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Impact of Mixing Camel Milk with Other Species Milk on the Physiochemical Properties and Sensory Acceptability of Yogurt

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ABSTRACT

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This experiment was conducted in the experimental laboratories of Tikrit and Kirkuk Universities throughout 2022-2023. This research study aimed to investigate the quality potential and shelf-life stability of yogurt prepared with different blend ratios (25-75% and 50-50%) of camel milk with cow, sheep, goat, or buffalo milk. The textural and sensory characteristics of the yogurt were carefully assessed during 3 weeks of cold storage. These characteristics were associated with protein content, titratable acidity, viscosity, water-holding capacity, and syneresis. Significant differences were observed between the blended camel sample and the other milk types (sheep, goat, and buffalo), indicating that its chemical properties are superior to those of the latter. The protein and ash contents of these blends were 5.25–5.48% and 0.92–0.97%, respectively. The DM content ranged from 11.64 to 13.58%. The camel milk and cow milk mixtures had significantly lower viscosity and pH, which was due to their soft texture. Overall, an increase in the percentage of camel milk resulted in reduced viscosity and coagulation time, which could be attributed to changes in protein characteristics. On the other hand, blends of camel and goat milk showed benefits in texture, viscosity, and overall stability. Storage studies showed that blends of camel milk with goat and buffalo had the highest water retention capacity and the lowest whey separation when compared with other blending treatments. Sensory evaluation also revealed that the camel-goat milk mixture was significantly more acceptable than cow milk in terms of texture and overall acceptability, but not in taste. The yogurt showed progressively poorer sensory qualities as storage time increased. At the same time, a 25:75 mixture of camel and cow milk retained better quality and stability. In conclusion, the present study's findings indicate that blending camel milk with non-bovine milk (goat and buffalo) yields high-quality yogurt with a stronger texture than cow's milk. Further studies are suggested to elaborate on the structural profiles of these yogurts by adding natural thickeners or fruit juices with good rheological properties and overall acceptability.

1-Introduction

Milk is a complete food for children as it provides the major nutrients required for growth and development. The importance of milk goes beyond providing mere nutrition; it is a vital source of macronutrients and micronutrients. It therefore plays a critical role in meeting the nutritional needs of human beings at all stages of life. Nowadays, scientific research is interested in camel breeding and the unique milk, due to its ability to produce large amounts of milk under dry environmental conditions (Pak et al., 2019). In the last decades, more attention has been given to studies of camel milk to understand its nutritional and medicinal advantages, especially its use in food processing and functional fermentation, such as yogurt (Ayoub et al., 2024; Ho et al., 2022). Camel milk is used for therapeutic nutrition in many countries for diseases such as hypertension, Anaemia, tuberculosis, and asthma. In addition to developing camel milk to control long-term blood sugar levels, it has been discovered that decreased insulin intake in diabetes patients (Mudgil et al., 2018; Ayyash et al., 2018), anti-carcinogenic properties (Ayyash et al., 2018; Al-Fakharany et al., 2018), it reducing cholesterol levels (Kaskous, 2016), offering antioxidant profiles (Ayyash et al., 2018). In recent studies, it was stated that camel milk has antibacterial properties (Kumar et al., 2016; Abusheliabi et al., 2017), Anti-obesity (Mudgil et al., 2018), and antiviral properties (Hara et al., 2002). Yogurt is a fermented food that is made when lactic acid bacteria turn milk into lactic acid. Also, yogurt is known as the oldest fermented product in the world, discovered by ancient humans in the Middle East and Asia, and is the most widely consumed fermented product worldwide (Khaliq et al. 2024). Therefore, yogurt made from milk fermented by various bacterial cultures consists of a mixed strain, such as *Streptococcus thermophilus* and *Lactobacillus delbrueckii subsp Bulgaricus*. Moreover, yogurt has

several healthy and nutritional benefits, including easily digestible and high nutritional value due to its richest sources of carbohydrates, proteins, lipids, vitamins, calcium and phosphorus, because proteins, lipids and lactose may be partially digested through fermentation so that yogurt is considered an easily digested product (Tamime&Robinson, 1999). In addition, bovine milk dominates global dairy markets due to its wide availability and economic significance. However, there is a great demand for alternatives to cow's milk due to their nutritional value and medicinal benefits. For example, camel milk has been associated with allergy-related problems, gastrointestinal disorders, and diabetic complications as a result of feed behaviours. It has a high tolerance to high salinity. It conserves water, making it the best ruminant for arid and semi-arid regions. Goats' and sheep's milk are highly digestible and rich in proteins and lipids (Deshwal et al., 2021). In fact, the physicochemical analysis was considered an important tool for detecting dairy product quality. Milk is the main source of essential nutrients for mammalian. Furthermore, different types of milk are used to make fermented products, especially cream, butter, ghee, and yogurt. Consumers are demanding milk and dairy products that are rich in nutrients (Khakhariya et al., 2023). Yogurt is widely consumed due to its functional and health benefits (Agustini et al., 2017). (Al-Hamdani et al., 2025) reported that using camel and goat milk blends with an acidity of 90% and fortified with buffalo milk with an acidity of 75.3% lead to reduced salty taste, an increased in texture, firmness and a reduction of acidity to half in processed yogurt. Additionally, a study by (Bhawna et al., 2020) found that fortifying camel milk with bovine proteins, Arabic gum, and gelatin produces yogurt with high sensorial profiles. The results showed better organoleptic tests, greater firmness, higher viscosity, and stronger gel networks. Finally, the objectives of our study were to

make functional yogurt from many types of species like camel, cow, sheep, goat and buffalo milk mixtures with ratios as (25-75 and 50-50%), then physiochemical and organoleptic tests to indicate of optimal mixed ratio.

