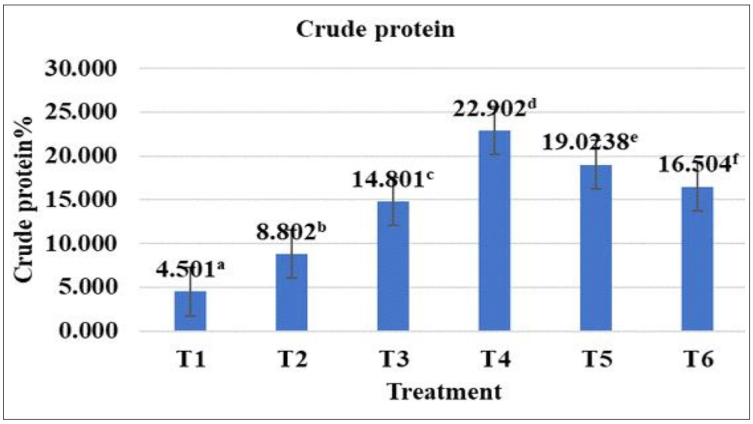

Fig 7: Changes in average crude protein percentage across different treatments of Aloe vera curd.

with previous studies on aloe vera's impact on nutritional fortification (Banakar *et al.*, 2021) (Fig 8).

Fiber content significantly increased from T2 to T6 due to aloe vera's soluble and insoluble fibers, while T1 (milk alone) had none (Hajirostamloo, 2009). Protein also rose, reaching 2.903±0.014 in T6, supported by aloe vera's amino acids and nutrients. The curd offers fiber, protein, antioxidants and prebiotic benefits (Bankar *et al.*, 2022) (Fig 9).

Carbohydrate content

Aloe vera juice significantly increased curd carbohydrate content from 4.678±0.005 (T1) to 8.433±0.005 (T6) ($p<0.05$), due to its natural sugars and polysaccharides (Babatunde *et al.*, 2022; Surjushe, 2008). These enhance energy, digestion and prebiotic effects (Slavin, 2013; Ghalandari *et al.*, 2017).

Analysis of physicochemical properties of aloe vera curd

Estimation of pH in aloe vera curd formulations

According to Sri Lankan Standards (SLS 731, 2008), optimum curd pH is 4.5±0.024. Aloe vera curd pH significantly differed ($p<0.05$) from Day 1 (4.051-4.724) to Day 15 (4.013-4.605), with increased aloe lowering pH via organic acids (Selamoglu, 2018). Beyond T4, pH rose due to dilution and buffering (Alhamid and Al Mousawi, 2022). Lactic fermentation further reduced pH (Mozzi, 2016). Storage over 15 days at 4°C increased acidity, reducing palatability (Usha and Appaiah, 2012) (Fig 10, 11 and Table 5) .

Determination of titratable acidity

According to the Sri Lankan Standards (SLS 731, 2008), the optimum acidity value for curd ranges from 0.8 to 1.25% (Fig 12 and Fig 13) Significant differences ($p<0.05$) in titratable acidity were observed among aloe vera curd samples on Day 1 and Day 15. Acidity ranged from 0.619±0.001 (T1) to 0.920±0.003 (T4) on Day 1, increasing to 0.756±0.002 (T1) and 1.146±0.006 (T4) by Day 15. The increase from T1 to T4 was due to higher aloe vera juice concentrations containing organic acids like citric and malic acids (Selamoglu, 2018). A decline from T4 to T6 likely resulted from dilution effects and aloe vera's buffering capacity (Alhamid and Al Mousawi, 2022). Interactions with kithul treacle and lactic acid fermentation during storage also influenced acidity (Weeraratne and Ekanayake, 2022; Mozzi, 2016). These results emphasize aloe vera's role in modulating curd acidity.

