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Optimization of the Production Process of Soft Cheese from Camel Milk Using Linear Programming Technique

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Abstract
It is widely reported that processing camel milk into cheese is a difficult one. In this study, soft white cheese was prepared using conventional cheese making methodology. A three way full factorial experimental design was employed taking cheese yield, fat content, moisture content and sensory quality of cheese as response variables and Total solid of milk, fat content and amount of coagulant (each at 2 levels) as the input variables. A linear programming technique was used to optimize the manufacturing process. Experimental results showed that, the average pH value of the whole milk is determined to be 6.65, titratable acidity 0.17 and specific gravity 1.029. The chemical analyses 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%. Finally, the optimization result suggested that soft cheese of an acceptable quality and an adjusted cheese yield of 14.57% could be produced by adjusting the fat content of camel milk to 1.82%, total solid level to 14% and using rennet powder at a ratio of 1.5mg $(100g)^{-1}$.
Keywords: Camel milk, Soft cheese, Coagulant, Linear programming.

1. INTRODUCTION

Several researches conducted on processing of camel milk into cheese, indicated that camel milk is more difficult for processing, owing to the smaller size of its fat globules and caseins micelles (Farrah and Ruegg, 1991).

For instance, Farah and Bachmann (1987) examined the rennet coagulation of camel milk from Northern Kenya using commercial calf rennet powder. The coagulation time of camel milk is much slower than cow milk and the camel casein micelles appear to form a less compact and looser network linked merely by contact with very little visible change in the original micellar structure. Furthermore, the effects of temperature, pH and calcium chloride on coagulation time of camel milk reduces with decreasing pH, with increasing temperature and added calcium. Mohammed and Larson (1989) studied the coagulation properties of Somali camel milk using bovine chymosin. The coagulation time for the milk was found to be 2 to 3 times longer than that of cow milk using the same concentration of chymosin enzyme.

To see the effect of the type of rennet source, Farah et al. (1993) extracted and fractionated bovine and camel rennet from abomassa of young calves. The result indicated that camel rennet coagulated camel milk less readily than cow milk. But the chymosin fraction of camel rennet coagulated cow and camel milk equally, where as the pepsin fraction coagulated more readily the camel milk than the cow milk.

Enzymes extracted from abomasums of small ruminants have also been investigated as to their potential to coagulate camel milk. Cheese making in the Sahara involves the addition of the peptic enzyme that is collected from rabbit stomach, or from the abomasums of young goats, to camel milk that causes the formation of a coagulum. This coagulated mass is soft like cotton wool (Rao *et al*., 1970).

Still there are other studies which coagulated camel milk from enzymes from plant extracts. Zubeir and Jabreel (2008) processed camel milk into cheese using Camifloc and calcium chloride. In the study, two types of cheeses were produced from camel milk, using Camifloc (CF cheese) and $CaCl_2$ in addition to Camifloc (CFCC cheese). The study revealed the usefuln ess of Camifloc in coagulation of camel milk. The time of coagulation was found to be about 2–3 h, and the yield of CFCC cheese was found to be higher than the CF cheese, while a shelf life of 4 days was obtained for both cheeses. Little has been said as to the possibility of improving the process of cheese manufacturing via optimization process. It would be possible to include process parameters that were reported to affect the yield and quality of camel milk cheese in process optimization so as to get better yield levels and acceptable quality. This study will try to fill this gap .

2. MATERIALS AND METHODS

2.1. Samples collection and handling: Samples of camel milk were collected from camel milk vendors in Addis Ababa, Bole Michael, who bring the milk from Mathahara area, Ethiopia. Camel milks were transferred into sterile containers after reception and transported to Holeta dairy processing laboratory, where analysis and processing of camel milk is done, using ice-boxes. Rennet powder and a cheese starter (lactic acid bacteria, LAB) and calcium chloride (food quality) used in this study were all of laboratory grades.