2-Materials and methods

1. Raw milk: Raw cow milk was purchased from a local market, while camel, sheep, and goat milk were obtained directly from rural breeders in villages located in the Hawija District, Kirkuk Province, Iraq. These milk species were selected for their nutritional characteristics, functional attributes, and documented variation in protein composition, fat globule size, and buffer capacity, all of which are known to be important for yogurt fermentation and texture. Camel milk is used in skin care due to its unique nutritional composition and high bioactive content. There are several challenges in using MC as an alternative to WG, especially when adding it to yogurt manufacture. The whey protein is likely to weakly gel, possess a relatively low level of κ -casein, and reports between studies suggest that firm curd has not been observed. To overcome these problems, a technological policy has been adopted that involves mixing camel milk with cow, sheep, or goat milk in specific ratios. This strategy is implemented to improve fermentation efficiency and gel structure, and to enhance sensory quality, consistent with the literature on mixed-milk yogurt systems.

A freeze-dried commercial starter culture (Cuisine RI1020 All-Natural Yogurt Culture Starter from the USA) was used to standardise acidification and reproducibility during dairy fermentations. This culture includes *Lactobacillus acidophilus*, *Streptococcus thermophilus*,

and *Lactobacillus delbrueckii subsp. Bulgaricus*, a bacterium that is key to making yogurt. Their symbiotic growth not only promotes the efficient production of lactic acid but also significantly contributes to yogurt flavor and consistency. Culture was purchased from the Iraqi market as a powder and used according to the manufacturer's instructions. The addition of *L. acidophilus* in this study was intended to further improve the functional and probiotic qualities of yogurt, as it had been found to do previously.

2. Yogurt preparation: The manufacture of yogurt was based on (Lee & Lucey, 2010), with some modifications. Raw milk samples were poured into sterilised plastic bottles and preheated to 45 °C in a water bath to facilitate fat separation and maintain consistency during processing. Fat was separated in a laboratory milk separator and pumped back through the milk three times to obtain uniform decreases in fat, as is practised for yogurt production. The separated subsamples of cream and skim milk were weighed to assess the optimal efficiency of fat standardisation (contribution to texture, viscosity, gel firmness, etc.) on yogurt performance.

Eight unique combinations were formed from camel milk with cows, sheep, goats, and buffalo milk. The selection of these milk species and their respective blending ratios was based on previously published evidence that mixing-milk systems can improve the rheological and sensorial properties of camel milk yogurt. This improvement is due to better protein-protein interactions and higher buffering capacity. After mixing, each formulation was heated at 85 °C for 30 minutes, a heat treatment widely reported to promote whey protein denaturation and whey protein-casein interactions, thereby improving yogurt gel structure and water-holding capacity. Immediately after heating, the

milk mixtures were rapidly cooled to 45 °C, an optimal temperature for starter culture activity. Also included was 3% commercial freeze-dried yogurt starter culture. *Streptococcus thermophilus*, *Lactobacillus delbrueckii subsp. bulgaricus* and *Lactobacillus acidophilus*, employed in yogurt because of their synergistic growth and efficient lactic acid production, were in the starter. According to several fermentation studies, *S. thermophilus* accelerates acidification, *L. delbrueckii subsp. bulgaricus* improves flavor and texture through proteolytic activity, and *L. acidophilus* boosts the product's functional and probiotic value.

The inoculated milk blends were transferred into sterilised plastic containers (200 mL) and incubated at 42 °C until the pH reached 4.7, a value commonly used to define the endpoint of yogurt fermentation and to ensure consistent gel formation. Following fermentation, all yogurt samples were stored at 4 °C and evaluated after 1, 7, 14, and 21 days of refrigerated storage to assess the effect of storage time on physicochemical and sensory characteristics.

3. Chemical analysis: yogurt was analysed to determine the percentages of fat and total solids using an Eko milk analyser

(Horizon, Bulgaria). To cross-check the analyser results, fat content was also analysed using the Gerber method as prescribed by IDF (2009). Titratable acidity was determined by AOAC (2023). pH measurements were carried out using a digital pH meter (Orion Lab Star PH111 Bench pH Meters, UK) on samples according to the prescribed method (Mbye et al., 2021). Additionally, the ash content of milk samples was determined by weighing the residue left after burning the samples at 550 °C for 24 h in the muffle furnace (AOAC, 2023). The protein content of both milk and yogurt was estimated using the Kjeldahl method (AOAC, 2023). Finally, viscosity was measured instrumentally (SAMA Tools digital rotary viscometer) at 60-minute intervals until the milk pH reached 4.6.

4. Storage analysis of yogurt: Yogurt samples were prepared according to Figure 1. The samples were stored for 1, 7, 14, and 21 days to determine water retention and whey separation.

