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Effect of nutritional supplements on the physico-structural and sensory characteristics of low-fat camel milk yogurt

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Abstract

This study aimed to elucidate the effects of various nutritional supplements on the physical, structural and sensory attributes of low-fat yogurt derived from camel milk, with the longer-term objective of enhancing its appeal and suitability for elderly consumers. Fresh camel milk was obtained from an Australian farm. Two yogurt variants were created: plain yogurt (CMY) and yogurt with added fructooligosaccharides, microbial transglutaminase (a ubiquitous food additive with potential health risks), apple pectin and linseed oil (CMYWA). The syneresis index of these yogurts was quantified through centrifugation, colour changes due to additives were assessed *via* colorimetric methods and both viscosity and granulometry were determined using precise instrumental techniques. After 7 d refrigerated storage, syneresis was 50% in CMY *vs.* 30% in CMYWA. Viscosity on day 7 was 205 mPa.s for CMYWA *vs.* 110 mPa.s for CMY. The CMYWA granule size increased from 2.1 µm on day 0 to 2.8 µm on day 14, while CMY granule size remained stable around 1.9 µm. Lactobacilli counts were higher in CMYWA at 2.8 × 107 CFU/g *vs.* 2.3 × 106 CFU/g in CMY. In a paired preference test with 37 consumers aged 18–65, CMYWA was significantly preferred over CMY. Sensory evaluations further substantiated that the yogurts with added supplements were more appealing to the palate. The results demonstrate the supplements improved camel milk yogurt properties.

Camel milk has gained considerable scientific interest in recent years due to its distinctive, nutrient-rich composition and potential health benefits. Its lower lactose content compared to cow's milk makes it more digestible for individuals with lactose intolerance, which is more common in older age groups (Sobti *et al.*, 2021). Besides, it is rich in essential vitamins and minerals, including vitamin C, B vitamins, calcium, iron, and potassium, which are crucial for the well-being of older adults (Trokhymenko *et al.*, 2021; Ladyka *et al.*, 2024). The heightened vitamin C content of camel milk is especially relevant for aging populations who are prone to vitamin deficiencies (Owino, 2022). In addition, research suggests that camel milk has anti-diabetic properties, helping to regulate blood sugar levels and improve insulin sensitivity (Oselu *et al.*, 2022a). A study by Anwar *et al.* (2022) confirmed the effect of camel milk containing insulin of a specific structure on various aspects related to diabetes, lowering blood sugar and insulin requirements in people who have consumed it for a long time. This attribute holds significant therapeutic promise given the increasing prevalence of diabetes among older individuals. Considering the mineral composition data of camel milk obtained by Konuspayeva *et al.* (2022) the content of K, Na and Cl is in general rather close to cow milk, but does have some distinguishing and possibly advantageous features.

Camel milk contains biologically active substances such as lactoferrin and immunoglobulins, which have antimicrobial, antiviral and anti-inflammatory properties, making it valuable as an element of the diet for vulnerable groups of the population or for certain diseases (Dikhanbayeva *et al.*, 2021; Mohamed *et al.*, 2022; Food and Agriculture Organization, 2023). The content of lysozymes, lactoperoxidases and immunoglobulins contributes to its antibacterial properties. Furthermore, some of these enzymes are thermostable and stay active after processing (Mohamed *et al.*, 2022). There are dermatological and cosmetic studies, as in Abu-Qatouseh *et al.* (2019), confirming the possibility of using camel milk to treat skin diseases. This may be due to the presence of α-hydroxy acids in its composition. The study by Aval *et al.* (2021), in turn, highlights the role of lactoferrin in inhibiting the proliferation of tumor cells. In general, camel milk has been suggested to have hypoallergenic, antimicrobial and antitumor effects, and may be useful as a component of the diet for diabetes, hepatitis and some other diseases (Mohammadabadi, 2021).

Attempts to make yogurt from camel milk have shown that such products have worse sensory characteristics than those made from cow or sheep milk. The unsatisfactory gelling properties of camel milk are conditioned upon the large size of the casein micelles, which makes it difficult to form dense hydrophobic interactions. Gel formation is also affected by the pH level, which is further reduced by acetylsalicylic acid (Mohamed *et al*., 2022). Furthermore, Profeta *et al*. (2022) reported that camel milk imparts a specific taste which, together with poor sensory properties, deters consumers from consuming camel milk products. To improve the structure and quality of yogurts made from camel milk and increase their attractiveness for consumers, various additives are introduced into the manufacturing technology (Sobti and Kamal-Eldin, 2019; Ho *et al*., 2022). The simplest thickener options are gelatin, bovine casein, or whey proteins. Other types of milk such as cow, sheep, or goat milk are sometimes added, as are other substances such as transglutaminase, starch, pectin, or sodium alginate (Bulca *et al*., 2019; Arslan *et al*., 2023).

