Heliyon 8 (2022) e11816

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Production and characterisation of camel milk yoghurt containing different types of stabilising agents

Stephen Oselu [a], Rebecca Ebere [a], Guyo Huka [b], Levi Musalia [c], Eunice Marete [d], Julius M. Mathara [e], Florence Mwobobia [a], Joshua M. Arimi [a,*]

[a] Department of Food Science, Meru University of Science and Technology, Meru, Kenya
[b] Department of Business Management, Meru University of Science and Technology, Meru, Kenya
[c] Department of Dry Land Agriculture and Natural Resources, Tharaka University College, Tharaka-Nithi, Kenya
[d] Department of Physical Sciences, Meru University of Science and Technology, Meru, Kenya
[e] Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology, Juja, Kenya

ARTICLE INFO

Keywords:
Corn starch
Modified starch
Camel milk yoghurt
Physicochemical properties
Rheological properties

ABSTRACT

As at 2020, Kenya was the best performing camel milk producer globally, with an annual production of 1.125 million tonnes. Despite the high production, about 50% of milk is wasted due to challenges affecting value addition to products such as yoghurt. The production of camel milk yoghurt faces multiple challenges, such as poor texture and weak structure, resulting in poor consumer acceptability. This study aimed to improve the physicochemical properties of camel milk yoghurt by adding different stabilising agents and calcium chloride. Yoghurt samples were processed using 3 L of camel milk, 6% sugar, 0.006% starter cultures, corn starch or modified starch and calcium chloride. The stabilisers were added at 2, 2.5, and 3% and Calcium Chloride at 0.075%. The milk was pasteurised at 90 °C for 30 min. Fermentation was performed for 6 h at 42 ±1 °C, and yoghurt was stored at 4 °C. The total titratable acidity, pH and viscosity were monitored hourly during fermentation and storage, while syneresis and water holding capacity were analysed at 1, 7, 14 and 21 days of refrigerated storage. The sensory evaluation was done using the 9-point hedonic scale to rate yoghurt samples' overall acceptability, colour, sweetness and thickness. The TTA of camel milk yoghurt increased with increasing fermentation time (0–6 h) and storage time from 1 to 21 days. The pH decreased with increasing fermentation time (0–6 h) and storage time from 1 to 21 days. The addition of stabilisers increased the viscosity of the yoghurt, with 3% corn starch exhibiting the highest viscosity throughout the fermentation and storage time. Corn starch had a higher effect on viscosity compared to modified starch. Calcium chloride further amplified the viscosity of the yoghurt. The addition of stabilisers reduced syneresis by over 44% compared to bovine yoghurt. In this study, the best results of viscosity, syneresis and sensory evaluation were observed when stabilising agents were added at the rate of 2.5% modified starch and 0.075% Calcium chloride.

1. Introduction

In Kenya, a significant part of camel milk is consumed locally. A small proportion of milk is marketed to urban areas. The production of camel milk yoghurt and other fermented camel milk products is problematic (Abou-Soliman et al., 2017; Berhe et al., 2017a; Konuspayeva, 2020; Odongo et al., 2016). Camel milk yoghurt is characterised by undesirable mouthfeel and overall acceptability due to weak texture, separation of whey, and thin consistency (Barnes et al., 1991; Farah et al., 1990; Khalifa and Zakaria, 2018).

According to Al-Zoreky and Al-Otaibi (2015), the texture is an essential factor influencing the mouthfeel, appearance and overall acceptability of yoghurt. However, the growth of commercial milk starter cultures in camel milk has proved possible despite its relatively lower rate of acidification compared to bovine milk (Al-Zoreky and Al-Otaibi 2015).

Further, yoghurt firmness is an essential feature for acceptability and quality (Barnes et al., 1991; Farah et al., 1990; Hashim et al., 2009; Khalifa and Zakaria, 2018). Several attempts have been made to enhance camel milk yoghurt firmness and prevent syneresis (Ibrahim and Khalifa

* Corresponding author.
E-mail address: jarimi@must.ac.ke (J.M. Arimi).

https://doi.org/10.1016/j.heliyon.2022.e11816
Received 23 April 2022; Received in revised form 25 August 2022; Accepted 15 November 2022

2015). The firmness of camel milk yoghurt could be improved by adding stabilisers such as k-carrageenan, corn starch, modified starch and gelatin, and salts such as calcium chloride (Hashim et al., 2009).

Mudgil et al. (2018) evaluated the impact of gelatin on the chemical composition, syneresis, rheological, microstructural and textural properties of camel milk yoghurt. In their study, addition of gelatin at 1 and 1.25% levels improved the microstructural features, syneresis and centrifugally separated whey. The addition of gelatin improved the textural and rheological properties of camel milk yoghurt as 1.25% gelatin showed results within a similar range to commercial and bovine milk yoghurt due to the significant shift from watery to the gel like phase. However, the sensory properties showed lower score for camel milk yoghurt in relation to bovine milk yoghurt.

Mohsin et al. (2019) added xanthan gum and dates paste to attain an adequate firmness factor and improve consumer acceptability in camel milk yoghurt, respectively. The addition of biosynthesized xanthan on camel milk date yoghurt showed shear-thinning with pseudoplastic properties. The higher concentrations of biosynthesized xanthan improved the rheological properties of camel milk yoghurt significantly. The study reported best textural properties, strengthened (dense) network of casein micelles of camel milk yoghurt and higher consumer preference by adding 0.75% of biosynthesized xanthan and 10% dates paste.

Moreover, different milk pasteurization techniques also affect the rheology of fermented camel milk products. Ayyash et al. (2022) evaluated the impact of heating (ultra-high temperature (UHT), low temperature long time (LTLT), high temperature short time (HTST)) and high-pressure processing (HPP) on the rheology of fermented camel milk. The fermented UHT processed camel milk had the highest viscosity followed by fermented HPP-treated milk. The fermented LTST and HTST treated milk showed the lowest viscosities. The study also reported a small deformation rheology of lower tan δ values for fermented HPP-treated camel milk than fermented heated camel milk. Hence, the rheological properties of fermented camel milk products can be improved by UHT and HPP processing compared to other heat treatments.

Other studies show that camel milk consistency can be enhanced by mixing it with milk from other livestock species like bovine milk (Ibrahem and El Zubeir, 2016).

To solve the problems associated with camel milk yoghurt processing, this study aimed to improve the physicochemical properties of camel milk yoghurt by adding different stabilising agents (thickeners - corn starch & modified starch) and calcium chloride. Camel milk yoghurt was produced using 3 L of milk for each experiment, 6% sugar, 0.006% starter cultures and varying amounts of stabilising agents. The stabilisers were added between 2 to 3% of either corn starch or modified starch and 0.075% Calcium chloride. The physicochemical properties analysed include total titratable acidity, pH, viscosity, syneresis and water holding capacity.

2. Materials and methods

2.1. Sample collection

Camel milk samples were purchased from the Anolei Women Group in Isiolo Town, Isiolo County, Kenya. The fresh camel milk was transported in 10-litre jerricans to Meru University of Science and Technology Food Science Laboratories.

2.2. Platform tests

Upon reception of camel milk, alcohol tests and clot on boiling tests were conducted (Parajuli et al., 2018). Alcohol tests were carried out by mixing 2 mL of 68% ethanol solution with 2 mL of camel milk. Clot on boiling test was conducted by boiling 5 mL of fresh camel milk in a test tube for five minutes.

2.3. Production of camel milk yoghurt

Every equipment was thoroughly cleaned and sterilised using hot water to destroy vegetative cells of microorganisms. After conducting the platform tests, the following formulation was used to develop camel milk yoghurt samples. For each experiment, 3 L of milk were pasteurised at 90 °C for 30 min in a controlled water bath according to the method described by Everett and McLeod (2005). Yoghurt was produced in a cheese vat (FT20-MKII, Hampshire, England) according to a standard procedure by Ibrahim and Khalifa (2015). Milk was first heated to 45 °C. Stabilisers and sugar were added and then mixed with milk during heating. The mixture was then pasteurised at 90 °C for 30 min. The pasteurised milk was cooled to 42 °C and then inoculated with starter cultures (Thermophilic Yoghurt Cultures, YF-L903, Chr Hansen, Denmark). Fermentation was carried out at 42 °C for 6 h. The yoghurt samples were kept under refrigerated conditions (4 °C) until analysed.

