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Optimization of the stabilizers and cow milk levels for the production of camel milk-based yogurt using response surface methodology

[1,2,*]Hamad, E.M. and [1]Musa, K.H.

[1]*Department of Food Science and Human Nutrition, College of Agriculture and Veterinary Medicine, Qassim University, 51452 Buraidah, Saudi Arabia*
[2]*Department of Dairy Science, Faculty of Agriculture, Cairo University, Egypt*

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Abstract

The production of yoghurt from camel milk (CML) is limited due to weak gel formation. As a trial to produce CML-set-type yoghurt, sixteen treatments were prepared from CML, cow milk, and stabilizers (gelatin and gum-Arabic; 1:1) using a D-optimal design. A desirable hardness of set-type yoghurt was obtained from CML (56%), cow milk (42%), and stabilizers (2%). Another study was designed to choose the best combination of stabilizers (1, 1.5 or 2% of gelatin in combination with 1% of gum-Arabic). The increased levels of gelatin resulted in a significant increase ($p < 0.05$) in the viscosity and consistency index of yoghurt milk, an increase ($p < 0.05$) in yoghurt hardness and viscosity, and a reduction in syneresis ($p < 0.05$). In conclusion, an acceptable set-type yoghurt can be produced by using a combination of CML and cow milk (1.3:1) and a stabilizers' mixture of gelatin (1 or 1.5%) and gum-Arabic (1%).

1. Introduction

Camel milk (CML) has been a well-known nourished food among inhabitants of the deserts of different countries (like Saudi Arabia and Egypt) for centuries. Due to its health benefits, it was in folk systems as a remedy or medicine (Abdel-Salam *et al.,* 2015). There are several reports about the beneficial characteristics of CML, such as its positive effects against diabetes, gastrointestinal disorders, food allergy, hepatitis C (Al-Haj and Kanhal, 2010; Kaskous, 2016; Mihic *et al.,* 2016) and its improvement of liver and kidney functions (Hamad *et al.,* 2011). Compared to ruminant milk, CML contains a higher quantity of vitamins C and B vitamins, unsaturated fatty acids, and minerals (Al-Shamsi *et al.,* 2018). In addition, CML has a higher number of protective proteins such as immunoglobulins, lactoferrin, and lysozyme and low levels of lactose and cholesterol (El-Agamy, 2009; Mudgil, Kamal, Yuen *et al.,* 2018). However, despite the health benefits of CML, the commercial availability of CML products is very few (Mudgil, Kamal, Yuen *et al.,* 2018).

Because of the high temperature of the dessert, CML was usually consumed as fermented milk (Farah and Fischer, 2004). Yoghurt is a famous fermented dairy product made by the action of lactic acid bacteria, and it showed an increased commercial demand due to its consumer acceptability and its beneficial effects (Tamime and Robinson, 2007). One of its standard commercial types is the set-type yoghurt (Kavas and Kavas, 2016). Due to the difficulty of coagulation of CML, the production of set-type yoghurt from CML is difficult (Galeboe *et al.,* 2018). Therefore, the characteristics of CML yoghurt cannot be compared with those of cow milk yoghurt. The consistency of fermented CML is poor. The fermentation of CML by starter bacteria takes a long time (around 18 hrs), and the final result is a flocculant precipitate rather than a coagulum or curd (Farah, 1996). These difficulties of fermenting CML are due to the presence of antimicrobial proteins (lactoferrin, lysozyme, and immunoglobulins) that prevent the growth of lactic acid bacterial culture (Elagamy, 2000), the presence of a meagre amount of β-casein and β-lactoglobulin fractions (Laleye *et al.,* 2008), and very low amount of κ-casein in CML (Shabo *et al.,* 2005). Some investigators tried enzymatic coagulation of CML. They found that CML has a very significantly higher coagulation time (Sagar *et al.,* 2016) with only flocs at the end rather than a firm coagulum (Mehaia,

*Corresponding author.
Email: *e.hamad@qu.edu.sa*

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1988; Mohammed and Larson-Raznikiewiz, 1989). The examination of the coagulum's characteristics revealed no curd formation in CML after fermentation (Mudgil, Jumah, Ahmad *et al.,* 2018).

