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Optimization of the Processing Conditions of Stirred Yoghurt from Camel Milk using Linear Programming Technique

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ABSTRACT:
This study focuses on the optimization of the processing conditions of stirred yoghurt made from camel milk to get a yoghurt of acceptable quality. The average pH value of whole camel milk employed in this study is determined to be 6.65, titratable acidity 0.17, and specific gravity 1.029. The chemical composition of whole camel milk on the other hand showed that, the average value of total solid is 10.55%, fat 3.6%, protein 2.49%, ash 0.79% and lactose 3.64%. Stirred yoghurt from camel milk was prepared using conventional yoghurt manufacturing methodology. A three way full-factorial experimental design was conducted taking viscosity of yoghurt (rheological improvement), synersis of yoghurt, and maximum fat level of the yoghurt as response variables and total solid level of milk, fat content of milk and level of pectin as process parameters. Linear programming technique was employed for optimization. Accordingly, the result indicated that good quality of stirred yoghurt (viscosity of 3.06cP) could be produced operating at 12.16% of total solid content, 0.9% fat level of camel milk and using commercial stabilizer (pectin) at a ratio of 0.0015%.
Keywords: Camel milk, Stirred yoghurt, Linear Programming.

INTRODUCTION

Researchers indicated that camel milk exhibits more or less similar proximate composition with that of cow milk (Farah*,* 1996). However, the processing properties of camel's milk are quite different from that of cow milk. Camel's milk is more difficult than cow's milk for cheese making. The cheese processed from camel milk is very soft, of low yield and with lesser materials recovered (Ramet, 2001). Moreover, it is indicated that, camel's milk is also more difficult to process into fermented milk products than cow's milk. Compared to fermented cow's milk products, the consistency of fermented camel milk is thin owing to the flocculent precipitates formed rather than a firm coagulum during the progress of fermentation (Farah *et al.,* 1990). Little has been said to exactly explain about the ascribed problems related to difficulty of camel's milk for processing. Farrah and Ruegg (1991) suggested that smaller size and different size distribution of the micellar structures of caseins and the globular structures of fats might have contributed to the difficulty of camel's milk for processing.

Besides its difficulty in processing, several attempts have been done to produce yoghurt products from camel milk. Hashim et al. (2009) for example investigated the quality and acceptability of a set type yoghurt made from camel milk. They manipulated the chemical aspect of yoghurt mix (ingredient proportion) by varying the proportion of Calcium Alginate, Calcium Chloride, and four flavoring fruit concentrates of the yoghurt mixes to see the effect in the acceptability of the yoghurt. Their result indicated that, acceptable camel's milk yoghurt comparable with that of cow's milk yoghurt could be produced by using appropriate formulation and processing techniques. There are still other studies which focused on the manipulation of microbial composition of yoghurt starter cultures to produce quality yoghurt products from camel milk. Farah et al. (1990) checked the possibility of improving the quality of traditional "Susa" using different kinds of mesophilic starter cultures. The result indicated that yoghurt made from camel milk can be improved by using a selected mesophilic starter culture. There are even other studies which checked whether the pre-fermentation steps of yoghurt processing could affect the quality of the yoghurt. Hassan et al. (2007) studied the effect of pasteurization and storage temperature on the chemical composition of fermented camel milk. It was indicated that there is a significant differences in the chemical composition of the fermented came milk product (Gariss) were observed owing to the differences in pasteurization temperatures and storage periods. The objective of this study was to assess the possibility of optimizing the processing of stirred yoghurt from camel milk with respect to a set of desired quality parameters through adjustment of the levels of major processing variables.

MATERIALS AND METHODS

Sample collection and handling: Samples of camel milk were collected from Mathahara area, Ethiopia. Camel milks were transferred into sterile containers after milking and transported to Holeta dairy processing laboratory using ice boxes to maintain the temperature around 4^0C where analysis of camel milk, stirred yoghurt and processing was carried out. A starter culture for yoghurt (freeze-dried Thermophilic lactic culture) was from Chr. Hansen's Laboratories A/S (Copenhagen, Denmark).

Stirred yoghurt processing: Eight yoghurt making trials from camel milk were conducted at Holeta agricultural research center dairy processing laboratory following the conventional stirred yoghurt making process as shown in Fig. 1 below. Yoghurt samples were taken for analyses after one day.