The experiments were conducted in three different sets of treatments, as shown in Table 1. The experiments were carried out in two steps. In the first step, the study investigated the effect of varying the quantity stabilisers (corn starch (Zesta, Trufoods, Kenya) and modified starch (System Stabilizer, Dicase Chemicals, Kenya)) on the physicochemical properties of camel milk yoghurt. From this first step, yoghurt containing 2.5% modified starch and 3% corn starch were selected for the second step. In the second step of experiments, the study assessed the effect of incorporating 0.075% calcium chloride on the physicochemical properties of camel milk yoghurt.

In the first step of the experiments, bovine yoghurt containing 0.5% corn starch (BYCS) was used as a control. Camel milk yoghurt was processed using 2%, 2.5% and 3% corn starch represented by CY2%CS, CY2.5%CS and CY3%CS, respectively. On the other hand, Camel milk yoghurt was also produced by adding 2%, 2.5% and 3% modified starch represented by CY2%MS, CY2.5%MS and CY3%MS, respectively.

In the second step of the experiments, camel milk yoghurt was produced using the formulations of experiments showing the best physicochemical results from the first step (camel milk yoghurt containing 2.5% modified starch (CY2.5%MSCaCl) and camel milk yoghurt containing 3% corn starch (CY3%CSCaCl)).

2.4. Determination of titratable acidity of camel milk yoghurt

The titratable acidity of yoghurt was determined hourly during fermentation (0–6 h) and at 1, 7, 14 and 21 days of refrigerated storage according to the method described by Sadler and Murphy (2010). The yoghurt sample (9g) was weighed in a 100 mL conical flask and then titrated against 0.1 NaOH after adding three drops of 1% phenolphthalein solution until a persistent faint pink colour was observed. The titratable acidity values were expressed as a percentage of lactic acid using the following formula in Eq. (1):

Table 1. The different sets of experiments according to the treatments.

Ingredients used	Bovine Yoghurt (Control)	1st set (Camel milk yoghurt containing stabilisers)	2nd set (Camel milk yoghurt containing stabilisers and calcium chloride.
Type of Milk	Bovine milk	Camel milk	Camel milk
Stabilising agents	Stabilizing agents added include corn starch (0.5%)	Stabilising agents include corn starch, and modified starch varied between 2%, 2.5% and 3% for each experiment.	Stabilising agents include corn starch (3%) and modified starch (2.5%)
Sugar	Sugar added (6%)	Sugar added (6%)	Sugar added (6%)
Calcium chloride	No salts added	No salts added	Calcium Chloride salts added (0.075%)

$$Lactic\ Acid\ (\%) = \left\{ \frac{\left[mL\ \frac{N}{10}\ alkali \times 0.009\right]}{ml\ of\ sample\ used} \right\} \quad \text{Equation 1}$$

2.5. Measurement of the pH of camel milk and camel milk yoghurt

The pH of yoghurt was measured hourly during fermentation (0–6 h) and at 1, 7, 14 and 21 days of refrigerated storage using a digital electronic pH meter (Hanna instrument pH, HI98129, Bucharest, Romania) according to the method described by Kaur Sidhu et al. (2020).

2.6. Measurement of the viscosity of camel milk yoghurt

The viscosity of camel milk yoghurt was determined hourly during fermentation (0–6 h) and at 1, 7, 14 and 21 days of refrigerated storage using a rheometer (RheolabQC, C04IP001EN-I, Graz, Austria), according to the method described by Renan et al. (2009). About 10 ml of each yoghurt sample was placed into the concentric cylinder rheometer cup. The rheometer was operated at a shear rate of $64S^{-1}$ for 120 s. The apparent viscosity readings were recorded at the tenth reading (12 s mark).

2.7. Determination of the syneresis on camel milk yoghurt

The syneresis of yoghurt was determined at 1, 7, 14 and 21 days, according to Bansal et al. (2016), with slight modifications. A 100 mL of yoghurt was placed on a funnel containing Whatman Filter Paper No. 1 and placed over a measuring cylinder for 24 h at 4 °C to separate whey from yoghurt. The whey was collected in a measuring cylinder, and syneresis (%) was calculated using the formula in Eq. (2)

$$syneresis\ (\%) = \frac{Volume\ of\ separated\ whey}{100\ mL\ of\ yoghurt} \times 100 \quad \text{Equation 2}$$

2.8. Determination of the water holding capacity of camel milk yoghurt

The water holding capacity of yoghurt samples was determined using a method described by Harte et al. (2007) at 1, 7, 14 and 21 days. A 2 mL of each yoghurt sample was centrifuged at 4000 rpm for 30 min at 10 °C using a refrigerated centrifuge (Micro High-Speed Benchtop Refrigerated Centrifuge, TGL-16M, Changsha, Hunan, China). The WHC (%) was calculated using the formula in Eq. (3)

$$WHC\ (\%) = \left(1 - \frac{V1}{V2}\right) \times 100\% \quad \text{Equation 3}$$

V_1 – Volume of whey after centrifugation.
V_2 – Volume of yoghurt.

2.9. Effect of stabilisers on the colour of camel milk yoghurt

Colour was measured at 1, 7, 14 and 21 days according to a method described by Archaina et al. (2019). The Hunter Lab colourimeter (Konica Minolta Spectrophotometer, VTL-CM700D, Osaka, Japan) was used to determine colourimetric results using Cie Lab coordinates (L *, a *, b *). The L * values were used to determine the effect of stabilising agents on the lightness (whiteness) of yoghurt BYCS (Control), CY2.5% MS, CY3%CS, CY2.5% MSCaCl and CY3% CSCaCl.

2.10. Sensory analysis of camel milk yoghurt containing different stabilisers

The sensory analysis of yoghurt stored overnight after processing was evaluated according to the method described by Barnes et al. (1991). This study used 32 untrained panellists (Students from the Department of Food Science at Meru University of Science and Technology) selected randomly. The panellists rated the products' features based on sweetness, mouthfeel, sourness, colour and overall acceptability. Yoghurt samples were served at about 7 °C, and a sample size of at least 40 mL of yoghurt was served in clear shot glasses. The sensory attributes were evaluated on the 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely) (Wichchukit and O'Mahony 2015). Clean potable water was provided in several cups for cleansing their palates after testing each yoghurt sample. All the study participants provided their informed consent to conduct sensory analysis of different formulations of camel milk yoghurt. This study was approved by the Meru University of Science and Technology Institutional Research Ethics and Review Committee (MIRERC).

2.11. Data analysis

All treatments were carried out in triplicates. Data analysis was conducted using Microsoft Excel (Version, 2016) and Statistical Package for the Social Sciences (SPSS software version 26). The means of triplicate values were subjected to analysis of variance (ANOVA) using descriptive statistics and Post-hoc using Least Significant Difference (LSD) options to determine statistical differences at a 95% confidence level. The means were considered significantly different if the P-value was less or equal to 0.05.

3. Results and discussion

3.1. Platform tests results

Camel milk yoghurt was processed using milk samples that passed the platform tests. Camel milk was acceptable only when there was no clotting or coagulation after alcohol and clot on boiling tests. The camel milk samples had a characteristic camel milk smell.

3.2. Effect of different stabilising agents on the total titratable acidity of camel milk yoghurt

The TTA of the processed yoghurt increased with increasing fermentation time from 0 to 6 h and with storage from 1 to 21 days (Figure 1). The TTA of control yoghurt increased from 0.18 to 0.79% after 6 h and to 0.9% after 21 days (Figure 1). The TTA of camel milk yoghurt containing 3% corn starch increased from 0.22 to 0.66 after 6 h and 0.85 after 21 days. The TTA of camel milk yoghurt containing 2.5% modified starch increased from 0.19 to 0.72 after 6 h and 0.85 after 21 days.