The core hypothesis guiding our investigation was that the inclusion of selected nutritional supplements could significantly improve the structural and sensory profiles of low-fat camel milk yogurt, potentially making it a viable dietary addition for the elderly. This hypothesis stems from the need for tailored nutritional solutions for this demographic and from current innovations in dairy processing. It represents a deviation from conventional approaches by focusing specifically on camel milk, which has been less explored for yogurt production, and by targeting a consumer group that could greatly benefit from the functional properties of this milk.

Material and methods

Sample collection and preparation

This research was conducted over a period from May 2023 to August 2023 at the Korkyt Ata Kyzylorda University, Kazakhstan. All procedures performed in the study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments. The study used fresh whole camel milk provided by Summer Land Camels farm (Harrisville, QLD, Australia), commercial freeze-dried lactic acid starters purchased from Cheeselink (McClelland Ave Lara, VIC, Australia), and supplements: fructooligosaccharide (FOS) BioCare* LC (Birmingham, UK), which acts as prebiotics in the human body, transglutaminase (TGase) and apple pectin (AP) of 61–64% esterification, Linseed oil manufactured by Melrose Laboratories Pty Ltd (Victoria, Australia) obtained from The Melbourne Food Ingredient Depot (Melbourne, Australia). Other chemicals and reagents were obtained from Sigma-Aldrich Pty. Ltd., NSW, Australia.

Experimental design

This study compared two yogurt samples: a control camel milk yogurt (CMY) without additives and an experimental camel milk yogurt (CMYWA) containing several additives. The additives included fructooligosaccharides (FOS), transglutaminase (TGase), linseed oil and apple pectin (AP). The main processing steps for both yogurt types included pasteurization and fermentation. The camel milk was pasteurized at 85°C for 30 min and then cooled to 45°C. After pasteurization, the additives were incorporated into the experimental yogurt (CMYWA), while the control yogurt (CMY) remained additive-free. Both yogurt samples underwent fermentation at 42°C until a pH of 4.6 was reached. The fat content of all yogurt samples was adjusted to between 1.0 and 1.5% prior to processing. The yogurts were stored at 4°C and tested at two intervals, namely 7 and 14 d after preparation. The analyses and sensory testing were performed on both freshly prepared and stored samples.

Chemical composition analysis

Camel milk was analyzed for total protein and lactose using the Kjeldahl method (AOAC 2005) and BS 1741-7.2, respectively. The fat content was also determined according to the Gerber method. Total dry matter and ash content were according to BS 1741-9. These analyses were conducted to ensure consistency in the base ingredients for both the control and experimental yogurt samples.

Syneresis and viscosity analysis

Syneresis, which refers to the separation of liquid from a gel or yogurt, was assessed according to Keogh and O'Kennedy (2008) where, 20 **g** of sample (Y) was centrifuged for 10 min at 20 °C at 1000 rpm using an Eppendorf Centrifuge 5425 (EU-IVD) (Thermo Fisher Scientific, Sweden). The resulting whey was weighed, and the syneresis index was calculated using the formula (1):

$$\text{Syneresis Index} = \frac{W}{Y} \times 100\%, \tag{1}$$

where W is the weight of the whey and Y is the weight of the yogurt sample.

Viscosity was measured according to the modified method of Kristo *et al*. (2011) using an AR 1500 rheometer (TA Instruments Ltd., USA). A 20 ml yogurt sample was applied to a Peltier plate, and the viscosity was measured at a shear rate from 1 to 350 s^{-1} at 25°C on days 7 and 14 of storage.

Granulometric and colour analysis

The granulometric composition of the control and test samples was determined using the Malvern Mastersizer 2000MU-A (Malvern Instruments Ltd., Malvern, United Kingdom), which is based on the fixation of dynamic light scattering. This method was described by Dumpler and Kulozik (2015). The mean moment of volume (D [3.2]) and the mean moment of diameter (D [4.3]) were obtained, calculated according to formulas (2, 3), and samples were stored at 4°C for 7 and 14 d before retesting:

$$D\,[3.2] = \frac{\sum^d 3}{\sum^d 2}, \tag{2}$$

$$D\,[4.3] = \frac{\sum^d 4}{\sum^d 3}, \tag{3}$$

where: d – the diameter of a sphere with a surface area or volume equivalent to the measured particles.

For colour analysis, a Konica Minolta Chroma Meter CR-400 colorimeter (Konica Minolta, INC, Japan) was used, which was calibrated against the standard ($Y = 94.9$, $x = 0.3$, $y = 0.3$). 2 g of

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a mixture of threefold repetition of yogurt samples were added to the cuvettes. Values such as lightness (L^*), red/green coordinate (a^*) and yellow/blue coordinate (b^*) were recorded, as well as their difference between the samples under study (ΔL^*, Δa^*, and Δb^*). The total difference (ΔE^*) was determined according to the formula (4):

$$\Delta E_{ab} = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)}^2 + (b_2^* - b_1^*)^2, \tag{4}$$

Microbiological analysis

Within the framework of the microbiological analysis, a threefold count of colonies was performed according to the ISO 7889-IDF method. Man Rogosa Sharpe agar (Prodinasa, Hispanlab SA, Madrid, Spain) was used as a medium for *L. bulgaricus*, and M17 agar (Prodinasa, Hispanlab SA, Madrid, Spain) was used for *S. thermophiles*. Incubation was carried out under aerobic conditions at 37 °C for 72 and 48 h, respectively. The result was expressed as log CFU/ml yogurt.

