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Evaluation of the physicochemical and sensory properties of yogurt produced from camel and cow milk

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ABSTRACT

This study investigates the feasibility and quality outcomes of producing yogurt from various proportions of dromedary camel (Camelus dromedarius) and zebu cow (Bos indicus) milk. Six treatment formulations were prepared: T1 (90% camel, 10% cow), T2 (80% camel, 20% cow), T3 (70% camel, 30% cow), T4 (60% camel, 40% cow), T5 (50% camel, 50% cow), and a control (100% cow milk). A completely randomized design was employed to assess the physicochemical properties and sensory acceptability of the resulting yogurt. The analysis was done according to standard methods for the examination of foods. The blending ratios significantly influenced yogurt properties, including pH (5.32–5.79 in raw milk vs. 4.25–4.48 in yogurt), titratable acidity (1.301–1.398% in milk vs. 1.317–1.412% in yogurt), and specific gravity (1.021–1.039 in milk vs. 1.025–1.048 in yogurt). Nutritional composition varied across treatments, with moisture content ranging from 81.05% to 83.40%, fat content from 3.53% to 4.20%, protein content from 4.14% to 4.42%, lactose content from 4.49% to 5.34%, and ash content from 1.55% to 1.64%. Sensory evaluation indicated that panelists preferred treatments T1, T2, and T5. The findings demonstrate that blending camel milk with cow milk can produce acceptable yogurt products with distinct physicochemical and sensory profiles, thereby offering a viable strategy for enhancing the utilization of camel milk in dairy processing.

Keywords: camel milk, cow milk, blended yogurt production, physicochemical properties, sensory evaluation

INTRODUCTION

Camel milk is crucial for food security and rural livelihoods in arid and semi-arid regions, especially during droughts when conventional livestock fail. Dromedary camels (*Camelus dromedarius*), which represent about 89% of the global camel population, are particularly valued for their resilience and consistent milk yield in harsh environments. In Ethiopia and the Horn of Africa, camel milk significantly contributes to the local dairy supply **[1]**. Camel milk differs from cow milk in nutritional composition, containing higher levels of vitamin C, unsaturated fatty acids, and antimicrobial compounds, while lacking β-lactoglobulin, a major allergen found in cow milk **[2]**, and **[3]**. However, its low-fat content and unique casein structure, characterized by a low κ-casein content, pose challenges for yogurt production, often resulting in poor coagulation and a weak texture **[2]**. Yogurt, a globally consumed fermented dairy product, is traditionally made from cow milk using thermophilic starter cultures such as *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* **[4]**. It is valued for its nutritional density and sensory appeal. Blending camel milk with cow milk may enhance texture, flavor, and consumer acceptability while retaining camel milk's nutritional benefits. Camels are integral to the livelihoods of pastoral communities, providing milk and meat, and serving as transportation in desert regions. Their physiological adaptations enable prolonged lactation, outpacing that of other livestock **[4]**, **and [5]**. Ethiopia produces approximately 75,000 tons of camel milk annually, critical for the sustenance of camel herders in arid environments **[5]**, **[6]**, and **[7]**. While most camel milk is consumed fresh, some is fermented into products like Dhanaan for use in soups and porridge **[3]**. Despite its nutritional benefits, yogurt production from camel milk is challenging due to its unique casein composition, which complicates coagulation. Camel milk contains only 0.5% kappa casein compared to 13.6% in cow milk **[8]**, and **[9]**. Previous research highlights difficulties in achieving adequate texture and sensory qualities in camel milk yogurt **[10]**. Thus, evaluations of yogurt made from blended camel milk and cow milk have improved yogurt production, enhancing the livelihoods of camel herders, expanding the dairy market, and increasing income opportunities **[8]**. Therefore, the objective of this study is to evaluate the physicochemical and sensory qualities of yogurt produced from blends of dromedary camel and zebu cow milk.

Scientific Hypothesis

Blending camel milk with cow milk in varying proportions will enhance the physicochemical and sensory properties of yogurt, making it comparable in quality to yogurt made solely from cow milk. Specifically, it is hypothesized that: Yogurt produced from camel and cow milk blends will show significant differences in physicochemical properties (pH, titratable acidity, specific gravity, fat content, protein levels, and overall nutrient composition) compared to yogurt made exclusively from cow milk. Sensory evaluation will indicate that particular blending ratios will improve consumer acceptability in terms of taste, texture, aroma, and overall preference compared to control yogurt made from cow milk.

Objectives

Primary objectives: evaluate the physicochemical and sensory properties of yogurt produced from varying blending ratios of dromedary camel milk and zebu cow milk, aiming to identify the optimal ratio that enhances product quality and consumer acceptability.

MATERIAL AND METHODS

The research was carried out at the Food Science and Technology Laboratory within the Hawassa University College of Agriculture.

Samples

Samples description: Fresh raw milk from dromedary camels and zebu cows was utilized for yogurt production. Camel milk was collected from Meki, while cow milk was obtained from local farmers in Dato-Hawassa.