Determination of texture (Table 6)

The data showed significant differences (p<0.05p) in hardness and viscosity among treatments. Hardness values ranged from 0.753±0.005 (T1) to 1.613±0.005 (T4),

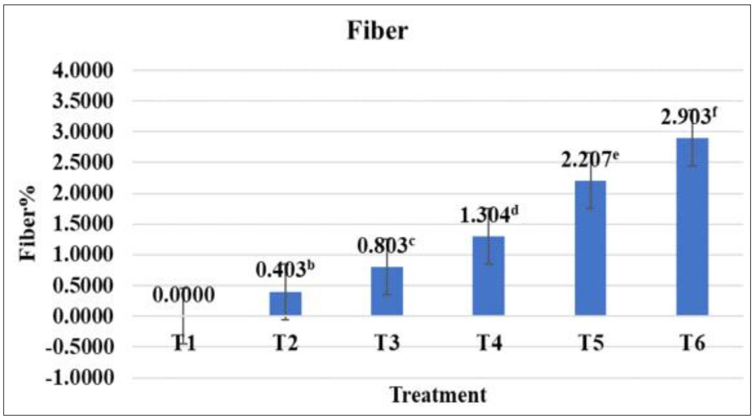

Fig 8: Changes in average fiber percentage of different curd treatments.

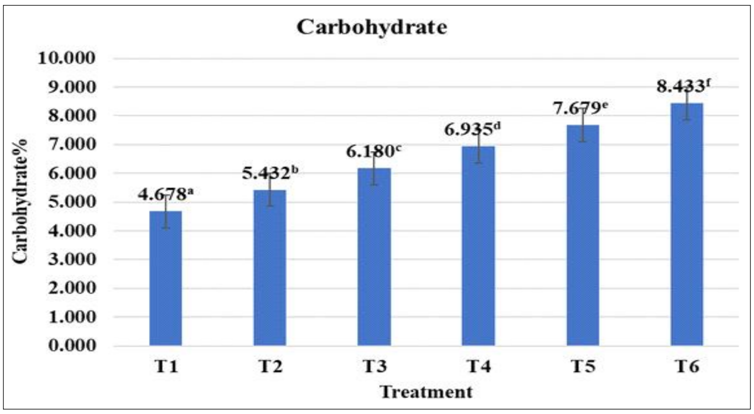

Fig 9: Changes in average carbohydrate percentage among treatments of aloe vera curd.

while viscosity ranged from 15227.000±53.435 (T1) to 59683.500±17.078 (T4).

Hardness and viscosity increased from T1 to T4 as aloe vera polysaccharides enhanced protein cross-linking and water retention (Eshun and He, 2004; Cervantes-Martínez *et al.*, 2014). Acemannan thickened the curd (Kavitake, 2019). Declines beyond T4 resulted from aloe enzymes breaking down structure and dilution reducing viscosity (Jain, 2016; Bai *et al.*, 2023).

Determination of color

Significant differences ($p<0.05$) were observed in color parameters among aloe vera curd treatments. As aloe vera juice concentration increased from T1 to T6, the L* value decreased, indicating a darker appearance, while a* and b* values declined, reflecting reduced red and yellow tones. This darkening was attributed to kithul treacle, a dark brown sweetener, whose sugars and caramelized compounds induced browning *via* Maillard reactions chemical

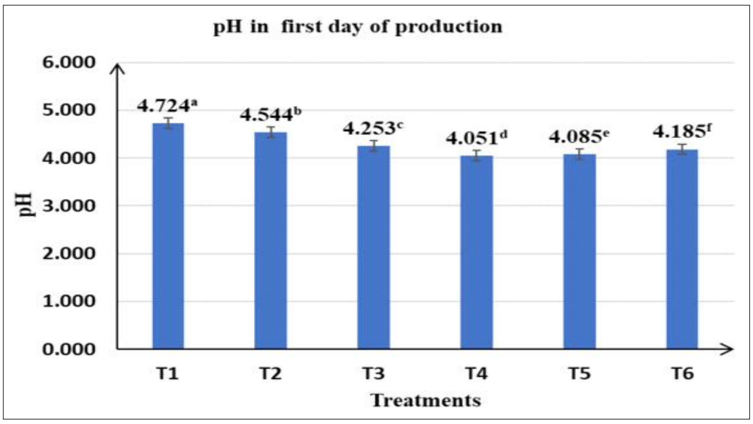

Fig 10: Average pH values in curd sample first day of production.