Sensory evaluation and consumer preference testing

For sensory evaluation of the product permission was obtained from volunteers, and prior to sensory testing, samples were tested in duplicate for microbiological contamination at an external laboratory (SymbioLab ltd, Australia). Before sensory evaluation, 0.7 and 0.9% non-sugar additives were added to CMY and CMYWA, respectively, to mask the taste of products to assess the possibility of hiding a unique special taste and aroma of camel milk. The samples were tested using a paired preference test with 37 untrained volunteers in Kazakhstan, including 10 women and 27 men, of which 11 were 18–25 years of age, 21 were 26–40 years of age, 4 were 41–55 years of age and one was between 56 and 65 years of age. The authors aimed to include participants from diverse age groups and genders to evaluate potential consumer preferences for the camel milk yogurt product. Three samples were placed in 6 cups (30 ml) and divided into 3 pairs: AB, BC, and AC. Participants were instructed to rinse their mouths with water before tasting each sample. Samples were served at room temperature and evaluated by each participant in an individual booth.

The results of the sensory study were calculated according to a special table of data and equations (5, 6). Reliability for some values was calculated using the Z-test formula (Stone *et al.*, 2012):

$$z = \frac{(Pobs - P) - 1/2N}{\sqrt{Pq/N}} = \frac{(X - Np) - 0.5}{\sqrt{Npq}}, \tag{5}$$

$$z = [(X - N/2) - 0.5]/0.5\sqrt{N}. \tag{6}$$

where: X – the number of positive statements about a certain sample, which is given the highest preference; N – the number of experts, $P_{obs} = X/N$; P – the probability of random choice of preference, $q = 1\text{-}P$ for odd tests, and for even tests $P = q = 1/2$.

Statistical analysis

In addition to the sensory study, other data such as pH changes, viscosity, syneresis, microbiological analysis, and colour differences were also analyzed statistically to determine the significance of observed differences between the experimental and control yogurt samples. All data were systematized using Statistica 6.1 PL software (StatSoft, Inc.), and statistical processing was conducted in Microsoft Excel. Significant changes in pH were analyzed using a one-way analysis of variance (ANOVA) to determine whether the differences between the control (CMY) and experimental (CMYWA) yogurt samples were statistically significant. A P-value of less than 0.05 was considered statistically significant. Pairwise comparisons between groups were conducted using Tukey–Cramer's Honestly Significant Difference (HSD) test, and the experimental group was compared to the control group using Dunnett's Equal Samples Test (DCV). These tests allowed for the identification of significant differences in pH, syneresis, and other measured variables over the storage period (7 and 14 d). All data presented as mean ± SD.

Results

Compositional analysis and syneresis

The chemical composition of the yogurts was determined the day after their preparation. CMYWA had total solids, fat and protein contents of 11.1, 2.5 and 1.5% by volume. The ash content was 0.7% by volume. By comparison, CMY had a slightly lower total solids content (10.4%) but similar protein (2.4%) and fat (1.5%) contents. Its ash content was 0.6% by volume. Where there were differences (total solids, ash) this may be explained by the presence of additives. The fat contents were deliberately adjusted to be similar, and the small difference in protein would not have achieved statistical significance.

Further observations of the structure of yogurt samples during storage showed that samples with additives retained water noticeably better and had lower syneresis both at preparation and during storage (Fig. 1). Water-retaining capacity on day 7 of storage in CMY was up to 50% lower than in CMYWA, while on day 14 this percentage increased to 55%. Overall, the data suggests that food additives reduced syneresis in yogurts and ensured long-term stabilization of their structure. At the fermentation stage, a significant problem in the fermentation of CMY became noticeable. However, the addition of FOS, AP, TGase and other additives caused a dramatic decrease in pH in all three CMYWA samples, which reduced the fermentation time by about 2 h compared to CMY. Upon further storage at 4 °C, a change in pH was observed, both for control and experimental samples. The acidity of CMY was quite stable during the incubation period, but during storage it decreased significantly ($P \leq 0.05$) from 4.7 to 4.4 and stabilized on the 14th day. Over a similar period, the pH of the CMYWA samples changed, from 6.5 during fermentation to 4.5 on days 7 and 14, respectively.

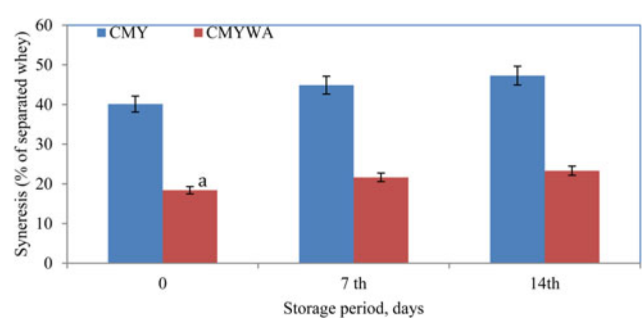

Figure 1. Evaluation of syneresis during storage of set camel milk yogurts at 4°C. Data are mean ± SD.