Several solutions have been suggested to address the challenges of producing set-type yoghurt from CML. One suggestion was to incorporate stabilizers and hydrocolloids in CML to develop an enhanced protein network of the final fermented milk. Hashim *et al.* (2009) produced CML yoghurt with good sensory attributes and acceptability when incorporated with 0.75% alginate and 0.075% calcium. Mudgil, Jumah, Ahmad *et al.* (2018) found that the addition of 1.25% gelatin (GL) resulted in CML yoghurt with microstructure features similar to that of the bovine milk yoghurt. Galeboe *et al.* (2018) suggested adding 1.2% of GL and 5% of bovine skim milk powder to produce yoghurt from CML with acceptable organoleptic and texture characteristics. Kavas and Kavas (2016) produced CML yoghurt with acceptable properties by adding 9% of rice flour, skim milk powder or their mixture (1:1).

On the other hand, Al-Zoreky *et al*. (2015) found no significant improvement in the consistency of CML yoghurt by using stabilizers. In another trial, exopolysaccharides producing culture was used to produce fermented CML with acceptable characteristics (Ibrahim, 2015). Other investigators effectively produce set-type yoghurt from CML by incorporation of 0.4% of microbial transglutaminase (Abou-Soliman *et al.,* 2017). All of the previous trials and reports indicated the need for more efforts to improve the quality of set-type CML yoghurt effectively.

It is obvious from all of the previous suggestions that using stabilizers and hydrocolloids and supplementation of CML with other milk types can help improve the texture and quality of CML yoghurt. Therefore, the present study was designed to optimize the processing of set-type yoghurt by using GL, gum Arabic (GA), and supplementation of bovine milk with the help of statistical tools for design. Response surface methodology (RSM) is a quite effective tool for optimizing the process parameters and ingredient levels in products. RSM's regression equations (D-optimal design) will help create an acceptable final product (Gupta and Premavalli, 2012). The study characterized the physicochemical and flow properties of the yoghurt formulated with camel milk, cow milk, and stabilizers (GL and GA).

2. Materials and methods

2.1 Materials

Camel milk was collected from Qassim University dairy farm, cow milk was purchased from El Marai Company, and yoghurt DVS culture (YC-X11) consists of *Lactobacillus bulgaricus* and *Streptococcus thermophilus* was obtained from Chr. Hansen's (Denmark). Gum Arabic (GA) and Gelatin (GL) were purchased from the local market.

2.2 Preparation of yoghurt

Yoghurt was prepared as described by Tamime and Robinson (2007) in the food processing pilot plant of the Food Science and Human Nutrition Department, Qassim University, Saudi Arabia. GA and GL were dissolved with continuous agitation in yoghurt milk before heat treatment. The mixture was heated in a water bath at 85°C for 5 mins, cooled to approximately 43°C, and then inoculated with a starter culture (3% v:v); transferred to sterile glass containers (200 ml capacity); incubated at 43°C until the milk was either completely coagulated or when pH-value reached 4.6. Samples from different treatments were stored at 4°C before analysis.

2.3 Yoghurt treatments

2.3.1 Treatments prepared for optimization study

In order to optimize the processing of set-type yoghurt from CML by using GL, GA, and supplementation of bovine milk, the response surface methodology (RSM) using a D-optimal mixture design was chosen as a statistical design tool. The hardness of yoghurt was chosen as the response. Sixteen runs were performed to cover as many as possible combinations of the factor levels (Table 1). Experimental data were fitted with statistical models to produce the response surface. The RSM was employed to analyze the effects of three factors on one response and to identify the combination that will optimize the yoghurt hardness. The pH value of 4.6 was chosen to be the endpoint of incubation due to the inability of some treatments to show a complete coagulum.

2.3.2 Treatments prepared for gelatin percentage study

A previous report showed a minimum increase in the hardness of gels obtained from a combination of GL and more than 1% of GA (Binsi *et al.,* 2017). Therefore, this study was designed to confirm the first study's findings and choose the best percentage of GL to be used combined with 1% of GA. Therefore, the following yoghurt treatments were prepared.

CML: Yoghurt was prepared from camel milk

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Table 1. Independent variables along with the observed values for the response variable (hardness) of yoghurt under different combinations of camel milk yoghurt based on the D-optimal mixture design.