Samples collection: A total of 20 liters of fresh camel milk and 10 liters of fresh cow milk were collected in sterile containers from local farmers in Meki and Dato-Hawassa, respectively. The collected samples were transported in iceboxes to the Food Science and Technology Laboratory at Hawassa University, where they were stored at 4°C until processing.

Samples preparation: The collected milk samples were blended in six treatment proportions, as detailed in Table 1. The experimental design employed a completely randomized design (CRD) with varying treatment groups.

Table 1 Blend preparations of camel and cow milk for yogurt preparation.

Run order	Camel milk (%)	Cow milk (%)
Control	0	100
T1	90	10
T2	80	20
T3	70	30
T4	60	40
T5	50	50

Note: Treatments 1 through 5 (T1–T5).
Source: Ibrahem and El Zubeir **[7]** and Chye et al. **[11]**.

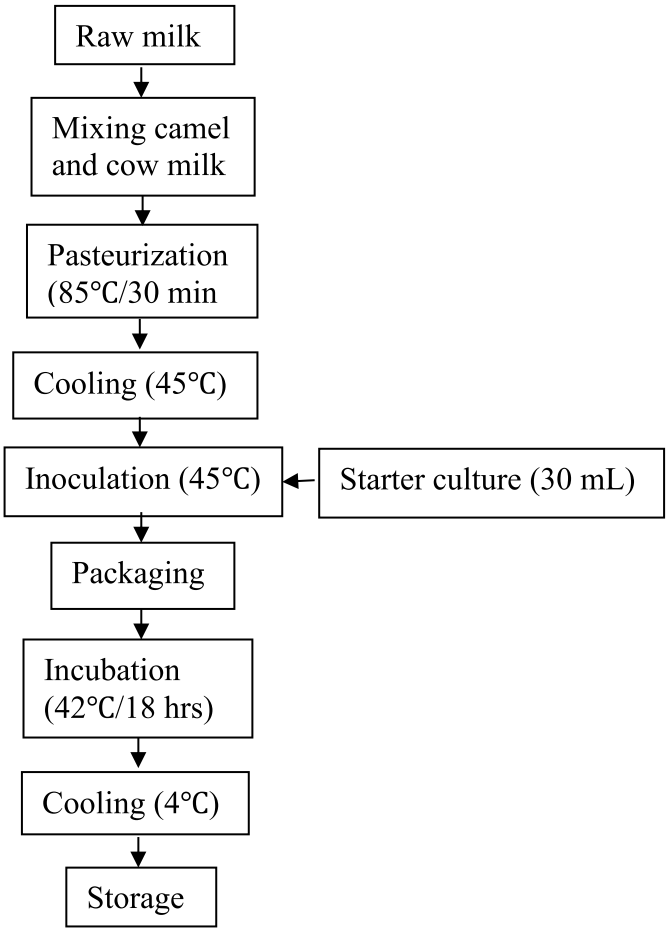

Figure 1 Yogurt production flow chart.

Number of samples analysed: 18

Chemicals

All chemicals utilized in the analyses, including sulfuric acid, amyl alcohol, phenolphthalein, formalin, copper sulfate, potassium sulfate, sodium hydroxide, hydrochloric acid, and boric acid, were of analytical grade and procured from reputable suppliers.

Animals, Plants and Biological Materials

The milk sources for this study were dromedary camels (Camelus dromedarius) and zebu cows (Bos indicus). The starter cultures employed for yogurt fermentation consisted of Lactobacillus delbrueckii subsp. bulgaricus and Streptococcus thermophilus.

Instruments

The instruments used in this study included a digital pH meter (InoLab D-82362, WTW GmbH, Weilheim, Germany), a specific gravity analyzer (DensiMat and Alcomat-2, Gibertini Electronical SRL, Milan, Italy), and a Gerber centrifuge for fat content determination (Gerber Instruments, Switzerland). Moisture and total solids analysis were conducted using a hot air oven from Memmert, Germany, while ash analysis was performed with a muffle furnace operated at 550°C (Nabertherm GmbH, Germany). Additionally, a Kjeldahl apparatus was utilized for protein determination.

Laboratory Methods

pH determination: The pH levels of the blended raw milk and yogurt samples were measured using a digital pH meter (InoLab D-82362, Weilheim, Germany) in accordance with AOAC protocols as described by Steegmans et al. **[12]**. Calibration of the pH meter was performed using pH 7.0 (phosphate buffer) and 4.0 (KCl) buffer solutions. After calibration, the electrode was immersed in 50 mL of each sample in a beaker until a stable reading was obtained.

Specific gravity determination: The specific gravity of the blended raw milk and yogurt samples was determined using a digital Gibertini-DensiMat and Alcomat-2 (Gibertini Electronical SRL, Milan, Italy) with slight modifications based on FAO s described by Omore & Staal **[13]** and El Zubeir & Jabbar **[14]**. This method helps detect milk adulteration with water. The instrument was calibrated by transferring 70 mL of 97%

alcohol (Fine Chemical General Trading 026029, Addis Ababa, Ethiopia) into a 100 mL graduated cylinder at room temperature. The electrodes of the Gibertini and temperature analyzer were introduced into a 70 mL milk sample placed in the graduated cylinder, and the specific gravity was recorded. The electrode, temperature analyzer, and cylinder were cleaned with distilled water between tests, and the electrode was stored in an electrode box after each test.