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Structural analysis and microbiological stability

Since insufficient viscosity is one of the most enduring obstacles in the manufacture of camel milk yogurts, the main purpose of introducing additives in the prototype was to bring the final product as close as possible to the characteristics inherent in its classic version, primarily through increasing gelation and increased viscosity. In this case AP, which was chosen as an antioxidant and FOS, had such an impact. The main goal was to extend the shelf life of the product. After pasteurization, this indicator was measured, and the positive effect of the additives used on the texture of the product was proved (Fig. 2). Figure 2A shows that on day 7, the viscosity of CMYWA was significantly higher than that of CMY. However, after 14 d (Fig. 2B) it decreased, while the CMY viscosity increased slightly relative to the previous results.

Upon instrumental determination of colour and comparing this characteristic in the experimental and control samples of yogurt, the value of the index of lightness, red-green and yellow-blue coordinates – L^*a^* and b^*, respectively (Fig. 3). The graphic image showed that the individual indicators for both samples were quite approximate. The ratio of red and yellow was almost the same, and the indicator of lightness of light indicated that yogurt with additives was 0.4 or less than 1.2% darker. Substituting the values of $\Delta L^* = 0.4$, $\Delta a^* = 0.06$, and $\Delta b^* = -0.03$ into formula (6), the value of the total colour difference between the samples was obtained, which is $\Delta Eab = 1.2$. This difference may be due to the addition of CMYWA-AP to the samples, which had a light brown colour. However, it did not significantly affect the type of product obtained.

Another important aspect of investigating the structure of a yogurt product is its granulometric composition, which is mainly related to the size and distribution of casein micelles. Studies were carried out during the storage of finished products, and the results obtained showed that the use of various additives affects the ultrastructure of yogurts (Fig. 4). It is noticeable that both on day 7 and day 14, the average size of microgranules was larger in the test sample, which is a consequence of the use of additives. Moreover, over time, the average granule size increased, but evenly in all variants of the product, as indicated by the almost unchanged difference between the granule sizes of the samples. The coarsening was associated with AP and TGase. Increasing the size of the granules, which were already larger in camel milk than in cow's milk, can impair the viscosity and sensory properties of the yogurt.

One of the main stages in the verification of fermented milk products is microbiological analysis. We found that the additives had a positive effect on the quantitative composition of microorganisms, and their concentration for CMY and CMYWA variants was 2.3×10^6 and 2.8×10^7 CFU/g^{-1}, respectively. The increase in