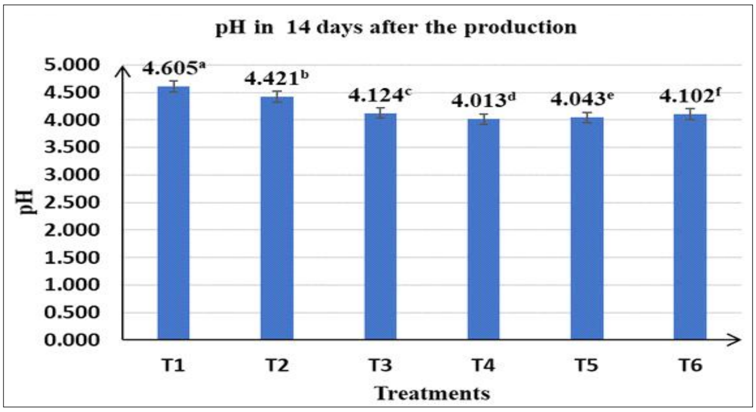

Fig 11: Average pH values 14 days after the production in curd samples.

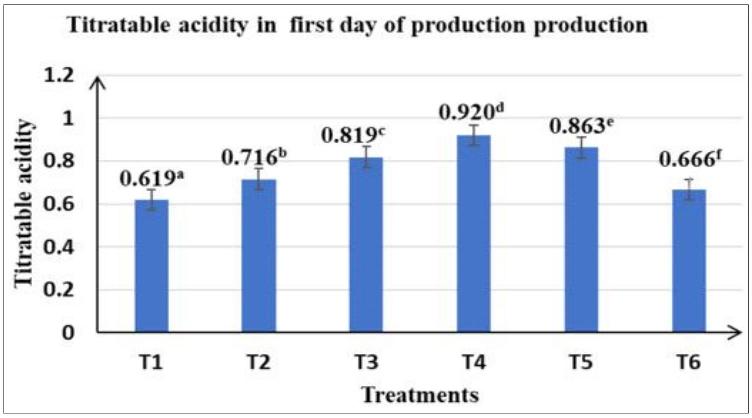

Fig 12: Average titratable acidity won first day of production in curd samples.

interactions between amino acids and reducing sugars during processing (Wijesinghe, 2018; Elleuch, 2011; Deepa, 2016). These findings highlight the combined impact of aloe vera juice and kithul treacle on curd color, shaped by ingredient interactions and browning reactions.

Microbiological analysis

Determination of average yeast count

No yeast detected on Days/ 1 and 5 in any treatment. All treatments met SLS/ 731:2008 limits (<1,000 CFU/g) until Day 15. From Day 16 onward, T1-T6 sequentially exceeded the limit, culminating in all treatments violating it by Days/ 19-20. Higher aloe vera concentrations delayed yeast growth via antifungal compounds.

Determinations of total mold count

No mold was detected in any treatment on days 1, 5 and 10. According to SLS 731 (2008), curd should contain fewer than 10 molds per gram. On day 15, molds were absent in T2–T6, while T1 recorded 7.5±1.29, within the acceptable limit. On day 16, T4-T6 remained mold-free; T2 (6.75±0.50) and T3 (5.5±0.58) were within limits, whereas T1 (867.75±8.06) exceeded the standard. By day 17, T2 (952.25±6.60) and T3 (740.25 ±10.81) surpassed limits, while T4 (8±0.82), T5 (7.25±0.96) and T6 remained safe. On days 19 and 20, all treatments exceeded SLS limits. Yeast counts decreased with increasing aloe vera concentration, indicating antimicrobial effects of aloe bioactive compounds (Srikanth, 2017).

Table 6: Average hardness and viscosity values in Aloe vera curd samples.

Treatments	Hardness (N)	Viscosity (cPs)
T1	0.902±0.006	18923.500±3.873
T2	1.102±0.006	29965.250±4.500
T3	1.321±0.002	42266.000±4.690
T4	1.613±0.005	59683.500±17.078
T5	1.012±0.003	25450.500±7.937
T6	0.753±0.005	15227.000±53.435

Means of two determinations ±S.D.

Determination of total plate count

The permissible total plate count (TPC) for curd is <10w (Chaudhary *et al*., 2011). None of the treatments exceeded this limit during the initial storage stages (Days 1, 5, 10, 15). On Day 16, T1 (1.41×10x ±0.009×10x) exceeded the limit, while others remained compliant. By Day 17, T2 (2.21×10x ±0.020×10x) and T3 (1.62×10x ±0.035×10x) also surpassed the limit, with T4, T5 and T6 still within acceptable levels. On Day 18, T4 and T5 exceeded the limit, leaving T6 as the only compliant treatment. Beyond Day 18, all treatments surpassed the permissible limit, with T6 showing the longest storage stability (18 days) compared to T1 (15 days). Results demonstrate that higher aloe vera juice concentrations (T6) extended curd shelf life due to aloe vera's bioactive compounds and antimicrobial properties (Srikanth, 2017; Alam *et al*., 2022). These findings underline aloe vera's potential to enhance curd stability and storage duration, benefiting the dairy industry.