The progressive increase in TTA values could be due to the conversion of lactose into lactic acid during fermentation (Al-Zoreky and Al-Otaibi, 2015; Fauziah et al., 2020; Sadler and Murphy, 2010). The control yoghurt (Bovine milk yoghurt) had the highest TTA throughout the fermentation and storage period compared to the camel milk yoghurt. The camel milk yoghurt had over four times more solids compared to bovine yoghurt. The higher amount of solids could have immobilised the aqueous phase and affected the activities of the thermophilic yoghurt cultures to break down sugars (Galeboe et al., 2018; Singh et al., 2017). The findings of this study exhibited similar trends of TTA in relation to stabilisers as observed in previous studies conducted by Al-Zoreky and Al-Otaibi (2015a); Bhagiel et al. (2015); Mbye et al. (2020).

The effect of adding calcium chloride on the titratable acidity of camel milk yoghurt containing 2.5% modified starch and 3% corn starch during fermentation and storage is shown in Figure 2.

The TTA of camel milk yoghurt containing calcium chloride increased with fermentation time from 0-6 h and 1–21 days during refrigerated storage (Figure 2). However, the TTA of the control yoghurt remained relatively higher than the TTA of all the camel yoghurt samples (Figure 2).

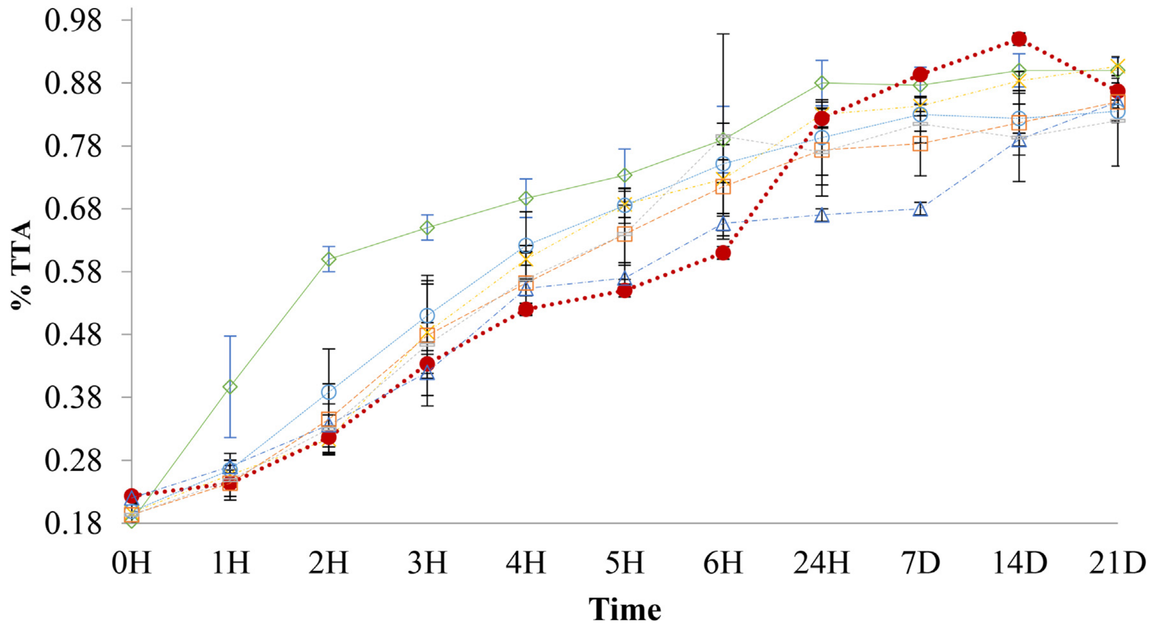

Figure 1. Effect of different stabilising agents in yoghurt formulations BYCS (◊), CY2%CS (×), CY2.5%CS (●), CY3%CS (△), CY2%MS (◌), CY2.5%MS (□), CY3%MS (-) on the Titratable Acidity (%) of camel milk yoghurt during fermentation (0–6 h) and storage (1–21 days).

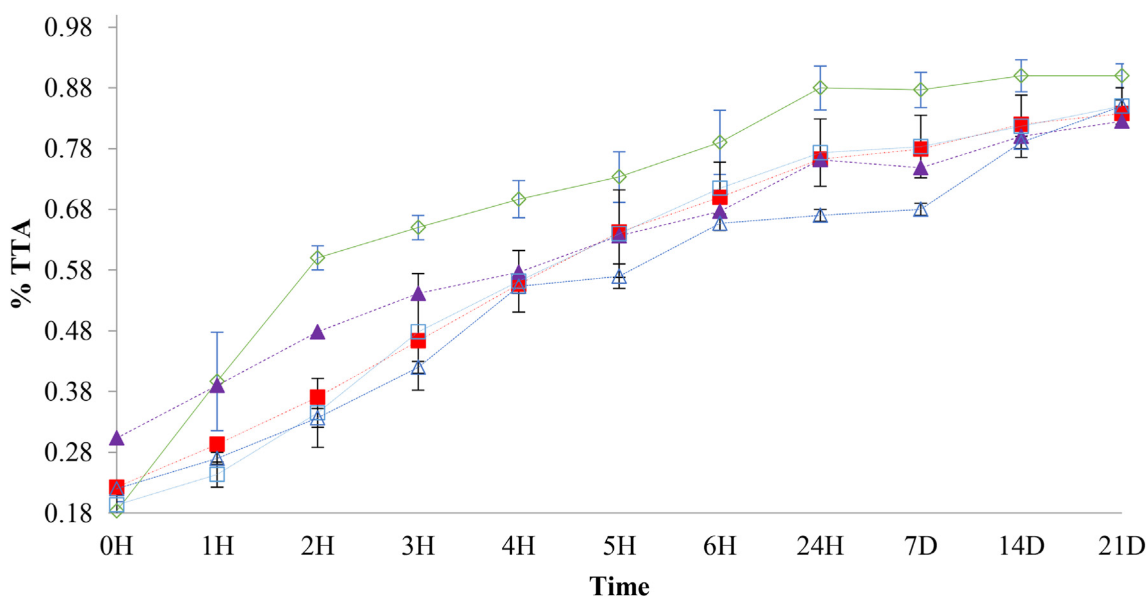

Figure 2. The effect of calcium chloride on the TTA of camel milk yoghurt formulations CY2.5%MSCaCl (■) and CY3%CSCaCl (▲) compared to BYCS (◊), CY3%CS (△), CY2.5%MS (□), during fermentation (0–6 h) and storage (1–21 days).

Increasing the concentration of stabilisers and incorporating calcium chloride in camel milk yoghurt lowered the TTA values of the yoghurt compared to samples without salts, as shown in Figure 2. The significantly lower TTA values could be due to the decreased viable total bacteria counts due to the higher viscosity in camel milk yoghurt samples and inhibition by Calcium chloride. The higher concentration of starches and calcium chloride may have increased viscosity (Khalifa and Ibrahim, 2015). In this study, it was observed that increasing the concentration of starch increased the viscosity of yoghurt samples, as discussed in section 2.4.4 (Figure 10).

3.3. Effect of different stabilising agents on the pH of camel milk yoghurt

The pH of the processed yoghurt decreased with increasing fermentation time from 0-6 h and storage time from 1 to 21 days (Figure 3). The pH of the control yoghurt (BYCS) decreased from 6.68 to 4.47 after 6 h and to 4.4 after 21 days (Figure 3). The pH of camel milk yoghurt containing 3% corn starch (CY3%CS) decreased from 5.86 to 4.47 after 6 h and 4.0 after 21 days. The pH of camel milk yoghurt containing 2.5% modified starch (CY2.5%MS) decreased from 6.34 to 4.89 after 6 h and 4.38 after 21 days.

The progressive decrease in pH values could be due to lactose conversion into lactic acid during fermentation and subsequent storage (Al-Zoreky and Al-Otaibi, 2015; Fauziah et al., 2020; Sadler and Murphy, 2010).