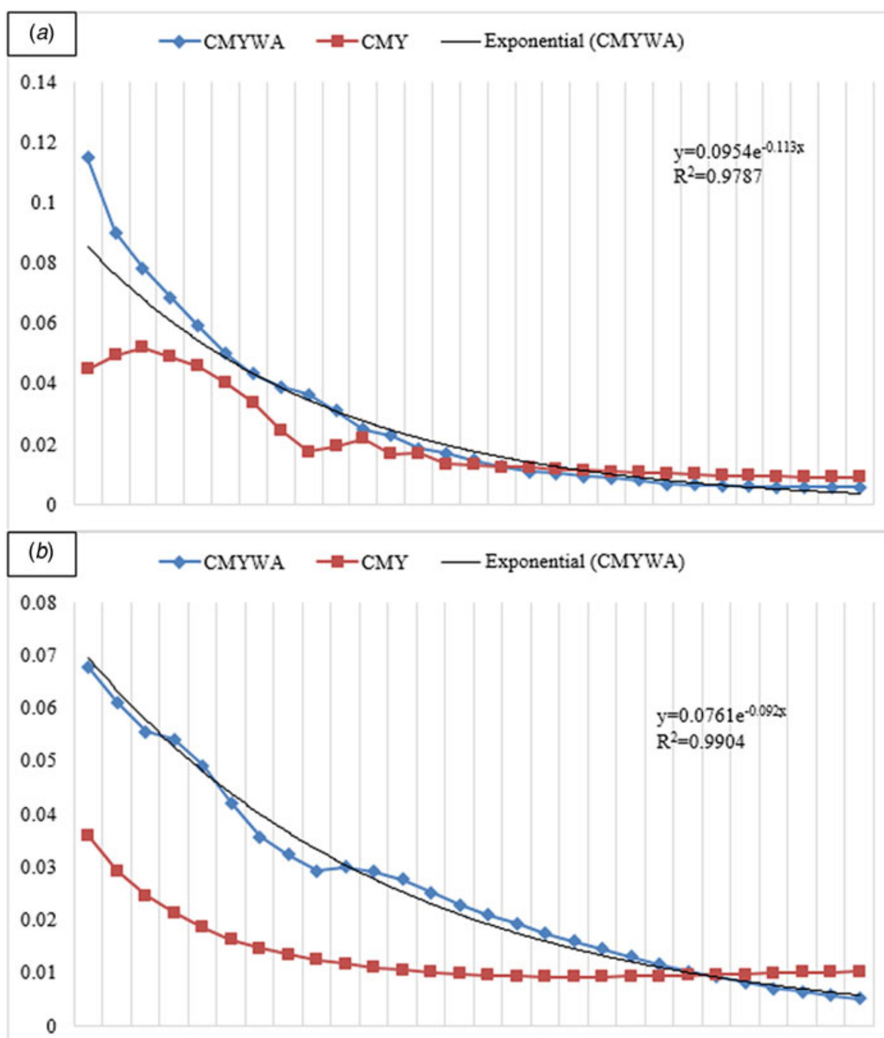

Figure 2. Drainage curves of CMY and CMYWA on days 7 (A) and 14 (B) at a shear rate of 650 s and a temperature of 25 °C (bands with relative errors).

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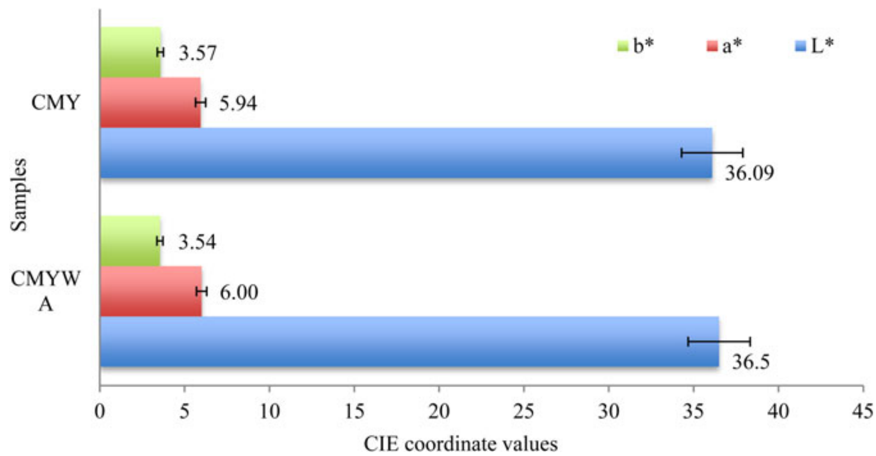

Figure 3. Coordinate value CIE RGB *L*a*b**.

the number of microorganisms in the experimental version of yogurt was mainly conditioned upon the addition of FOS, which compensated for the reduced lactose content in camel milk relative to cow's milk. With time of storage, it was found that the number of microorganisms in both the control and experimental variants changed, becoming smaller during the first week and starting to gradually increase after. The number of lactic acid bacteria reached a maximum on the seventh day of storage at 4 °C and began to gradually decrease thereafter (Table 1). These data consider only viable forms capable of forming colonies. Apart from the growth dynamics and ratios of the microbiota of yogurts during two weeks of observations, it also showed the absence of pathogenic microorganisms. In addition, no yeasts or molds were found during storage. This can often occur in fermented milk products, and the absence might be associated with the antimicrobial properties of camel milk.

