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Article

Evaluation of camel milk for selected processing related parameters and comparisons with cow and buffalo milk

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ABSTRACT

Cow and buffalo milk and camel milk were analyzed and compared for processing related parameters. The average heat stability of cow, buffalo and camel milk samples analyzed was 1807.4 seconds, 1574.6 seconds and 133.6 seconds respectively at 140 °C. Thus, the heat stability of camel milk was significantly lower than the cow milk and buffalo milk. The average rennet coagulation time (RCT) of cow, buffalo and camel milk was 310.6 seconds, 257.4 seconds and 604.2 seconds respectively. Thus, RCT of camel milk was significantly higher than the cow milk and buffalo milk. The camel, cow and buffalo milk samples showed negative alcohol stability. The rate of acidity was increased propositionally with time in camel milk with no curd formation and weaker body.

KEYWORDS

Camel milk; processing; rennet coagulation time; heat stability.

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1 Introduction

Camel (*Camelus dromedaries*) milk and its products may be one of the economical ways to improve the social life of camel owners. Camel milk is an important source of proteins for the people living in the arid lands of the world. Various researchers have worked on camel milk which are related to production or composition aspects (Farah 1993; Wangoh 1997; Konuspayeva *et al.* 2009; Al Haj and Al Kanhal 2010; Yoganandi *et al.* 2015 a,b,c,d). Camel milk is considered to have anti-cancer, hypo-allergic, and anti-diabetic properties (Agrawal *et al.* 2003, Magjeed 2005; Shabo *et al.* 2005; Konuspayeva *et al.* 2008). Camel milk can be considered as a good food of high nutritive and therapeutic applications. In the western world, camel milk is experiencing a novel awareness in these days and even the FAO has stepped in promoting camel milk (Ramet 2001).

Various researchers have tried to prepared various milk products from camel milk like ice cream (Abu-Lehia *et al.* 1989), butter (Farah *et al.* 1989), fermented products (Farah *et al.* 1990; Fguiri *et al.* 2015), probiotic frozen yoghurt (Al-Saleh *et al.* 2011) and cheese (Inayat *et al.* 2007; El Zubeir and Jabreel 2008), khoa (Chaudhary *et al.*, 2016), ghee (Parmar 2013). Butter was reported to be only produced from camel cream at a high churning temperature of 20 ^{o}C - 25 ^{o}C. These temperatures are higher than those values reported for bovine milk butter manufacture of 8 ^{o}C - 12 ^{o}C (Rüegg and Farah 1991). Chaudhary et al (2016) compared the various chemical compositions and characteristics of the khoa prepared from the camel milk with that prepared from the cow and the buffalo milk samples. The khoa prepared from the camel milk had the higher moisture, ash, acidity, soluble nitrogen, free fatty acids and peroxide value, but lower in fat, protein and lactose contents than that prepared from the cow and buffalo milk samples. Chaudhary (2013) also prepared the burfi and gulabjamun from camel milk khoa. Lad (2016) worked to enhance the quality of gulabjamun prepared from camel milk khoa. Camel milk exhibits a two to three fold longer rennet coagulation time compared with bovine milk (Farah and Bachmann 1987). Countries like India, UAE having camel milk parlor in which various products prepared from camel milk are available which have high demand. However, publications dealing with the processing related parameters of camel milk are relatively scarce and much of the information is approximate and fragmental (Farah and Bachmann 1987; Mohammed and Larsson-Raznikiewicz 1989; Farah and Atkins 1992; Kouniba *et al.* 2005). Up to the early 1970, research on camel milk was limited to studies on general composition and milk yields. Much of the work so far has been carried out by the individuals with little institutional support. Thus the research remained isolated with little impact on dairy camel production (Farah 1993). Development and research activities on domestic animals are mostly concentrated on species and breeds of animals available in Asian countries. That leads to less concentration on several species of animals native to the countries. The camel is certainly one of the most neglected species of the domestic animals (Knoess 1979). Thus, fewer data on camel milk processing are available, compare with cow and buffalo milk. Processing related parameters such as alcohol stability, heat stability, rennet coagulation time (RCT) and rate of acid production are not well studied.

