Development of Yogurt from Camel Milk Using Exopolysaccharide Producing Lactic Acid Bacteria

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ABSTRACT

This research was conducted to develop and evaluate improved camel milk yogurt using a combination of exopolysaccharide (EPS) producing lactic acid bacteria (LAB), starch (S) and camel milk powder (CMP). The experiment had five treatments with YF-L904 culture used as EPS producing LAB and YC-X 11 culture as non-EPS producing LAB. Both strains of LAB composed of Streptococcus thermophilus (ST) and Lactobacillus, delbrueckii ssp bulgaricus (LB). About 400ml of camel milk sample was used for each treatment. The results show that both additives (starch and CMP) had significantly increased (P<0.05) protein, lactose, total solid, and solid not fat. The level of syneresis of yoghurt with EPS and starch was significantly (P<0.05) lower than the other yoghurt samples. Yogurt with EPS and starch had the highest viscosity and the lowest syneresis value (36.17s and 36.67%, respectively) among the treatments considered. The highest level of syneresis was observed on the yoghurt produced with CMP (68.33%) as compared to yogurt produced with starch alone (36.67%) and starch with CMP (54.67%). The level of starch inclusion in the yogurt had significant effect (P<0.05) on reducing syneresis and increasing viscosity. The texture value of yogurts produced with starch had significantly (P<0.05) higher firmness, elasticity, cohesiveness and adhesiveness in both camel and cow milk yogurt. However, CMP addition did not improve the textural properties of both camel and cow milk yogurt. In conclusion, using EPS producing LAB and addition of starch in yogurt making from camel milk could improve viscosity and textural properties and reduce the syneresis of the product.

Key words: Camel milk, Starch, Syneresis, Texture, Viscosity, Yogurt

INTRODUCTION

Earlier studies indicated that camel milk could not be processed in to different dairy products, but used only for drinking (Yagil *et al*., 1984). The difficulties might be related to the absence of the whey protein (β-LG) and a low proportion of κ-casein in camel milk that cause differences in dairy processing (Yonas Hailu *et al*., 2016). Even though there are difficulties of processing camel milk, some researchers reported that various products are produced from camel milk including yogurt (El-Zubeir and Jabreel, 2008; Rüegg and Farah, 1991; Aleme Asrasie *et al*., 2013).

Camel milk whey protein doesn't contain β-LG and has lower amount of k-casein (Shamsia, 2009) which could lead camel milk to coagulate slowly and have poor texture. Yogurt texture is a very important characteristic that affects its quality such as appearance, mouth feel and overall acceptability. The most common sensory attributes related to yogurt texture are thickness /viscosity, smoothness and sliminess (or ropiness). Many quality problems, such as low viscosity or high syneresis, which occur during milk product manufacturing, are often solved by increasing the total solid or adding stabilizers, such as milk powder, modified starch, carrageenan, guar gum, pectin, gelatin and sodium caseinate. Yoghurt from camel milk stabilized with gelatin and corn starch was acceptable and comparable with cow milk yoghurt (Muliro, 2007). Stabilizers and polysaccharide-producing cultures have also been used to improve texture and prevent syneresis (Escalante *et al*., 1998).

Lactic acid bacteria (LAB) are used in many fermented foods particularly fermented dairy products such as cheese, buttermilk, and fermented milks. Some LAB produces lactic acid and carbon dioxide that contributes to texture and shelf life of fermented foods some also produces acetic acid, diacetyl, and acetaldehyde for flavour. In addition, certain strains of LAB are able to synthesize exopolysaccharides (EPS) that play a major role as natural texturizer in industrial production of yoghurt, cheese, and milk-based desserts. In general, EPS are known to have highly significant effects on the texture properties of many types of fermented milk products (Cerning, 1990). Moreover, they are considered as natural bio thickeners since they are produced *in situ* by LAB starter culture and helps to avoid the use of some other stabilizers which are prohibited or restricted (Amatayakul *et al*., 2005). A protein gel (mainly casein) interacts with EPS that formed in the protein matrix, can reduce the amount of free water and minimize syneresis (Tamime *et al*., 1984).

The bovine milk products fermented with EPS-producing cultures obtain high viscosity, high creaminess as well as an increased water-binding capacity (Rawson and Marshall, 1997). However, camel milk fermented products have not been developed using EPS producing LAB and starch as additive so far. Therefore, this study was conducted with the objective of developing yogurt from camel milk using EPS producing thermophilic lactic acid bacteria, tapioca starch and camel milk powder.

MATERIALS AND METHODS

Milk Sample Collection

Fresh camel milk samples were collected from camel rearing pastoralists in Erer valley of Babile district, eastern Hararghe Zone, Ethiopia. Milk was sampled by directly milking into clean containers. Throughout the experiment, around 18 litres of camel milk samples were collected from eight different camels and was brought to Haramaya University Dairy Technology Laboratory using clean plastic containers (Jerry-cans) within two hours. Cow milk, which was used for comparison, was collected from Haramaya University dairy farm. Both milk samples were collected early in the morning.

Materials

Additives (stabilizers) such as camel milk powder (CMP) (which constituents 25g fat, 40g carbohydrates, 25g protein and 1.6g salt per 100g) (*Camelicious*, Dubai, United Arab Emirates), Starter cultures (YF-L904, used as EPS (+ve) and YC-X11 used as EPS (-ve)) (Chr Hansen A/S, Denmark), and Tapioca Starch (Cream Tex® 75720 (Sino-Thai Starch Co., Ltd, Thailand) were donated from Denmark.