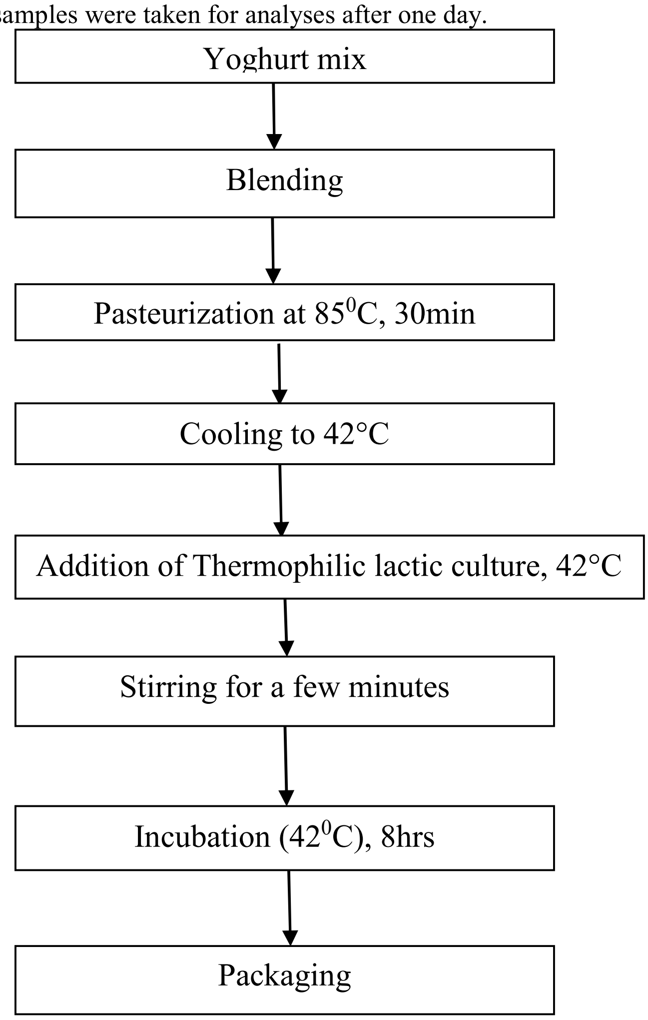

Figure 1: General flow sheet of stirred yoghurt production.

Yogurt samples were made from camel milk following the procedure described by Hashim *et al* (2009). Yogurt was made by dissolving pectin (2 levels); other ingredients were added accordingly. The mixture was heated in a water bath at 85°C for 30 min, cooled to approximately 42°C, inoculated with commercial yogurt culture at a rate of 0.2g/1L of the mix, transferred to plastic cups and incubated at 42°C for 4h, stirred and stored at 4°C overnight before testing.

Physical and Chemical Analyses: All the milk treatments and the processed stirred yoghurts were analyzed for total solid, ash, titratable acidity, pH and specific gravity according to official AOAC (2000) method. Protein was determined by aldhyde titration method and fat by Gerber method (1982). Lactose and solid non fat were determined by difference. Apparent viscosity (expressed in cP) was measured using SV10 vibroviscometer, 3 dial readings were taken at 30-s intervals and their mean value was reported. Viscosity measurements were performed at room temperature, which was maintained by a circulating water bath. Synersis was measured according to the method described by Goncalvez *et al.,* (2003) in which yoghurt sample (30g) was centrifuged at 1100 rpm for 10 minutes. The clear supernatant was poured off, weighed and recorded as synersis (%). Duplicate measures were performed for each sample.

Experimental Designs A 3-way Full Factorial experimental design, with two levels of total solid concentrations (unconcentrated milk and concentrated milk), two levels of milk fat content (whole milk and skimmed milk), and two levels of pectin amount ($0.9 g 1000 g^{-1}$ yoghurt and $1.5 g 1000 g^{-1}$) as the main effects, were used to investigate their effects on the fermentation progress physicochemical properties (viscosity and acidity), synersis as well as sensory attributes of yoghurt.