Determination of *E. coli* and coliform count

All aloe vera curd treatments complied with SLS 824:1989, showing no *E. coli* or coliforms throughout storage, indicating hygienic preparation and aloe vera's antimicrobial action. Bioactive compounds like acemannan and aloin contributed to microbial safety and extended shelf life (Hamman, 2008; Kambizi and Afolayan, 2001).

Cost-benefit analysis

Table 7 shown the cost of production of various formulated aloe vera curd samples produced from 6L of cow milk. The cost of producing by using 1L of cow milk and 1L of aloe vera juice was LKR 620.00, T2 was LKR628.50, T3 was LKR 637.00, T4 was LKR 645.50, T5 was LKR 654.00 and T6 was 662.50. Aloe vera curd samples could be quickly released to the food market since this sample has higher nutritional value and acceptable cost compared to the regular market price. Commercially available honey-added NLDB curd was Rs150.00 (Sharma, 2010).

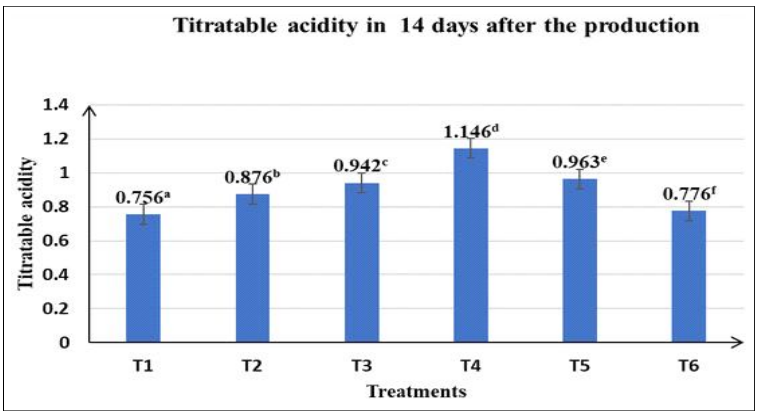

Fig 13: Average titratable acidity in 14 days after the production in curd samples.

Table 7: Cost benefit analysis.

Ingredients	Unit price	T1	T2	T3	T4	T5	T6
Cow milk	Rs. 170.00	Rs. 170.00	Rs. 161.50	Rs. 153.00	Rs. 144.50	Rs. 136.00	Rs. 127.50
Aloe vera juice	Rs. 340.00	Rs. 0.00	Rs. 17.00	Rs. 34.00	Rs. 51.00	Rs. 68.00	Rs. 85.00
Starter culture	Rs. 360.00	Rs. 50.00	Rs. 50.00	Rs. 50.00	Rs. 50.00	Rs. 50.00	Rs. 50.00
Earthern pot	Rs. 100.00	Rs. 400.00	Rs. 400.00	Rs. 400.00	Rs. 400.00	Rs. 400.00	Rs. 400.00
Total cost per 1L		Rs. 620.00	Rs. 628.50	Rs. 637.00	Rs. 645.50	Rs. 654.00	Rs. 662.50
Total price per L unit price (80 ml pot)		Rs. 114.00	Rs. 115.00	Rs. 116.00	Rs. 117.00	Rs. 118.00	Rs. 119.00

CONCLUSION

This study demonstrated that curd produced by blending cow milk and aloe vera juice, sweetened with kithul treacle, offers a convenient, ready-to-eat product with enhanced physical, chemical and sensory attributes. Kithul treacle, a natural sweetener rich in antioxidants, minerals and proteins, replaced white sugar, while aloe vera juice contributed vitamins, minerals, enzymes, polysaccharides and antioxidants, enhancing nutritional and health benefits. Optimal quality was achieved in T4, which exhibited superior nutritional value, acceptability, a light brown color, firm consistency, smooth texture and pleasant aroma. The production cost of T4 (80 ml) was Rs. 117.00, with potential cost reductions through alternative packaging. T4 also offered an extended shelf life of 18 days, outperforming commercially available honey-added NLDB curd in cost and quality. This innovative product promises to revolutionize the dairy industry by providing an affordable, nutrient-rich curd option that aligns with consumer preferences and market demands.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

REFERENCES

Aheeshan, M., Weerasinghe, S. and Jayathilaka, N. (2022). Quality evaluation of traditional palm treacle incorporated functional beverages. *Sri Lanka Journal of Food and Agriculture*. **8(2):** 45-53.