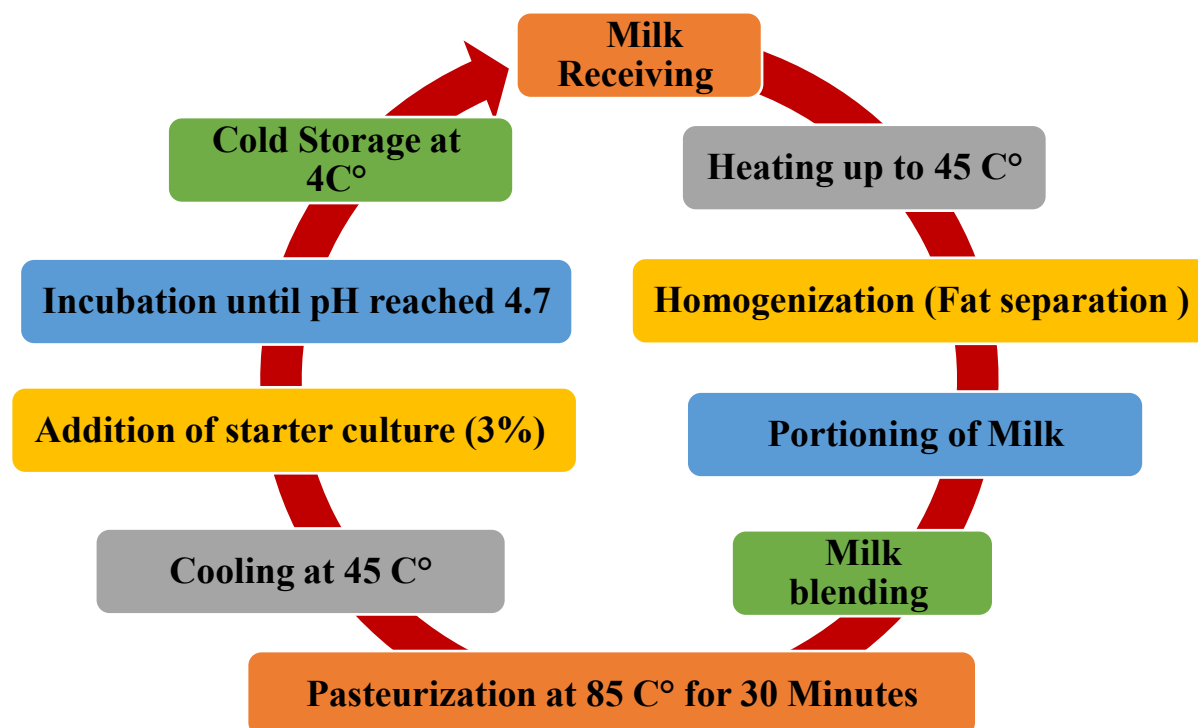


Figure 1 Steps of Yogurt production

5. Determination of wheying-off and water retention: according to the method described by (El-Hatmi et al., 2015), weighing 25 g. From yogurt and filtered by filter paper no. 615. Then measured the aqueous phase which passed through the paper. The Wheying-off index performed at 4° at 120 minutes. Water retention was estimated by adding 20 g of the yogurt samples to Falcon tubes, which were centrifuged at 1800 rpm for 30 minutes. Afterwards, pellet and serum phase were weighed, and water retention was calculated according to the formula below:

$$\text{Water retention} = 1 - \frac{Wt}{Wi} \times 100$$

Where Wt is the weight (g) of the pellet, and Wi is the initial weight (g) of the sample.

6. Organoleptic tests: The panel consisted of five trained, experienced panellists, academic staff who regularly consumed food products at the College of

Agriculture, Kirkuk, Iraq. The panellists were familiar with the questionnaires on sensory characteristics, and the following vocabulary was employed during the sensory evaluation. A structured score sheet adapted from previously reported works was employed to assess the attributes of mixed-milk yogurt. Colour and Taste, Aroma and Texture, and Overall acceptability score were assessed using a ten-point hedonic scale. Evaluation of up to approximately 50 mL of each yogurt sample was presented in original coded containers, and drinking water was offered for palate cleaning; this was done between samples. All evaluations were presented to the panel according to the modification method elucidated by Anli et al.

7. Treatments of Yogurt: Camel milk was mixed with other species milks to form Eight treatments: [A] camel – cow milks (25-75), [B] camel – cow milks (50-50), [C]

camel – sheep milks (25-75), [D] camel – sheep milks (50-50), [E] camel – goat milks (25-75) and [F] camel – goat milks (50-50). [G] camel – buffalo milks (25-75) and [H] camel – buffalo milks (50-50).

8. Statistical analysis: Milk blends were prepared under controlled laboratory conditions, and all treatments were produced in triplicate to ensure experimental reliability. Fermentation was conducted under standardised conditions to allow proper comparison between treatments and to minimise variability arising from processing parameters. This experimental design was chosen to address reproducibility concerns and to facilitate meaningful comparison with similar studies reported in the literature. All statistical

Table 1. Protein, Ash and Dry Matter content for blends of camel and cow, sheep, goat and buffalo milk.

Milk transactions	Protein %	Ash %	Dry Matter %
A	3.29 d	0.87 c	11.2 d
B	3.30 d	0.72 e	9.43 e
C	5.48 a	0.97 a	13.58 a
D	5.25 a	0.92 b	11.64 c
E	4.62 b	0.71 e	11.30 d
F	4.26 c	0.61 f	11.52 c
G	4.32 c	0.81 d	11.88 b
H	4.63 b	0.87 c	13.63 a

- The mean averages are triplicated samples.
- The different letters in Colman clearly show the significant difference at ($p \leq 0.05$).
- The Ratios of Blends: (A) Camel milk with cow's milk in a ratio of 25-75; (B) Camel milk with cow's milk in a ratio of 50-50; (C) Camel milk with sheep's milk in a ratio of 25-75; (D) Camel milk with sheep's milk in a ratio of 50-50; (E) Camel milk with goat's milk in a ratio of 25-75; (F) Camel milk with goat's milk in a ratio of 50-50; (G) Camel milk with buffalo milk in a ratio of 25-75; (H) Camel milk with buffalo milk in a ratio of 50-50

As shown in Table 1. Evaluates the high content of protein and dry matter content in a mixture of camel milk with sheep milk. In addition, some blend treatments high significant increase in the percentage of protein, such as treatments E and H. In contrast, these blends were significant

analyses were conducted using SAS Version 9.0. Data are presented as the arithmetic mean \pm standard deviation. Differences in the treatments were evaluated by one-way ANOVA. A p-value of ≤ 0.05 was considered statistically significant.

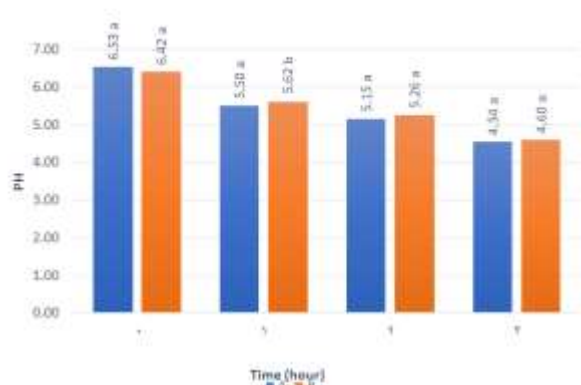
3-Results and Discussion:

The prepared and processed yogurt was made from several blends of camel, cow, sheep, goat, and buffalo milk, with different ratios. The percentages of protein, ash, and dry matter in the blends were determined. Also, sensorial profiles were estimated to detect optimal ratio mixtures. The findings were listed in Table 1.

superior compared to other ratios. Regarding to previous studies proofed that while raising sheep, goat and buffalo milk ratios in the mixture may led to increase of protein and dry matter contents in the same mixture, so our result come agreed with previous studies by (Hinz et al., 2012; Ahmadoon, 2012; Mustafa et al., 2015)

who found that increasing of camel milk ratio in the mixture led to decreasing of protein and dry matter contents in same blend. Furthermore, the results are revealed in Table 1. For ash, total solids were higher in treatments C and D across all blends, with slight, significant differences in ash content. Whereas parameters C, G, and H were superior to other treatments. Moreover, the same treatments were found to have remarkable increases in total solids (Khalifa & Zakaria, 2019; Choudhary et al., 2024). The ANOVA analysis revealed a significant difference ($P \leq 0.05$) in pH between yogurt samples from treatments A and B during the fermentation process. The time was controlled to determine viscosity, pH, and titratable acidity, which were considered three essential criteria in our investigation. To perform sensory tests: whey-off and water retention.