Titratable acidity (TA) determination: Titratable acidity (TA) was determined by titration as described by Steegmans et al. **[12]** and Omore & Staal **[13]**, with minor modifications. The TA of the blended raw milk and yogurt samples, expressed as a percentage of lactic acid, was measured by titrating 9 mL of the milk sample with 0.1 N standard sodium hydroxide solutions. The endpoint was indicated by a faint pink color using phenolphthalein as the indicator (eq. 1).

$$\text{Titrtable Acidity (\%Lactic acid)} = \frac{0.1\text{NAOH (ml)} \times 0.009}{\text{Volume of sample (mL)}} \times 100 \quad (1)$$

Moisture content: The moisture content of the yogurt samples was determined according to the methodology of Steegmans et al. **[12]**. A pre-weighed, dried moisture plate containing 10 g of yogurt was placed in an air oven at 105°C for 1 hour. After drying, the moisture dish was cooled in a desiccator and reweighed. The moisture content was calculated from weight loss (eq. 2).

$$Moisture\ content\ (\%) = \frac{\text{weight of fresh sample weight of dry sample}}{\text{weight of fresh sample}}\ x\ 100 \quad (2)$$

Total solid (TS) content: To measure the total solids (TS) content, 20 mL of blended milk and yogurt samples were mixed, and 5 mL were transferred to a pre-weighed, dried flat-bottom crucible. The samples were dried at 102°C in a hot air oven for 3 hours. After drying, the crucibles were cooled in desiccators before reweighing, and the TS content was calculated according to Steegmans et al. **[12]**, (eq 3).

$$\text{Total Solid (\%)} = \frac{\text{dry yogurt}}{\text{weight of the sample}} \times 100 \quad (3)$$

Total protein content: Total protein content was determined using the Kjeldahl method [12]. Ten milliliters of milk samples were placed in a white porcelain bowl, and 0.5 mL of a 0.5% phenolphthalein solution and 0.4 mL of saturated aqueous potassium oxalate were added, and the mixture was let to stand for two minutes. The mixture was titrated with 0.1 N NaOH until a pink color appeared. Two milliliters of neutral 40% formalin were added to eliminate the pink color. The protein percentage was calculated by multiplying the volume of 0.1N NaOH added after formalin by 1.74. The crude protein content of the yogurt sample was determined by multiplying its nitrogen content by 6.38. The procedure comprised: Digestion: Five grams of samples of milk and yogurt were heated to 38°C in a water bath before being put into a Kjeldahl flask. One milliliter of copper sulfate solution, 15 g of potassium sulfate, and 25 mL of sulfuric acid concentration were added. After the combination was broken down into a clear solution, it was left to cool. Distillation: After setting the digestion flask within the distillation equipment, 30 mL of distilled water and 75 mL of a solution containing 50% sodium hydroxide were added. Following the distillation of ammonia, 50 mL of a 40% boric acid solution were added using bromocresol green indicator until a blue hue developed. After adding 0.1N hydrochloric acid to the sample until a light pink tint appeared, the burette reading was taken and recorded to the closest 0.01 mL. Water was used in place of the sample in a blank test. The following formula was used to determine the milk samples' nitrogen percentage (eq. 4 and 5):

$$\%N = \frac{(\text{Vs-Vb})\text{HCL consumed} \times \text{NHCL} \times 1.4007}{\text{sample weight}} \times 100 \quad (4)$$

$$\%P = \%N\,X\,6.38 \quad (5)$$

Where;

6.38 is the dairy product conversion factor.
%N is the nitrogen percentage by weight.
Vs is the amount of HCl needed to titrate the sample.
Vb is the volume of HCl used to titrate the blank
P is the protein percentage.

Fat content: The Gerber method was utilized to ascertain the fat content of the milk and yogurt samples **[12]**. Ten milliliters of sulfuric acid were added to a butyrometer, followed by 10 mL of the sample and 1 mL of amyl alcohol. The butyrometer was sealed and agitated in a water bath at 65°C for 5 minutes. A Gerber centrifuge was used to centrifuge the sample at 1100 rpm for 5 minutes. After centrifugation, the sample was re-immersed in the water bath at 65°C for an additional 5 minutes, and the fat percentage was calculated using a butyrometer scale **[15]**.