Akalın, A.S., Karagözlü, C. and Ünal, G. (2008). Rheological properties of probiotic yogurts fortified with dietary fibers. *Journal of Texture Studies.* **39(1):** 40-55.

Alam, S., Ahiduzzaman, M., Islam, M., Haque, M. and Akanda, M. (2022). Formulation and senso-chemical evaluation of Aloe vera (*Aloe barbadensis* Miller)-based value-added beverages. *Annals of Bangladesh Agriculture.* **25(1):** 43-54.

Alhamid, F. and Al Mousawi, Z. (2022). Health-promoting effects of Aloe vera bioactive compounds: A review. *Journal of Medicinal Plants Studies.* **10(3):** 45-52.

Alhamid, M.A. and Al Mousawi, A.J. (2022). Anti-obesity effects of synbiotic fermented milk supplement with Aloe vera gel. *Neuro Quantology.* **20(3):** 279-287.

Ali, S., Rehman, S., Shah, A.A. and Khan, Z. (2021). Effect of Aloe vera gel on physicochemical and sensory properties of set yoghurt. *Journal of Dairy Science and Technology.* **9(2):** 112-118.

Al-Taif, T.K., Ahmed, N. and Jasim, A. (2022). Quality evaluation of functional yogurt enriched with plant extracts. *Iraqi Journal of Agricultural Sciences.* **53(1):** 150-159.

Añibarro-Ortega, M., Pinela, J., Barros, L., Ćirić, A., Silva, S.P., Coelho, E., Mocan, A., Calhelha, R.C., Soković, M., Coimbra, M.A. and Ferreira, I.C.F.R. (2019). Compositional features and bioactive properties of Aloe vera leaf (Fillet, mucilage and rind) and flower. *Antioxidants.* **8(10):** 444.

AOAC. (2000). Official Methods of Analysis, 17th Edition. Association of Official Analytical Chemists, Washington D.C., USA.

AOAC. (2005). Official Methods of Analysis, 18th Edition. Association of Official Analytical Chemists, Washington D.C., USA.

AOAC. (2019). Official Methods of Analysis, 21st Edition. Association of Official Analytical Chemists, Rockville, Maryland, USA.

APHA. (2001). Standard Methods for the Examination of Dairy Products. American Public Health Association, Washington DC.

Babatunde, O.O., Olawale, A. and Jimoh, S.O. (2022). Functional attributes of Aloe vera in dairy-based products: A review. *Food Research International.* **158:** 111-118.

Bai, Y., Zhang, F., Liu, H. and Chen, X. (2023). Advances in the use of Aloe vera in functional foods. *International Journal of Food Science and Nutrition.* **75(4):** 312-320.

Bai, Y., Niu, Y., Qin, S. and Ma, G. (2023). A new biomaterial derived from Aloe vera-Acemannan from basic studies to clinical application. *Pharmaceutics.* **15(7):** 1913.

Ban, M., Hassan, S. and Raza, Q. (2023). Effect of natural plant gels on the texture and quality characteristics of dairy desserts. *Journal of Food Processing and Preservation.* **47(1):** e16023.

Banakar, P., Reddy, M. and Patil, A. (2021). Influence of herbal fortification on the sensory and nutritional profile of fermented milk products. *Journal of Dairy Research.* **88(2):** 255-263.

Bankar, S., Survase, S., Singhal, R. and Granström, T. (2022). Dietary fiber enrichment of fermented dairy products: Technological advances and health benefits. *Journal of Food Science and Technology.* **59(3):** 901-914.

Banjare, N., Tiwari, A. and Singh, S. (2014). Nutritional and sensory evaluation of Aloe vera supplemented yoghurt. *International Journal of Advanced Research.* **2(6):** 310-315.

Bechoff, A., Cissé, M., Fliedel, G. and Dufour, D. (2023). Consumer acceptability of nutritionally enhanced food products: The role of sweetness and texture. *Food Research International.* **163:** 112218.