Camel (*Camelus dromedaries*) population in Gujarat state of India was reported to be 0.3 lacks which contributed 7.6% in India (4.0 lacks) and ranked 2nd position (Livestock census 2014). However, the information on processing related parameters of camel milk produced in Gujarat is not available. Therefore, there is a need to undertake systematic study to generate

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data. Hence, the present study aimed to study the selected processing related parameters of camel (milk collected from Anand and Kheda district) and its comparison were carried out with cow and buffalo milk. Moreover, this information will be beneficial to manufactures/industrial personnel as well as policy makers involved in processing of milk and milk products prepared from camel milk.

2 Material and Methods

The three different milk samples of camel, cow and buffalo were studied. The pooled milk samples of camel milk (8 samples, from Anand and Kheda district of Gujarat state, India) as well as cow milk (8 samples) and buffalo milk (8 samples) were collected from the local herd maintained in village nearby Anand. Samples were transported to the laboratory, where they were stored at 4 °C before its analysis. Total 24 samples (8 each of camel, cow and buffalo milk) were analyzed for gross chemical composition of camel, cow and buffalo milk samples as described in BIS Handbook (SP 18: part XI, 1981). These samples were also analyzed for processing related parameters such as alcohol stability, heat stability, rennet coagulation time (RCT) and rate of acid production. All the chemicals used for chemical analysis were of analytical reagent grade.

2.1 Gross chemical composition of milk

The milk fat content in all the milk samples were estimated by following the Gerber method, solid not fat (SNF) and total solids content were calculated by gravimetric method (SP 18: part XI, 1981). Lactose content was determined using Lane and Eyon method, milk protein content was determined using micro-Kjeldahl method of nitrogen estimation (percent total protein was obtained multiplying the percent nitrogen by a factor of 6.38), ash (a grey white residues obtained after incineration of milk at 500 to 550 °C) content was determined using gravimetric method and acidity (% lactic acid) as described in BIS Handbook (SP 18: Part XI 1981).

2.2 Processing related properties

Processing related properties includes alcohol stability, heat stability, rennet coagulation time (RCT) and rate of acid production.

2.3 Alcohol stability

In a test tube, 5 ml milk samples was taken and added an equal volume of ethyl alcohol (75% and 68% by volume for cow, buffalo and camel milk). Formation of flakes or curd on the sides of the test tube indicated the positive test while no changed in milk considered as negative test (SP 18: Part XI 1981).

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2.4 Heat stability

Heat coagulation time (HCT) was determined in a thermostatically controlled oil bath at 140 °C according to the method of Davies and White (1966). In a test tube, 3 ml of milk sample was taken and kept in controlled oil bath having 140 °C and noted down the time. Gradually rotated the test tube in oil bath and observed for flakes formation (coagulation occurred) and noted down the time. The total time was considered as HCT.

2.5 Rennet coagulation time

The time from rennet addition to the onset of gelation (rennet coagulation time, RCT) is an important practical consideration in cheese making. The determination of RCT involves measurement of the time elapsed between the addition of a known amount of rennet (diluted) to a known volume of milk at a given temperature and the onset of gelation (usually assessed visually).

For determination of rennet coagulation time (RCT), a macro film technique was used that is developed by Sharma and Bhalerao (1963). Two test tubes of different diameter were taken. The five ml milk sample was taken in test tube with bigger diameter and brought its temperature to 40 °C, keeping it in water bath. 0.2 ml 1% rennet solution were added and started the stop watch soon after addition of rennet. Mixed the content thoroughly and insert another test tube so that a film was formed in the annular space. Incubated at 40 °C till the first appearance of clotting in the film was observe. Noted down the time.

2.6 Rate of acid production

In the present investigation, rate of acid production in camel milk was measured by adding starter culture of Streptococcus thermophilus in camel milk at the rate of 2% rate of milk and incubated at 37 °C for 24 hours and acidity (in percent lactic acid) was measured at every 2 hours interval (SP 18: Part XI 1981).

2.7 Statistical analysis

The data obtained during investigation were subjected to statistical analysis using completely randomized design (Rudolf *et al., 2010*). The data are mean (average) of 8 replicates for each type of milk.