Treatments	X_1	X_2	X_3^*	Hardness (g)	pH Value	
					Before Incubation	After Incubation
1	50	49.5	0.5	37	6.75	4.42
2	60	40	0	24	6.75	4.51
3	53	45	2	275	6.44	4.6
4	40	58	2	334	6.43	4.4
5	52	48	0	35	6.74	4.4
6	59	40	1	44	6.54	4.49
7	53	45	2	291	6.4	4.43
8	45	55	0	48	6.75	4.35
9	42	56	2	295	6.42	4.47
10	56	44	0	28	6.7	4.46
11	50	49.5	0.5	36	6.63	4.45
12	46	52	2	299	6.48	4.35
13	40	60	0	64	6.77	4.47
14	60	40	0	28	6.71	4.47
15	59	40	1	57	6.53	4.49
16	40	60	0	45	6.76	4.41

X_1: camel milk (%), X_2: cow milk (%), X_3: stabilizer (%)

*Stabilizer is consisting of GA and GL (1:1)

(100%) and used as a control.

COW: Yoghurt was prepared from bovine milk (100%) and used as a control.

T1: Yoghurt was prepared from a mixture of CML and bovine milk (1.3:1, respectively) with the addition of GA (1%) and GL (1%).

T2: Yoghurt was prepared from a mixture of CML and bovine milk (1.3:1, respectively) with the addition of GA (1%) and GL (1.5%).

T3: Yoghurt was prepared from a mixture of CML and bovine milk CML and bovine milk (1.3:1, respectively) with the addition of GA (1%) and GL (2%).

2.4 Chemical composition and pH-value

Fat, protein, lactose, and total solids were determined in yoghurt milk using the pre-calibrated Lactostar milk analyzer (Funke-Gerber, Berlin, Germany). The pH measurements were carried out using a Laboratory pH meter (Type 3305, Jenway Co, England).

2.5 Color parameters measurement

The color of yoghurt samples was measured using a colorimeter (Model Hunter Lab Color Flex) as described by Francis (1983). The L, a, and b values were recorded, with L denoting lightness on a 0–100 scale from black to white; a, red (+) or green (-); and b, yellow (+) or blue (-).

2.6 Physical and rheological properties

2.6.1 Hardness

The hardness of the yoghurt samples was determined using a texture analyzer (Brook-field texture analyzer-CT III, USA) attached to a 5 kg load cell as previously described (Mudgil, Jumah, Ahmad *et al.,* 2018).

2.6.2 Apparent viscosity of yoghurt

Measurements of the apparent viscosity of yoghurt samples were carried out according to Denin-Djurdjević *et al.* (2002). Brookfield Programmable viscometer (Model RVDV-III Ultra; Brookfield Engineering Laboratories, Stoughton, MA, USA) and Rheocalc software (ver. 2.5, Brookfield Engineering Laboratories, Inc.) were used for viscosity measurements. All yoghurt samples were tempered for 5 mins at 20±1°C. The RV spindle number 3 at 250 rpm was used.

2.6.3 Syneresis

Syneresis of yoghurt was determined by centrifugation, as Keogh and O'Kenned (1998) described. Duplicate measures were taken for each sample.

2.6.4 Flow behavior and viscosity of yoghurt milk

The Brookfield Programmable viscometer (Model RVDV-III Ultra; Brookfield Engineering Laboratories, Stoughton, MA, USA) and Rheocalc software (ver. 2.5, Brookfield Engineering Laboratories, Inc.) were used for flow behavior and viscosity measurements of yoghurt milk samples. UL-adaptor at ambient temperature (25°C) was used. The flow behavior was determined according to the method of Behnia *et al.* (2013). The consistency index (K) and the flow behavior index (n) were calculated.

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2.7 Statistical analysis

The experimental design and statistical analysis were performed using response surface methodology (RSM) with Design Expert Version 6.0.10 (Stat-Ease Inc. MN, USA) software and SPSS statistical package (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp, USA). Results are expressed as means with standard deviation (SD) of three measurements. The significance of differences among mean values was evaluated by analysis of variance (ANOVA). Differences were considered significant at $p < 0.05$.