2.2. Cheese Processing: Eight cheese making trials from camel milk were conducted at Holeta agricultural research dairy processing laboratory following the conventional cheese making process as shown in Fig. 1 below. Cheese samples were taken for analyses after one day. Fresh camel milk with a pH of 6.5 – 6.7 was pasteurized at 65^{0}C for 30 minutes after different milk treatments used in the study (such as skimming, concentrating and blending). Then the milk was cooled to a temperature of 42^{0}C. After that calcium chloride and starter culture were added and left to rest for 60 min. To this

end, rennet was added and left to stand for 8 hours to allow the formation of the cheese mass. The curd had been intermittently cut to facilitate drainage of whey. Finally, the curd was separated from the whey by filtration and hung with cheese cloth for 24 hours to drain.

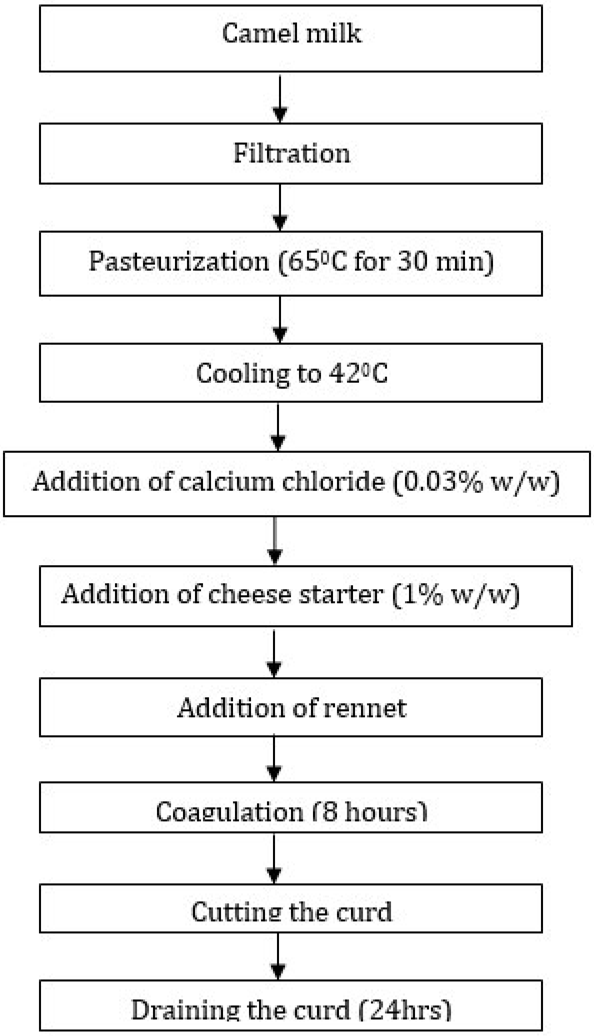

Figure 1: General procedure for production of soft cheese from camel milk.

2.3. Physical and Chemical Analyses: All the milk treatments and the processed cheese were analyzed for total solid, ash, titratable acididity, 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.

2.4. Cheese Yield: Actual cheese yield was calculated as the ratio of mass of the cheese obtained by the mass of milk used to prepare the cheese expressed in kg $(100kg)^{-1}$ of milk where as adjusted cheese yield (to 60% moisture content) was calculated by the following formula as:

$$\text{Adjusted Yield }(kg(100kg)^{-1}) = \text{Actual Yield} * \frac{(100 - \text{Moisture actual level})}{(100 - \text{Moisture desired level})} x100 \qquad \text{Eq. 1}$$

2.5. Microbiological Analyses: All the milk treatments and the processed cheese were analyzed for **t**otal plate count according to the method described by Van den Berg (1988), *Coliforms and Entrobacteriaceae* counts according to the method described by Richardson (1985) and Yeasts and Moulds were determined according to the method described by Harrigan and MacCance (1976).