Physicochemical Analysis of Milk and Yogurt

The chemical composition of milk and yogurt that include fat, protein, lactose, TS and SNF was analysed at Haramaya University Dairy Technology laboratory using MilkoScan (MilkoScan™ FT1 FOSS, Hillerød, Denmark). The pH values of raw milk as well as yogurt were, however, analysed using digital pH meter (pH-016 PH METER).

Procedure for Yogurt Production

Yoghurt samples were prepared according to Lee and Lucey (2010) and Dirar (1993) methods with slight modifications. Fresh camel milk sample was first filtered using sterile cheese clothes to remove impurities. The raw milk was heated to 40^{o}C for 1 minute before adding tapioca starch and/or CMP. Then, tapioca starch and camel milk powder were immediately added to the camel milk followed by mixing at 5.0x10^{3} rpm for 2 minutes using an Ultra-Turrax T18 homogenizer (IKA-Labortechnik, Staufen, Germany) to evenly disperse and thoroughly mix tapioca starch and CMP. After proper mixing, the milk was pasteurized at 85^{o}C for 30 min as described by Dirar (1993) and rapidly cooled to 43^{o}C. Then, starter cultures (YF-L904 as EPS (+ve) and YC-X11 as EPS (-ve) were inoculated at a concentration rate of 0.8ml for 400ml of milk sample (Tesfamariam Berhe *et al.,* 2018). The inoculated milk samples were incubated at 43^{o}C. The pH of the milk was monitored until it reached pH 4.6 using digital PH meter. The same procedure was used to produce yogurt from cow milk for comparison.

Treatments of Yogurt

The experiment had five treatments. In addition to starch and CMP, two types of starter cultures: YF-L904 as EPS producing LAB (YEPS) and YC-X 11 as non-EPS producing LAB (YNEPS) were used in treatment setups as follows:

Treatment 1 (YNEPS): Camel milk + EPS (-) LAB

Treatment 2 (YEPS): Camel milk + EPS (+) LAB

Treatment 3 (YEPS+S): Camel milk + EPS (+) LAB+ Starch (5%)

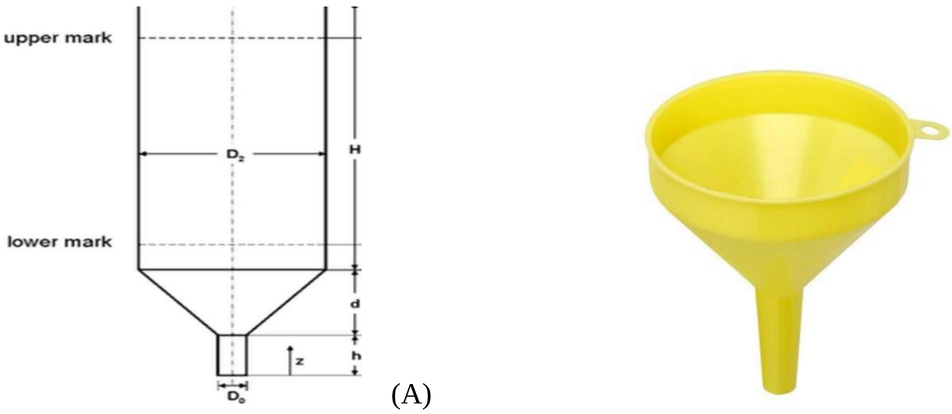
Treatment 4 (YEPS+CMP): Camel milk + EPS (+) LAB+ Camel milk powder (5%)

Treatment 5 (YEPS+S+CMP): Camel milk + EPS (+) LAB+ Starch (2.5%) + Camel milk powder (2.5%). A 400ml of camel milk sample was used in blue cap reagent bottles for each treatment.

The concentration level of starch and CMP was based on the trial done for Paneer type cheese at Copenhagen University Dairy Technology Pilot Test, Denmark; and the concentration level for both EPS-producing thermophilic LAB and non-EPS producing LAB was used according to Tesfamariam Berhe *et al*. (2018). Both strains of LAB composed of *Streptococcus thermophilus* (ST) and *Lactobacillus delbrueckii ssp bulgaricus* (LB). The same procedure was followed for cow milk yogurt and all treatments were done in triplicates. T1 yogurt (YNEPS) was comparable with T2 yogurt (YEPS) whereas T3 (YEPS+S), T4 (YEPS+CMP) and T5 (YEPS+S+CMP) yogurts were compared with each other due to the presence of additives (CMP and starch) in addition to exopolysaccharides producing LAB.

Viscosity Analysis

Viscosity of yogurt was analysed and evaluated by simple posthumous funnel test. The Posthumous funnel test is an empirical and fast method used to evaluate the viscosity of yoghurts and other fermented dairy products. It is based on the time needed to the yoghurt to pass through the posthumous-funnel. The procedure was filling the funnel with yoghurt to the upper mark (on the inside), while keeping the hole at the bottom of the funnel closed with a finger. Then the finger removed and the stopwatch started at the same time. And then the time it takes is measured until the lower mark or the metal pin sticking out is visible. The flow time is an indication of the viscosity and mouth-feel of the yoghurt. This method was applied for camel milk yogurt, however, it was not applied for cow milk since cow milk yogurt had higher viscosity especially for the yogurt that produced using starch. The viscosity of cow milk yogurt was therefore measured using plastic funnel. Yoghurt samples of 200ml were poured in to plastic funnel for each treatment and allowed to pass through the hole of plastic funnel and measured the time elapsed. Figure 1 shows dimensions and height of posthumous funnel and plastic funnel used for this experiment.



(A) (B)

Figure 1. Posthumous funnel (A) and plastic funnel (B)

Note: $\mathbf{D_0}$ = the lower hole diameter (**4.5mm**), H= height (**108mm)** and **D2**= the upper hole diameter (**60mm**). Cow milk yogurt was measured using plastic funnel (the lower hole diameter =**10mm** and the upper hole diameter=**100mm**).