3. Results and discussion

3.1 Optimization study

In this study, the RSM was used to examine the functional relationship between the ratio of camel milk, cow milk, and stabilizer (1:1 mixture of GA and GL), as investigated variables, and hardness as the response. The range of CML milk and cow milk was between 40 and 60%, and the stabilizer was used in the range from 0 to 2%. To find the interactions between these three parameters (CML milk, cow milk and stabilizer) on the hardness of yoghurt, a statistical analysis was applied.

The combination of GL and GA in this study was used due to the suggestions from previous studies that the addition of hydrocolloids (such as GA) with gelatin could help in producing more stable gels with improved texture (Pranoto *et al.,* 2007; Yang *et al.,* 2012; Binsi *et al.,* 2017).

Experimental data were obtained according to the design of the RSM presented in Table 1. The hardness value was selected as the response in the D-optimal mixture design for blend optimization of yoghurt as it considered as a key factor that decides the acceptability of set style yoghurt. The changes in hardness response for the yoghurt component are shown in Table 1. The pH values were also reported for all treatments, and as anticipated, the pH values were lower after incubation. The decrease in pH is due to the production of acid by the lactic acid bacteria. Moreover, it can be noticed that the increasing of cow milk percentage resulted in higher hardness values (Table 1) and improved visual appearance of the resulting coagulum (Figure 1). An acceptable hardness as well as visual appearance of coagulum were obtained by the addition of 53%, 45%, 2% of CML, cow milk and stabilizers, respectively (Table 1 and Figure 1).

The responses for the D-optimal mixture designs were modelled to fit a second-order polynomial equation. Other investigators have also reported RSM in the optimization of product ingredients and process variables (Yaakob *et al.,* 2012). The responses of these models can be plotted as a function of the three components (cow milk, camel milk and stabilizers) in the mixture keeping the total as 100. The variation in hardness with varying contents in the mixture has been depicted in Figure (2 A, C, B and D). The response surface equation for the fitting of hardness data based on the quadratic models is:

$$\text{Hardness} = 16.99X_1 + 48.62\,X_2 + 40401.3\,X_3 + 84.48\,X_1X_2 - 41751.36\,X_1X_3 - 42665.06\,X_2X_3$$

Where X_1 is camel milk (%), X_2 is cow milk (%), and X_3 is stabilizer (%).

The measured fit of the model data (R^2) for the response was high, and according to the variance analysis, the model was significant ($P < 0.001$). The R^2 value for hardness was 0.9522, and the lack-of-fit test was not significant ($P > 0.05$), which also showed a good fit between the experimental data and the model. In addition, the predicted R^2 is in reasonable agreement with the adjusted R^2 (0.8432 and 0.9282, respectively).

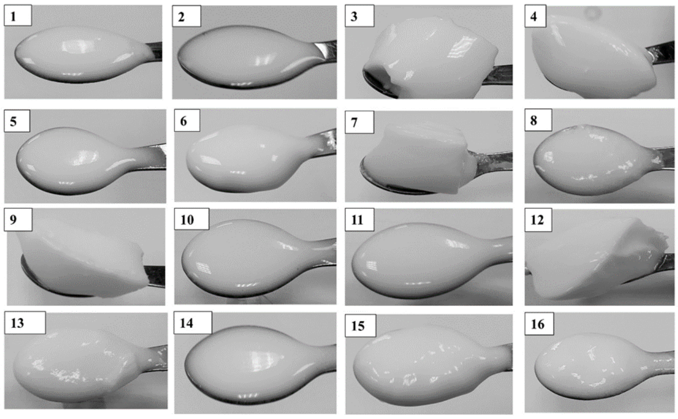

Figure 1. Visual appearance of camel milk yoghurt treatments. Refer to Table 1 for treatment description.

Furthermore, the statistical analysis showed that the proposed model was acceptable, having no significant lack of fit and high R^2 values for the response. In addition, the fitted equations had high R^2 values. This indicates their good prediction accuracy for the hardness of yoghurt containing varying levels of camel milk and cow milk. The desired maximization of such fitted polynomials was performed by numerical procedures using the mathematical optimization method of the design expert software package. The defined criterion for the optimization was set to maximize of hardness as it is the most crucial parameter in yoghurt development studies. The software proposed the solutions for maximization of the hardness of yogurt by describing the interactive effects of process parameters and their subsequent effects on response.