Statistical Analyses: The statistical analyses were performed using SPSS soft ware (version 15). Significant differences were defined at $P < 0.05$. Results are presented as mean values ± SD of two analyses. An ANOVA was performed to evaluate the main effects and interactions of total solid concentration, milk-fat, rennet level on yield, physico - chemical and sensory properties of soft cheese made from camel milk as well as the main effects and interactions of total solid concentration, milk-fat and pectin level on the physicochemical and sensory properties of stirred yoghurt made from camel milk. Then TORA software (2003, version1.0) was employed to

determine the optimal processing conditions of soft cheese from camel milk through linear programming methodology.
The format of a linear programming model involves an objective function:
Z=CX
Subject to a set of constraints:
AX ≤ b, Where:
Unconcentrated milk has about 10% total solid and concentrated milk has 14% total solids. Whole milk has 3.6% fat and skimmed milk has 0.3% fat
Z = the value of the objective function, maximizing the viscosity of stirred yoghurt
C = the vector of coefficients of factors determining viscosity of stirred yoghurt.
X = the vector of factors determining of stirred yoghurt.
A = the matrix of technical coefficients that relate factors to constraints, and
B = vector of constraint values that are limits on the level of constraints.

Results and Discussions

Physical properties of camel milk treatments: Evaluation of the physico – chemical properties of milk prior to processing indicated that the average pH value of the whole milk is determined to be 6.65, titratable acidity 0.17 and specific gravity to be 1.029. Omer and Eltinay (2009), Zubeir and Jabreel (2008) and Mehaia (2006) found similar results for physical properties of whole camel milk in which pH and acidity were found to be 6.57 and 0.2, 6.6 and 0.19, 6.62 and 0.15 respectively where as Inayat *et al.* (2003) found similar results for physical properties of skimmed camel milk in which pH and acidity were found to be 6.87 and 0.2. Mehia (1997) found that there was no change in the pH value of skimmed camel milk when concentrated using ultra filtration at volume concentration ratio of 1.7.

Table 1: Physical properties of camel milk

Type of camel milk	pH values	Titratable acidity%	Specific gravity
whole milk	6.65± 0.02	0.17± 0.01	1.029± 0.001
Skimmed milk	6.62± 0.01	0.19± 0.01	1.030± 0.002
Conc. Whole milk	6.60± 0.02	0.20± 0.01	1.039± 0.001
Conc. Skimmed milk	6.58± 0.03	0.20± 0.01	1.040± 0.001

Results are mean values of duplicates± standard deviation

Chemical properties of camel milk treatments: The chemical composition of milk showed that the average value of total solid is 10.55 for whole milk, 7.77 for skimmed milk, 13.89 for concentrated whole milk and 10.81 for concentrated skimmed milk. Similarly, the average values of fat are 3.6, 0.3, 4.82 and 0.4 of protein are 2.49, 2.57, 3.52 and 3.55 of ash are 0.79, 0.96, 1.17 and 1.27 and Lactose 3.64, 3.81, 5.55 and 5.58 for whole milk, skimmed milk, concentrated whole milk and concentrated skimmed milk respectively. Mehaia (2006) reported the levels of total solid, fat, protein, ash and lactose in whole camel milk to be 12, 3.6, 3.2 and 0.81 percents respectively. Zubeir and Jabreel (2008) found the levels of total solid, fat, protein, and ash in whole camel milk to be 8.5, 2.5, 4.5, and 0.20 respectively. Inayat *et al.* (2003) found similar results for chemical composition of skimmed camel milk in which the levels of total solid, fat, protein, lactose and ash to be 7.93, 0.29, 3.56, 3.14 and 0.93 respectively. Mehia (1997) concentrated skimmed camel milk using ultra filtration and hence changed the value of total solid from 8.5% to 10.5%, protein from 2.77 to 4.69 and ash from 0.83 to 0.96 percent at 1.7 volume concentration ratio.

Table 2: Chemical Composition of camel milk treatments used for yoghurt making

Type of camel milk	Total solids%	SNF%	Fat%	Protein%	Ash%	Lactose%
Whole milk	10.55± 0.26	7.15 ± 0.06	3.60 ± 0.14	2.49 ± 0.11	0.79 ± 0.08	3.64 ± 0.12
Skimmed milk	7.77 ± 0.42	7.14 ± 0.10	0.30 ± 0.10	2.57 ± 0.12	0.96 ± 0.04	3.81 ± 0.05
Conc.whole milk	13.89± 0.02	9.07 ± 0.03	4.82 ± 0.11	3.52 ± 0.12	1.17 ± 0.05	5.55 ± 0.08
Conc. skimmed milk	10.81± 0.02	10.41 ± 0.04	0.40 ± 0.10	3.55 ± 0.10	1.27 ± 0.06	5.58 ± 0.06