The pH of camel milk yoghurt containing 3% corn starch with 0.075% calcium chloride (CY3%CSCaCl) decreased from 5.83 to 4.69 after 6 h and to 4.39 after 21 days (Figure 4). The pH of camel milk yoghurt containing 2.5% modified starch with 0.075% calcium chloride (CY2.5% MSCaCl) decreased from 6.04 to 4.88 after 6 h and to 4.47 after 21 days.

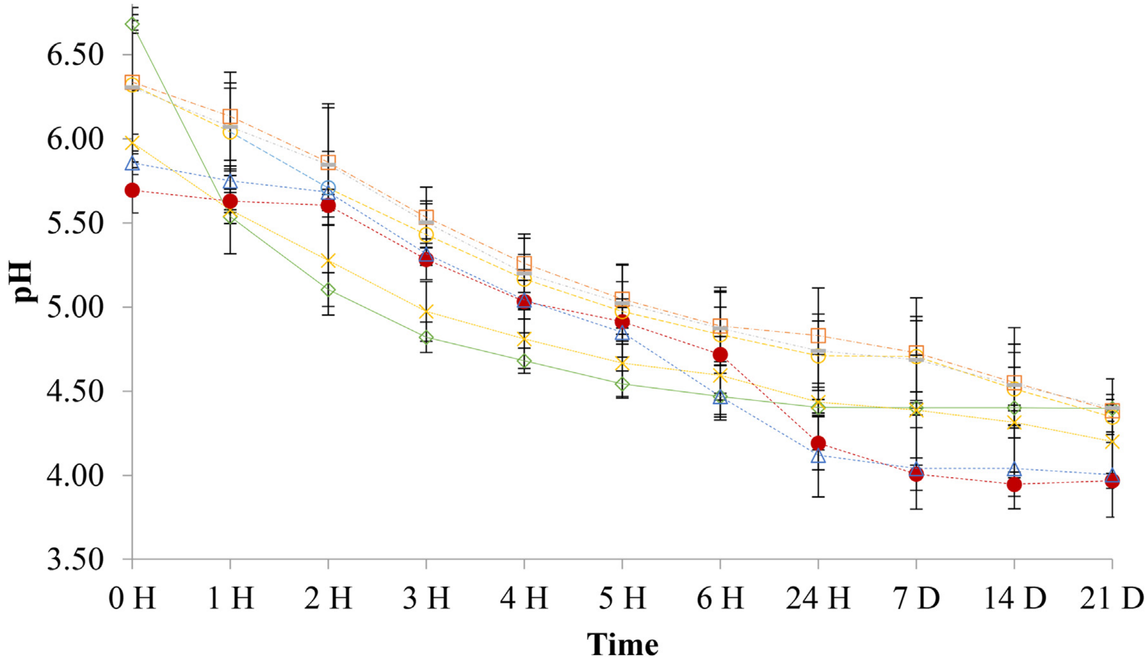

Figure 3. Effect of different stabilising agents in yoghurt formulations; BYCS (◊), CY2%CS (×), CY2.5%CS (●), CY3%CS (Δ), CY2%MS (○), CY2.5%MS (□), CY3%MS (-) on the PH of camel milk yoghurt during fermentation (0–6 h) and storage (1–21 days).

Other researchers have reported similar trends (Bornaz et al., 2009; Ibrahim and Khalifa, 2015). The addition of calcium chloride did not significantly affect the pH values compared to yoghurts without the salt.

3.4. Effect of different stabilising agents on the viscosity of camel milk yoghurt

The viscosity increased with increasing fermentation time from 0-3 h (Figure 5), and after that, it plateaued and dropped after 6 h. The viscosity of control yoghurt (BYCS) increased from 0.01 to 0.35 Pa.s after 6 h but reduced to 0.21 Pa.s after 21 days of storage (Figure 5). The viscosity of yoghurt containing 3% corn starch (CY3%CS) recorded the highest viscosity than the other yoghurt formulations, which increased from 0.34 to 0.81 Pa.s after 2 h but reduced to 0.51 after 6 h and 0.26 Pa.s after 21 days (Figure 5). Besides, the viscosity of camel milk yoghurt containing 2.5% modified starch (CY2.5%MS) increased from 0.02 to 0.3 Pa.s after 6 h but also reduced to 0.11 Pa.s after 21 days.

At 0 h, the viscosity of control (BYCS) and camel milk yoghurt with 2.5% modified starch (CY2.5%MS) was significantly lower than camel yoghurt with 3% corn starch ($P < 0.05$). Generally, the addition of corn starch had a higher influence on viscosity compared to modified starch.

The higher viscosity of camel milk yoghurt with 3% corn starch at 0 h (before fermentation) ($P < 0.05$) could be attributed to the gelation properties of corn starch (Galeboe et al., 2018; Gawai et al., 2017; Singh

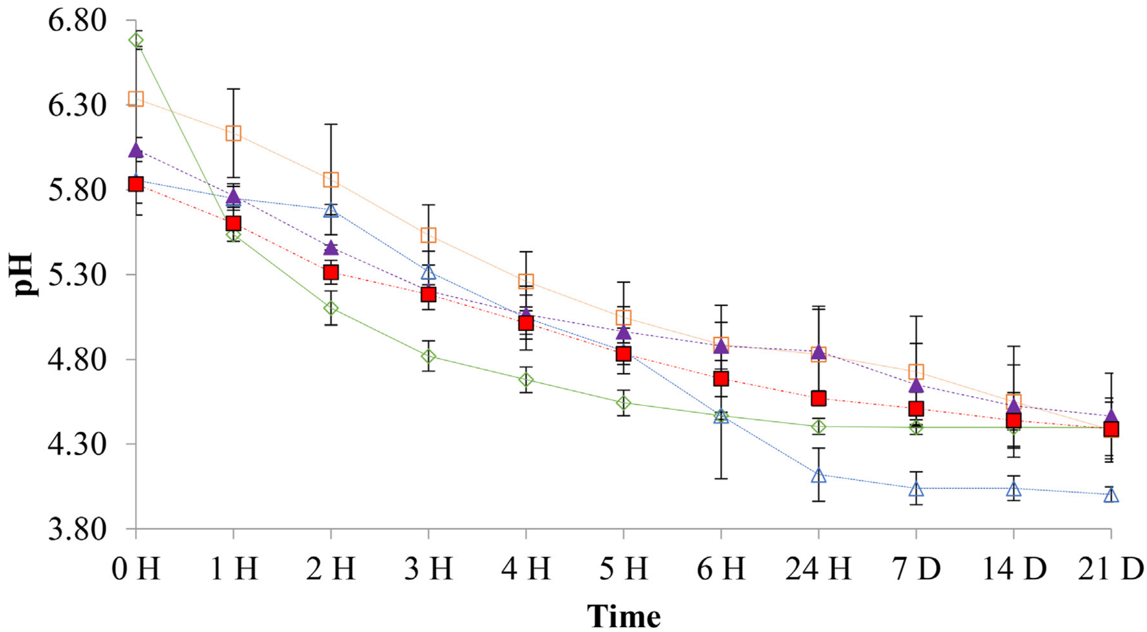

Figure 4. The effect of calcium chloride on the PH of camel milk yoghurt formulations CY2.5%MSCaCl (■) and CY3%CSCaCl (▲) compared to BYCS (◊), CY3%CS (Δ), CY2.5%MS (□), during fermentation (0–6 h) and storage (1–21 days).