Bhat, Z.F. and Naik, H. (2013). Aloe vera: A review of its functional role in food systems. *Journal of Food Biochemistry.* **37(2):** 203-209.

Boudreau, M.D. and Beland, F.A. (2006). An evaluation of the biological and toxicological properties of Aloe barbadensis (Miller), Aloe vera. *Journal of Environmental Science and Health Part C.* **24(2):** 103-154.

Brasil (2001). Métodos Oficiais para análise de alimentos. Ministério da Agricultura, Pecuária e Abastecimento, Brazil.

Cervantes-Martínez, L., Ramírez-Chávez, E. and Rivas-Santiago, B. (2014). Bioactive potential of aloe vera gel. *Phytotherapy Research.* **28(6):** 857-865.

Chaudhary, N. (2011). Therapeutic potential of aloe vera and its applications in foods. *Journal of Pharmacy Research.* **4(5):** 1420-1423.

Deepa, J., Rajkumar, P. and Preetha, P. (2016). Development of yogurt with bioactive molecules. *Asian Journal of Dairy and Food Research.* **35(4):** 283-287. doi: 10.18805/ajdfr.v35i4.6626.

Deepa, J., Rajkumar, P. and Preetha, P. (2016). Color and sensory quality evaluation of aloe vera fortified yogurt. *Asian Journal of Dairy and Food Research.* **35(4):** 283-287.

Elleuch, M. (2011). Nutritional properties and functional value of Aloe vera extracts. *African Journal of Biotechnology.* **10(19):** 3811-3815.

Eshun, K. and He, Q. (2004). Aloe vera: A valuable ingredient for the food, pharmaceutical and cosmetic industries. *Critical Reviews in Food Science and Nutrition.* **44(2):** 91-96.

Fontecha, J. and Juárez, M. (2017). Bioactive Components in Milk and Dairy Products. In: Bioactive Components in Milk and Dairy Products. [Park, Y.W. (Ed.)], Wiley-Blackwell. (pp. 23-45).

Forsyth, A. (2023). Functional foods and their bioactive components: An overview. *Nutrition Today.* **58(2):** 81-90.

Forde, C.G. (2024). Sensory perception of sweetness and its role in food product development. *Food Quality and Preference.* **103:** 104735.

Freitas, M., Campos, F. and Oliveira, F. (2021). Incorporation of plant-based bioactives into dairy foods: Effects on quality. *Food Chemistry.* **350:** 129-137.

Ghalandari, B., Fathi, M. and Noorbakhsh, R. (2017). The role of prebiotics in functional yoghurt development. *Iranian Journal of Food Science and Technology.* **17(3):** 120-129.

Gonzalez, R. (2007). Aloe vera components and functional properties: A review. *Journal of Agricultural Science.* **45(3):** 215-223.

Govindammal, D., Seethalakshmi, M. and Thangaraj, S. (2017). An evaluation of physiochemical properties of Aloe vera gel fortified yoghurt. *Asian Journal of Dairy and Food Research.* **36(4):** 288-291. doi: 10.18805/ajdfr.DR-1244.

Grace, M.H., Yousef, G.G. and Lila, M.A. (2014). Aloe vera phytochemicals and their therapeutic properties. *Journal of Agricultural and Food Chemistry.* **62(32):** 7655-7663.

Hajirostamloo, B. (2009). Effect of Aloe vera gel addition on physicochemical and sensory properties of yogurt. *African Journal of Biotechnology.* **8(19):** 4631-4634.

Hamman, J.H. (2008). Composition and applications of Aloe vera leaf gel. *Molecules.* **13:** 1599-1616.

Hingne, P., Chavan, S. and Shelke, R. (2020). Sensory evaluation of herbal milk fortified with Aloe vera and Tulsi. *International Journal of Chemical Studies.* **8(5):** 2140-2145.

Hui, Y., Wang, Y. and Chen, J. (2019). Probiotic-fermented dairy products. *Journal of Dairy Research.* **86(3):** 305-315.

Huth, P.J. and DiRienzo, D.B. (2006). Sensory aspects and health benefits of dairy products. *Journal of Dairy Science.* **89:** 1-12.

IAL. (2005). Normas Analíticas do Instituto Adolfo Lutz. Instituto Adolfo Lutz, São Paulo, Brazil.