Syneresis Analysis

The syneresis of yogurt samples were monitored after 24h of storage at 4°C by measuring the quantity of whey separated. Ten gram of yogurt sample was poured into a graduated cylinder and put in to a centrifuge (350xg, 20^{o}C for 10 minutes) (Centurion scientific Ltd, West Sussex BN16b1AW, UK). The amount of the watery part, which was separated on the top in graduated cylinder was measured and calculated according to the following formula (Farnsworth *et al*., 2006 and Jacek Domagała, 2012) with slight modification.

$$\text{Syneresis (\%)} = \frac{\text{Whey expelled (g)}}{\text{Initial yogurt (g)}} 100$$

Texture profile Analysis of Yogurt

Texture analysis was performed by using a TA XT2 texture analyzer (Stable Micro Systems Ltd, court, surrey GU7 1 YL, UK). A cylindrical probe of 35mm diameter was used with a pre-test, compression and post-test of a sample, where the speed of the probe used in the procedure was 1.0mm/s, 2.0mm/s and 10.0mm/s, respectively. Compression distance was 20 mm in to the sample. All samples height was 80ml. Four parameters were evaluated for texture; (1) Firmness (hardness) defined as the maximum peak force during the first compression cycle (first bite), (2) Elasticity (springiness) height that the food recovers during the time elapses between the end of the first bite and the start of the second bite, (3) Adhesiveness the negative area for the first bite, representing the work necessary to pull compressing probe away from sample, (4) Cohesiveness defined as the ratio of the positive force area during the second compression to that during the first compression. Figure 2 shows the four parameters used in this experiment.

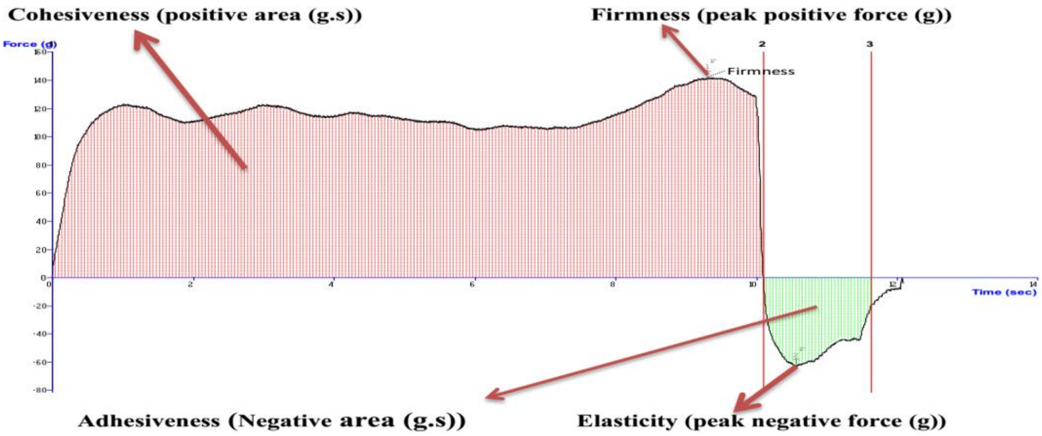


Figure 2. Example of Texture Profile Analysis curve

Acceptability Test

Sensory quality and acceptability of yogurt was performed by ten voluntary panellists selected based on the criteria suggested by Hashim (2002): age between 18 and 34 years, and usual consumers of camel milk or fermented camel milk and yogurt from milk of other species to rate the acceptability of the yogurt based on colour, taste, aroma, texture and overall acceptability using a 7-point hedonic scale (1 = dislike extremely, 2 = dislike moderately, 3 = dislike slightly, 4 = neither like nor dislike, 5 = like slightly, 6 = like moderately and 7 = like extremely). The sample was coded with three digits before given to the panellists. The sample was taken out from the refrigerator and thawed to the room temperature before presented to the panellists. Pure water was given to the panellists to drink and rinse their mouth before testing and evaluating the next yogurt sample.

Statistical Analysis

A Complete Randomized Design (CRD) with one-way analysis of variance (ANOVA) was performed to analyse data on physicochemical analysis, textural properties and sensory evaluation. Means were separated by Least Significant Difference (LSD) procedure using SAS statistical software version 9.1 (SAS institute. Cary, NC, USA). All values were reported as mean ± standard error mean (SEM) and significances were determined at $P<0.05$. All samples were conducted in triplicates.

RESULTS

Physicochemical Properties of Camel and Cow Milk

Results of the physicochemical properties of raw camel milk used for the yogurt making experiment observed in the current study (Table 1) are within the range reported by different authors.

Table 1. Physicochemical composition of raw camel and cow milk samples used for yogurt making

Variables	**Values**	
	Camel Milk	**Cow Milk**
Fat (%)	3.67±0.84	3.55±0.19
Protein (%)	2.50±0.09	3.16±0.15
Lactose (%)	4.93±0.06	4.40±0.18
SNF (%)	7.88±0.19	8.33±0.33
TS (%)	11.81±0.86	11.95±0.48
pH	6.54±0.01	6.60±0.01

Values in the table are mean±SE of three replications; Total Solid (TS), Solid Not Fat (SNF)

Yogurt Physicochemical Composition

Differences in physicochemical compositions were observed between the yogurt made without additives (T1 and T2) and with additives (T3, T4 and T5) (Table 2). Accordingly, treatment 4 (YEPS+CMP) and treatment 5 (YEPS+S+CMP) were significantly higher (*P<0.05*) protein, SNF, and TS compared to the other treatment samples. This was due to the added CMP that could increase the chemical compositions compared to yogurt produced without CMP additions. Treatment 3 (YEPS+S) and treatment 5 (YEPS+S+CMP) were also showed significantly (*P<0.05*) higher lactose content due to the addition of starch (Table 2). The presence of exopolysaccharides produced by LAB did not bring any change on physicochemical composition. However, it contributed to the specific rheology and texture of the products. Cow milk yogurt produced with starch (YEPS+S) also had significantly (*P<0.05*) higher lactose (7.72±0.75) compared with the other treatment groups of cow milk yogurt sample.