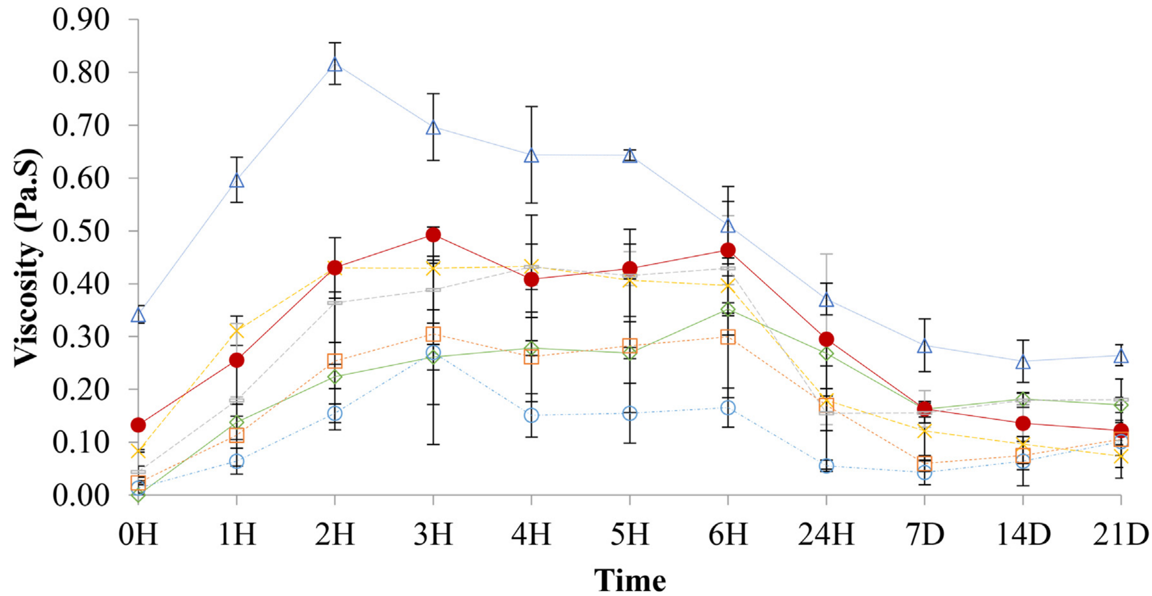

Figure 5. Effect of different stabilising agents on the viscosity of yoghurt formulations; BYCS (◊), CY2%CS (×), CY2.5%CS (●), CY3%CS (△), CY2%MS (○), CY2.5%MS (□), CY3%MS (-) during fermentation (0–6 h) and storage (1–21 days).

et al., 2017). Perhaps, this is due to the interactions between casein micelles and corn starch that enhanced the viscosity of the camel milk containing 3% corn starch (Figure 5) (Galeboe et al., 2018). These findings portrayed similar trends to the findings of other researchers, including Al-Zoreky and Al-Otaibi (2015), Bhattarai et al. (2015); Ibrahim and Khalifa (2015); Macit and Bakirci (2017). Wang et al. (2013) also reported similar trends of increasing viscosity with increasing amounts of corn and modified starch.

Incorporating stabilising agents and 0.075% calcium chloride increased the viscosity of camel milk yoghurt with increasing fermentation time from 0 to 6 h (Figure 6). The addition of calcium chloride increased the viscosity of camel milk yoghurt further. The incorporation of salts increased the maximum viscosity of camel milk yoghurt with 3% corn starch from 0.8 to 0.96 Pa.s. The viscosity of camel milk yoghurt containing modified starches and calcium chloride did not change throughout the storage period of up to 21 days. In contrast, the viscosity of yoghurts with corn starch and calcium chloride decreased after 1 day and during the storage period up to 21 days.

Therefore, based on viscosity, camel yoghurt containing 2.5% modified starch and 0.075% calcium chloride (CY2.5%MSCaCl) provided the best results on storage (21 days). This could be attributed to the gelation of modified starch and calcium chloride stabilisation of the milk protein structure (Galeboe et al., 2018; Gawai et al., 2017; Singh et al., 2017).

3.5. Effect of different stabilising agents on the syneresis on camel milk yoghurt

The control bovine milk yoghurt exhibited the highest syneresis, which did not change with storage time compared to the camel milk yoghurts (Figure 7). The syneresis of the camel milk yoghurt was lower

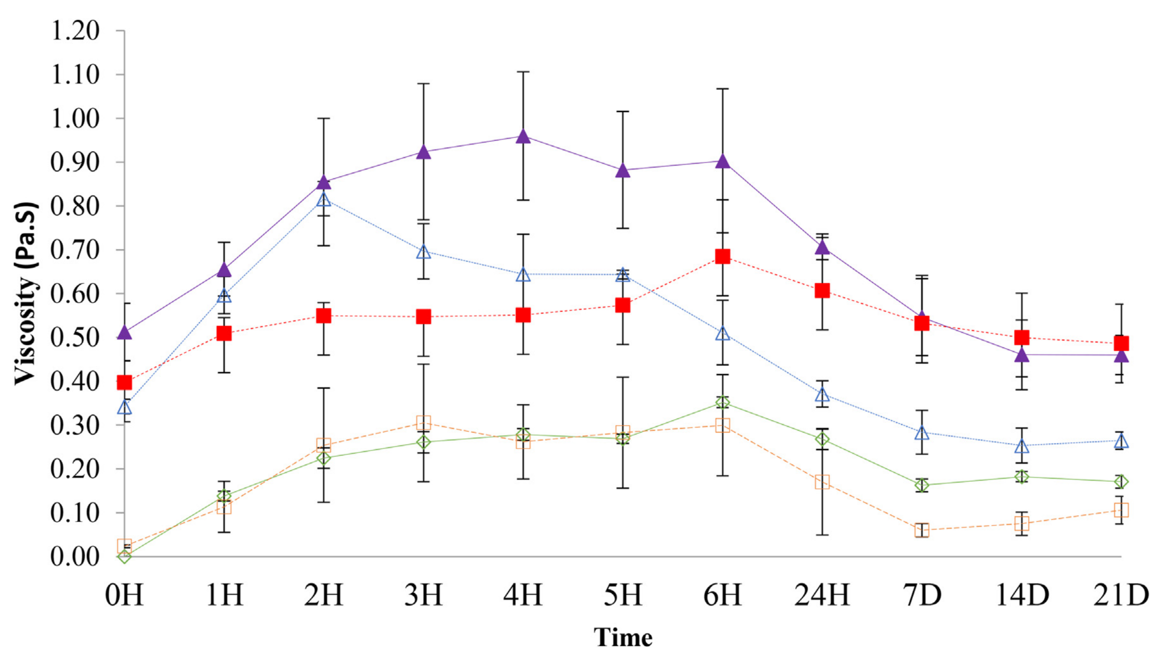

Figure 6. The effect of calcium chloride on the viscosity of camel milk yoghurt formulations CY2.5%MSCaCl (■) and CY3%CSCaCl (▲) compared to BYCS (◊), CY3% CS (△), CY2.5%MS (□), during fermentation (0–6 h) and storage (1–21 days).