Lactose content: The lactose percentage in the milk and yogurt was calculated by subtracting the percentages of fat, protein, and total ash from the percentage of total solids **[16]**, (eq. 6).

$$\text{Lactose (\%)} = \text{\%total solids - (\% fat + \% protein + \% ash)} \quad (6)$$

Solids-not-fat (SNF) content: The Solids-not-fat (SNF) content of the yogurt was determined by subtracting the fat percentage from the total solids percentage **[12]**, (eq. 7).

$$(\%)\ \textit{Solids-not-fat} = \%\ \textit{Total solids} - \%\ \textit{fat} \quad (7)$$

Ash content: For ash measurement, 20 mL of dried milk and yogurt samples were ignited in a muffle furnace, with the temperature gradually raised to 550°C. The total ash concentration was determined by the residue remaining after combustion, which should appear as light grey or white ash, indicating complete carbon removal **[12]**, (eq. 8).

$$\text{Ash (\%)} = \frac{\text{Residue weight}}{\text{Sample weight}} \times 100 \quad (8)$$

Sensory evaluation: A panel of 50 untrained judges, including students from the Hawassa University College of Agriculture, evaluated the yogurt samples for general acceptability and quality using a hedonic scale. The samples were assessed for color, mouthfeel, texture, flavor, and overall acceptability on a nine-point scale. Each sample was served in transparent glasses, with a minimum volume of 40 mL, and maintained at a temperature below 7°C. Panelists rated the sensory attributes on a scale from 1 (extreme dislike) to 9 (extreme like). Spring water was provided for palate cleansing between samples. Prior to the evaluation, panelists were informed of the study's purpose and provided their informed consent **[7]**, **[10]**.

Description of the Experiment

Study flow: In the experiment's first phase, we collected samples from individual dairy farmers in Meki (Camel milk) and Dato-Hawassa (cow milk). Afterwards, we prepared the samples for individual and blended experiments and laboratory analyses. First, we determined the essential characteristics such as pH, specific gravity, titratable acidity, moisture content, total solids, protein, fat, lactose, solids-not-fat, and ash. In the next phase, we performed individual experiments to determine the consumer acceptability of camel milk blended with cow milk yogurt. Finally, we processed the obtained results, subjected them to statistical analysis and verified the validity of our hypotheses.

Quality Assurance

Number of repeated analyses: 6

Number of experiment replication: Each experiment was conducted in triplicate.

Reference materials: For sample collection, 20 liters of fresh camel milk and 10 liters of fresh cow milk were obtained from farmers in Meki and Dato-Hawassa, respectively. The samples were transported in sterile containers within iceboxes and stored at 4°C upon arrival at the Food Science and Technology Laboratory at Hawassa University. The milk was blended into six treatment combinations, ranging from 100% cow milk to equal parts camel and cow milk, following a completely randomized design. A total of 18 samples were analyzed. All chemicals used, including sulfuric acid, amyl alcohol, phenolphthalein, formalin, copper sulfate, potassium sulfate, sodium hydroxide, hydrochloric acid, and boric acid, were of analytical grade from certified suppliers. Biological materials included milk from dromedary camels (*Camelus dromedarius*) and zebu cows (*Bos indicus*). Yogurt fermentation utilized starter cultures of *Lactobacillus delbrueckii subsp. bulgaricus* and *Streptococcus thermophilus*. Instruments included a digital pH meter (InoLab D-82362), specific gravity analyzers (DensiMat and Alcomat-2), a Gerber centrifuge for fat analysis, a hot air oven for moisture and solids determination, a muffle furnace for ash analysis, and a Kjeldahl apparatus for protein quantification. These materials supported the comprehensive analysis of physicochemical properties, compositional attributes, and sensory quality of the yogurt samples.

Calibration: All analytical instruments in this study were calibrated according to the manufacturers' specifications to ensure precision, consistency, and reproducibility. The digital pH meter was standardized with buffer solutions at pH 4.0 (potassium chloride) and pH 7.0 (phosphate buffer) for accurate pH determination. The Gibertini-DensiMat and Alcomat-2 specific gravity analyzers were calibrated using 70 mL of 97% ethanol in a 100 mL graduated cylinder at ambient temperature, ensuring reliable density readings. A 0.1 N sodium hydroxide solution served as a standard reagent for titrimetric analyses, validating the accuracy of acidity and protein measurements. After calibration, the stability and correctness of instrument readings were confirmed with additional standard solutions, reinforcing the integrity of the data collected throughout the experiments.

Laboratory accreditation: The experiments were conducted in the Food Science and Technology laboratory at Hawassa University, a recognized government institution in Ethiopia.

Data Access

All data generated from the experiments are presented in the manuscript, providing transparency and facilitating the reproducibility of the findings.

Statistical Analysis

Data were analyzed using Design-Expert 7.0 and SAS JMP 14 (Cary, North Carolina, USA).

One-way ANOVA was employed to assess differences among treatments, with panelists' influence as a blocking factor in the sensory quality analyses. Mean separation was performed using Duncan's Multiple Range Test and Tukey's Honestly Significant Differences (HSD) at a 5% significance level. Results are presented as mean ± standard deviation (SD.

Reporting and transparency statement

This experimental study did not involve randomization or blinding. All samples were included in the analysis, ensuring comprehensive results.

RESULTS AND DISCUSSION

Physicochemical Properties of Blended Raw Milk and Yogurt

The blended raw milk and yogurt produced from cow milk (control) and various milk mixtures exhibited average pH values ranging from 5.32 to 5.79 for blended raw milk and 4.03 to 4.88 for yogurt (Table 2).