2.6. Sensory Evaluation: Ten panelists experienced in the evaluation of soft cheese were chosen from the staff members and students for the assessment of the sensory attributes of soft cheese samples. Flavor, test, texture, appearance, aroma and stickiness of the samples were evaluated. A nine-point hedonic scale was utilized in this study (9 = like extremely, 5 = neither like nor dislike and 1 = dislike extremely). Panelists were also asked to list if they have any comment. The cheeses were randomly coded with three-digit numbers. Cheeses manufactured on the same day were served together. Each attribute was separately scaled and analyzed.

2.7. Experimental design: For the cheese production, a 3-way full factorial 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 coagulant amount (3mg100g^{-1} yoghurt and 15 mg100g^{-1}) as the main effects, was applied to investigate their effects on the yield, fat content and sensory quality of cheese.

2.8. 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 level, milk-fat level, rennet level on yield, physico chemical and sensory properties of soft cheese made from camel milk. Principal components analysis (PCA) was used to reduce the large set of cheese sensory data into manageable size for modeling purpose. 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:

$AX \leq b$, Where:
Z = the value of the objective function, maximizing a cheese yield
C = the vector of coefficients of factors determining cheese yield.
X = the vector of factors determining cheese yield.
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.

3. Results and Discussions

3.1. 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 (see Table 1). Omer and Eltinay (2009) found similar results for physical properties of whole camel milk in which pH and acidity were found to be 6.57 and 0.2 respectively, Zubeir and Jabreel (2008) 6.6 and 0.19 respectively and Mehaia (2006), found them to be 6.62 and 0.15 respectively. 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

3.2. Selection of coagulant for soft cheese processing from camel milk

Coagulants of plant origin such as lemon juice and juice of ginger as well as a commercial coagulant powder (rennet) were compared and the best of them was used in this experiment.

Table 2: Cheese yield of different coagulants

Coagulant type	Actual cheese yield (g/100gmilk)	Total solids(%)	Adjusted cheese yield(g/100gmilk)
Lemon	-	-	-
Ginger	14.3	39.11	13.98
Rennin	18.1	32.6	14.57

As it can be seen from Table 2, lemon juice did not coagulate camel milk. On the other hand juices of ginger was the successful candidates of plant extracts which is able to coagulate camel milk. It produced soft cheese with an actual cheese yield of 14.3% and with an adjusted yield of 13.8%. The probable reason for the success of ginger could be that the presence of proteolytic enzymes in the juices and the failure of lemon juice could be due to the absence of it. Milks of cow origin could easily be coagulated into cheese using proteolytic enzymes of different origin, acidic juices of fruits such as lemon or the combination of both. The result on Table 2 however indicates that unlike cow's milk, camel's milk could only be coagulated into cheese mass only by the action of proteolytic enzymes. Not by the action of acid (lower pH) of the juice. As enzymes are site specific, they would have a better chance to catalyze the break down of the outer shell of casein micelles (hydrophobic interactions) which held them as colloidal suspensions. Given the finer structure of casein micelles in camel milk, it needs further work to unravel the mechanism behind this difference. Due to its better performance (Table 2), rennin is thus used for cheese manufacturing in this study.

3.3. Yield and Chemical composition of soft cheeses made from camel milk: As can be seen from Table 3, varying amount of cheese with varying level of components was found by subjecting camel milk for different levels of total solid, fat and rennet. Taking total solid, fat and rennet as the independent variables and adjusted yield, total solid, fat, protein and ash levels of cheese as the dependent variables, a series of three – way ANOVAs were conducted to see whether there exist a significant variation in the adjusted yield, total solid, fat, protein and ash levels of cheese for the given values of independent variables. The result indicated that the level of cheese yield adjusted to constant moisture content (60%) is affected by all the three variables. Adjusted cheese yield of camel milk could be improved by concentrating the milk ($p = 0.000$), using whole milk than skimmed milk ($p = 0.000$) and by using higher level of rennet ($p = 0.001$). The reason for increased level of cheese yield by raising the total solid level of milk could be due to the fact that, during the formation of cheese curd, the more the total solid in the milk means the more materials embedded in t he matrix of the curd and consequently increase the yield for the cheese.