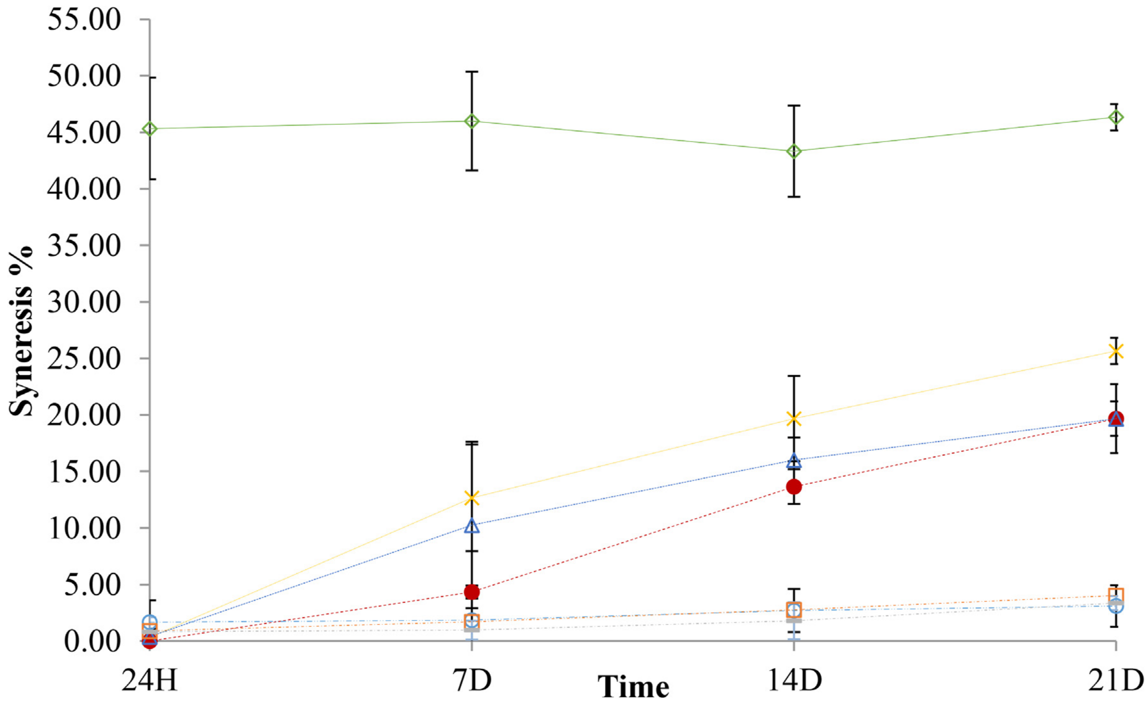

Figure 7. Effect of different stabilising agents on the syneresis of yoghurt formulations BYCS (◊), CY2%CS (×), CY2.5%CS (●), CY3%CS (Δ), CY2%MS (○), CY2.5%MS (□), CY3%MS (-) during fermentation (0–6 h) and storage (1–21 days).

by over 44% compared to bovine milk yoghurt. The syneresis of camel milk yoghurt containing modified starches did not change dramatically during storage time from 1 to 21 days (Figure 7). However, the syneresis of camel milk yoghurt containing corn starches increased significantly during storage up to 21 days.

The syneresis of camel yoghurt containing 3% corn starch (CY3%CS) increased from 0.4% to 19.67% (50 times) after 21 days of storage. Additionally, the syneresis of camel milk yoghurt containing 2.5% modified starch (CY2.5%MS) increased from 0.90 to 4.03% (3.5 times) after 21 days (Figure 7).

Camel milk yoghurt samples displayed lower syneresis due to the relatively higher concentrations of stabilisers (2–3%) than bovine yoghurt (0.5%), which acted as a water binding matrix. These results are supported by the findings of other researchers, including Al-Zoreky and Al-Otaibi (2015), Galeboe et al. (2018); Joon et al. (2017); Mudgil et al. (2018); Sobti et al. (2020). The higher concentrations of starch could have immobilised the aqueous phase of camel milk yoghurt (Galeboe et al., 2018; Joon et al., 2017; Mudgil et al., 2018). Furthermore, adding corn starch and modified starch may have prompted the build-up of gel network with the casein micelles in the camel milk yoghurt mixture,

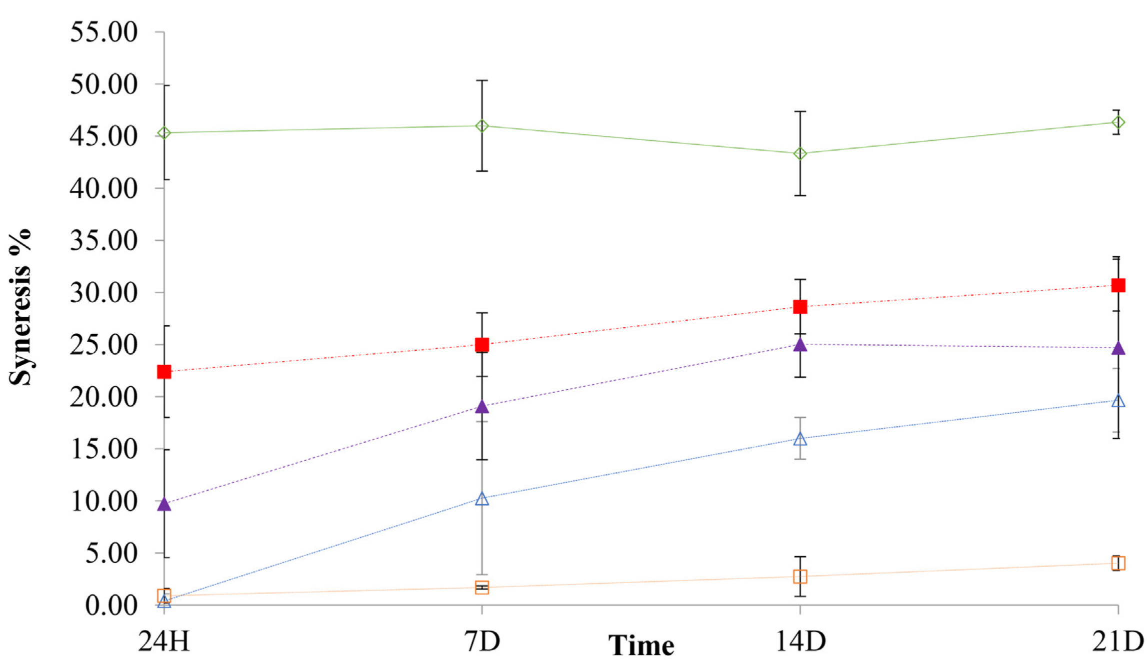

Figure 8. The effect of calcium chloride on the syneresis of camel milk yoghurt formulations CY2.5%MSCaCl (■) and CY3%CSCaCl (▲) compared to BYCS (◊), CY3% CS (Δ), CY2.5%MS (□), during storage from 1-21 days.

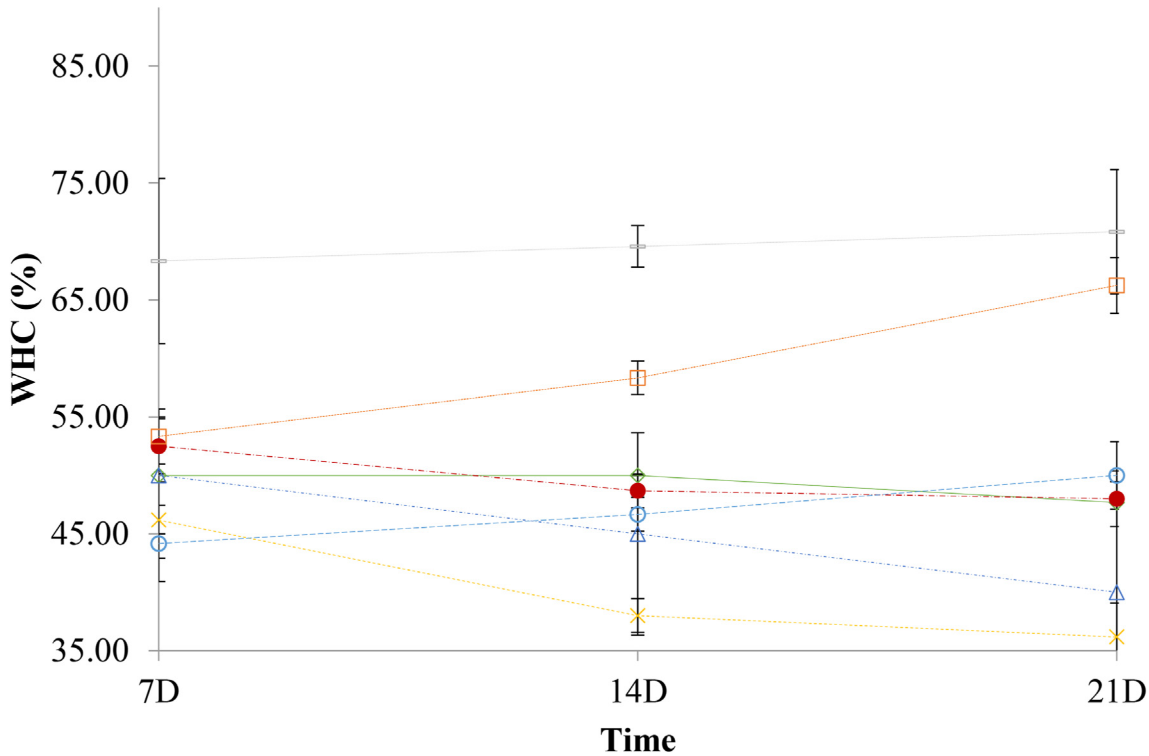

Figure 9. Effect of different stabilising agents on the water holding capacity of yoghurt formulations; BYCS (◊), CY2%CS (×), CY2.5%CS (●), CY3%CS (△), CY2%MS (◌), CY2.5%MS (□), CY3%MS (-) during storage 7–21 days.