Table 2. Physicochemical properties of camel and cow milk yogurt (%)

Parameters	Treatments (Mean±SE)				
	T1 (YNEPS)	T2 (YEPS)	T3 (YEPS+S)	T4 (YEPS+CMP)	T5 (YEPS+S+CMP)
Camel milk yogurt					
Fat	3.42±0.58	3.27±0.45	3.21±0.62	4.37±0.46	3.75±0.49
Protein	2.54±0.08^{c}	2.50±0.10^{c}	2.32±0.06^{c}	3.36±0.12^{a}	2.93±0.07^{b}
Lactose	3.73±0.14^{b}	3.84±0.10^{b}	6.97±0.94^{a}	5.29±0.50^{ab}	5.63±0.53^{a}
TS	11.23±0.60^{b}	11.07±0.50^{b}	12.65±0.81^{ab}	14.48±0.49^{a}	13.80±0.46^{a}
SNF	7.76±0.23^{b}	7.76±0.35^{b}	9.65±0.71^{a}	10.11±0.29^{a}	9.94±0.56^{a}
Cow milk yogurt					
Fat	3.31±0.18	3.29±0.09	3.49±0.12	3.90±0.68	3.86±0.25
Protein	3.10±0.15	3.02±0.12	2.84±0.13	3.59±0.44	3.21±0.17
Lactose	4.65±0.10^{b}	4.52±0.06^{b}	7.72±0.75^{a}	4.67±0.49^{b}	5.67±0.43^{b}
TS	11.39±0.41	11.08±0.28	13.54±0.38	12.63±1.85	13.66±0.17
SNF	8.11±0.27^{ab}	7.89±0.15^{b}	9.93±0.24^{a}	9.27±1.36^{ab}	9.82±0.15^{ab}

Note: T1(Y_{NEPS}) =yogurt produced with non-EPS LAB, T2(Y_{EPS}) = yogurt produced with EPS LAB, T3(Y_{EPS+S}) = yogurt produced with EPS producing LAB and starch, T4($Y_{EPS+CMP}$)= yogurt produced with EPS producing LAB and camel milk powder and T5($Y_{EPS+S+CMP}$)= yogurt produced with EPS producing LAB, starch and camel milk powder. Means with the different letter within the same row are significantly different at (P< 0.05) with LSD. Each value is the mean of three replication (n=3). Total Solid (TS), Solid Not Fat (SNF). The same procedure was followed for cow milk yogurt.

Yogurt Rheological Properties

Viscosity and syneresis

The yogurt produced from camel milk with exopolysaccharides producing lactic acid bacteria and starch had a very good viscosity and less amount of whey separation compared to the yogurt produced with non-exopolysaccharides producing LAB (Figure 3). The syneresis value (71%) for camel milk yoghurt made with non-EPS was higher that yoghurts with EPS (67%)). Less viscosity was observed in camel milk yogurt produced with non-EPS (19.23 sec.) due to the absence of EPS when compared to T2 (21.6 sec.) (Figure 3). Therefore, the level of syneresis of T3 was significantly (*P<0.05*) lower than the other yoghurt samples.

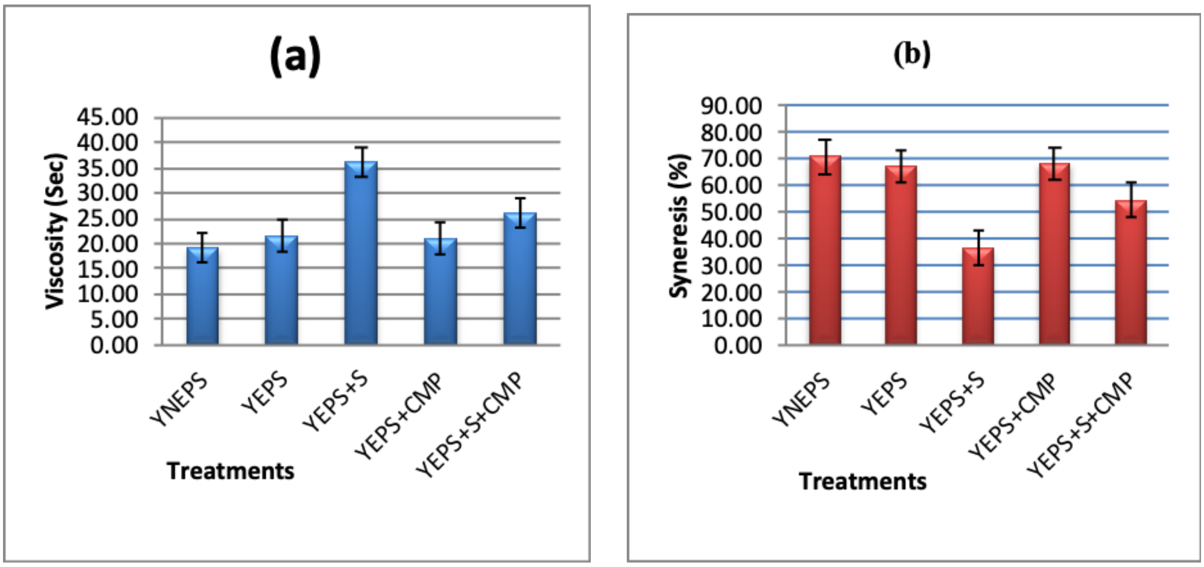


Figure 3. Camel milk yogurt viscosity and syneresis:

Yogurt produced with non-EPS producing Lactic Acid Bacteria (YNEPS), Yogurt produced with EPS-producing Lactic Acid Bacteria (YEPS), Yogurt produced with EPS-producing Lactic Acid Bacteria and Starch (YEPS+S), Yogurt produced with EPS-producing Lactic Acid Bacteria and Camel Milk Powder (YEPS+CMP) and Yogurt produced with EPS-producing Lactic Acid Bacteria, starch and camel milk powder (YEPS+S+CMP). Vertical bars indicate standard errors (SE) of least square means (n = 3).

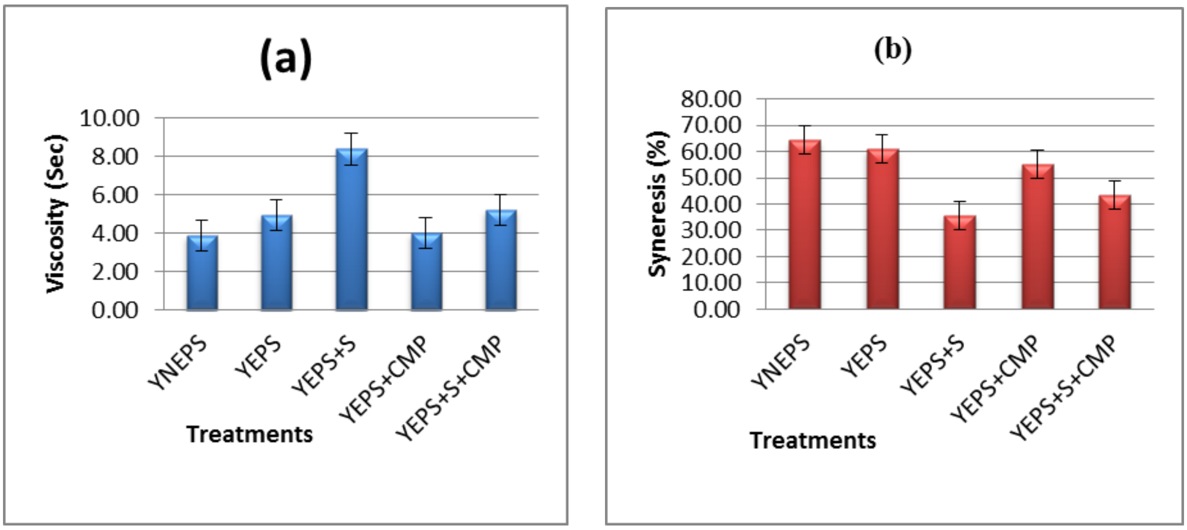


Figure 4. Cow milk yogurt viscosity and syneresis:

Yogurt produced with non-EPS producing Lactic Acid Bacteria (YNEPS), Yogurt produced with EPS-producing Lactic Acid Bacteria (YEPS), Yogurt produced with EPS-producing Lactic Acid Bacteria and Starch (YEPS+S), Yogurt produced with EPS-producing Lactic Acid Bacteria and Camel Milk Powder (YEPS+CMP) and Yogurt produced with EPS-producing Lactic Acid Bacteria, starch and camel milk powder (YEPS+S+CMP). Vertical bars indicate standard errors (SE) of least square means (n = 3).

The highest level of syneresis was observed with the yogurt treated with CMP (T4, 68.33%). On the other hand, the amount of starch added to the yogurt showed significant effects ($P<0.05$) in reducing syneresis and increasing viscosity (Figures 3 and 4).

Yogurt texture

T1 yogurt found to be lower in firmness in both camel and cow milk yogurt compared with T2 (Figures 5a and 6a). T3 Yogurt was significantly different ($P<0.05$) in firmness of camel and cow milk yogurt as compared to T4 and T5 (Figures 5a and 6a). In general, firmness, cohesiveness, elasticity and adhesiveness of the yogurt texture were positively affected in T3 yogurt samples made from both cow and camel milk (Figures 5 and 6). T3 yogurt was also more gel stable due to the mixture with tapioca starch.