Fat level of the milk affects the cheese yield in similar manner in which the more fat is available in the curd, the more it is incorporated in the matrix of the curd and hence the more will be the yield of the cheese. When the level of rennet is increased, the chymosin could access more proteins on the surface of casein micelles and act up on them and consequently incorporate them into the cheese mass. Mehaia (2006) also reported that the level of cheese yield could be improved from 13.9g $(100g)^{-1}$ milk to 20.2g$(100g)^{-1}$ milk by concentrating whole camel milk using ultra filtration technique. On the other hand verdier *et al.* (2001) found similar result in that there is a linear relationship between fat and protein levels in milk and cheese yield, in which the latter increases linearly as the levels of the formers are increased as analyzed on 189 manufactures of pressed uncooked cheeses. Similarly, the study conducted by Jaeggi *et al.* (2006) on sheep milk showed that seasonal changes had a significant impact on milk composition, thereby affecting cheese yield. Cheese yields were directly related to the level of fat and casein in the initial milk. Comparison was also done on the variation of total solid, fat and protein levels of the different cheeses obtained through processing of different kind of milk treatments. The result of comparison indicated that there is a significant variation in total solids of cheese produced between concentrated and unconcentrated milk cheeses ($p = 0.000$), between whole and skimmed milk cheeses ($p = 0.000$) and between cheeses made by higher and lower level of rennet ($p = 0.000$). Verdier et al. (2001) reported that the higher protein is in milk the higher will be the cheese yield. Fat level of the milk could also affect the total solid of cheese. When the factors determining the level of fat in the final processed cheese are considered, it is only the level of fat in the milk found to be important. Neither concentrating the milk ($p = 0.155$) nor using higher level of rennet ($p = 0.094$) could impart significance variatio n in fat level of cheese. This could be due to the insignificant role of fat in the direct formation of cheese mass. Fat is not directly converted into curd by the action of rennet rather it is incorporated into the cheese curd indirectly by binding to protein molecules as they are precipitated and coagulated by direct action of rennet.

Table 3: Yield (g/100g milk) and chemical composition of soft cheese from camel milk using full factorial experiment (2^3)

Cheese made from:	Rennet level	Actual yield	Adjusted yield	Total solids%	SNF%	Fat%	Protein%	Ash%
Whole milk	High	18.10±1.14	14.57±1.14	32.20±0.23	18.60±0.33	13.6±0.20	14.61±0.04	2.23±0.05
	Low	17.20±1.34	13.29±1.34	30.90±0.11	17.50±0.13	13.4±0.10	14.17±0.05	2.12±0.04
Skimmed milk	High	14.44±1.56	10.07±1.56	27.9±0.31	26.8±0.21	1.1±0.10	21.05±0.02	2.25±0.06
	Low	12.96±1.47	8.32±1.47	25.7±0.22	24.9±0.17	0.8±0.10	20.62±0.07	2.11±0.06
Conc. whole milk	High	19.40±1.36	16.68±1.36	34.4±0.15	18.4±0.19	14.0±0.30	14.4±0.04	2.37±0.01
	Low	18.50±1.27	15.30±1.27	33.1±0.14	17.6±0.25	13.6±0.40	14.86±0.05	2.22±0.03
Conc. Skimmed milk	High	15.34±1.16	11.58±1.16	30.2±0.28	28.2±0.46	1.3±0.20	19.1±0.01	1.84±0.04
	Low	13.94±1.09	9.79±1.09	28.1±0.42	26.4±0.53	1.0±0.10	21.32±0.01	1.66 ±0.05

Results are mean values of duplicates± standard deviation
High = 15mg/100g milk , Low = 3mg/100g milk

Table 4: Sensory results of camel cheese varities produced using Full factorial experiment (2^3)