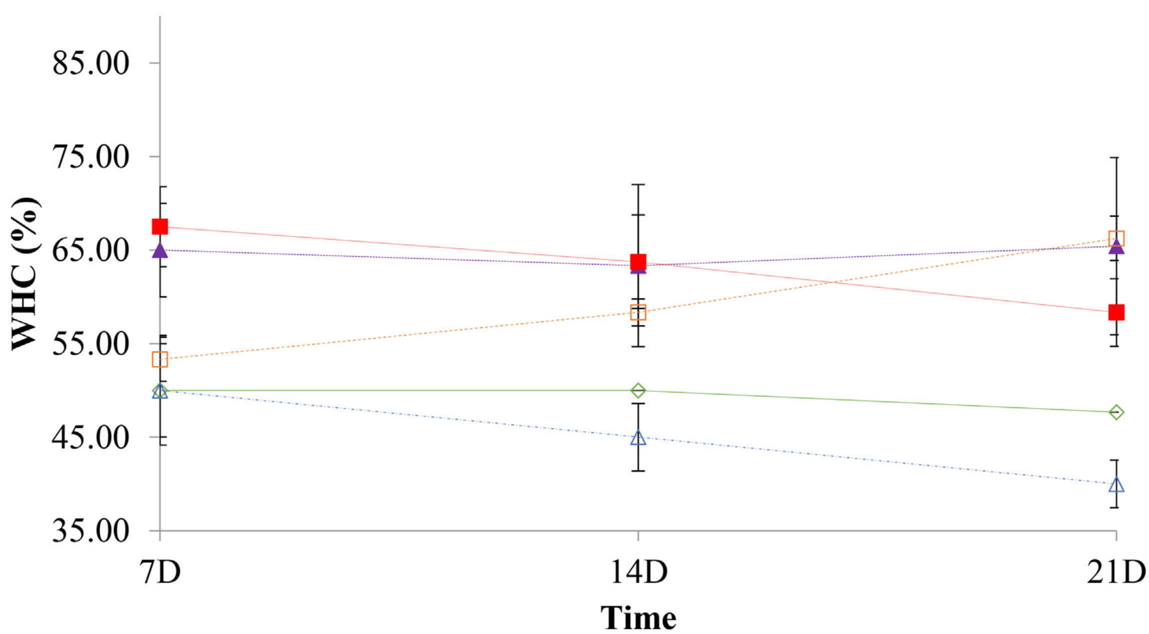

Figure 10. The effect of calcium chloride on the water holding capacity of camel milk yoghurt formulations CY2.5%MSCaCl (■) and CY3%CSCaCl (▲) compared to BYCS (◊), CY3%CS (△), CY2.5%MS (□), during storage from 7-21 days.

rendering all camel milk yoghurt samples less susceptible to syneresis during storage. Supavititpatana et al. (2008) also observed that increasing the concentration of stabilisers lowered syneresis in camel milk yoghurt.

Water mobility within the stabilisers during storage leads to higher syneresis. These findings agreed with the trends reported in other studies (Kamal-Eldin et al., 2020; Mudgil et al., 2018; Ramirez-Santiago et al., 2010; Shori 2013).

Modified starch seems to be a better stabiliser to reduce syneresis in camel milk yoghurt since all yoghurt containing modified starch exhibited the lowest syneresis level compared to yoghurts containing corn starch (Figure 7). The effect of adding calcium chloride on the

Table 2. Effect of different stabilising agents on the colour (L*, a*, b*) values of camel milk yoghurt at different sampling times.

Time	Colour	BYCS (Control)	CY3%CS	CY2.5% MS	CY2.5% MSCaCl	CY3% CSCaCl
1D	L*	58.02 ± 0.4[a]	55.86 ± 0.51[a]	57.06 ± 2.58[a]	57.90 ± 6.97[a]	58.55 ± 4.62[a]
7D	L*	61.14 ± 2.91[a]	58.25 ± 1.22[a]	56.87 ± 3.04[a]	57.71 ± 4.53[a]	55.59 ± 2.31[a]
14D	L*	60.99 ± 3.40[a]	58.59[a] ± 2.14[a]	58.86 ± 4.21[a]	52.35 ± 6.03[b]	49.21 ± 4.16[b]
21D	L*	56.46 ± 1.08[a]	62.01 ± 0.94[a]	56.30 ± 3.30[a]	56.31 ± 15.76[a]	45.88 ± 0.65[b]

Values are means (±SD) of three independent determinations. Mean values with different superscript letters (a and b) in a row for each sample are significantly different at $P \leq 0.05$.

syneresis of camel milk yoghurt during storage is shown in Figure 8. Surprisingly, the introduction of salts led to a general increase in syneresis in the yoghurts even after 24 h of storage compared to those without calcium chloride. The syneresis also increased with increasing storage time. Generally, the syneresis of camel milk yoghurt containing 3% corn starch with 0.075% calcium chloride (CY3%CSCaCl) increased from 9.73% to 24.70% after 21 days of storage. Additionally, the syneresis of camel milk yoghurt containing 2.5% modified starch with 0.075% calcium chloride (CY2.5%MSCaCl) increased from 22.40 to 30.70% after 21 days (Figure 8). These increases in yoghurts with calcium chloride were approximately 5 times higher than similar yoghurt formulations without calcium chloride.

The incorporation of salts (0.075% calcium chloride) decreased the tendency of casein to coagulate near the isoelectric point, leading to the production of camel yoghurt (CY2.5%MSCaCl and CY3%CSCaCl) with a relatively weaker gel compared to yoghurt samples without calcium chloride (CY2.5%MS and CY3%CS). The weaker gels also led to an increase in syneresis during storage (Figure 8). The trends of these findings were similar to those reported by Everett and McLeod (2005), Kamal-Eldin et al. (2020), Mbye et al. (2020); Mudgil et al. (2018); Nassar et al. (2020); Sobti et al. (2020). It is worth noting that yoghurt with modified starch at 2.5% and without salts exhibited the lowest syneresis than all the other yoghurts.

3.6. Effect of stabilising agents on the water holding capacity (WHC) (%) of camel milk yoghurt

The ability of yoghurt to retain water into the curd is called water holding capacity (Sakandar et al., 2014). The camel milk yoghurt with 3% Modified starch had the highest WHC followed by the yoghurt containing 2.5% modified starch, while yoghurt containing 2% corn starch exhibited the lowest WHC (Figure 9). These findings were in agreement with the studies conducted by Al-Zoreky and Al-Otaibi (2015), Ibrahim and Khalifa (2015), Kamal-Eldin et al. (2020).