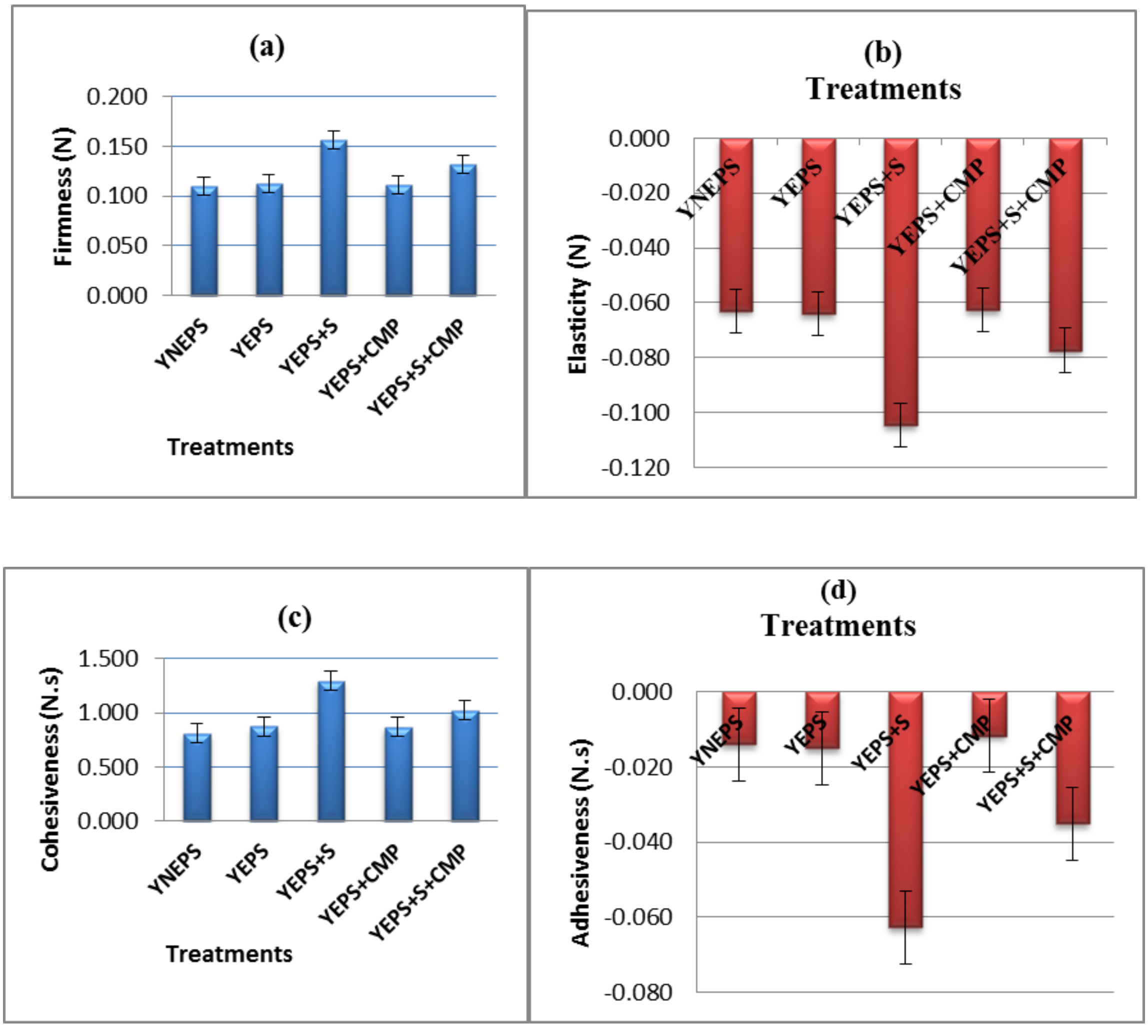


Figure 5. Texture properties of camel milk yogurt

Yogurt produced with non-EPS producing LAB (YNEPS), yogurt produced with EPS-producing LAB (YEPS), yogurt produced with EPS-producing LAB and Starch(YEPS+S), yogurt produced with EPS-producing LAB and camel milk powder (YEPS+CMP) and yogurt produced with EPS-producing LAB, starch and camel milk powder(YEPS+S+CMP. Vertical bars indicate standard errors (SE) of least square means (n = 3). Firmness (a), Elasticity (b), Cohesiveness (c) and Adhesiveness (d)