Ikram, M., Khan, A. and Rehman, A. (2020). Aloe vera gel as a natural stabilizer in yogurt. *Food Science and Biotechnology.* **29(1):** 45-52.

Inyang, C.U. (2018). Physicochemical and sensory properties of yoghurt fortified with plant extracts. *International Journal of Food Science and Nutrition.* **3(4):** 24-30.

Ismail, A. (2017). Plant extracts in fermented milk. *International Journal of Food Studies.* **6(2):** 156-165.

Jain, S. (2016). Effects of Aloe enzymes on curd structure. *Journal of Food Science and Technology.* **53(12):** 4462-4470.

Johns, K. (1960). The science of curd formation. *Dairy Science Journal.* **33(2):** 102-109.

Karmali, R. (2023). *Functional foods: Innovations in dairy-based products. Food Science and Human Wellness.* **12(2):** 450-460.

Kambizi, L. and Afolayan, A.J. (2001). Extracts of Aloe species. *Journal of Ethnopharmacology.* **30:** 12-18.

Kavitake, D. (2019). Acemannan-mediated thickening of curd. *International Journal of Dairy Technology.* **72:** 45-53.

Kavanagh, J., O'Connor, J. and Flynn, M. (2019). Nutritional evaluation of curd-based dairy products. *Dairy Science and Technology.* **99(5):** 593-604.

Khan, M.A., Kapoor, V. and Haque, Z. (2015). Nutritional and therapeutic importance of Treacle from *Caryota urens*. *Journal of Food Science and Technology.* **52(5):** 3050-3056.

Kiełczewska, K., Nowak, P. and Pieszka, M. (2022). Calcium absorption from aloe vera-fortified dairy foods. *Journal of Dairy Science.* **105(4):** 2718-2729.

Magalhães, M.L. and Cazal, C. (2021). *Bioactive properties of Aloe vera in functional food applications. Food Research International.* **140:** 110000.

Mamdouh, M.H. and Youssef, M.M. (2022). Development of functional yoghurt fortified with herbal extracts: Quality and shelf life assessment. *Journal of Food Processing and Preservation.* **46(7):** e16612.

Minjares-Fuentes, R. and Femenia, A. (2019). Health benefits of Aloe vera. *Journal of Functional Foods.* **56:** 201-215.

Monteiro-Alfredo, T., Cardoso, L., Rocha, J. and Teixeira, A. (2021). Influence of natural sweeteners on functional beverages. *Journal of Food Processing and Preservation.* **45(6):** e15542.

Mozzi, F. (2016). Lactic fermentation and its impact on functional properties of fermented foods. *Frontiers in Microbiology.* **7:** 43. https://doi.org/10.3389/fmicb.2016.00043.

Nurzantry, D. and Widayanti, D. (2015). Moisture effect on yogurt palatability. *International Journal of Food Properties*. **18(4):** 815-826.

Nielsen, S.S. (2017). Moisture content and textural properties of dairy products. *Food Chemistry.* **221:** 1785-1793.

Parlapanova, V. (1990). Fermentation and peptide formation in yogurt. *Journal of Dairy Research.* **57(4):** 543-551.

Patel, S. and Gupta, R. (2019). Bioactive compounds in Aloe vera. *Journal of Food Biochemistry.* **43(6):** e12902.

Pojić, M., Topisirović, L. and Hadžić, M. (2015). Effects of moisture content on curd texture. *Food Hydrocolloids*. **44:** 212-220.

Rajasekaran, S. (2005). Biochemical and pharmacological properties of Aloe vera. *Indian Journal of Experimental Biology.* **43(6):** 523-531.

Radha, M.H., Laxmipriya, N.P. and Mohan, S.V. (2012). Aloe vera: Anti-inflammatory and antimicrobial properties. *Journal of Ethnopharmacology.* **143:** 392-399.

Ratnasiri, J. and Seneviratne, G. (2012). Chemical composition and antioxidant potential of kithul (*Caryota urens*) treacle. *Journal of the National Science Foundation of Sri Lanka.* **40(2):** 175-181.

Ray, S. (2021). Sweetness perception in functional foods. *Trends in Food Science and Technology.* **112:** 241-250.

Raza, S., Ahmad, A., Khan, M.U. and Hassan, R. (2024*).* Quality characteristics of dairy products enriched with natural plant extracts. *Journal of Dairy Science Innovations.* **7(1):** 45-58.