Regarding pH, it was measured until the coagulation point during incubation, at 4.7.



- The mean averages are triplicated samples.
- The different letters in bars clearly show the significant difference at ($p \leq 0.05$).
- (A) Camel milk with cow's milk in a ratio of 25-75; (B) Camel milk with cow's milk in a ratio of 50-50.

As shown in Figure 2. The coagulation time in treatments A and B was approximately 3 hours. The dropped pH in treatment A after three hours was faster than that of treatment B, which reached (4.45 and 4.60), respectively. The result of our investigation was significantly in agreement with many studies by (Mustafa et al. 2015; Bulca et al. 2019), which ranged between (4.72-4.91). On the other hand, there are no significant differences ($P \geq 0.05$) in the titratable acidity and viscosity of yogurt samples in the studied mixtures during the fermentation period. However, the investigation by Mustafa et al. (2015) reported that no remarkable effects on pH were observed in yogurt samples produced from camel and bovine milk. At the same time, it could significantly influence yogurt blends in the same mixtures.

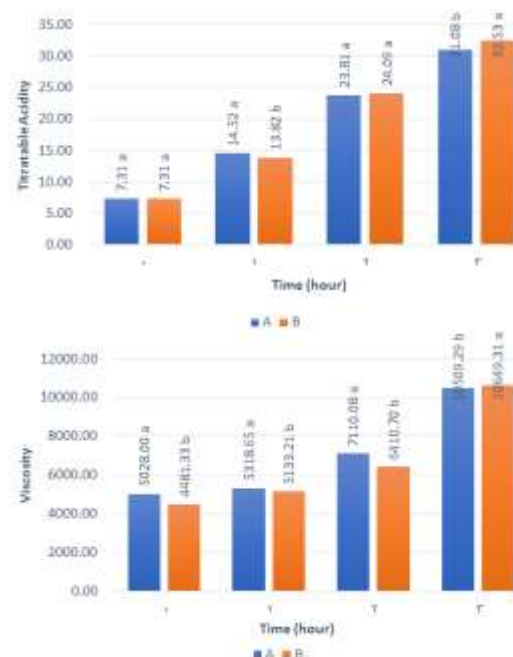
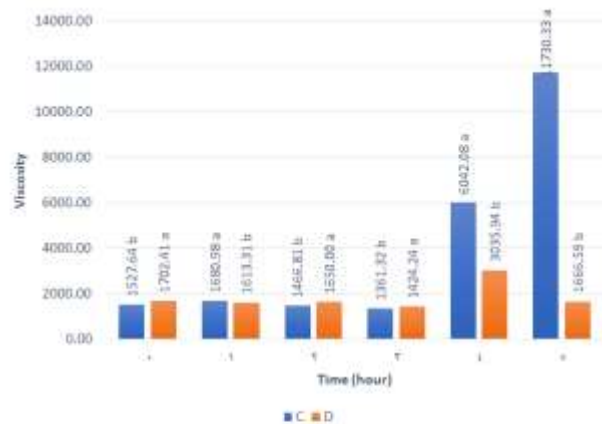


Figure 2 shows the effect of mixture ratios on pH, titratable acidity and viscosity in treatments A and B.

Our results are in complete agreement with the findings of (Mbye et al., 2021) regarding viscosity, pH, and titratable acidity. Figure 2. Clarifies the effect of blend ratios of camel and cow milk and coagulation period on titratable acidity and viscosity.

The result in Figure 2. Mentioned to viscosity values of the studied mixtures of milk, there was a big effect in both blends at the end of the fermentation period. In contrast, viscosity was increased after three hours of fermentation, and the viscosity was high in treatment B that reaching

($1.009,29 - 1.749,31$ mPa. s.). This remarkable agreement with the results of (Nguyen et al., 2018). Statistically, our results revealed that the fermentation period for treatments C and D was the longest among all treatments, except for treatments G and H, which had the same time. During

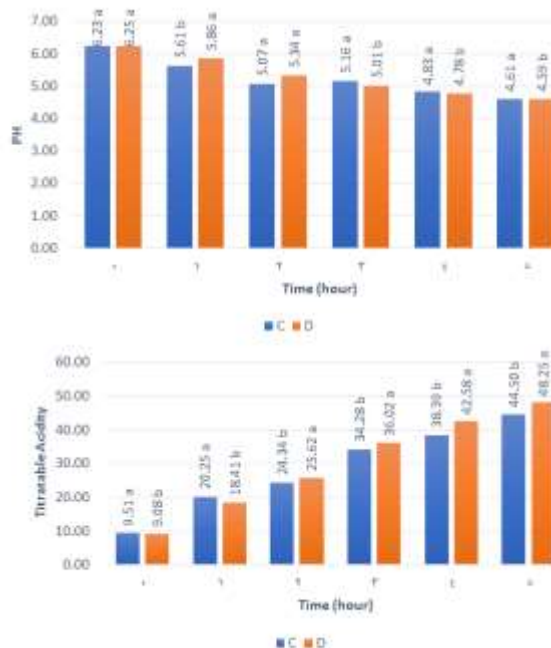


- The mean averages are triplicated samples.
- The different letters in bars clearly show the significant difference at ($p \leq 0.05$).
- (C) Camel milk with sheep milk in a ratio of 25-75; (D) Camel milk with sheep milk in a ratio of 50-50.

Figure 3 clarifies pH, titratable acidity and viscosity in treatments C and D.