Cheese made from:	Rennet level	Appearance	Color	Aroma	Flavor	stickiness
Whole milk	High	8.2±0.75	8.2±0.40	8.4±0.50	6.4±0.80	6.4±2.05
	Low	7.8±1.60	8.2±0.4	7.8±0.75	7.4±1.36	6.4±2.05
Skimmed milk	High	6.6±1.50	7.40±1.02	7.4±0.49	7.4±0.80	6.8±0.75
	Low	6.4±1.2	7.60±0.8	7.2±0.75	6.0±1.41	6.2±1.33
Conc. whole milk	High	6.2±1.32	8.0±0.8	6.4±1.02	6.6±0.49	6.4±0.49
	Low	6.2±1.32	7.8±0.75	6.4±0.80	6.6±0.49	6.6±0.49
Conc. Skimmed milk	High	5.4±1.02	7.0±0.89	6.4±1.34	5.4±1.02	4.8±1.16
	Low	6.4±1.02	6.6±0.49	5.8±0.98	5.8±0.98	5.6±0.49

Results are mean values of duplicates± standard deviation High = 15mg/100g milk, Low = 3mg/100g milk

Concentrating the milk or usage of varying level of rennet for cheese making couldn't bring in any significant difference (p=0.054 and p=0.692 respectively). The probable reason for this variation could be due to the difference on the color of fat globles which could be removed together with the cream during skimming of camel milk. The rating for aroma and flavor is affected only by concentrating the milk (p=0.000 and p=0.049 respectively). Skimming and rennet level couldn't contribute to any variation in aroma and flavor of cheeses produced from camel milk. The probable reason for variation in flavor and aroma of cheeses made from camel milk with concentration could be due to higher retention of salt, sugar and other taste and aroma components. The variation of concentration, skimming and renneting levels didn't affected the stickiness of cheese made from camel milk.

3.4. Principal components analysis: PCA is included in this study as a data reduction technique to summerize the large set of sensory descriptive parameters into smaller set of sensory descriptive parameters and thereby reduce the number of constriant functions as small as possible. Three important steps are carried out.

Step 1, Assessment of the suitability of the data for PCA: As can be seen from Table 6, the value of KMO's measure of sampling adequacy is 0.610 which is greater than the minimum value 0.6 indicating that the size of sample is adequate to consider PCA as appropriate tool to reduce the sensory data at hand and the Bartlett's test of sphericity is significant (p<0.000) indicating that the intercorrelation among the items is so strong to be considered in PCA. Summerizing the two tests indicated that the sensory data collected in the varieties of camel cheeses is suitable to be considered in PCA.

Table 5: KMO and Bartlett's tests

Type of test:	Value
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.610
Bartlett's test	
Approx. Chi-Square	37.764
Sig.	0.000

KMO values greater or equal to 0.6, acceptable

Step 2, Factor extraction: The test result of factor extraction indicated that, only the factors with eigen values of 1.0 or more are items 1 and 2 (Table 6). The rest (3, 4 & 5) appeared with eigen values less than 1.0 indicating that all the factors (sensory descriptors) could be loaded on only two summarized descriptor variable that could explain about 43% of the variation in the data whereas if all the factors are summarized as (loaded on) only two descriptor variables, they cumulatively could explain about 67.1% of the variation in the data. To strengthen the idea that all the descriptors could be loaded on two factors, a scree test method was used. As it can be seen from Figure 2, the first break appeared at the second factor (second dot) indicating that the number of factors to be retained are two.

Table 6: Total variance explained (Eigen values) of cheese sensory data

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	Variance (%)	Cumulative %	Total	Variance (%)	Cumulative (%)
1	2.147	42.943	42.943	2.147	42.943	42.943
2	1.208	24.154	67.097	1.208	24.154	67.097
3	0.830	16.591	83.688			
4	0.441	8.819	92.508			
5	0.375	7.492	100.000			

Extraction Method: Principal Component Analysis.