Based on the solution suggested by the D-optimal analysis, the combination of camel milk (56%), cow milk (42%), and stabilizer (2%) is expected to give a hardness

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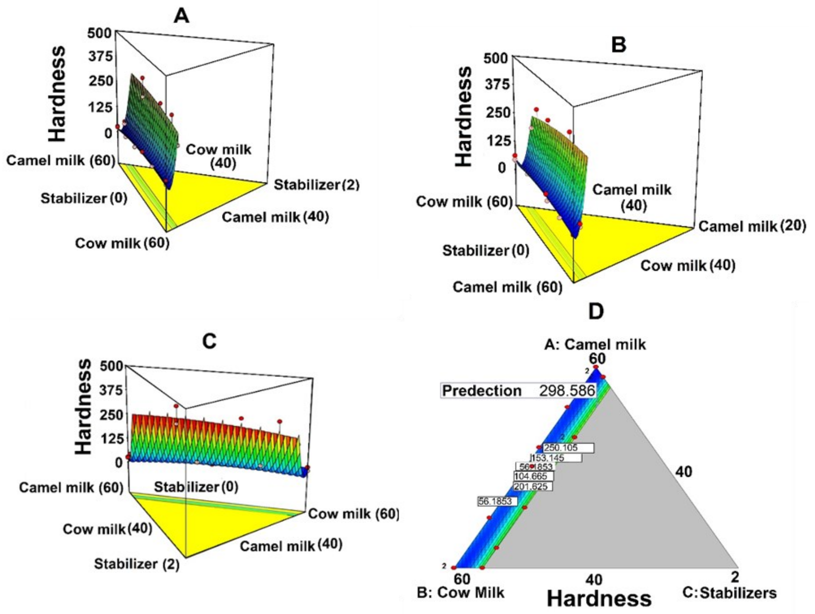

Figure 2. Response surface plots. A, B and C: The effects of the operating interaction parameters on the mixture components (cow milk, camel milk and stabilizers, respectively) against hardness. D: The prediction points for the hardness of yoghurt made based on camel milk.

predicted value of 298.59 (Figure 2D). The yoghurt was then prepared using the optimized ingredient composition. The predicted hardness parameter responses and the actual obtained hardness values were similar ($p > 0.05$); hence the fitted models are suitable for predicting the responses.

It is worth noting that the improved gel network of the resultant yoghurt from CML and cow milk combination (1.3:1) in the presence of GL (1%) and GA (1%) may be partially due to more interaction between GA (anionic hydrocolloid) and positive charges of GL. Similar findings were observed by Binsi *et al.* (2017).

3.2 Gelatin percentage study

As mentioned previously, the combination of GL with other hydrocolloids could result in higher thermal stability of the obtained gels (Somboon *et al.,* 2014). The higher thermal stability of resultant GL gels increases the ability of GL to be used in several food applications. This could be due to the formation of polymer complexes between GL and GA throughout electrostatic attractions as they are charged polymers (Sworn, 2000; Yang *et al.,* 2012).

On the other hand, it was found that the improved hardness of GL gels by the addition of GA did not increase with high concentrations of GA. The best improvement in GL gel characteristics was found with 1% GA, and there was a minimum improvement with the increase in GA concentration (Binsi *et al.,* 2017). Therefore, the present study was designed to choose the best concentration of GL (1, 1.5, 2%) combined with a constant concentration of GA (1%) as stabilizers to optimize set-style camel milk yoghurt.

3.2.1 Physical and rheological properties

Table 2 shows the physical and rheological properties of yoghurt milk treatments. As it can be noticed, the pH values of all treatments were similar between treatments and controls. In addition, the viscosity of both camel and cow milk was relatively similar ($p > 0.05$). However, the viscosity of yoghurt milk increased proportionally with the increase of GL addition ($p < 0.05$).