However, the viscosity values reached higher levels of significance after 5 hours of fermentation, with treatment C (11730.33 mPa. s.) being higher than treatment D (1666.59 mPa. s.). This supports the idea that minimising the camel milk concentration in mixtures increases viscosity and decreases titratable acidity during yogurt production. The main causes of this state may be attributed to chemical and physical constituents of sheep and goat milk (Balthazar et al., 2017). During fermentation of camel and sheep mixtures, particles formed, with this phenomenon more pronounced with increasing amounts of camel milk in the blends. Moreover, Omar et al. (2018) reported that proteolytic activity in camel milk was higher than in bovine milk, potentially leading to the formation of combined and clustered particles in milk. This also applies to sheep milk. Regarding ANOVA analysis, there were no statistically significant differences

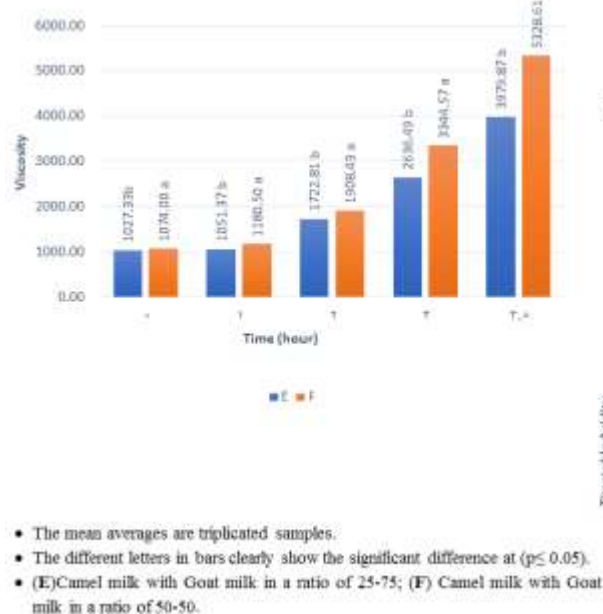
5 hours of fermentation, the pH value started at 6.25 at the beginning of incubation. It reached 4.59 at the end of fermentation, as shown in Figure 3, in complete agreement with previous investigations.



($P \geq 0.05$) in titratable acidity among yogurt mixture samples in treatments C and D at the beginning of fermentation. However, a significant increase ($P \leq 0.05$) in the percentage of titratable acidity was observed in treatments C and D (44.50-48.25) after five hours of fermentation, with positive correlations.

As can be seen from Figure 4, the determination of pH in the treatments E and F showed that the pH gradually dropped at the end of the fermentation period after three and a half hours. It provided remarkable values that range between (4.49-4.51) in E and F samples. Regarding the ANOVA analysis, the results revealed no significant differences ($P \geq 0.05$) in pH values among yogurt samples in E and F mixtures at the start of fermentation. However, it subsequently developed during fermentation, resulting in significant differences between its treatments. In addition, it noted significant differences ($P \leq 0.05$) in pH, titratable acidity, and

viscosity after 3.5 hours of fermentation. According to our notes and findings, the antibacterial properties of camel milk have prevented and inhibited the growth of starter cultures and the breakdown of casein



Further studies same our current investigation by (Mustafa et al., 2015) who proved that using of blends from camel and cow milk with ratios (75-25, 50-50, 25-75% and 100% camel milk) on the chemical composition, pH, titratable acidity and sensory properties on yogurt, then found that optimal yogurt sample with good texture was from pure bovine milk and higher bovine milk with camel milk mixtures.

(El-Zubeir et al., 2012) showed that yogurt manufactured from camel milk had a watery texture compared with yogurt from bovine mixed milk, which agreed with our results. The results were encouraging and statistically significant after 3.5 hours of fermentation and incubation. In terms of viscosity, it reached in treatment F as (5328.63 mPa. s). Meanwhile, titratable acidity value recorded its significantly superior levels at the end of coagulation for all studied ratios, which ranged between (35.20-35.30). Our results were consistent with previous studies (El-Zubeir et al.,

molecules in goat and sheep milk. As shown in Figure 4, our results listed the effects of the mixtures and fermentation time on viscosity and titratable acidity.

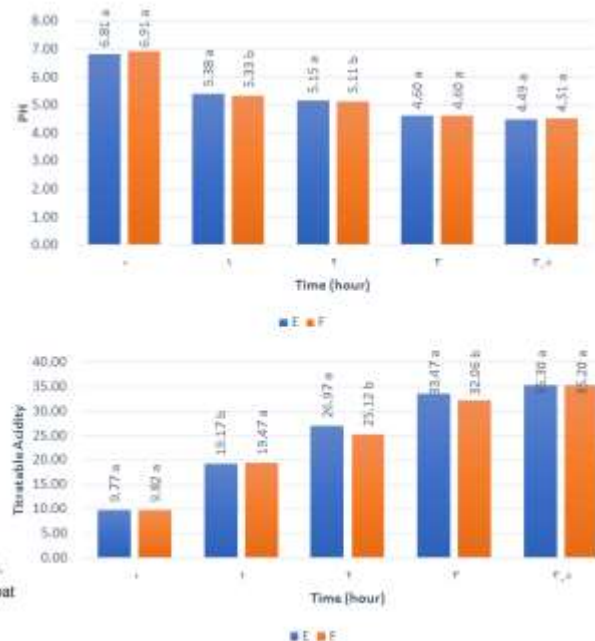


Figure 4 refers to the fact that pH, titratable acidity and viscosity in treatments E and F.

2012; Bulca et al., 2019; Ibrahim et al., 2021).