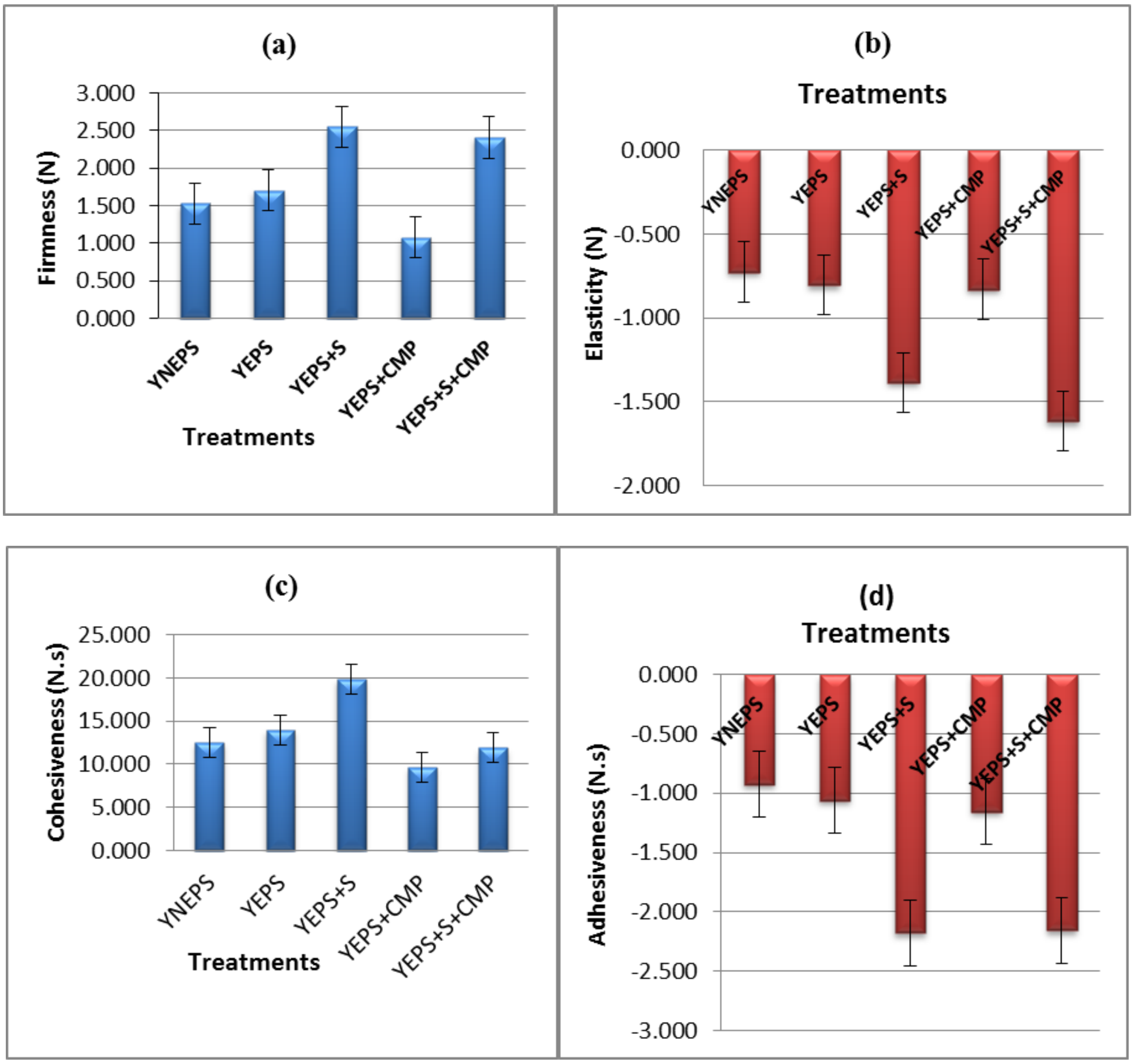


Figure 6. Texture properties of cow milk yogurt

Yogurt produced with non-EPS producing LAB (YNEPS), yogurt produced with EPS-producing LAB (YEPS), yogurt produced with EPS-producing LAB and Starch (YEPS+S), yogurt produced with EPS-producing LAB and camel milk powder (YEPS+CMP) and yogurt produced with EPS-producing LAB, starch and camel milk powder (YEPS+S+CMP. Vertical bars indicate standard errors (SE) of least square means (n = 3). Firmness (a), Elasticity (b), Cohesiveness (c) and Adhesiveness (d)

Acceptability of Camel and Cow Milk Yogurt

There was no significant difference (P>0.05) in the average mean scores of all treatments in camel milk yogurt (Table 3). Most of the panellists described that some of the camel milk yogurt taste was slightly salty. However, cow milk yoghurt produced with non-EPS producing LAB (YNEPS) was rated the most preferred in color and was significantly different (P<0.05); On the other hand, the color of T4 yoghurt (YEPS+CMP) from cow milk yogurt was rated less preferred and significantly different ($P<0.05$) from the other all cow yogurt samples. This was most probably because of an addition of CMP to cow milk. The color of T1 (YNEPS) of cow milk yogurt was accepted due to the absence of any addition. However, there was no significantly different (P>0.05) in the average mean scores of aroma, texture and overall acceptability (Table 3).

Table 3. Sensory properties of camel and cow milk yogurt

Treatments	Sensory Parameters (Mean±SE)				
	Colour	Taste	Aroma	Texture	Overall Acceptability
Camel milk yogurt					
T1(YNEPS)	6.33±0.20	5.33±0.20	6.00±0.17	5.10±0.10	5.23±0.53
T2 (YEPS)	6.10±0.20	5.23±0.29	5.66±0.52	5.33±0.37	5.53±0.23
T3 (YEPS+S)	6.43±0.29	5.80±0.10	5.86±0.29	5.66±0.20	5.93±0.34
T4 (YEPS+CMP)	6.66±0.20	5.56±0.29	6.10±0.72	5.56±0.29	6.00±0.17
T5 (YEPS+S+CMP)	6.66±0.20	5.66±0.20	6.10±0.20	5.70±0.00	6.00±0.17
Cow milk yogurt					
T1(YNEPS)	6.55±0.11^{a}	5.89±0.22^{ab}	5.89±0.48	6.00±0.19	5.88±0.29
T2 (YEPS)	6.44±0.29^{ab}	6.00±0.19^{ab}	5.89±0.22	6.11±0.11	6.11±0.22
T3 (YEPS+S)	6.44±0.11^{ab}	6.66±0.19^{a}	6.11±0.11	6.00±0.57	6.44±0.22
T4 (YEPS+CMP)	5.77±0.39^{b}	5.67±0.57^{b}	5.55±0.22	5.89±0.61	5.55±0.58
T5 (YEPS+S+CMP)	6.22±0.11^{ab}	6.00±0.19^{ab}	6.11±0.11	6.00±0.19	6.00±0.19

^{a,b,c}: Means with different superscript in the same column are significantly different at p<0.05. Each value was the mean of three replications (n=3)

DISCUSSION

Physicochemical Properties of Milk and Yogurt

The results observed for milk physicochemical properties in the current study are found within the range reported by Al-Zoreky and Al-Otaibi (2015); and Mortada and Omar (2013). The average mean value of fat, protein and lactose of the current findings were also found in the range reported by Knoess *et al*. (1986). The presence of exopolysaccharides which was produced by LAB did not bring any change on physicochemical composition. However, it contributed a lot to the specific rheology and texture of the yogurt samples.

Yogurt Rheological Properties

In the present study, yogurt produced from camel milk with EPS producing LAB and starch had a very good viscosity and less amount of whey separation. The result agrees with the findings of Early (1998) who reported that the viscosity of yoghurt is usually enhanced by the addition of stabilizers and thickeners such as modified or natural starches, alginates, carrageenan, edible gums, pectin and celluloses. Corn starch was also reported to be better in reducing syneresis and increasing viscosity compared with the other stabilizers used in the experiments (Athar *et al*., 2000). Moreover, Vedamuthu (1991) and Hess *et al.* (1997) found that ropy strain of *L. delbrueckii ssp. bulgaricus* and *S. thermophilus* used to produce smooth and viscous yogurt. These bacteria, often called slime-producing bacteria, produce exopolysaccharides, which helps to increase the viscosity.