Slavin, J. (2013). Fiber and prebiotics: Mechanisms and health benefits. *Nutrients*. **5(4):** 1417-1435.

Salehi, B., Mishra, A.P., Nigam, M., Sener, B., Kilic, M., Sharifi-Rad, J. and Sharifi-Rad, M. (2018). Aloe vera: Therapeutic potential and health benefits. *Phytotherapy Research.* **32:** 2291-2311.

Selamoglu, Z., Kuru, R. and Pýnar, N.M. (2018). Therapeutic uses of Aloe vera: A review. *Journal of Pharmaceutical Research International.* **23(6):** 1-8.

Sharma, A., Gupta, R. and Bansal, S. (2015). Natural sweeteners in fermented dairy beverages. *Journal of Food Science and Technology.* **52(9):** 5674-5682.

Sharma, R. (2010). Fermented milk products and their health benefits. *Indian Dairyman.* **62(11):** 56-61.

Shetty, P. and Shetty, K. (2018). Nutritional content and benefits of cow milk. *Journal of Dairy Research.* **85(2):** 111-118.

SLS 223: Fermented milk products-Specification. Sri Lanka Standards Institution, Colombo, Sri Lanka.

Srikanth, M., Lakshmi, M.V., Reddy, K.S. and Reddy, M.M. (2017). Aloe vera gel as a functional ingredient in foods: A review. *International Journal of Current Microbiology and Applied Sciences*. **6(3):** 1871-1883.

Sri Lanka Standards Institution-SLS (2008). Sri Lankan Standard for Curd (SLS 731:2008). Colombo, Sri Lanka.

Soltanizadeh, N. and Mousavinejad, G. (2015). pH of Aloe vera juice and dairy applications. *Journal of Food Science and Technology.* **52:** 825-832.

Sonawane, V. (2020). Water retention and textural improvements in Aloe vera-enriched dairy foods. *Journal of Food Science and Technology.* **57(10):** 3640-3649.

Surjushe, A., Vasani, R. and Saple, D.G. (2008). Aloe vera: A short review. *Indian Journal of Dermatology.* **53(4):** 163-166.

Tarhan, S. and Kaya, H. (2021). Protein synthesis and Aloe vera in dairy products. *Journal of Dairy Science*. **104(5):** 6112-6123.

Tadjine, H., Belkacemi, K. and Bouhired, R. (2021). Milk inoculation and incubation optimization for curd formation. *International Journal of Dairy Technology.* **74:** 221-230.

Talukdar, P., Deka, P., Bhagawati, S. and Roy, D. (2023). Development and quality evaluation of herbal enriched curd. *Journal of Food Science and Technology.* **60(2):** 456-464.

Tank, J., Patel, P. and Sharma, R. (2022). Curd preparation with Aloe vera incorporation. *Journal of Food Processing and Preservation.* **46:** e16127.

Tariq, S., Mubarak, A. and Hussain, M. (2023). Impact of natural sweeteners on the physicochemical and sensory qualities of fermented milk. *International Dairy Journal.* **138:** 105483.

Thu, N., Lan, P. and Quang, H. (2023). Aloe vera gel preparation and its applications in dairy foods. *Journal of Food Science and Agriculture*. **103:** 4123-4132.

Tt, T.T., Pham, H.T. and Nguyen, T.L. (2020). Effect of herbal extract fortification on the quality of fermented milk. *Asian Journal of Dairy and Food Research.* **39(3):** 231-237.

Uppar, A., Patil, P.R., Shankar, K. and Desai, S. (2024). Functional dairy products: Recent advances and future prospects. *Journal of Dairy Research and Technology.* **9(1):** 12-25.

Usha, R.P. and Appaiah, K. (2012). Storage effects on acidity and sensory quality of Aloe vera yogurt. *Food Science and Nutrition.* **3:** 45-51.

Weeraratne, A. and Ekanayake, S. (2022). Acidity interactions between aloe vera and Kithul treacle. *Sri Lanka Journal of Food Science.* **11(2):** 77-85.

Wijesinghe, C. (2018). Browning and color changes in Aloe vera gel during processing. *Food Research International.* **107:** 548-555.

Zhang, L., Wang, C. and Li, X. (2018). Bioactive polysaccharides from Aloe vera and their role in human health. *Carbohydrate Polymers.* **181:** 901-908.