Table 2 Physical properties of blended raw milk and yogurt.

T.	blended raw milk			Blended yogurt		
	pH	TA (%)	SG	pH	TA (%)	SG
Control	5.79 ± 0.000^{a}	1.301 ± 0.031^{d}	1.021 ± 0.001^{bc}	4.880 ± 0.017^{a}	1.317 ± 0.003^{d}	1.048 ± 0.001^{a}
T1	5.32 ± 0.014^{d}	1.398 ± 0.015^{a}	1.039 ± 0.001^{a}	4.030 ± 0.061^{f}	1.412 ± 0.003^{a}	1.025 ± 0.001^{bc}
T2	5.47 ± 0.021^{c}	1.382 ± 0.007^{b}	1.036 ± 0.001^{a}	4.210 ± 0.001^{e}	1.409 ± 0.011^{a}	1.029 ± 0.001^{bc}
T3	5.58 ± 0.014^{b}	1.371 ± 0.021^{bc}	1.030 ± 0.001^{b}	4.350 ± 0.091^{d}	1.379 ± 0.010^{b}	1.031 ± 0.001^{b}
T4	5.63 ± 0.014^{ab}	1.368 ± 0.030^{bc}	1.028 ± 0.001^{b}	4.520 ± 0.085^{c}	1.370 ± 0.022^{b}	1.036 ± 0.001^{b}
T5	5.70 ± 0.020^{a}	1.346 ± 0.013^{c}	1.023 ± 0.001^{bc}	4.670 ± 0.060^{b}	1.328 ± 0.031^{c}	1.042 ± 0.001^{ab}

Note: T – treatment, [a-f] Note: a-d data within the same column with different superscript letters are substantially ($p<0.05$) different from one another; all data are displayed as mean ± standard deviation; Treatments 1 through 5 (T1–T5).

The results indicate that blending proportions significantly influenced the pH values of the yogurt samples. The TA of the produced yogurt was significantly affected by the blending proportions, with titratable acidities ranging from 1.301% to 1.398% for blended raw milk and 1.317% to 1.412% for yogurt. The specific gravity of the milk samples ranged from 1.025 to 1.048, with no significant differences ($p>0.05$) between T1 and T2 or between T3 and T4. Specific gravity is commonly used in quality assessments to detect milk adulteration or cream removal. This measurement is influenced by temperature and the milk's composition, particularly its fat content.

Treatments T1 and T2 showed lower pH values than the other treatments, with an increase in the camel milk proportion correlating with lower pH **[17]**. Similar findings on the influence of milk type and blending ratios on acidity have been reported in studies of raw and fermented milk blends **[18]**. The yogurt made from pure cow milk (control) had the highest pH value (5.79), which exceeds the pH of 4.4 reported by Khalifa & Al-Haj **[17]**. These variations may arise from differences in milk volumes used, incubation times during coagulation, and blending ratios **[17]**, and **[18]**. In yogurt, TA reflects the lactic acid generated during lactose fermentation by lactic acid bacteria **[19]**, which is essential for flavor and quality assessment. The TA values observed in this study exceed those reported by Khalifa & Al-Haj **[17]**, namely 0.162% and 1.05%, likely due to differences in milk type and preparation methods **[20]**. The differences may be attributed to the type of milk used, yogurt preparation methods, and environmental factors **[17]**. Notably, yogurts from treatments T3 and T4 exhibited lower TA than the control and other treatments, potentially due to the higher camel milk content, which possesses antibacterial properties that inhibit the growth of lactic acid bacteria **[20]**, **[21]**. These findings align with Belay et al. **[21]**, who emphasized the importance of fat and solids-not-fat in determining milk density, although the specific gravity observed in this study was lower than that reported in other research **[22]**, and **[23]**.

Composition of Blended Raw Milk

The average moisture contents of camel and cow raw milk are summarized in Table 3. Treatments T2, T3, and T4 did not show significant differences in moisture content ($p > 0.05$), whereas all other treatments showed substantial differences at $p < 0.05$. Significant differences ($p < 0.05$) in TS content were observed among the treatments, ranging from 13.19% to 13.29% (Table 3). The 100% cow milk (control) had a higher TS content (13.29%) than the other treatments. Treatments T1 and T2, which contained a higher percentage of camel milk, displayed noticeably lower TS levels ($p < 0.05$). The protein content varied between treatments, ranging from 3.89% to 5.36% (Table 3).

Table 3 indicates that the average fat content of the milk samples ranged from 5.10% to 6.25%. The fat content of the 100% cow milk (control) was significantly different ($p < 0.05$) from that of the other treatments. The average lactose levels in the milk samples ranged from 5.10% to 6.25% (Table 3). These findings align with typical lactose concentrations, which range from 3.6% to 5.5%. The average ash concentration in the milk samples ranged from 1.58% to 1.67% (Table 3). The highest ash levels were observed in the 100% cow milk (control) and the T5 treatment (50% camel and 50% cow milk blend). As presented in Table 3, the raw milk samples exhibited a higher SNF content, ranging from 6.11% to 8.19%. The SNF content of 100% cow milk was numerically greater than that of the treated milk samples (T1 to T5) but not significantly different ($p > 0.05$). The differences between T1 and T2 were also not statistically significant ($p>0.05$).