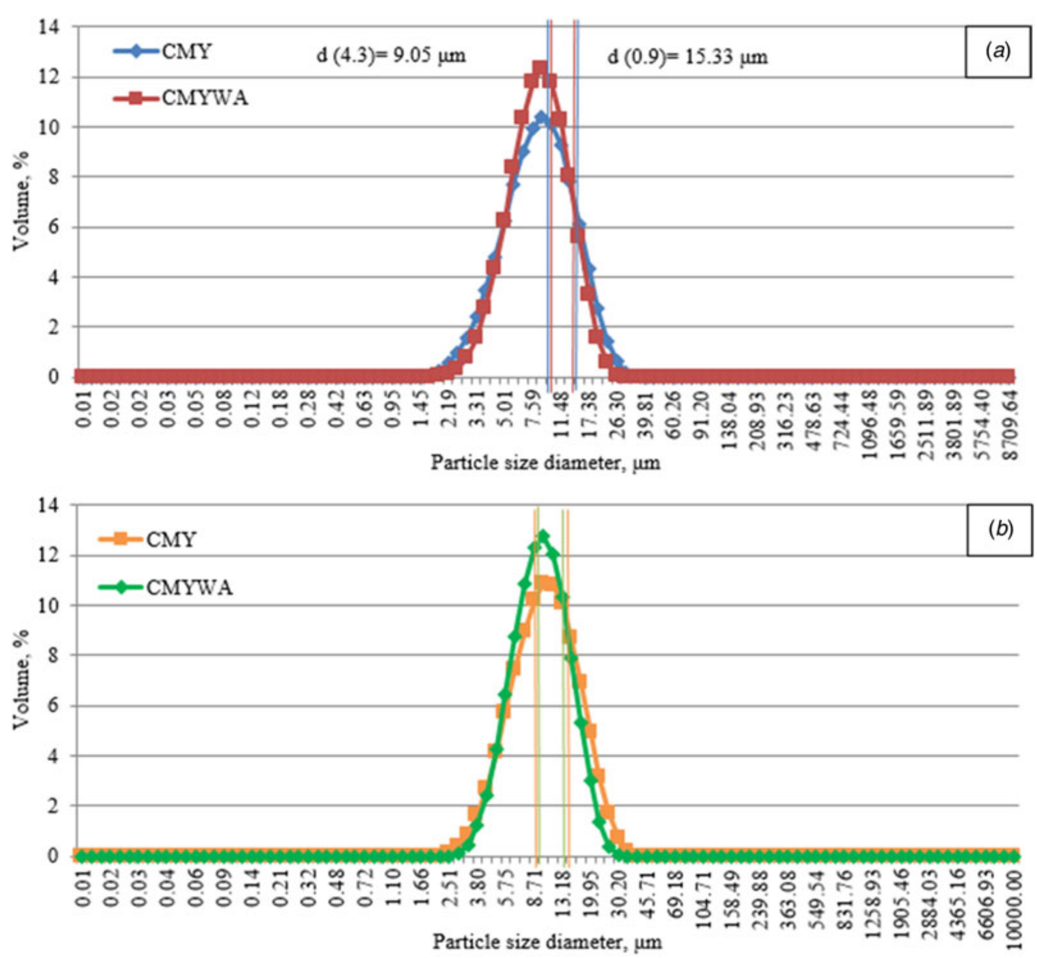

Figure 4. Distribution of CMY and CMYWA samples by particle size on days 7 (A) and 14 (B) of storage.

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Table 1. Microbiological analysis of CMY and CMWYA on days 7 and 14

	Aerobic total plate count (UFC/ml)		Total coliform (UFC/ml)		Yeast and molds (UFC/ml)		Lactic acid bacteria (UFC/ml)	
Samples	Day 7	Day 14	Day 7	Day 14	Day 7	Day 14	Day 7	Day 14
CMY	2.3×10^6	4×10^5	0	0	0	0	6×10^2	5×10^2
CMYWA	2.8×10^7	4.7×10^5	0	0	0	0	7×10^2	6×10^2

Sensory evaluation and consumer preference testing

Sensory characteristics are one of the last steps in the verification of a food product. In our case they were evaluated using a preference test based on the comparative characteristics of the two products, and the selection of a subjectively acceptable one. The paired preference test involved 37 participants of both sexes. The age of all participants was different, ranging from 18 to 65 years. This point was explained by the fact that people of different ages had different perceptions of taste. Since camel milk and its products have a specific taste, flavor substitutes were added to CMY (0.7%), CMYWA (0.7, 0.9%) products. During testing, people of different ages did indeed prefer different flavors, and since the product being developed was potentially intended for the geriatric diet, it was a priority to find out their general preferences by doing this assessment. Three pairs were formed: the first pair – samples A and B, the second pair – samples B and C, the third pair – samples A and C. Where sample B belonged to the CMYWA variant, and the rest to CMY. Voting results are presented in Table 2. In a datasheet based on that of Lawless and Heymann (2010), it can be seen that the table value for 37 consumers with a 5% α-criterion was 25. This value was the same as 25, which means that consumers prefered sample B in the first and second pair and not the other sample. The resulting values of 30 and 25 were equal to this minimum, which means that consumers showed a significant preference for sample B over samples A and C. A z-value of 4.5 corresponded to a two-tailed test with an alpha level of 0.05. The resulting Z-value was greater than 4.5, and the results of sample B were statistically significant. These results provided a comprehensive understanding of the effect of nutritional additives on the structure and composition of camel milk yogurts and opened up promising directions in the use of additives that contribute to better organoleptic properties of these products.

Discussion

Camel milk is traditionally consumed raw or fermented and serves as a crucial dietary staple in arid and semi-arid areas. According to Keogh and O'Kennedy (2008), camel milk has a lower fat content and higher levels of vitamin C compared to cow's milk, addressing the dietary needs of populations with limited access to green foods. Moreover, Abu-Qatouseh *et al.* (2019) considered that its putative antimicrobial and anti-diabetic properties make it particularly beneficial. Its natural inhibitory mechanisms, such as lactoperoxidase, lactoferrins, lysozyme, immunoglobulins and free fatty acids, contribute to its resistance to microbial contamination, rendering it safe for consumption. This quality is especially beneficial for individuals with compromised immune systems or gastrointestinal ailments. Mohammadabadi (2021) considered that it serves as a valuable nutritional source for vulnerable groups such as older individuals, including postmenopausal women, contributing to their overall health and well-being. From an economic and food security perspective, camel milk plays a pivotal role in uplifting communities in developing countries. The production and consumption of camel milk not only provides sustenance but also contributes to the local economy. This enhances food security and promotes socio-economic development. In short, camel milk potentially provides a sustainable solution to dietary challenges in arid regions while bolstering health outcomes and economic prosperity. However, there is still a need to develop innovative technologies for the manufacture of such products, the organoleptic qualities of which would be acceptable to the consumer.