3 Results and Discussion

The gross compositions of camel, cow and buffalo milk were analyzed. The mean values of gross composition of different types of milk are shown in Table 1.

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Table 1

Types of milk	Gross composition (%)*					
	TS	Fat	SNF	Protein	Lactose	Ash
Camel	11.89	4.39	7.46	2.93	4.15	0.72
Cow	13.12	4.62	8.42	3.28	4.37	0.69
Buffalo	15.56	6.41	8.94	3.82	4.63	0.70

*Mean values of eight replications

These data indicated that total solids content was lower in camel milk but ash content was relatively higher than other cow and buffalo milk. These data are well correlated with values reported by Yoganandi *et al.* (2015a,d).

3.1 Alcohol stability

The alcohol test determines the susceptibility of milk to coagulate due to development of acidity, disturbed salt balance or high albumin-globulin content. The milk giving a positive alcohol test will, coagulates upon heat treatment. The alcohol stability of milk from cow, buffalo and camel milk were studied. Ethyl alcohol of 68% by volume and 75% by volume were used to measure the alcohol stability. The collected cow, buffalo and camel milk samples showed negative alcohol stability *i.e.* there were no visible flakes/coagulation formation in all milk samples. No data is reported on alcohol stability of camel milk. Thus, comparison is not possible. Unnikrishnan et al (1988) found wide variation in the alcohol stability in both buffalo and cow milk. The buffalo milk coagulated in the ranged from 60 – 72% against 70 – 80% for cow milk. Wang et al (2016) reported that goat milk exhibited a markedly lower alcohol stability than cow milk. The goat milk produced a much flocculated precipitate but the cow milk produced no flocculated precipitate.

3.2 Heat stability

Heat stability of milk is defined as the time necessary to initiate coagulation in milk at definite temperature (generally at 140 °C). The coagulation is indicated by flocculation, gelation or changes in protein sedimentability (Rose 1963). For bovine milk, the most widely used temperature for heat coagulation is 130 or 140 °C (Farah and Atkins, 1992). Heat stability of cow, buffalo and camel milk samples was measured by heating milk at 140 °C in oil bath and data are shown in Table 2.

The range of HCT of camel milk samples analyzed was 129 to 140 seconds at 140 °C. Similarly in cow milk samples HCT ranges from 1798 to1816 seconds and in buffalo milk it varied from 1563 to 1581 seconds. Thus among all the milk samples analyzed, camel milk have poor heat stability ($p<0.05$) and such milk did not be withstand high heat treatments Moreover, HCT of buffalo milk was significantly lower than that of cow milk.

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Table 2. Heat stability of cow, buffalo and camel milk

Type of milk	Heat Coagulation Time (HCT) (seconds)	
	Range	Average
Cow	1798 – 1816	1807.4
Buffalo	1563 – 1581	1574.6
Camel	0129 – 0140	133.6
SEm	2.8449	
CD	8.7659	
CV %	0.5428	

5% level of significant (i.e., p<0.05).
SEM=Standard error of mean, CD=Critical difference, CV=Coefficient of variance

Farah and Atkins (1992) analyzed heat coagulation time for cow milk at 130 °C that is about 40 min at pH 6.7, whereas camel milk coagulates in 2 to 3 min at this temperature and pH. Kouniba *et al.* (2005) carried out an experiment to check heat stability of camel milk. They found out that heat stability of camel milk was relatively lower at high heat treatments. Heat coagulation time in the range of 100-130 °C was too short (< 2 min.).

Compositional differences and heat-induced interaction between the caseins and whey proteins, particularly κ-casein and β-lactoglobulin, are reported to be responsible for these differences (Haynes and Fox 1975; Fox and Hoynes 1976). It is possible that camel casein contained so little k-casein that it escaped detection or was obscured by other casein fractions. The camel milk contains k- casein only 5 percent of total casein, compared to bovine milk (13.6%) (Ramet 1991 ; Farah 1993) and buffalo milk contains 12 percent of total casein. The evidence for presence of β- lactoglobulin in camel milk is conflicting (Farah 1986). The β-lactoglobulin concentration in milk is reported 0.93 and 02-0.4 percent in buffalo and cow milk respectively (Sahai 1996). The impact of other little-known factors in camel milk such as the level of soluble calcium and phosphate, as well as the concentration of colloidal calcium phosphate and the nature of its binding to casein, might also be considered (Farah 1986).