However, Figure 5 shows the treatment G and H combinations for pH, titratable acidity, and viscosity. Late in the fermentation phase, pH values rose, notably in treatment G, which reached 4.29. Meanwhile, it was higher for treatment H at the beginning of coagulation, especially during the first 3 hours, when the values ranged from 4.61 to 5.11. This indicated that camel milk commonly had a higher pH, which may be attributed to differences in its protein composition and buffering capacity; however, our result was consistent with previous studies by Guinee et al. (2015) and (Choudhary et al., 2024). Regarding statistical analysis, no significant difference in titratable acidity was observed at treatment G. In contrast, the treatment H was of remarkable value, especially in the last hours of fermentation, which states that the effect of pH combination with titratable acidity was not affected except during the last hour of fermentation, particularly in treatment H, was ranged between (25.23-

34.30). For these reasons, our results showed that minimising the camel milk concentration in blends led to higher viscosity, a faster decrease in pH, and superior titratable acidity during yogurt production. Moreover, the proteolysis of camel milk was higher than that of buffalo and other species, which may have led to the formation of particles in milk. Consequently, this effect led to the rapid breakdown of casein particles, consistent with previous studies. Regarding all that has been mentioned above, the natural microbial load in camel milk was inhibited and reduced by starter, leading to the

hydrolysis of caseins in cow, goat, sheep, and buffalo milk.

Similar studies to ours have confirmed that camel milk blends with cow, sheep, and goat milk affect the chemical composition, pH, and viscosity of yogurt (Bulca et al., 2019). Which found that the best treatment was camel and bovine milk with a ratio (20-80%), also the other blends with sheep and goat milk were acceptable. Finally, the current study was in agreement with (Eissa et al., 2011), who stated that increases in acidity and decreases in pH during storage of the studied milk blends may be attributed to variations in natural microbial loads and milk nutrient composition.

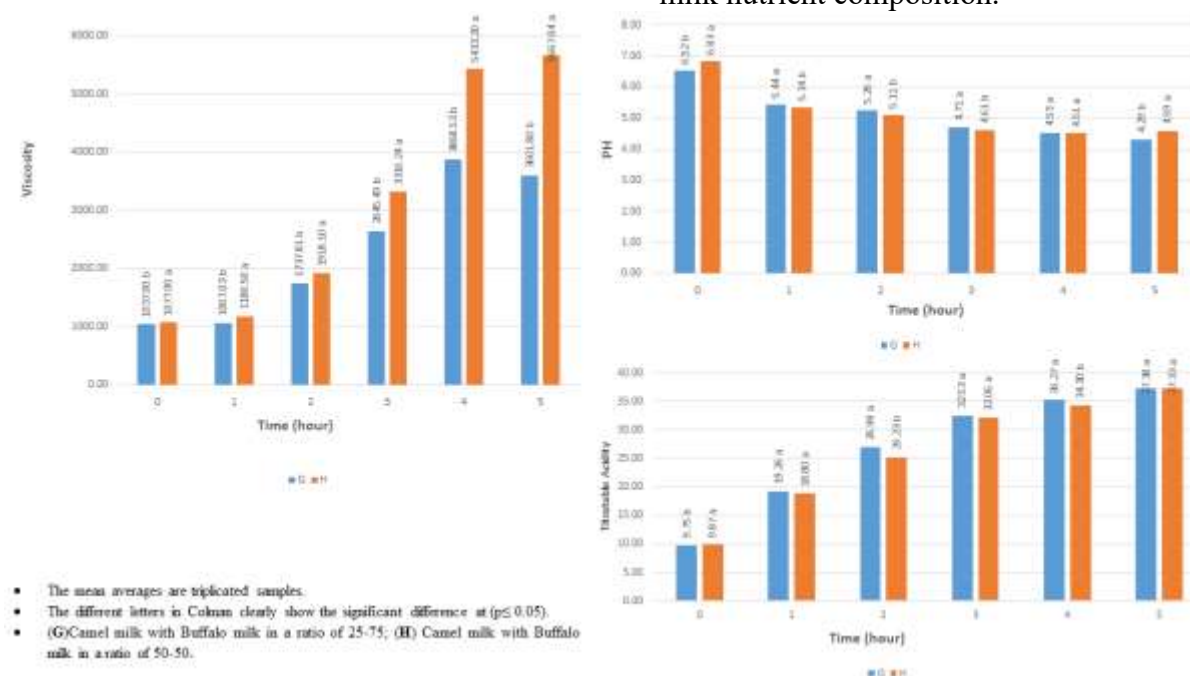


Figure 5 shows pH, titratable acidity, and viscosity for treatments G and H.

As a result of static analysis, during storage periods of (1, 7, 14, 21 days), analyses were carried out to determine water retention and whey-off; these results are listed in Table 2. It was noticed that a statistically significant inverse relation. Also, a remarkable relationship between wheying-off and water retention was observed from the first to the fourteenth days of storage. Therefore, the goat milk blends (E and F) were statistically superior from day 1 to day 20 during analysis, with water retention ranging from 32.80% to 36.36%. Also, the same mixtures showed superior water retention and Whey-off during the final

storage periods at 14 and 21 days. Our study found that the least water retention in treatments A and B was 2.53% and 3.61%, respectively. This indicates that the yogurt texture is weakened due to the use of high proportions of bovine milk in camel milk blends. Consequently, treatments E and F showed the least Whey-off during the first week, indicating greater homogeneity in their mixtures. Thus, camel and goat milk mixtures result in a firmer, better-textured product than other blends.

All therapies enhanced water retention on day seven. Treatment F outperformed the others by 25.6%. E and F reduced wheying-

off, whereas C and D enhanced it. Interestingly, camel and goat milk yogurt was hard and stable. Camels and cows, and sheep milk combinations were softer and more cohesive.

On the fourteenth day, all treatments increased water retention, but treatment F had the highest value at 31.32%, while treatment A had the lowest at 7.55%. Higher camel milk concentrations increased wheying-off, notably in treatments C and D. Due to enzyme activity and casein hydrolysis, yoghurt structure gets weakened over storage, especially in blends with greater camel milk contents.

Table 3. Water retention and wheying-off in camel milk blends with cow, sheep, goat and buffalo milk.

