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Influence of Thermal Treatments on Physico-Chemical properties of Camel Versus Buffalo Milk

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Abstract: An *in vitro* study was conducted to observe the influence of heat treatment on physico-chemical properties of camel milk versus buffalo milk. The experiment was designed with 2×4 factorial arrangements where in two categories of milk (camel and buffalo) were treated with four thermal treatments (Ambient temperature/no heat treatment, low temperature long time (LTLT), high temperature short time (HTST) and 90ºC for 10min). Two-way interaction of treatment variables was recorded to observe the significant impact of treatments over dependent variables (Physico-chemical). Experiment was replicated three times each in duplicate batches to observe the statistical differences among the variables. Results revealed that compared to buffalo milk, camel milk was more acidic and low in specific gravity, viscosity, conductivity and refractive index. Thermal treatments (Ambient temperature, LTLT, HTST and 90ºC for 10min) applied to both types of milk gradually increased the acidity, viscosity and conductivity, and decreased the specific gravity and refractive index with increase in thermal temperature. Raw camel milk was found rich in protein SNF, ash and casein contents, and poor in total solids, fat, non-casein nitrogen, non-protein nitrogen and whey protein contents against buffalo milk. Linear decrease in lactose, SNF, Non-casein nitrogen (NCN),non-protein nitrogen (NPN) and whey protein contents and increase in Total solids (TS), fat, protein and casein contents was recorded with increase in thermal temperature (Ambient temperature, LTLT, HTST and 90ºC for 10min). Moreover, the increase in denaturation percent in camel milk was observed with increase in heat treatment, but the extent was not comparable with buffalo milk.

Keywords: Thermal Treatment, Physical, Chemical, Variation, Camel Milk

1. INTRODUCTION

Camel milk at camel habitat zones (sandy desert, coastal mangroves areas) of Sindh, Pakistan has never been sold/marketed to a significant extent probably due to unawareness, herder's cultural belief and/or consumer's drinking habits. In most of the cases, herders either do not sell the milk and feed to young ones or give it free of cost. However, in last couple of decades, camel milk is getting known to public and is being sold locally and/or at urban markets as a whole or mixed with milk of cattle and buffalo, when market demand is increased than the usual supply. According to the pastoralists view, camel milk has its own unique attributes and properties, superior over milk of other dairy breeds. In fact, it has rich source of proteins with potential antimicrobial and defensive activities (Ahmad *et al.,* 2010) which might enhance its keeping quality and can be stored at room temperature for longer periods than milk of other animals (Yassin *et al*., 2015). This makes raw camel milk a marketable commodity, even under high temperatures with very basic hygienic conditions (Yaqoob and Nawaz, 2007). In most camel rearing societies, the camel milk is mostly consumed in its raw state without being subjected to any sort of processing treatment (Sisay and Awoke, 2015). However, the consumption of processed products like sour milks, cheese (kurth), khoya, butter and ghee have also been reported (Qureshi, 1986). Nevertheless, before processing for product manufacturing, milk has to go through certain thermal temperatures, which might bring changes in physical, chemical and sensorial properties of milk. The severity of changes depends upon the duration and extent of thermal temperatures. Therefore, this study was aimed to observe the impact of thermal treatment on physico-chemical characteristics of camel milk against buffalo milk.

2. MATERIALS AND METHODS

An *in vitro* study was designed with 2×4 factorial arrangements at the Department of Animal Products Technology, Faculty of Animal Husbandry and Veterinary Sciences, Sindh Agriculture University Tandojam. Two categories of milk (camel and buffalo) were treated with four thermal treatments (Ambient temperature/no heat treatment, 63^0C for 30 min., 72°C for 15sec and 90ºC for 10min). Two-way interaction of treatment variables was recorded to observe the significant impact of treatments over dependent variables (Physico-chemical and sensorial). A total of three trials each in duplicate batches were conducted, and in each batch, milk (camel/buffalo) was measured in four equal volumes and coded with A/A_1, B/B_1, C/C_1

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and D/D_1. Batch A/A_1 was kept as raw (at ambient temperature/no heat treatment), batch B/B_1 was treated with heat treatment of 63^0C for 30 min., batch C/C_1 was heated at 72°C for 15sec and batch D/D_1 was processed at 90ºC for 10min.