3.3 Rennet coagulation time (RCT)

In the investigation, RCT of all three milk samples of camel, cow and buffalo was determined by adding 1% rennet solution to different milks and kept them at 40 °C water bath. The data obtained for RCT content of camel, cow and buffalo milk are presented in Table 3.

The range of RCT of camel milk samples analyzed was 595 to 618 seconds and having mean value of 604.2 seconds at 40 °C. Similarly in cow milk samples RCT ranged from 294 to 326 seconds and having mean value of 310.6 and in buffalo milk it was 243 to 270 seconds and having mean value of 257.4 seconds. Thus RCT of camel milk was significantly higher than the cow milk and buffalo milk. The observed data showed that range of RCT of camel milk was approximately 2 times higher than that of cow and buffalo milk. Similarly RCT of buffalo milk was significantly lower than that of cow milk.

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Table 3 Rennet coagulation time for cow, buffalo and camel milk

Type of milk	Rennet Coagulation Time (sec)	
	Range	Average
Cow	294-326	310.6
Buffalo	243-270	257.4
Camel	595-618	604.2
SEm	4.881	
CD	15.039	
CV %	2.793	

5% level of significant (i.e., p<0.05).
SEM=Standard error of mean, CD=Critical difference, CV=Coefficient of variance

Mohammed and Larsson-Raznikiewicz (1989) studied the coagulation properties of Somali camel milk using bovine chymosin. With the same chymosin concentration, the coagulation time for camel milk was 2 to 3 times longer than that for cow milk. Farah and Bachmann (1987) examined the rennet coagulation of 10 individual camel milk samples from Northern Kenya using commercial calf rennet powder. They observed that rennet coagulation time for camel milk at pH 6.65 is 840 seconds and RCT of cow milk at pH 6.65 is 300 seconds. With the same amount of rennet the coagulation time of camel milk was two to three fold longer than that of cow milk. That may be because of low amount of kappa casein that is only about 5 percent of the total casein, compared with about 13.6 percent in bovine casein (Farah 1993) and presence of β-lactoglobulin has not been clearly identified (Farah 1986).

Renneting is probably low, because the mean size of casein micelles in camel milk is bigger than that of cow and buffalo milk. In comparison of these milk, the size of casein micelles is bigger camel milk (320 nm) followed by buffalo milk (110-160 nm) and cow milk (70-110 nm). Bigger the size of casein micelles, less will be the κ-casein content. Electron micrographs showed that the network formed at the coagulation point was less compact than in renneted cow milk, and the micelles were linked merely by contact adhesion, with little change in the original micellar structure, whereas the network formed in cow milk consisted of fused micelles (Farah and Bachmann 1987).

3.4 Rate of acid production by starter culture

Fermented milk products are known for their taste, nutritive value and therapeutic properties. The preservation of food by fermentation is one of the oldest methods known to mankind. A typical example is lactic acid fermentation, which is widely used for the preparation of several fermented milk products, such as dahi (curd), yoghurt, acidophilus milk, shrikhand and various varieties of cheeses. For that starter culture was used. Lactic acid bacteria like *Lactococcus, Lactobacillus, Streptococcus* and *Leuconostocs* are often called dairy starter cultures, which are used for the production of various fermented milk products. Starter culture

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should grow properly and should produce required acidity in limited time and should produce fine and firm curd.

The figure 1 showed the graphical presentation of data on rate of acid production in camel milk.