Table 3 Composition of blended raw milk.

T.	Moisture content (%)	Total Solid (%)	Fat (%)	Protein (%)	Lactose (%)	SNF (%)	Ash (%)
Contr.	85.92 ± 0.639^{a}	13.29 ± 0.007^{a}	5.10 ± 0.000^{b}	5.36 ± 0.014^{a}	5.77 ± 0.127^{a}	8.19 ± 0.181^{a}	1.67 ± 0.007^{a}
T1	83.06 ± 0.448^{d}	12.36 ± 0.014^{c}	6.25 ± 0.071^{a}	3.89 ± 0.007^{d}	5.42 ± 0.042^{b}	6.11 ± 0.226^{c}	1.59 ± 0.000^{b}
T2	83.65 ± 0.512^{dc}	12.37 ± 0.014^{c}	6.05 ± 0.014^{a}	4.10 ± 0.000^{dc}	5.48 ± 0.007^{d}	6.32 ± 0.513^{c}	1.58 ± 0.007^{b}
T3	83.92 ± 0.711^{c}	12.78 ± 0.007^{b}	5.66 ± 0.007^{b}	4.48 ± 0.007^{c}	5.13 ± 0.007^{d}	7.12 ± 0.119^{b}	1.59 ± 0.007^{b}
T4	84.11 ± 0.559^{c}	13.19 ± 0.014^{a}	5.39 ± 0.141^{bc}	4.92 ± 0.007^{b}	5.12 ± 0.000^{d}	7.80 ± 0.454^{a}	1.63 ± 0.007^{ab}
T5	84.88 ± 0.792^{b}	13.19 ± 0.007^{a}	5.25 ± 0.000^{bc}	5.22 ± 0.007^{a}	5.57 ± 0.028^{ab}	7.94 ± 0.331^{a}	1.66 ± 0.007^{a}

Note: T – treatment, Contr. – Control, [a-d] Note: a-d data within the same column with different superscript letters are substantially ($p<0.05$) different from one another; all data are displayed as mean ± standard deviation; Treatments 1 through 5 (T1–T5).

The moisture content of blended raw milk in this study was lower than the values reported by Shamsia **[18]** and Hashim et al. **[10]**, which were 88.17% and 87.71%, respectively. This variation may be attributed to seasonal changes in milk composition and the availability of drinking water for camels **[18]**. The average TS content found in this study was greater than that reported by Hashim et al. **[10]** and Ibrahem and El Zubeir **[7]**. Blending with cow milk affects the TS content of camel milk, and seasonal variations typically lower TS during hotter months due to increased water content **[18]**. The protein levels in these blends were higher than those found by Asres and Mohamad **[5]**. Variations in protein content may result from environmental factors, species differences, feeding practices, and lactation stages **[17]**, and **[18]**. The protein levels observed in blended raw milk align with the quality standards set by the United States FDA (2.73%) and the European Union (EU) (2.9%) **[15]**, and **[19]**. The findings of this study reveal a higher fat content in both the control and blended raw milk compared to the 3.86% reported by Kučerová et al. **[20]**. According to FDA regulations, fluid raw milk must have a minimum fat content of 3.25%, while EU quality standards require at least 3.5% fat for unprocessed raw milk **[15]**, and **[24]**. Therefore, the fat content observed in this study meets the recommended levels set by both FDA and EU quality standards. Specifically, the results are consistent with those reported by Ait et al. **[25]**, who found a lactose level of 4.51%. Additionally, the findings support previous research by Ho et al. **[26]**, which indicated that camel milk may provide beneficial effects for individuals with lactose intolerance, as it contains lower lactose levels compared to cow's milk. These results are higher than those reported by Selda et al. **[27]** and Shamsia **[18]**, which ranged from 0.80% to 0.97%. Variations in ash content across different studies can be attributed to various genetic and environmental factors **[17]**, and **[18]**. The maximum SNF content observed in this study was 8.19%, which is lower than the 8.44% reported for cow milk in selected areas of the Amhara and Oromia regions of Ethiopia [**28**]. Furthermore, higher values of 9.31% in the Western Amhara region **[16]**, 8.96% in Bahir Dar city **[16]**, and 8.75% in Dire Dawa city **[16]** indicate that the results obtained in this study fall below the quality standards established by the FDA (8.25%) and EU (8.5%) **[15]**, **[20]**, and **[24]**.

Composition of Blended Yogurt

The mean moisture content of blended yogurt, derived from camel and cow milk, ranged from 81.05% to 83.40% (Table 4).