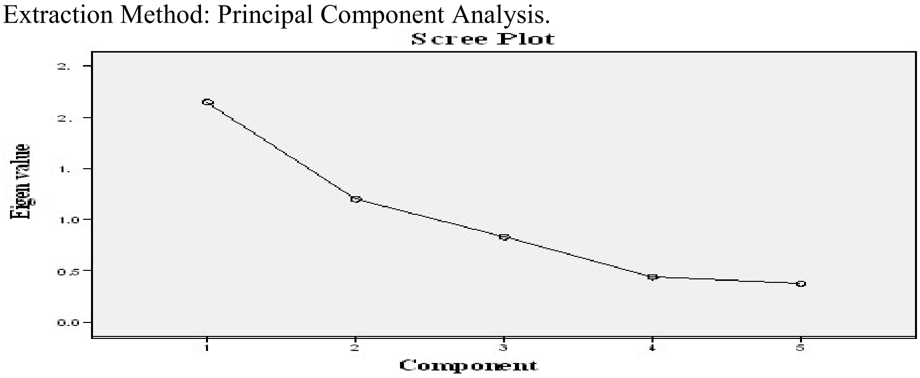

Fig 2: Scree plot of the factor extraction step

Step 3, Factor rotation and interpretation: As can be seen from Table 7, flavor and stickiness loaded more on component 2 whereas aroma, color and appearance loaded more on component 1. Looking at the nature of descriptors, the general name for component 1 could be wholsomness and that of component 2 could be mouth feel of the cheese varities. The results of this analysis supports the use of two genaral sensory descriptors of camel cheese varities (wholsomness and mouth feel) instead of individual sensory descriptors (appearance, colour, aroma flavor and stickiness) thereby enabling to reduce the number of equations used in LP optimization technique.

Table 7: Rotated components matrix

	Component	
	1	2
Flavor	0.388	0.799
Aroma	0.794	
Stickiness	0.619	0.632
Color	0.514	
Appearance	0.778	0.462

3.5. Optimization of cheese 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 adjusted cheese yield (A.Y) subjected to certain restrictions. The first restriction (constraint function) is to limit the fat content (F.C) of the cheese not to exceed 19% as the most suitable use of soft cheese made from camel milk is as a spread cheese. The other constraint function set was the moisture content (M.C) of soft cheese. From both functional and microbial point of view, the maximum limit was set not to exceed 63%. These limits were set according to Codex general standards for soft cheese. The third type of constraint function was the wholesomeness of the cheese obtained from the PCA of sensory data of cheeses made from camel milk which was set to be in the range of 5 to 9 in nine point hedonic scale to ensure that the final processed cheese is accepted by consumers.

Max $AY = 1.801C + 5.146S + 1.634R$,

(5.842) (16.690) (5.299) Adjusted $R^2 = 0.957$

Subjected to;

$F.C = 0.000C + 2.384S + 0.000R \leq 19.00\%$, (8.229) Adjusted R^2 = 0.937

$$M.C = -2.250C - 4.65S - 1.70R \le 63.00\%,$$
(-12.344) (-25.511) (-9.326) Adjusted R^2 = 0.983

$$WS = 5 \le -1.05C + 0.783S + 0.000R \le 9,$$
(-1.953) (21.583) Adjusted R^2 = 0.86

Table 8: Optimum point of operation for soft cheese processing from camel milk

Variable	Coded value	Actual value	Objective coefficient
Concentration	2.00	14%	1.801
Skimming	1.46	1.82%	5.146
Rennet level	2.00	15mg/100g	1.634
Adjusted Yield	-	14.38%	-

Final iteration=4 Objective value (Maximum cheese yield=14.38%)

Instructing all the above information to LP optimization technique, the output in Table 8 was generated using the software TORA. As can be seen, the result suggests that good quality camel cheese with an adjusted yield of 14.38% could be produced operating at 14% of total solid content of milk, 1.82% fat level of milk and using commercial rennet powder at a ratio of 15mg/100g.

4. CONCLUSIONS

The experimental result indicated that coagulation of camel milk could be possible only by the action of proteolytic activity of enzymes of plant extract juices rather than on the action of acidity of the juices. Furthermore, it is necessary to control the fat level, total solid and rennet level of camel milk to a soft cheese from camel milk with better yield and acceptable quality.

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