Analysis of physico-chemical characteristics: Milk (camel/buffalo) of all the batches was analyzed for titrable acidity, specific gravity, viscosity and conductivity, and moisture, whey protein, lactose and solids not fat contents (SNF) using standard methods of Association of Official Analytical Chemists (AOAC, 2000).

pH values: pH values were examined using pH meter (Hanna Instruments, Model No.H-8417). The electrode and temperature probe was dipped in milk sample, and the pH value appeared on the screen of pH meter was recorded.

Refractive index : The refractive index of milk samples was recorded using Refractometer (Model RX-5000α, ATAGO. Co. LTD, Tokyo, Japan).

Fat content: Fat content of milk sample was analyzed using Gerber method (James, 1995). Milk sample (11ml) was measured in butyrometer to which 90% sulfuric acid (10ml) and amyl alcohol (1ml) was added, and closed with rubber cork. Sample was thoroughly mixed and placed in a Gerber centrifuge machine (Funk Gerber, Model No. 12105, Germany). It was centrifuged for 5 min at 1100rpm, and transferred to water bath (pre- maintained at 65ºC) to separate clear layer of fat and dissolved components. The volume of transparent oily liquid was noted on the butyrometer scale as percent of fat.

NPN content: The method of International Dairy Federation (IDF, 1993) was followed to determine the NPN content of milk. Sample (10ml) was measured in a pre-weighed conical flask to which trichloro acetic acid (TCA) solution (40ml) was added, and contents with flask were weighed. After swirling/mixing of solution, it was left to stand approximately for 5min to allow the precipitate settle. Contents of the flask were filtered through filter paper into clean, dry conical flask, and then mixed filtrate (20ml) was analyzed for N %age. The protein equivalent of non-protein nitrogen content was calculated from the result by multiplying with 6.38 factors.

Denaturation: Denaturation percent was computed from whey protein nitrogen (raw milk) and whey protein nitrogen (heated milk) using following formula:

$$\text{Denaturation \%} = \frac{\text{WPN (raw milk)} - \text{WPN (heated milk)}}{\text{WPN (raw milk)}} \times 100$$

Whereas : WPN = Whey Protein Nitrogen

Statistical analysis: Computerized statistical package *i.e.* Student Edition of Statistic (SXW), Version 8.1 (Copyright 2005, Analytical Software, USA) was used to analyze the data. Statistical procedure of analysis of variance (ANOVA) under Linear Models was applied, and in case of significant differences the treatment variables were further differentiated using least significant difference (LSD) test.

3. RESULTS AND DISCUSSION

Thermal effect on physical characteristics of camel milk versus buffalo milk:

The present study revealed that the average acidity percent (Table-1) of both camel and buffalo milk was considerably increased with increase of treatment temperature. The acidity of control camel milk (0.13%) and heat treated milk at 65^0C (30min), 72^0C (15sec) and 90^0C (10min) (0.15, 0.16 and 0.17%, respectively) recorded significantly lower contrast to that of buffalo milk (0.16, 0.18, 0.19 and 0.20%, respectively). Similar increasing trend in acidity of camel milk was also reported in a study conducted by Arab (2017), who reported 0.14, 0.15, and 0.16%, in heat treated camel milk at above mentioned temperatures and time combinations, respectively. The findings of the present study also appeared in accordance with Alkaladi *et al.* (2014) who found significant effect of heat treatment on acidity and noted inverse proportional relationship between acidity with pH values. Results mentioned in Table-1 indicate remarkable and gradual decrease in the pH values of camel milk as well as of buffalo milk in a consequence of increase in temperature regime. The pH values of raw camel and buffalo milk appeared 6.51 and 6.48, respectively and application of heat treatment of 65ºC for 30min (LTLT) significantly decreased these values up to 6.45 and 6.44, respectively. Further, considerable ($P<0.05$) decrease in pH values occurred when these both type of milks were heated at 72ºC for 15 sec (HTST) (6.38 each) and at 90^0C for 10min (6.24 and 6.25, respectively). It is noteworthy that differences in pH values of raw as well treated camel milk versus buffalo milk existed non-significant ($P>0.05$). These results are disagreed with the findings of Alkaladi *et al.* (2014) who reported that the pH values slightly increased with heat treatments. They reported the pH value of 6.50 of camel milk heated at 63°C for 30 min in comparison to the pH value of control (6.40). These observations are agreed to the range of camel milk reviewed by Khan and Iqbal (2001). **(Table-1)** indicates the average specific gravity of camel milk versus buffalo milk. It was noted that specific gravity of camel milk with or without thermal treatments found prominently lower ($P<0.05$) in contrast to buffalo milk.