There was no significant difference ($p > 0.05$) in moisture content between the control yogurt and treatment T5 (50% cow milk and 50% camel milk). The overall solid percentage in blended yogurt varied from 12.07% to 13.03% (Table 4). Treatment T1 exhibited the lowest TS content, while the control yogurt (100% cow milk) had a significantly higher TS content ($p<0.05$) than other treatments. The average fat content of the yogurt samples ranged from 3.53% to 4.20% (Table 4). The fat levels in both the 100% cow milk yogurt and T5 treatment differed significantly ($p<0.05$) from those in other treatments. Table 4 presents the protein content of yogurt produced from various blends of cow and camel milk. Treatment T1 (4.14%) had a numerically lower protein content compared to the other treatments. Notably, the protein levels in the control (100% cow milk) and T5 (50% cow milk) were significantly higher ($p<0.05$) than in the other treatments. The mean lactose content of the yogurt samples ranged from 4.49% to 5.34% (Table 4). The lowest lactose level was observed in T1 (4.49%), while the control yogurt made from 100% cow milk exhibited the highest lactose content (5.34%), which was significantly greater ($p<0.05$) than that of the other treatments. The SNF content of the yogurt ranged from 7.87% to 9.38% (Table 4), with the control yogurt (100% cow milk) having the highest SNF percentage. Yogurt produced from treatment T1 exhibited a numerically lower SNF content compared to the other samples. Among the blended yogurt samples, treatment T5 had the highest ash content (1.63%), while T1 had the lowest (1.55%), with differences significant at $p<0.05$ (Table 4).

Table 4 Composition of blended yogurt.

T.	Moisture content (%)	TS (%)	Fat (%)	Protein (%)	Lactose (%)	SNF (%)	Ash (%)
Contr.	83.40 ± 0.712^{a}	13.03 ± 0.141^{a}	3.65 ± 0.028^{c}	4.42 ± 0.028^{a}	5.34 ± 0.339^{a}	9.38 ± 0.627^{a}	1.64 ± 0.007^{a}
T1	81.05 ± 0.439^{c}	12.07 ± 0.424^{c}	4.20 ± 0.141^{a}	4.14 ± 0.042^{b}	4.49 ± 0.396^{c}	7.87 ± 0.363^{c}	1.55 ± 0.007^{b}
T2	81.75 ± 0.722^{b}	12.08 ± 0.141^{c}	4.20 ± 0.071^{a}	4.25 ± 0.014^{ab}	4.69 ± 0.240^{b}	7.88 ± 0.375^{c}	1.56 ± 0.000^{b}
T3	82.02 ± 0.901^{b}	12.78 ± 0.141^{b}	4.01 ± 0.141^{b}	4.33 ± 0.042^{ab}	4.90 ± 0.039^{ab}	8.77 ± 0.442^{b}	1.56 ± 0.007^{b}
T4	82.61 ± 0.081^{ab}	12.82 ± 0.000^{ab}	3.87 ± 0.141^{bc}	4.37 ± 0.014^{ab}	4.97 ± 0.090^{ab}	8.95 ± 0.121^{ab}	1.60 ± 0.007^{a}
T5	83.08 ± 0.091^{a}	12.89 ± 0.141^{a}	3.53 ± 0.000^{c}	4.39 ± 0.028^{a}	5.20 ± 0.113^{a}	9.36 ± 0.287^{a}	1.63 ± 0.007^{a}

Note: T – treatment, Contr. – Control, [a-c]data within the same column with different superscript letters are substantially ($p<0.05$) different from one another; all data are displayed as mean ± standard deviation; Treatments 1 through 5 (T1–T5).

The control, T4, and T5 showed no significant differences among themselves, nor did T1, T2, and T3 differ from one another.

The moisture content observed in this study was lower than the values reported by Shamsia **[18]** and Hashim et al. **[10]** which were 88.17% and 87.71%, respectively. These differences may be attributed to seasonal variations in milk composition and the availability of drinking water for camels **[18]**. The higher water content of camel milk likely contributed to the reduction in TS as the proportion of camel milk increased **[18]**. The TS content in this study was somewhat higher than the 12.2% reported by Hashim et al. **[10]** and significantly higher than the 9.24% noted by Ibrahem and El Zubeir **[7]**. These results were lower than those reported by Belay et al. **[21]** but comparable to the 3.53% reported by Khalifa & Al-Haj **[17]**. Factors such as feed, lactation stage, and water availability significantly influence fat content in camel production **[18]**. The total protein content across all samples ranged from 4.14% to 4.42%, consistent with findings by Hashim et al. **[10]**, and **[18]**. The higher protein levels in the control and T5 samples may be attributed to the higher protein content of cow milk compared to camel milk **[29]**. This finding contrasts with Alaa et al. **[30]**, who reported no significant variation in lactose levels across different milk blends. The variation in lactose content may be influenced by microbial activity in raw milk, which can alter lactose levels based on temperature and storage duration **[18]**. Chye et al. **[11]** demonstrated that prolonged storage at elevated temperatures increases bacterial counts, accelerating lactose fermentation and reducing its content. The SNF values observed in this study were higher than the 7.95% reported by Amirdivani & Baba **[31]** for set-type yogurt formulated with pure lactic acid bacterial cultures. The ash content observed in this study was greater than the 0.84% reported by Shamsia **[18]** and the 0.71% by Hashim et al. **[10]** for camel milk yogurt produced in Sudan **[20]**. It was also higher than the 0.99% reported by Ibrahem and El Zubeir **[7]** for camel milk yogurt. Variations in ash content may be due to species differences **[17]**. These compositional differences are consistent with broader findings on milk blends and yogurt properties **[18]**.