Bouzar *et al*. (1996) and Folkenberg *et al. (*2006) also reported that some EPS-producing LAB showed a higher viscosity and a lower degree of syneresis compared with non-EPS-producing LAB. Using ropy-exopolysaccharide (ropy-EPS) producing starter cultures, syneresis could be overcome since non-EPS starter cultures had the highest level of syneresis (Amatayakul *et al*., 2006). Therefore, the level of syneresis of T3 (yoghurt with EPS and starch) was significantly (*P<0.05*) lower than that of the other yoghurt samples.

According to the report of Sodini *et al* (2004), as cow milk powder increases the protein content of yogurts, the viscosity, gel strength, and whey retaining ability of the yogurt made from cow milk also increase. However, addition of camel milk powder to both cow and camel milk did not contribute for reducing syneresis and increasing viscosity and also did not improve the texture in general (Figures 3 and 4). In contrast, viscosity and syneresis were positively affected by the addition of starch; this might have arisen from the high-water binding capacity of starch both in camel and cow milk (Figures 3 and 4).

The addition of CMP weakens the gel matrix and weak gel that could lead to spontaneous whey separation, having poor texture. Improved yogurt viscosity is observed when the total solids content of milk is increased (Guirguis *et al*., 1984; Becker and Puhan, 1989; Wacher-Rodarte *et al*., 1993). However, T4 yogurt (YEPS+CMP) of the current result observed did not agree with the above findings since the addition of CMP to both camel and cow milk yogurt did not reduce the syneresis of the yogurt and also did not increase the viscosity of the final product. This report clearly shows the difficulty of producing yogurts with acceptable rheological properties with the addition of CMP. Nevertheless, the report of Mortada and Omer (2013) indicated that camel milk yoghurt treated with 5 and 7% skim milk powder improved the viscosity value ($P \leq 0.01$) during storage period. The report of Todoric and Bajic (1979) also demonstrated that addition of skim milk powder to yoghurt improved viscosity and prevented whey separation. According to Tamime and Robinson (1985), viscosity of the product is directly proportional to the level of protein present. Added CMP, which comprised of extra protein, however, could not improve the viscosity of the current yogurts. This means that the current finding did not agree with the report of Tamime and Robinson (1985). The possible reason for poor interaction between proteins needs to be investigated.

The highest firmness values observed in T3 (YEPS+S) were due to the combined effects of high solid content of starch and the presence of exopolysaccharides (EPS). This result agrees with the finding of Kessler (1981) who reported the importance of starch for the yogurt firmness. Ropiness and the protein matrix that are more responsible for hardness (Tunick, 2000). Other researchers (De Vuyst and Degeest, 1999; Hassan *et al*., 2002) also reported that EPS could improve the texture of bovine yogurt, because exopolysaccharide produced by LAB interacts with the free water in the gel-like structure. Thus, the yogurts made from EPS producing starters showed better textural characteristics.

The added starch with the presence of EPS entered in to the protein matrix and strengthens the internal bonds thereby improved the cohesive properties of the product. This might be due to the protein matrix in yogurt are more responsible for cohesiveness (Tunick, 2000). Rawson and Marschall (1997) also revealed that adhesiveness and cohesiveness could be linked to EPS produced by specific strains of yoghurt *Streptococcus thermophilus* and *Lactobacillus bulgaricus*.

In general, firmness, cohesiveness, elasticity and adhesiveness of the yogurt texture were positively affected in T3 (YEPS+S) yogurt samples made from both cow and camel milk. The T3 samples were more gel stable due to the mixture with tapioca starch. According to the report of Sandoval-Castilla *et al*. (2004) the solubilized molecules of modified tapioca starch might be integrated to the casein micelle network and be responsible for structure openness. Yogurt produced with EPS-producing LAB (YEPS) also had a positive contribution for textural properties as compared with non-EPS producing LAB. Therefore, desirable texture properties of yoghurts with low syneresis, especially camel milk yogurt, were achieved using EPS producing LAB together with Starch. However, yogurt produced with CMP, showed no positive effect on viscosity, syneresis and textural properties. For camel milk yogurt, this might be attributed to the highest antimicrobial factors present in camel milk that may cause the difficulty of producing fermented camel milk products with good consistency (El-Agamy *et al*., 1992). This might be related to the added camel milk powder comprised of extra antimicrobial factors. The second reason for both camel and cow milk yogurt could be due to the larger casein micelle present in camel milk and camel milk powder. Eksterend *et al*. (1980) found out that the content of k-casein decreases with increasing casein micelle size.

There was no significant difference in the average mean scores of acceptability of all treatments in camel milk yogurt and the majority of the panellists described that some of the camel milk yogurt taste was slightly salty. This was in line with the report of El-Agamy (1994) and Indra and Erdenebaatar (1994) who reported that the taste of camel milk is salty due to camels' feeding system.

CONCLUSION

We found that the use of exopolysaccharides producing LAB for developing yogurt from camel or cow milk can improve sensory and textural qualities of the products. The viscosity of yogurt was increased and similarly the level of whey separation (syneresis) was decreased in product made with EPS producing LAB. Yogurt produced with EPS producing LAB and starch had a better texture compared to that of yogurt produced with CMP. Viscosity and syneresis was significantly improved by the addition of tapioca starch which may arise from high water binding capacity of starch. Generally, tested EPS producing LAB and addition of tapioca starch positively affect textural properties (such as firmness, elasticity, cohesiveness and adhesiveness), of both camel and cow milk yogurt. However, addition of CMP to both camel and cow milk could not improve the texture and viscosity of both camel and cow milk yogurt.

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