However, there was gradual significant decrease in specific gravity of camel milk as well as in buffalo milk with increase in heating temperatures. For instance, raw camel milk had specific gravity 1.026 and it was decreased to 1.024 at LTLT, 1.022 at HTST and 1.020 at 90^{0}C for 10min. It is of interest to note that the specific gravity of buffalo milk was also affected by thermal processing in similar manner. Raw buffalo milk had 1.032 specific gravity, and it was decreased to 1.031 for milk heated at LTLT, 1.029 at HTST and 1.027 at 90^{0}C for 10min. On contrary, Arab (2017) reported inverse trend in specific gravity of camel milk treated with LTLT, HTST and at boiling temperature. He noted 1.0298 specific gravity of raw camel milk and was increased with increase in thermal treatment i.e. 1.0319, 1.0306 and 1.0326, respectively at LTLT, HTST and on boiling temperature. Results shown in Table-1 revealed that raw camel milk had significantly ($P<0.05$) low viscosity versus buffalo milk (1.67 v/s 1.99cP).

Table-1 Influence of thermal treatment on physical characteristics of camel versus buffalo milk

Physical characteristic	Source of milk	Without treatment (Raw)	Thermal treatment			LSD (0.05)	SE±
			65°C (30 min)	72°C (15 sec)	90°C (10 min)		
Acidity (%)	Camel	0.13f	0.15e	0.16d	0.17c	0.0081	0.0039
	Buffalo	0.16d	0.18c	0.19b	0.20a		
pH values	Camel	6.51a	6.45b	6.38c	6.24d	0.0254	0.0123
	Buffalo	6.48a	6.44b	6.38c	6.25d		
Specific gravity	Camel	1.026e	1.024f	1.022g	1.020h	0.0008	0.0004
	Buffalo	1.032a	1.031b	1.029c	1.027d		
Viscosity (cP)	Camel	1.67f	1.79e	1.93d	2.28a	0.0815	0.0394
	Buffalo	1.99cd	2.08c	2.17b	2.31a		
Conductivity (mS/cm)	Camel	4.67g	4.79f	4.93e	5.28d	0.0815	0.0394
	Buffalo	5.72c	5.80c	5.90b	6.04a		
Refractive index	Camel	1.3445e	1.3443f	1.3441g	1.3439h	0.00082	0.00099
	Buffalo	1.3453a	1.3450b	1.3449c	1.3446d		

Means with different letters in same row varied significantly from one another.
Data are average of three trials each in duplicate.