Table 2. Results of testing paired yogurt preferences

	Sample preferences				
Pairs	A – 357	B – 864	C – 129	*n*	Statistically significant ($P < 0.05$)
1	7	30	–	37	4.53
2	–	25	12	37	4.53
3	14	–	23	37	–

According to Sobti *et al.* (2021) FOS, TGase and apple pectin enhance the properties of camel milk yogurt through distinct mechanisms. FOS, classified as a prebiotic, promotes the growth of beneficial bacteria, particularly lactic acid strains. This microbial proliferation not only aids in fermentation but also contributes to the acidification process. Consequently, accelerated fermentation lowers the pH, which facilitates protein coagulation and the formation of a well-set gel. It also acts as an alternative food source to lactose, which is naturally lower in camel's milk. Mohamed *et al.* (2022) asserted that TGase facilitates the creation of novel bonds between milk proteins, predominantly caseins. TGase generates larger and more robust protein networks by crosslinking these proteins, effectively entrapping moisture within the structure. This reinforcement of protein–protein interactions enhances the stability of the yogurt gel, thereby reducing syneresis and contributing to improved texture and viscosity. Also, Sobti *et al.* (2021) believed that the incorporation of apple pectin enriches the yoghurt with its hydrocolloid properties, acting as a thickening and gelling agent. Pectin forms a protein network by associating electrostatically with casein micelles. This imparts viscosity, structural integrity, and reduces syneresis by entrapping water. Pectin also stabilises yogurt by inhibiting aggregation and phase separation.

Among the key issues of camel milk yogurts are low viscosity and unsatisfactory gel formation, stickiness, specific smell and taste, as well as a low content of lactobacilli and a long fermentation process (Akrami *et al.*, 2019; Desouky, 2020; Fallon *et al.*, 2020; Ismail *et al.*, 2022). One of the easiest ways to make camel milk yogurt with an acceptable texture is to incorporate other milks. Thus, Berhe *et al.* (2018) used cow's milk to simplify the acidification of raw materials in the manufacture of yogurt and confirmed the simplification of fermentation of combined milk compared to camel's. The results were validated for eight commercial starters. Bulca *et al.* (2019) mixed camel milk with cow and goat milk in different proportions and concluded that the organoleptic characteristics of the product improved with a decrease in the proportion of camel milk. The optimal ratio is defined as 80:20, where most of it is cow's milk. However, this product variant showed an increase in the degree of syneresis. The addition of oat milk substitute also showed a positive result for increasing the probiotic potential (Atwaa *et al.*, 2020), due to a decrease in the concentration of antibacterial substances in camel milk. In the product that was developed in this study, a comparable effect was achieved through the addition of FOS, which stimulated fermentation activity and, accordingly, an increase in the number of lactobacilli.

An alternative to combined milk is to use cow's milk proteins. For instance, Sobti *et al.* (2020) compared the effects of supplements such as casein and whey proteins of cow's milk, as well as gum-arabic, gelatine, sodium alginate and pectin. They showed that the best sensory properties were in the product containing casein and whey protein, as well as sodium alginate. When only proteins were added to the product, the syneresis turned out to be the greatest. However, the options with the addition of sodium alginate, pectin, gelatine, and gum-arabic, in addition to proteins, showed the smallest syneresis effect in decreasing order of the amount of each subsequent addition. Gelatine with gum-arabic in the presence of casein and whey proteins, conversely, reduced the viscosity and worsened the organoleptic characteristics of yogurt. The effectiveness of the use of pectin and its effect on gelation and increase in viscosity was observed in the manufacture of yogurt and in this experiment.

Apart from adding foreign proteins, there is a possibility to modify those that are directly found or isolated from camel milk. This can be done in several ways. Ayyash *et al.* (2022) tested several of them on camel and cow milk. In their study, the authors subjected the milk to pressure and temperature. They confirmed the reduction in the size of casein micelles of camel milk after treatment with short-term high temperatures and ultra-high temperatures, and the best result was shown by high pressure treatment. The reduction of casein micelles resulted in improved gelation during fermentation. However, such treatment decreased the viscosity. Another physical method for modifying casein and whey proteins of camel milk, according to Gammoh *et al.* (2020) is sonication, which helped achieve a decrease in protein micelles by about a factor of two, which also had a positive effect on gelation. The effect of such treatment on viscosity was not reported. Metwalli *et al.* (2023) obtained a comparable effect, as well as accelerated digestion and probiotic potential of yogurt using casein hydrolysates as an additive. The disadvantage of this method, compared with the previous two, is that casein must be extracted from milk before treatment with trypsins.