3.2.2 Flow behavior and viscosity of yoghurt milk

The addition of GL with different percentages

Table 2. Physical and rheological properties of yoghurt milk treatments

Treatments	pH-value		Viscosity (mPa.s)	Consistency Index (K)	Flow behavior (n)	Confidence (%)
	Before incubation	After incubation				
COW	6.65±0.18^{a}	4.54±0.17^{b}	2.02±0.08^{c}	2.6±0.03^{b}	0.92±0.01^{b}	98.93±0.04^{a}
CML	6.57±0.16^{a}	4.65±0.14^{ab}	1.22±0.04^{c}	1.80±0.70^{b}	0.94±0.01^{b}	98.30±0.17^{a}
T1	6.61±0.18^{a}	4.6 3± 0.12^{ab}	5.01±0.49^{c}	4.55±2.86^{b}	0.93±0.02^{b}	99.37±0.61^{a}
T2	6.63±0.11^{a}	4.73±0.13^{b}	16.26±3.35^{b}	21.23±14.70^{ab}	0.81±0.11^{b}	98.73±1.53^{a}
T3	6.57±0.13^{a}	4.72±0.15^{b}	49.83±4.20^{a}	72.73±40.33^{a}	0.67±0.06^{b}	99.10±0.10^{a}

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different ($P<0.05$).

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affected the flow behavior of yoghurt milk (Table 2). The flow behavior index (n) for all treatment and control samples is less than 1 (ranged from 0.67 to 0.94), which indicates that both cow and camel milk samples have a non-Newtonian flow behavior (pseudoplastic fluids). These results are in line with Paradkar *et al.* (2001), who also found cow milk has a non-Newtonian flow behavior index (n = 0.87). It seems that the addition of GL increases the non-newtonian flow behavior as the value of (n) decreases proportionally with the addition of GL. In addition, the consistency index (K) for cow and camel milk controls was 2.6±0.03 and 1.80±0.70, respectively ($p > 0.05$). This might explain the lower values of viscosity of camel milk than those of cow milk. Moreover, the addition of GL resulted in a steady increase of (K) values. This was correlated with the higher viscosity of treatments.

Flow behavior results showed that the addition of GL resulted in higher viscosity and more non-Newtonian behavior (Table 2). This might be explained by the ability of GL to bond with water in addition to some possible variations in protein-protein interactions in three -dimensional protein networks of milk samples. These results were correlated with the visual appearance (Figure 3) and hardness of yoghurt treatments (Table 3).

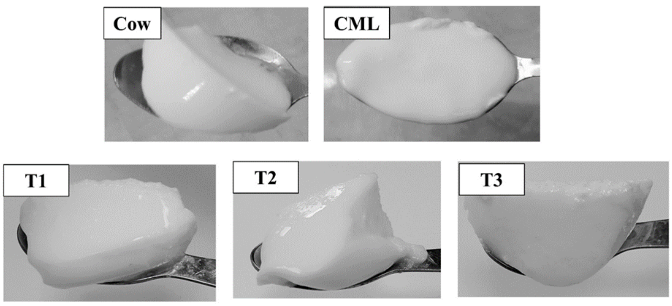

Table 3. Visual appearance and hardness (g) of yogurt treatments.

3.2.3 Physical and rheological properties of yoghurt treatments

3.2.3.1 Hardness and apparent viscosity of yoghurt treatments

The physical and rheological properties of yoghurt treatments are presented in Table 3. It is obvious that the hardness of yoghurt made from cow milk is about ten times higher than that of yoghurt made from camel milk (238±6 vs 20±2 g for cow and camel milk yoghurt, respectively). The same trend was also repeated in the results of apparent viscosity (264±6 vs 2±0.7 mPa.s for cow and camel milk yoghurt, respectively). This is because camel milk is challenging to be coagulated and form a gel (Galeboe *et al.,* 2018). Several investigators discussed reasons for the difficulty of camel milk coagulation such as the presence of antimicrobial proteins and a meager amount of β-casein, β-lactoglobulin fractions, and κ-casein in camel milk (Elagamy, 2000; Shabo *et al.,* 2005; Laleye *et al.,* 2008).

On the other hand, the addition of GL from 1 to 2% resulted in a gradual increase in both hardness (226±8 to 657±41 g) and viscosity (322±40 to 1972±66 mPa.s) of the resultant yoghurt (Table 3). Compared with control (cow), treatments T1 and T2 showed an acceptable gel formation, while the gel of T3 was harder than normal (Figure 3). These results are in agreement with other investigators who found that the firmness of the CML yoghurt increased significantly with increasing the levels of GL (Hashim *et al.,* 2009). In addition, other studies found that the addition of 1.2% of GL resulted in CML yoghurt with microstructure features similar to that of the bovine milk yoghurt (Galeboe *et al.,* 2018; Mudgil, Jumah, Ahmad *et al.,* 2018).