However, in both cases, it was increased gradually with application of LTLT treatment (1.79 and 2.08cP, respectively) followed by HTST (1.93 and 2.17cP, respectively) and 90^{0}C for 10min (2.28 and 2.31cP, respectively). Nevertheless, the increase in viscosity of thermally treated milk (camel v/s buffalo) found significant except at 90^{0}C for 10min where differences were non-significant ($P>0.05$). It is noteworthy, that evaporation of moisture content had occurred due to application of heat treatment which indirectly enhanced the proportion of total solids content in milk, and eventually resulted in increase in viscosity accordingly (El-Agamy, 2009). Findings of present study are in line with reported study of Yoganandi *et al*. (2014). The conductivity of buffalo milk and camel milk was affected markedly by the different thermal treatments (Table-1). The mean conductivity was observed as 4.67 and 5.72mS/cm, respectively for non-heated camel and buffalo milk and it was increased to 4.79 and 5.80mS/cm, respectively for milk heated at LTLT, 4.93 and 5.90mS/cm, respectively for HTST and 5.28 and 6.04mS/cm, respectively for 90°C treated milk. Current findings are in line with Arab (2017) who observed slight increase in conductivity of camel milk with application of heat treatments. Refractive index of camel milk was noted markedly different from that of buffalo milk either treated at LTLT, HTST, 90°C and/or without heat treatment (raw). The refractive index of non-heated camel and buffalo milk was recorded as 1.3445 and 1.3451, respectively, and it was decreased to 1.3443 and 1.3450, respectively at LTLT, 1.3441 and 1.3449, respectively, at HTST and 1.3439 and 1.3446, respectively at 90°C. The findings of Yoganandi *et al*. (2014) supported the results of present study. They reported that the refractive index of milk is directly related with its total solids and/or moisture content. However, the findings of Arab (2017) are not in line with the findings of the present study, who noted no significant change in refractive index of control and treated camel milk samples with the application of thermal treatments.

Thermal effect on chemical characteristics of camel milk versus buffalo milk:

The thermal influence on total solids (TS) content of camel milk v/s buffalo mentioned in **(Table-2)** showed increasing trend with application of increase in heat treatment. TS content of raw camel milk appeared comparatively low (10.63%) against buffalo milk (14.72%) and similar trend was noted when heat treatment was applied at LTLT (10.58 V/S 14.8%, respectively), HTST (10.69 V/S 14.90%, respectively) and/or at 90°C for 10 min (10.79 V/S 15.04%, respectively). TS content of camel milk although varied at LTLT V/S HTST yet found statistically similar to each other, while significantly ($P< 0.05$) different at 90°C for min. In case of buffalo milk, there were no significant influence of thermal treatment of LTLT on TS content but when it was increased to HTST and 90°C for 10 min, there were significant gradual increase in TS content (14.90 and 15.04%, respectively). On contrary, Farah (1996) reported that the LTLT did not affect the chemical composition of camel milk. However, findings of Hattem *et al.* (2011) support the present study where they found an increase in the concentration of TS content of raw milk from 9.9% to 10.0, 10.05 and 10.16% when heated at LTLT, HTST and 90^{0}C for 30 min., respectively. It is noteworthy, that there were wide variation in TS content of milk of camel v/s buffalo, thus in order to observe the prominent differences in organic and inorganic component of camel milk V/S buffalo milk, the data were further computed on dry matter basis (DMB). Table-2 reveals that although there were slight gradual increase in fat content of raw camel milk with application of LTLT and HTST treatment (from 27.83 to 28.27 and 28.58% DMB, respectively), but this increase in fat content existed statistically non-significant ($P> 0.05$). However, there was significant increase in fat content at thermal application of milk at 90°C for 10 min against raw camel milk (from 27.83 to 29.56% DMB). Similarly, for fat content of buffalo milk, the trend of increase in fat content was similar to camel milk, but significant ($P < 0.05$) variation was observed at thermal treatment of HTST and of 90°C for 10 min (from 37.87 to 39.02 and 39.16% DMB, respectively).