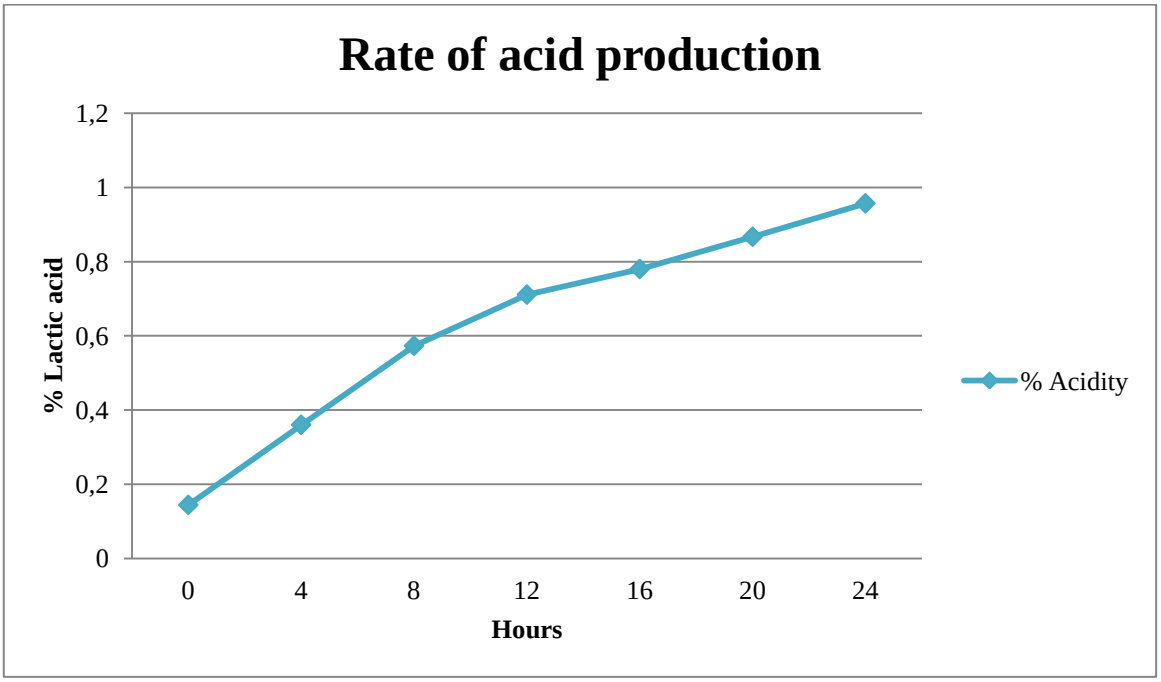

Figure 1 Rate of acid production in camel milk by Streptococcus thermophilus

The initial acidity observed was 0.144% and gradually the acidity was increased in camel milk. After 24 hours, acidity reached to 0.957% lactic acid but the curd formed was having very weak consistency and it was flow-able.

Magdi *et al.* (2010) carried out a research on biochemical changes occurring during fermentation of camel milk by selected bacterial starter cultures. The camel milk was inoculated with 5 different starter cultures that are *Streptococcus thermophilus* 37, *Lactobacillus delbrueckii sub sp. bulgaricus* CH2, *Lactococcus lactis, Lactobacillus acidophilus* and mixed yogurt culture (*S. thermophilus* and *L. bulgaricus* 1:1) and fermented at 43 °C for 6 h and changes occurred were observed. After 6 hours incubation lactic acid produced by these strains was 0.6, 0.73, 0.23, 0.47, and 0.85% lactic acid respectively but with weak curd formation.

4 Conclusions

The processing related parameters such as alcohol stability, HCT, RCT and rate of acid productions were studied. The camel, cow and buffalo milk samples showed negative alcohol stability. The heat stability of camel milk was significantly lower than the cow milk and buffalo milk but rennet coagulation time of camel milk was significantly higher than the cow milk and buffalo milk. The rate of acid production useful in fermented dairy products. The rate of acidity was increased propositionally with time in camel milk. After 24 hours, the camel became

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thicker but the curd formed was having very weak consistency and it was flow-able. These parameters will be useful in manufactured of various dairy products from camel milk.

5 Authors' contribution

Shyam P. Sagar has conducted the experiment and the laboratory analysis of the samples. Bhavbhuti M. Mehta helped in analysis the samples, analyzed the data as well as editing the paper. K.N. Wadhwani helped in procuring the camel milk. V.B. Darji has helped in statistical analysis of the data and K.D. Aparnathi supervised the experiment.

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