Results are mean values of duplicates± standard deviation

Physical properties of stirred yoghurt made from camel milk

Physical properties of yoghurt play an important role in determining its quality. Table 3 depicts the physical properties of yoghurt made from camel milk from different treatments. As it can be seen from Table 3, the titratable acidity of yoghurt decreased as the fat content of milk is decreased by decreaming (skimming) and increased when the milk is concentrated. The probable reason for the decrease in titratable acidity of yoghurt on using skimmed milk could be due to the removal of fatty acids present in camel milk during removal of the cream where as concentrating the milk could improve the fatty acid level in the milk base and consequently on the acidity of the yoghurt made. The other probable reason for increased acidity of yoghurt made from concentrated milk could be due to the increased level of concentration of lactose which is the starting material for the production of lactic acid through fermentation.

Table 3: Physical properties of yoghurt from whole camel milk

Camel yoghurt made from:	Pectin level	pH	Titrat. acidity (%)	Viscosity(cPs)	Synersis (%)
Whole milk	High	4.29±0.01	0.59±0.02	2.55±0.12	58±0.10
	Low	4.30±0.01	0.56±0.03	2.21±0.11	71±0.10
Skimmed milk	High	4.35±0.02	0.43±0.03	1.84±0.21	79±0.12
	Low	4.33±0.01	0.41±0.03	1.51±0.09	90±0.11
Conc. Whole milk	High	4.31±0.01	0.86±0.01	3.54±0.14	49±0.13
	Low	4.30±0.02	0.83±0.02	3.21±0.11	60±0.13
Conc. Skimmed milk	High	4.28±0.01	0.76±0.02	2.72±0.21	70±0.09
	Low	4.31±0.01	0.80±0.03	1.78±0.13	80±0.11

Source: Laboratory result High = 1.5g/1000g milk, Low = 0.9g/1000g milk

Similar results were found by Sloucum *et al.* (1998) in which whole milk as a result of its higher fat content and hence fatty acid level resulted in higher degree of acid development during yoghurt production than skim milk and consequently in lower level of proteolysis in processing whereas Modler *et al*. (1983) found that yoghurt made from concentrated milk showed increased level of acid development than less concentrated milk**.** On the other hand, Hashim *et al.* (2009) found that the use of stabilizers at different level could not impart any variation in acidity of yoghurt made from camel milk.

Viscosity: Viscosity is the other very important factor determining the quality of yoghurt. Yoghurts with higher viscosity are liked by consumers owing to better mouth feel than thin yoghurts. The probable reason for the increased level of viscosity on using whole milk than skimmed milk (p=0.000) is due to the contribution of fat on the thickening of gel during fermentation of milk to yoghurt and on that of using concentrated milk than unconcentrated milk (p=0.000) is due to the improved amount of protein concentration together with fat which have a great role in thickening of the gel formed during fermentation process. Similarly, the role of stabilizers such as pectin on viscosity development could be attributed to their ability to contribute to the thickening of the gel formed during fermentation process. The primary aim of hydrocolloid addition is their ability to form linkages among themselves and with milk constituents (mainly protein particles) and bind water, resulting in viscosity enhancement, body, texture, and mouth feel improvement. The higher level the pectin is used, the more will be its contribution to the thickness of yoghurt gel and thereby enhancing the development of viscosity of the processed yoghurt made from camel milk treatments. Similar results were found by other scientists. Modler *et al*. (1983) for example found that yoghurt showed an improvement in its viscosity with increasing protein content. El-Khair (2009) also found that milk concentrated by ultra filtration technique improved the apparent viscosity of yoghurt during processing.