Table-2 Influence of thermal treatment on chemical characteristics (% DMB) of camel versus buffalo milk

Chemical component	Source of Milk	Without treatment (Raw)	Thermal treatment			LSD (0.05)	SE±
			65ºC (30 min)	72ºC (15 sec)	90ºC (10 min)		
Total solids content (%)	Camel	10.58f	10.63ef	10.69e	10.79d	0.0852	0.0412
	Buffalo	14.72c	14.80c	14.90b	15.04a		
Fat content (%DMB)	Camel	27.83e	28.27e	28.58e	29.56d	0.8107	0.3919
	Buffalo	37.87c	38.56bc	39.02ab	39.46a		
Protein content (%DMB)	Camel	30.14a	30.48a	30.63a	31.05a	0.9184	0.4440
	Buffalo	26.86c	27.65bc	28.12b	28.35b		
Lactose content (%DMB)	Camel	33.62a	33.22a	31.33b	29.08c	1.3279	0.6419
	Buffalo	29.37c	26.95d	25.50e	24.10f		
Ash content (%DMB)	Camel	7.63e	8.82c	9.46b	10.31a	0.2345	0.1134
	Buffalo	5.90h	6.85g	7.36f	8.08d		
Solids not fat content (%DMB)	Camel	72.17a	71.73a	71.42a	70.44b	0.8107	0.3919
	Buffalo	62.13c	61.45cd	60.98de	60.54e		

Means with different letters in same row varied significantly from one another.
Data are average of three trials each in duplicate.

(Table-2) further indicates a comparative variation in fat content of camel milk versus buffalo milk, whereby fat content appeared comparatively (($P< 0.05$) abundant in buffalo milk in each of raw and thermal treated milk. One of the reasons behind this might be attributed with extent of heat treatment applied to milk that may have induced the evaporation of water from milk parallel to their corresponding temperatures resulting increase in the total solids content . Ultimately fat content was increased over total solids contents accordingly. Present trend of increase in fat content appeared relatively similar to that of recorded by Arab (2017) and Alkaladi *et al.* (2014). They also found gradual increase in the fat content of camel milk when heated at 63, 72 and 90°C, respectively. Nevertheless, Hattem *et al.* (2011) disagreed with the present findings; they reported that the similar heat treatments had no significant influence on fat content. Results presented in the Table-2 reveals that thermal treatments of LTLT, HTST and 90°C for10 min had no significant influence on protein content of camel milk, although slight increase occurred in contrast to raw camel milk (from 30.14% DMB to 30.48, 30.63 and 31.04% DMB, respectively). In case of buffalo milk, LTLT treatment (27.65% DMB) did not show any significant variation ($P>0.05$) in protein content against raw buffalo milk (26.86% DMB), while at heat treatment of HTST and 90°C for10 min (28.12 and/or 28.35% DMB, respectively), it varied significantly ($P>0.05$). Similar trend of increase in protein content of raw camel milk parallel to increase in heat treated milk was reported in study conducted by Arab (2017) *i.e.* control milk 2.74% and heat treated at 63, 72 and 100°C 2.85, 2.78 and 2.99%, respectively. Parallel effect of heat treatments on the protein content of camel milk was recorded by Hattem *et al.* (2011) *i.e.* 3.2% in raw milk and 3.2, 3.3 and 3.4%, respectively in milk heated at LTLT, HTST and 90^0C for 30min. Table-2 shows that the average lactose content in raw camel milk gradually decreased with increase in application of heat treatment of LTLT, HTST and 90°C for 10min (from 33.62 to 33.22, 31.33 and 29.08% DMB). However, this decrease in lactose content of raw camel milk versus LTLT treated milk found statistically non-significant ($P> 0.05$), while versus HTST and 90°C for 10min significant ($P< 0.05$). Table-2 further reveals that there was comparative ($P< 0.05$) gradual decrease in lactose contents of raw buffalo versus heat treated milk at LTLT, HTST and 90°C for 10min (from 29.37 to 26.95, 25.50, and 24.10% DMB, respectively). The present result did not match with the findings of Arab (2017) and Elamin and Wilcox (1992), who reported slight increase in lactose content of camel milk with increase in temperature and time combination. Average ash content of raw camel milk (Table-2) was noted as 7.63% DMB and it was increased to 8.82, 9.46 and 10.31% DMB, respectively at application of thermal treatment of LTLT, HTST and 90°C for 10 min). In case of ash content of buffalo milk (5.90% DMB), the increase observed as 6.85, 7.36 and 8.08% DMB, respectively at thermal treatment of LTLT, HTST and 90°C (10 min). The increasing trend in ash content of both camel and buffalo milk was observed significant ($P<0.05$) with increase in heating temperature. Similar trend for ash content was recorded in different studies conducted by Hattem *et al. (*2011) and Arab (2017) in camel milk under different heat treatments *i.e.* from 0.68% to 0.70, 0.71 and 0.73%, respectively in raw milk versus thermal treated milk (LTLT, HTST and 90°C for 10 min). Results mentioned in Table-2 reveal gradual decrease in SNF contents of camel and buffalo milk with increase in thermal application. Moreover, the SNF content in raw camel milk was 72.17% DMB and it was decreased to 71.73, 71.42 and 70.44% DMB, respectively at thermal treatment of LTLT, HTST and 90°C for 10min. This decrease in SNF content of camel milk was only significant ($P<0.05$) at thermal temperature of 90°C for 10min. SNF content in raw buffalo milk recorded as 62.13% DMB and it was gradually decreased to 61.45, 60.98 and 60.54% DMB in buffalo milk, respectively at LTLT, HTST and 90°C for 10 min. Although decrease in SNF content was linear, but comparative variation was observed at HTST and 90°C for 10 min. Present findings are supported by Hattem *et al.* (2011) who found significant influence on the chemical composition of milk heated at different thermal treatments. It is surprisingly to note that protein, lactose, ash and SNF contents in camel milk were found significantly ($P<0.05$) abundant versus buffalo milk in each of raw as well as heat treated milk (LTLT, HTST and 90°C for 10min).