The introduction of calcium chloride in the yoghurts affected WHC differently. The water holding capacity of camel milk yoghurt containing 3% corn starch with 0.075% calcium chloride (CY3%CSCaCl) increased from 62.5% to 65.42% after 21 days of storage. On the other hand, the water holding capacity of camel milk yoghurt containing 2.5% modified starch with 0.075% calcium chloride (CY2.5%MSCaCl) decreased from

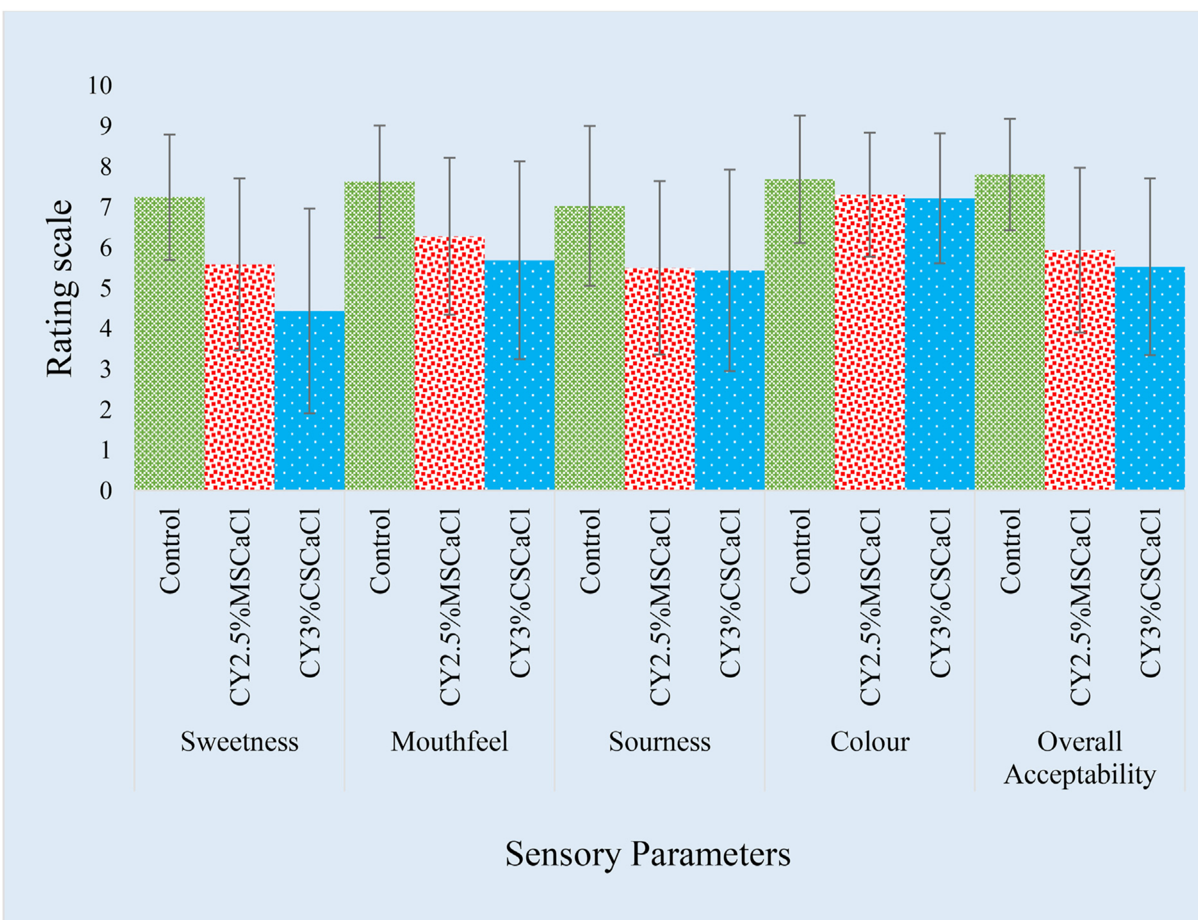

Figure 11. Effect of different stabilising agents on the sensory properties of different formulations of camel milk yoghurt compared to bovine yoghurt.

70.0% to 58.33% after 21 days (Figure 10). However, the water holding capacity of control yoghurt (BYCS) was not significantly different from CY3%CSCaCl and CY2.5%MSCaCl after 1 day of storage ($P > 0.05$). After 21 days, the WHC of control yoghurt (BYCS) was significantly lower than CY3%CSCaCl and CY2.5%MSCaCl ($P < 0.05$).

Stabilisers are known to perform two basic functions in yoghurt. According to Karaca (2013) and Milani and Koocheki (2011), stabilisers improve the structure of yoghurt and enhance water binding capacity, hence improving the general texture of yoghurt. By enhancing yoghurt's water-binding capacity, stabilisers minimise water flow in the matrix space and may interact with the protein in the food matrix, improving the hydration behaviour in yoghurt (Abou-Soliman et al., 2017; Al-Zoreky and Al-Otaibi, 2015; Bulca et al., 2019).

3.7. Effect of different stabilising agents on the colour (L*) values of camel milk yoghurt at different sampling times

Table 2 shows the effect of different stabilising agents on the colour values of camel milk yoghurt prepared using corn starch, modified starch and calcium chloride during storage for up to 21 days.

After 1 day of storage, the lightness (L*) of control yoghurt was not significantly different from all camel milk yoghurt samples (Table 2). After 21 days of storage, the lightness (L*) of camel milk yoghurt containing 3% corn starch and 0.075% calcium chloride (CY3%CSCaCl) was significantly lower than control yoghurt and all camel milk yoghurt samples (Table 2). There was no significant difference between the colour of different yoghurt samples except camel milk yoghurt containing 3% corn starch and calcium chloride. This indicates that the addition of these stabilisers does not affect the lightness of camel milk yoghurt.

These findings were in line with studies of other researchers who confirmed non-significant changes in most of the camel milk yoghurt colour (L*) values despite the addition of different stabilising agents (Bouaziz et al., 2021; Karaca, 2013; Koca and Metin, 2004; Macit and Bakirci, 2017). Other studies that found similar trends during camel milk yoghurt storage include Kamal-Eldin et al. (2020a); Sobti et al. (2020); Sobti and Kamal-Eldin (2019).

3.8. Effect of different stabilising agents on the sensory properties of camel milk yoghurt

Control yoghurt samples obtained the highest preference rates regarding sweetness, sourness, mouthfeel and overall acceptability (Figure 11). However, the preference rating for colour was not significantly different among various processed yoghurt samples ($P > 0.05$).

Control yoghurt scored the highest preference rating based on all sensory parameters, with a rating of 7.81 $\pm$1.378 (like very much). Camel milk yoghurt containing 2.5% modified starch and 0.075% calcium chloride, followed by a mean value of 5.94 $\pm$2.031 (like slightly). Camel yoghurt containing 3% corn starch and 0.075% calcium chloride had a rating of 5.53 $\pm$ 2.185 (like slightly) (Figure 11).

Adel et al. (2011) also found the scores of taste, colour, texture, flavour and overall preference of camel milk yoghurt to be significantly ($P \leq 0.05$) lower than those of bovine yoghurt. The low organoleptic attributes of camel milk yoghurt samples could be associated with several factors involving elevated levels of polyunsaturated fatty acids and high concentration of salts (Eissa et al., 2011, 2011, 2011; Hailu et al., 2018; Hashim et al., 2009).

4. Conclusion

The viscosity of camel milk yoghurt containing corn starches was the highest (0.82 Pa.s) during fermentation but decreased during storage up to 21 days. The viscosity of camel milk yoghurt containing modified starches did not change during storage. Although the addition of salts increased the viscosities of yoghurt (0.96 Pa.s) further, it also increased the syneresis of camel milk yoghurt containing modified starch. Therefore, in formulating camel milk yoghurt containing salt, there is a need to compromise the advantage of salt on viscosity and its negative effect on syneresis. For longer storage periods of camel milk yoghurt, up to 21 days, modified starch is recommended compared to corn starch.

Declaration

Author contribution statement

Stephen Oselu:Conceived and designed the experiment; Performed the experiments; Analysed and interpreted the data; wrote the paper.

Rebecca Ebere; Guyo Huka; Levi Musalia; Eunice Marete; Julius M. Mathara; Florence Mwobobia: Conceived and designed the experiments; Analysed and interpreted the data.

Joshua M. Arimi: Conceived and designed the experiments; Analysed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Funding statement

This work was supported by National Research Fund (NRF), Kenya (NRF/2/MMC/176) and MUST4th Internal Research Funding.

Data availability statement

Data included in article/supp. material/referenced in article.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

Supplementary content related to this article has been published online at https://doi.org/10.1016/j.heliyon.2022.e11816.

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