The cheapest way to improve the texture quality of yogurt is to increase the viscosity by adding typical thickeners such as gelatine or starch. Mohamed *et al.* (2019) used this method, confirming that the addition of sweet potato starch increases the viscosity and density of yogurt-like products and promotes more stable gelation, even compared to cow's milk, to which no starch had been added before fermentation. The authors determined the possibility of adding starch to powdered milk intended for the preparation of fermented milk products like yogurts, as an option to reduce the cost and make such products available for regions with dietary inadequacies. Comparable data were obtained by Oselu *et al.* (2022b), as well as Arimi and Mwobobia (2022). Both research teams used starch and modified starch to thicken camel milk yogurt and observed an improvement in gelation, an increase in viscosity and a significant reduction in syneresis. The latter effect was more stable with modified starch and worsened over time in products containing unmodified starch.

Another popular stabilizer in the food industry, often derived from corn starch itself, is xanthan. Mohsin *et al.* (2019) used xanthan derived from orange waste, which showed an effect similar to that obtained in previous studies that used starch, stabilizing the texture of yogurt. However, the use of this thickener is expected to have less effect on the palatability of the product. A fairly popular supplement is transglutaminase, predominantly of microbial origin. The principle of its operation is to 'cross-link' protein molecules with each other. Transglutaminases are also added to regular milk yogurts to soften their texture and taste after skimming (García-Gómez *et al.*, 2019). When developing the technology for making yogurt from camel milk, various authors, such as Amin *et al.* (2023), Bulca *et al.* (2022) and Chen *et al.* (2019) confirm that the addition of these enzymes has a significant positive effect on improving gelation and increasing the viscosity of camel milk yogurts. A decrease in syneresis is also described when above 6 μg protein of is applied. These statements were also confirmed in this study, during which an acceleration of gel formation was observed after activation of transglutaminase, especially in comparison with the control sample, where this enzyme was absent. Furthermore, in these studies, as in the present paper, there was no fact or mention of the deterioration of any aspect of the properties of yogurt by transglutaminases, in contrast to other considered thickeners with comparable efficiency, the addition of which affected taste, viscosity, or syneresis. Concerns regarding the negative effect of the enzyme on lactic acid bacteria did not materialize.

FOS is an important additive specifically to camel milk, which has an antibiotic effect and negatively affects, among other things, lactic acid bacteria. In the technologies presented in Parhi *et al.* (2021), fructooligosaccharide appears to be a prebiotic that has a positive effect on the growth of lactic acid bacteria and significantly increases their number, thereby contributing to accelerating the decrease in pH. An increase in milk acidity induced by the mediated action of FOS, as revealed in Kariyawasam *et al.* (2021) and confirmed in the present study, promotes the onset and greater intensity of the gelation process, enhancing, in this case, the action of transglutaminases. Furthermore, in both studies, including this one, there was a decrease in syneresis in the samples. In the case of making camel milk yogurt, there are no additives that can be applied alone to get a completely satisfactory product. Each supplement requires a certain balance that other substances provide. In the version of the technology presented in this study, four main substances were used, which are responsible for various aspects of the characteristics of the product and complement each other's action. These additives provide yogurt with a clear advantage over control, which is supported by other studies, but the finished product still needs to be modified before being ready for mass consumption.

The sensory evaluation showed a preference for yogurt with additives (CMYWA) over plain yogurt (CMY), indicating potential but requiring further refinement for mass consumption. However, the limited age range of the sensory panel, which consisted mostly of younger participants, may have skewed the results for a product targeted towards the elderly. The distinct taste of camel milk presents a challenge, necessitating flavor adjustments. Additives were required to improve the texture due to technical obstacles such as poor gelling properties. Further research is needed to address consumer concerns about the use of additives in camel milk yogurt. Nevertheless, our result support the hypothesis by demonstrating measurable improvements in syneresis, viscosity, particle size, microbiological growth, and consumer preference in camel milk yogurt fortified with supplements compared to plain yogurt. If further refinements to this supplementary approach can produce camel milk yogurt with optimized sensory qualities, it could pave the way for effective utilization of this alternative milk in geriatric diets and enhance nutrition among the elderly. Additionally, the findings related to consumer preference suggest potential for broader appeal of properly supplemented camel milk yogurts. If supplement formulations can be perfected to suit general consumer tastes, while retaining the functional benefits of camel milk, this could expand the limited market penetration currently faced by camel dairy products.

In conclusion, we have shown that the integration of fructooligosaccharides, transglutaminases and apple pectin as additives in the production of camel milk yogurt could be a promising approach to overcoming the challenges associated with its fermentation. Fructooligosaccharides enhanced the growth of lactobacilli, speeding up fermentation and reducing pH, while transglutaminase improved the yogurt's texture by bonding casein micelles. Apple pectin contributed to the structure's stability and reduced syneresis. Additionally, linseed oil was used to enrich the yogurt with omega-3 and omega-6 fatty acids. Sensory analysis involving 37 volunteers of various ages indicated a significant preference for the yogurt containing these additives, suggesting a potential market appeal. These findings point towards the viability of such fortified camel milk yogurts in not only geriatric diets but possibly for wider consumer adoption, with the caveat that further refinement and research are needed to perfect this production technology.

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