Thermal effect on protein fractions of camel versus buffalo milk:

Table-3 indicates that there were gradual increase in casein and Non casein contents and decrease in non-protein and whey protein contents of both type milk (camel and buffalo) with increase in thermal temperatures (*i.e*. LTLT, HTST and 90°C for 10 min). In the current study the average of casein content in control/raw camel milk was recorded as 21.25% DMB, and it increased to 21.72, 21.98 and 22.18% DMB, respectively LTLT, HTST and 90°C for 10 min. Similarly in buffalo milk, the casein content of control/raw milk noted as 17.97% DMB, and it increased to 18.52, 18.83 and 19.28% DMB, respectively at above said thermal temperatures. Present findings are in accordance with reported study of Hattem *et al.* (2011), who found 72.622% of casein content in control milk, while 74.814, 77.783 and 88.792% for casein of thermally heat treated milk (LTLT, HTST and 90^0C for 30min., respectively).

Similarly, the present results also correlate with the findings of Hassan *et al.,* (2009) who found mean value of 0.348 and 0.391% for casein of control and heated milk (85^0C minutes 5min.). **(Table-3)** illustrates that the non casein nitrogen, over control and/or against heat treatments of LTLT and HTST remained significantly ($P< 0.05$) low in camel milk (1.0287, 0.9657 and 0.8481% DMB, respectively) compared to that of buffalo milk (1.377, 1.0336 and 0.8484% DMB, respectively). On the other hand, at higher thermal temperature of 90°C (10min), the concentration of NCN content was inverse whereby it was low in buffalo milk (0.6026% DMB) contrast to camel milk (0.6920% DMB). Present findings are in line with reported studies of Arab (2017) and Hattem *et al.* (2011), they also noted decreasing trend in Non casein nitrogen of camel milk with increase in application of thermal temperature to milk. The average NPN content in control buffalo milk observed as 0.0942% DMB and it reduced to 0.0907, 0.0835 and 0.0753% DMB, respectively at LTLT, HTST and 90°C for 10min. Nevertheless, NPN content of raw camel milk noted to be 0.1260% DMB, the decrease was noted as 0.1193, 0.1113 and 0.1008% DMB, respectively on above said thermal temperatures. The NPN content was remarkably high in camel milk than that of raw buffalo milk at LTLT, HTST and/or at 90°C for 10min. **(Table-3)**. These results correlate with the observation of Hassan *et al.* (2009) who reported the average value for NPN of control and heat treated (85^0C/5min.) as 0.029 and 0.025%, respectively.