3.2.3.2 Syneresis

On the other hand, syneresis of yoghurt was affected by the type of milk and the addition of GL (Table 3). Syneresis of camel milk yoghurt (44.1±4.0%) was higher than cow milk yoghurt (63.8±2.8%). As can be seen, the addition of GL resulted in lower syneresis of yoghurt treatment. The addition of 2% GL showed no syneresis at all (0.0%). This is due to GL – as a hydrocolloid – developing and enhancing the protein network of the final fermented milk by improving water holding capacity. As noted, syneresis of treatments T1 and T2 is comparable with control (cow) and may be accepted by consumers better than T3.

The reduction in syneresis in the present study may

Table 3. Physical and rheological properties of yoghurt treatments.

Treatments	Yoghurt Hardness (g)	Yoghurt Viscosity (mPa.s)	Syneresis (%)	Color Measurement		
				L-Value	a-Value	b-Value
COW	238 ± 6^{c}	264 ± 6^{d}	44.1 ± 4.0^{b}	4.76 ± 0.03^{a}	87.72 ± 0.42^{a}	-2.61 ± 0.04^{b}
CML	20 ± 2^{d}	2 ± 0.7^{c}	63.8 ± 2.8^{c}	1.19 ± 0.28^{c}	76.90 ± 0.29^{d}	-1.53 ± 0.29^{a}
T1	226 ± 8^{c}	322 ± 40^{c}	33.8 ± 2.6^{b}	1.79 ± 0.42^{bc}	80.48 ± 0.40^{c}	-2.14 ± 0.25^{ab}
T2	451 ± 27^{b}	858 ± 32^{b}	6.1 ± 1.8^{c}	2.79 ± 1.26^{ab}	83.67 ± 1.28^{b}	-2.54 ± 0.39^{b}
T3	657 ± 41^{a}	1972 ± 66^{a}	ND	3.63 ± 1.40^{a}	84.47 ± 1.40^{b}	-2.52 ± 0.10^{b}

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different ($P<0.05$). ND: Not detected.

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be due to the stabilization of the formed gel due to more junction zones between GL and GA in the gel network (Binsi *et al.,* 2017). Similar observations in dairy foods were reported by Hansen (1993) due to the interaction between negative (such as GA) and positive (such as GL) charges of stabilizers on the surface of casein micelles that help bind water molecules in the intermediate spaces, which resulted in a reduction of syneresis. These findings are in agreement with other studies that found an improvement in the characteristics of the resultant CML yoghurt by the addition of stabilizers (Hashim *et al.,* 2009; Al-Zoreky *et al.,* 2015; Galeboe *et al.,* 2018; Mudgil, Jumah, Ahmad *et al.,* 2018).

3.2.3.3 Color parameters measurement

Hunter-color values are presented in Table 3. Cow milk is whiter than camel milk, as the L-value was higher by three folds. In addition, cow milk showed a higher a-value (redness). On the contrary, camel milk showed a higher b-value than cow milk, implying more blueness of camel milk than cow milk. All of these differences in colour values were significantly different ($p < 0.05$). It can be noticed that the addition of GL increased L- and a- values and decreased b-values of yoghurt treatments. The addition of 2% of GL (T3) resulted in an elevation in L- and a- values and a reduction in b-value that appeared similar to cow milk yoghurt ($P > 0.05$). These results align with Choobkar *et al.* (2018), who found that the industrial GL showed the highest L-value and the lowest b-value.

4. Conclusion

Yoghurt containing varying proportions of camel milk, cow milk, and stabilizer (gelatin and gum Arabic) has been formulated with the help of a D-optimal mixture design. The hardness of the resultant yoghurt decreased with increasing the levels of camel milk. The D-optimal analysis suggested a combination of camel milk (56%), cow milk (42%), and stabilizer (2%, gelatin: gum Arabic; 1:1) that might develop an acceptable set-type yoghurt based on camel milk. On the other hand, the effective combination of gelatin and gum Arabic hydrocolloids was also investigated. In sum, an acceptable set-type yoghurt based on camel milk can be produced by combining camel milk and cow milk (1.3:1, respectively) with the addition of gelatin (1 or 1.5%) and gum Arabic (1%).

Conflict of interest

The authors declare no conflict of interest.

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