Milk transactions	Day 1		Day 7		Day14		Day21	
	Water retention	Wheying-off	Water retention	Wheying-off	Water retention	Wheying-off	Water retention	Wheying-off
A	2.53 h	17.58 b	4.16 h	13.57 e	7.51 g	11.16 h	8.49 h	13.77 g
B	3.61 g	13.76 e	5.43 g	9.69 g	7.55 g	13.09g	9.32g	15.29 f
C	31.58 c	15.64 c	30.00 d	21.88 c	38.46 a	24.70 e	13.23 f	37.15 c
D	28.49 f	30.56 a	32.13 c	26.64 a	36.57 b	29.40 b	19.18 c	25.06 d
E	32.80 b	12.29 f	44.74 a	24.26 b	32.76e	32.77 a	31.25 a	47.72 a
F	36.36 a	12.55 f	25.62 f	11.54 f	31.32 f	15.40 f	14.82 e	19.39 e
G	30.55 d	17.55 b	38.69 b	21.22 d	35.60 c	27.34 d	24.27 b	39.82 b
H	29.36 e	15.27d	26.54 e	13.49 e	34.06 d	28.98 c	18.64 d	19.37 e

- The mean averages are triplicated samples.
- The different letters in Colman clearly show the significant difference at ($p \leq 0.05$).
- The water retention and Wheying-off were described as (%).
- (A) Camel milk with cow's milk in a ratio of 25-75; (B) Camel milk with cow's milk in a ratio of 50-50; (C) Camel milk with sheep's milk in a ratio of 25-75; (D) Camel milk with sheep's milk in a ratio of 50-50; (E) Camel milk with goat's milk in a ratio of 25-75; (F) Camel milk with goat's milk in a ratio of 50-50; (G) Camel milk with buffalo milk in a ratio of 25-75; (H) Camel milk with buffalo milk in a ratio of 50-50

Regarding the ANOVA analysis results, the sensory evaluation of camel milk blended yogurts over 1, 7, 14, and 21 days of refrigerated storage (Table 3) showed a progressive decrease in colour, texture, aroma, taste, and overall acceptability scores. This trend highlights the sensitivity

Finally, water retention decreased across all treatments, especially in the camel and cow milk blends. Treatments E, F, and G demonstrated the highest retention values (39.82% and 47.72%) and the lowest Wheying-off compared to the other treatments. However, it was observed that mixing camel milk with goat and buffalo milk resulted in greater stability during long-term storage than when mixing camel milk with cow or sheep milk. Our result was in agreement with the findings of (Jandal 2013, El-Hatmi et al., 2015; Mustafa et al., 2015), and (Bulca et al., 2019).

of yogurt sensory quality to storage time, especially beyond 7–14 days.

This was consistent with a recent research that longer storage times were found to be a major factor enhancing post-acidification, syneresis, and loss of texture in yogurt, leading to poor sensory quality (Terzioglu

et al., 2023). Acid production and metabolism by the microflora during storage further change flavour and mouthfeel, rendering it unacceptable to panellists.

Gel network and sensory stability tend to be lower for camel milk yogurts unless mixed with other milks (Khalel et al. 2023). Acidification and proteolytic modifications would account for the stronger aroma and taste decrease observed in blends after 14 and 21 days.

Blending camel milk with cow, sheep, goat, and buffalo milk had a significant influence on the quality of yoghurt. On days 1 and 7, blends of sheep-buffalo milk were rated better in flavor, texture and acceptability than goat-cow blends. These findings agree with the report where higher TS, as well as fat and protein contents in milk samples from sheep and buffaloes, also made yogurt better sensorially (Li et al., 2025).

These observations agree with previous results for fermented mixed milk products, in which sheep milk enhances body and creaminess. A buffalo paste increases viscosity and richness, which contribute favourably to consumer acceptance (Terzioglu et al., 2023). The higher sensory scores of mixed milk yogurts may be due to a better gel network and a better balance of taste created by the compatibility of contrasting properties of mixed milks.

Likewise, texture scores decreased overall across treatments during storage (indicative of physical modifications, i.e., reductions in gel strength and syneresis). A comparative

weak gel can be obtained in camel milk yogurt, due to the distinctive casein micelle structure. It may not have a satisfactory texture without support from blending or stabilisers. Apparently, the effect is lessened when mixed with sheep or buffalo milk. Nonetheless, post-acidification and protein hydrolysis during extended storage also cause textural degradation.

Colour scores declined somewhat during storage; this reduction probably reflected the influence of light-scattering phenomena associated with variations in protein and fat dispersion. While small, these changes are consistent with sensory alterations observed in mixed-milk yogurts during refrigerated storage (37).

Last and most importantly, overall acceptability combines all sensory attributes and is the primary determinant of consumer preference. In the present study, yogurt made from sheep or buffalo milk had higher acceptability values during early storage (days 1 and 7). Still, all blends showed declines after day 14. Moreover, this decline aligns with the current literature, which indicates that yogurt sensory quality is best when consumed within 7–14 days of production, as extended cold storage often results in adverse changes in flavor, acidity, and texture (Wang et al., 2025; Kiyanisefat et al., 2025). These findings are significant for dairy producers aiming to formulate stable mixed-milk yogurts with satisfactory shelf life and consumer acceptance. The figure 6. Listed all interactions of treatments and sensorial properties within storage days in samples.

Table 3. Organoleptic tests of camel milk blends with cow, sheep, goat and buffalo milk during storage periods (1, 7, 14, 21 days).

Milk transactions		Sensorial Properties				
Traits	Storage/Days	Color	Texture	Aroma	Taste	Overall Acceptability
A	1	7.30	7.00	6.50	6.88	7.95
	7	7.90	7.20	6.35	7.25	6.91
	14	6.80	6.98	5.90	6.30	6.75
	21	5.67	5.13	5.45	6.10	6.30

B	1	7.55	7.70	7.20	7.35	8.15
	7	8.11	7.56	7.02	7.20	8.09
	14	7.42	6.75	6.89	6.90	7.85
	21	6.89	6.10	6.23	6.10	7.43
C	1	7.14	7.91	6.90	7.50	7.80
	7	7.09	7.88	6.76	7.40	7.76
	14	6.89	6.69	5.95	6.90	7.62
	21	5.98	6.19	5.65	6.33	7.38
D	1	7.66	7.87	7.30	7.35	8.10
	7	7.11	7.79	7.25	7.10	8.08
	14	6.91	7.15	6.95	6.90	7.95
	21	5.87	6.42	6.45	6.12	7.74
E	1	7.52	7.96	8.20	6.15	6.15
	7	6.94	7.63	8.10	6.05	5.98
	14	6.91	7.34	8.00	5.87	5.71
	21	5.79	6.96	7.98	5.52	5.46
F	1	7.15	7.85	7.90	6.10	5.85
	7	7.10	7.79	7.82	6.07	5.71
	14	5.99	7.32	7.80	5.95	5.38
	21	5.86	6.97	7.35	5.74	4.90
G	1	7.89	8.15	7.50	8.15	7.85
	7	7.52	8.09	7.25	7.91	7.40
	14	6.31	7.91	7.10	7.37	6.32
	21	5.88	7.42	6.90	6.88	5.98
H	1	7.95	8.10	7.60	8.40	8.25
	7	7.76	8.01	7.55	8.36	8.10
	14	6.58	7.87	7.35	7.45	7.65
	21	5.36	7.66	7.20	6.20	7.05