Sensory Quality of Yogurt

The sensory evaluation results for yogurt produced with various blends of camel and cow milk are presented in Table 5. This study revealed that yogurt made from a combination of camel and cow milk was equally acceptable as yogurt produced solely from cow milk. The blending ratio influenced the yogurt's color, with the control and T5 (equal amounts of cow and camel milk) exhibiting similar colors that were significantly different ($p<0.05$) from other treatments (T1 to T4). All yogurt samples scored above 8 for texture (Table 5), though higher proportions of camel milk in T1, T2, and T3 likely contributed to their lower texture ratings.

Table 5 Consumer acceptability of produced yogurt.

T.	Color	Texture	Flavor	Mouthfeel	Overall acceptability
Control	9.18 ± 0.478^{a}	8.96 ± 0.380^{a}	8.66 ± 0.183^{a}	8.95 ± 0.481^{a}	8.48 ± 0.264^{a}
T1	9.10 ± 0.379^{b}	8.20 ± 0.116^{d}	7.58 ± 0.334^{c}	7.70 ± 0.428^{c}	7.55 ± 0.186^{c}
T2	9.12 ± 0.250^{b}	8.40 ± 0.439^{c}	7.66 ± 0.301^{c}	8.00 ± 0.118^{b}	7.63 ± 0.460^{c}
T3	9.13 ± 0.397^{b}	8.45 ± 0.269^{c}	8.39 ± 0.235^{b}	8.03 ± 0.267^{b}	7.96 ± 0.453^{b}
T4	9.11 ± 0.159^{b}	8.70 ± 0.217^{b}	8.57 ± 0.179^{a}	8.08 ± 0.235^{b}	8.22 ± 0.544^{ab}
T5	9.17 ± 0.133^{a}	8.75 ± 0.348^{b}	8.55 ± 0.249^{a}	8.80 ± 0.171^{a}	8.25 ± 0.204^{ab}

Note: T – treatment, $^{a\text{-}d}$ data within the same column with different superscript letters are substantially ($p<0.05$) different from one another; all data are displayed as mean ± standard deviation; Treatments 1 through 5 (T1–T5).

The smoother texture observed in blended yogurt with less camel milk (T5) aligns with **[32]**, who noted that yogurt's smoothness can be enhanced by higher fat content. In contrast to Khalifa & Al-Haj **[17]**, who reported lower flavor ratings (4.7%) for yogurt made with cow milk, the control group in this study scored 8.66 for flavor. Khalifa & Al-Haj **[17]** also noted significantly lower scores for blended yogurt, ranging from 2.07 to 3.07 at $p<0.05$, contrasting with the flavor assessments in this study. A similar trend was observed in mouthfeel scores, where panelists often struggled to distinguish between mouthfeel and flavor, as Rogers [33] also reported. Overall acceptability scores for the yogurt samples ranged from 7.55 to 8.48, indicating that blending proportions significantly affected acceptance ($p<0.05$). The control sample made from cow milk alone received the highest acceptance score of 8.48, aligning with findings by Khalifa & Al-Haj **[17]**, who reported that cow milk yogurt achieved the highest consumer preference **[18]**. These sensory findings are further supported by microbial quality studies comparing bulk tank and vending machine milk, which highlight the importance of hygienic handling for consumer acceptance **[20]**.

CONCLUSION

The evaluation of yogurt produced from blends of camel and cow milk showed significant variations in physicochemical and sensory properties, influenced by the blending ratio. Increasing camel milk proportions lowered pH and protein content while raising acidity and fat levels, whereas cow milk contributed higher protein, lactose, and solids-not-fat (SNF). Specific gravity and ash content showed minimal variation across treatments. Sensory evaluation revealed that cow milk yogurt (control) achieved the highest scores for flavor, texture, mouthfeel, and overall acceptability, while camel-rich blends scored lower due to lower protein and SNF levels. Notably, the 50:50 blend (T5) produced yogurt with comparable moisture, protein, ash, and sensory ratings to cow milk yogurt, indicating that camel milk can be successfully incorporated without compromising consumer preference. Cow milk yogurt consistently exhibited superior physicochemical and sensory properties, while the 50:50 blends (T5) achieved comparable scores in most parameters, indicating that camel milk can be successfully incorporated without compromising consumer acceptance. Camel-rich blends (T1 and T2) increased fat content but decreased protein, lactose, and sensory scores, emphasizing the necessity for balanced proportions to optimize yogurt quality. Overall, blending ratios were critical in determining yogurt quality, with cow milk enhancing nutritional density and sensory appeal and camel milk contributing higher fat and acidity.

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