Table-3 Influence of thermal treatment on protein fractions (% DMB) of camel versus buffalo milk

Protein fraction	Source of Milk	Without treatment (Raw)	Thermal treatment			LSD (0.05)	SE±
			65°C (30 min)	72°C (15 sec)	90°C (10 min)		
Casein content (%DMB)	Camel	21.25c	21.72b	21.98a	22.18a	0.2374	0.1148
	Buffalo	17.97g	18.52f	18.83e	19.28d		
Non casein nitrogen (%DMB)	Camel	1.0287b	0.9657c	0.8481d	0.6920e	0.0115	0.0055
	Buffalo	1.3770a	1.0336b	0.8484d	0.6026f		
Non protein nitrogen (%DMB)	Camel	0.1260a	0.1193b	0.1113c	0.1008d	0.00498	0.0024
	Buffalo	0.0942e	0.0907e	0.0835f	0.0753g		
Whey Protein (%DMB)	Camel	4.84c	4.52d	3.89f	3.04g	0.0530	0.0256
	Buffalo	5.79a	5.17b	4.07e	2.63h		

Means with different letters in same row varied significantly from one another.
Data are average of three trials each in duplicate.

Furthermore, Hattem *et al.* (2011) also obtained the same results for NPN of control as 0.40% whereas, 0.038, 0.038 and 0.037% of thermally treated (63^0C/30 min., 7 2^0C for 15 seconds and 90^0C for 30min., respectively) camel milk. In the current investigation the percent of whey protein decreased with increase in thermal treatment (Table-3). The average percent of whey protein in raw camel milk and/or of buffalo milk found 4.84 and 5.78% DMB, respectively, and their percent declined to 4.52, 3.89 and 3.04% DMB, and 5.17, 4.07 and 2.63% DMB, respectively at LTLT, HTST and/or 90°C (10min) thermal treatments. The concentration of whey protein was significantly ($P<0.05$) more in buffalo milk contrast to that of camel milk at thermal treatment of LTLT and HTST but at 90°C (10min.) its level was inverse. Findings of present study are in line with the results of Arab (2017) who also reported relatively similar concentration of whey protein in thermally treated camel milk. Decreasing trend in whey protein was reported in different studies in thermally treated camel milk (Hattem *et al.*, 2011; Hefnawy and Mehana, 1988). It was noted that there were linear increase in denaturation percent in both of camel and buffalo milks with increase in thermal temperatures. The denaturation occurred comparatively more in buffalo milk than camel milk at each thermal temperature of LTLT, HTST and 90^0C for 30min. The average denaturation percent in buffalo and camel milk at LTLT thermal treatment was noted as 10.18 and 6.99%, respectively and was increased to 28.87 and 19.26%, respectively at HTST and 53.62 and 36.21%, respectively at application of 90°C (10min). The present findings are in line with Farah (1996) who reported that LTLT cause little denaturation in comparison to high temperature (80^0C and 90^0C) which cause 70 to 80% denaturation. Similarly, Arab (2017) and Hattem *et al.* (2011) were in opinion of similar trend in increase in denaturation in camel milk, whereby they attributed an increase in denaturation percent with extent of thermal temperature.

4. CONCLUSIONS

Linear increase/decrease in physico-chemical characteristics appeared with extent of thermal treatment applied to camel and/or buffalo milk. Raw camel milk was recorded more acidic and low in specific gravity, viscosity, conductivity and refractive index; and rich in protein, SNF, ash and casein contents, while poor in total solids, fat, non-casein nitrogen, non-protein nitrogen and whey protein contents against buffalo milk. The increase in denaturation percent in camel milk was not comparable with buffalo milk.

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