Synersis: The other very important physical property considered during evaluation of yoghurt quality is its behavior toward synersis. If yoghurt is subjected to higher degree of synersis, its shelf life could extremely be diminished as the gel formed could easily expel whey from the gel matrix leading to a suspension of yoghurt materials in whey with in short period of time. Yoghurt with high degree of synersis is not liked by consumers. Thus it is imperative to asses as how the proposed processing variables (skimming, concentration and pectin level) affect the degree of synersis of yoghurt. Comparison of the synersis of yoghurt using two-way ANOVA indicated that synersis on yoghurt made from camel milk could significantly be varied by changing the fat content of the milk base (p=0.000), concentrating the milk (p=0.000) and using varying amount of pectin (p=0.000) during yoghurt production. The synersis of yoghurt is decreased by using milk with higher level of fat content (whole milk) than with lower level of fat content (skimmed milk), on using concentrated milk than unconcentrated milk and on using higher level of pectin than lower level of pectin. The yoghurt processed from whole camel milk exhibit lower degree of synersis than that of yoghurt processed from skimmed milk. The probable reason for this variation is due to the contribution of fat in strengthening the gel matrix of yoghurt which is formed during the progress of fermentation thereby protecting materials embedded in the gel (including water) from expulsion. Similarly, the yoghurt processed from concentrated camel milk exhibited lower degree of synersis than the yoghurt processed from unconcentrated milk. In the concentrated milk, the initial levels of protein and fat before the onset of fermentation is high. This high level of fat and proteins contributes to a larger extent to the strength of gel formation during the progress of fermentation. The higher their initial concentration meant that the higher binding among biomolecules that participate in the formation of gel matrix of the yoghurt thereby protecting the materials embedded in the matrix from expulsion. The other important processing variable which contributes to the synersis of yoghurt is the level of pectin used during yoghurt processing. The usage of stabilizers during yoghurt processing is due to their ability to strengthen the gel of yoghurt. The decrease of synersis on using higher level of pectin is due to the higher degree of binding among biomolecules with the facilitation of pectin molecules via cross linking the components of the matrix thereby reducing synersis. El-Khair (2009) in his study showed that concentrating milk has contributed in reduction of synersis during yoghurt processing. Modler *et al*. (1983) also found that yoghurt showed decreased level of synersis with increasing protein content.

Optimization of stirred yoghurt processing conditions from camel milk: Multiple regression technique was used to fit the data relating the processing variables to the desired response variables. The objective function of the optimization problem was maximization of the viscosity (μ) of stirred yoghurt subjected to certain restrictions. The first restriction (constraint function) is to limit the fat content (F.C) of the yoghurt not to exceed 4.5%, the level of the intended type of yoghurt, medium fat yoghurt. The second constraint function set was the acidity of stirred yoghurt. From health point of view, the maximum limit was set not to exceed 0.6. This limit was set according to the Codex general standards for yoghurts. The third restriction was set on the synersis of yoghurt. The linear programming optimization algorithm was set to include only those yoghurts which are subject to the possible minimum synersis in the optimum solution by restricting the synersis function not to exceed a value of 60% (average of all treatments).

Max $\mu = 0.771C + 0.909S + 0.471P$,
(4.650) (7.850) (2.418) Adjusted $R^2 = 0.936$

Subjected to;
$FC = 0.785C + 3.210S \leq 19.00\%$,
(5.953) (13.899) (1.473) Adjusted $R^2 = 0.892$
$TA = 0.308C + 0.118S + 0.000R \leq 0.6$
(17.112) (6.539) 0.974) Adjusted $R^2 = 0.934$
$S = -9.020C - 20.310S - 11.175P \leq 60\%$
(-22.422) (-50.486) (-27.778) Adjusted $R^2 = 0.916$

Instructing all the above information to LP optimization technique, the following output table was generated using TORA software.

Table 4: Linear programming output summary for maximization of viscosity of yoghurt.

Variable	Coded value	Actual value	Objective coefficient
Concentration	1.54	12.16%	1.801
Skimming	1.02	0.9%	5.146
Pectin level	2.00	0.0015%	1.634
Viscosity	-	3.06cPs	-

Final iteration=4 Objective value (Maximum viscosity=3.06cPs)

As it can be seen from Table 4, the result suggests that good quality camel yoghurt with good rheological property (μ=3.06cP) could be produced operating at 12.16% of total solid content of milk, 0.9% fat level of milk and using commercial stabilizer (pectin) at a ratio of 0.0015%.

CONCLUSIONS

The experimental result indicated that, it is necessary to control the fat level, total solid of raw camel milk as well as pectin level in processing stirred yoghurt from camel milk to attain the most important objectives of yoghurt processing.

ACKNOWLEDGEMENTS

We would like to extend our great appreciation to Holeta Agricultural Center of Ethiopian Institute of Agricultural Research for their generous provision of the facilities, chemicals and technical assistance of the expertise of their dairy laboratory.

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