- Values are means of three independent determinations.
- (A) Camel milk with cow's milk in a ratio of 25-75; (B) Camel milk with cow's milk in a ratio of 50-50; (C) Camel milk with sheep's milk in a ratio of 25-75; (D) Camel milk with sheep's milk in a ratio of 50-50; (E) Camel milk with goat's milk in a ratio of 25-75; (F) Camel milk with goat's milk in a ratio of 50-50; (G) Camel milk with buffalo milk in a ratio of 25-75; (H) Camel milk with buffalo

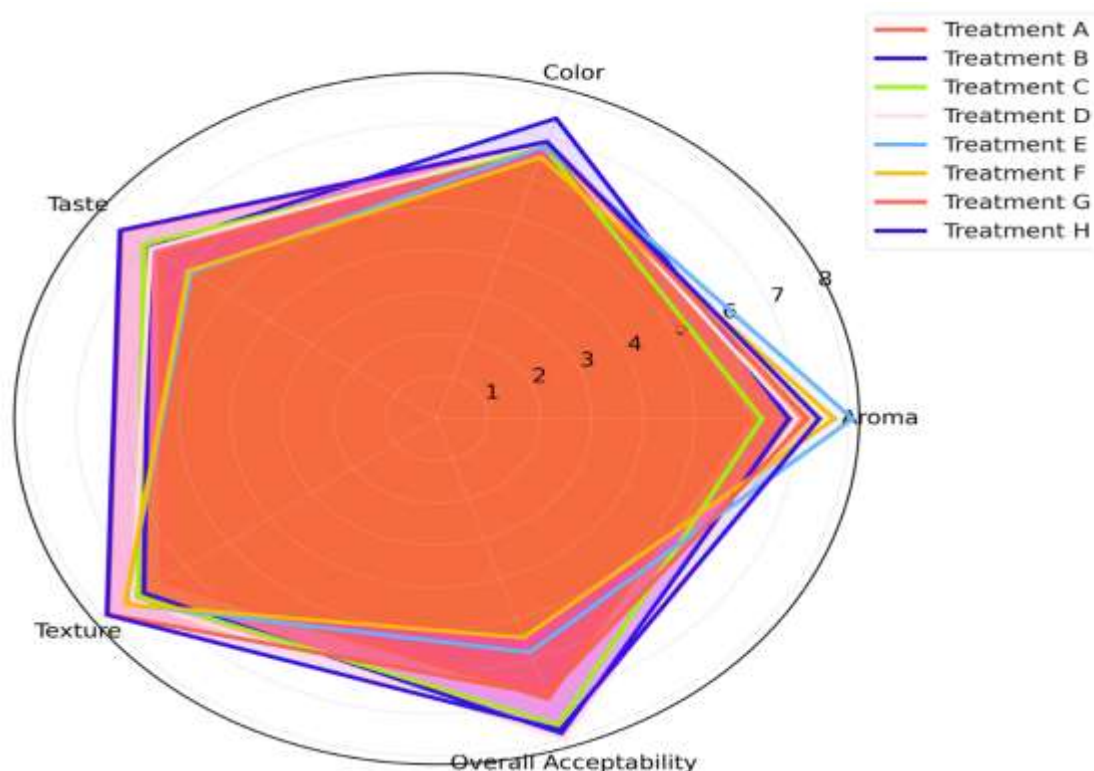


Figure 6 shows the effect of treatments and storage days on sensory profiles.

4- Conclusion

In the current study, various blends of camel milk with other species' milk, including cow, sheep, goat, and buffalo milk, were investigated. Our study highlighted the importance of modifying camel milk to enable coagulation and fermentation. Since camel milk has significant economic and medicinal importance, it is commonly used to treat diabetes, cancer, and asthma. Furthermore, camel milk has a unique composition, nutritional and therapeutic characteristics, and plays an importance role in human nutrition. The main objectives of our study were to combine all the functional and therapeutic characteristics of camel milk and to create blends with other species' milk for yogurt production. It was observed that treatments E and F were superior in most properties compared to other milk blends, followed by camel-buffalo milk, camel-cow milk, and finally camel-sheep milk. After three weeks in cold storage, an increase in wheying-off and water retention

(%) was observed. The camel milk blends with goat and buffalo milk showed greater resistance to changes than those with sheep and cow milk, which had a soft, fragile texture and low textural integrity, making them easily broken during storage. In terms of sensorial properties, we recommended consuming yogurt made from blends of camel milk with other species' milk within 2 weeks of production to ensure acceptability, better palatability, and higher consumer preference. Also, it is recommended that further research explore both compositional and thermal modifications to optimise camel milk characteristics. Future studies should evaluate different mixture ratios and suggest the use of fruit juices as natural stabilisers to enhance the sensory appeal, texture, and general acceptability of functional yogurt made from camel milk blends.

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Contribution Statement

Atheer JM Jandal: Conceptualization, Investigation, Methodology, Writing – original draft.

Mohanad Mahdi Jumaa Jandal: Formal analysis, Investigation, Writing – review & editing, funding acquisition.

Ahmad Hamad Muhammed Conceptualization, Investigation, Writing – review & editing.

All authors have read and agreed to the published version of the manuscript.

Supplementary Materials

The main drafts are following below under request:

- ▶ Table S1: All traits in three repeated samples for each studied parameter.
- ▶ Table S2: original analysis output draft.

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Conflicts of Interest

The authors declare no conflict of interest.

Data availability

Data will be made available upon request.

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