**Some aspects of the ethanol stability of red deer milk (*Cervus elaphus hispanicus*):
a comparison with other dairy species**

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ABSTRACT

The ethanol stability, a freshness and heat stability indicator, of Iberian red deer milk was determined. Additionally, the interspecific differences in composition, physical, hygienic and technological parameters, in bulk tank milk obtained from red deer, sheep, goats and cows were compared. Red deer milk ethanol stability was similar to that of sheep milk; bovine milk was the most stable and goat milk the least. Ethanol stability was influenced by pH; within the range studied, increased pH increased stability, this effect being more noticeable in bovine milk than in milk from the other species. Milk composition presented evident differences among species, as did somatic cell counts, total bacterial count, pH and titratable acidity or density. The results suggest that milk of red deer is very similar to that of sheep, but is even richer in fat and proteins, making it an interesting and novel product with high potential in dairy industry.

1. Introduction

Mammalian milk is designed to provide the necessary nutrients and energy for the growth and development of the neonate during the first months of life. Additionally, recognition of the benefits of including milk from other species in the human diet has led to the development of the dairy industry, where cow and buffalo milks comprise more than 96% of the global milk production (FAOSTAT, 2016). The other three commercial species noted in FAOSTAT (2016), goat, sheep and camelids, account for about 3.5% of the total milk production. However, other minor dairy species play an important role because of their nutritional, economic, social or cultural value in certain regions of the world. This is the case for mare, yak, reindeer, or moose milk (Claeys et al., 2014; Medhammar et al., 2012).

Milk from these and other species is generating interest due to its potential bioactive properties. Research into mare, donkey or dromedary camel has increased knowledge of the proteins, peptides (Chianese et al., 2010; Guo et al., 2007; Mazhitova & Kulmyrzaev, 2016), fatty acids and mineral profile (Claeys et al., 2014) or antimicrobial, antioxidants (Kumar, Chatli, Singh, Mehta, & Kumar, 2016), and antidiabetic (Malik, Al-Senaidy, Skrzypczak-Jankun, & Jankun, 2012) properties of milk from these species. This is also the case for red deer milk where it has been noted that whey proteins and whey peptides showed bioactive and health-promoting properties (Ha, Bekhit, McConnell, Mason, & Carne, 2014). In addition, the protein digestibility of red deer milk is higher than cow milk (Opatha Vithana, Mason, Bekhit, & Morton, 2012) and the potential of red deer milk in terms of cheese production has been suggested because of its good performance, due to the high content in caseins and fat (Ha et al., 2014).

Cheese production trials performed developed recently in New Zealand (Ashton, 2013) and Spain (unpublished data) have shown high cheese yields (more than 30%) revealing the aptitude of red deer milk for a future dairy industry. The technological suitability of red deer milk to elaborate fermented milks has been previously confirmed by Garcia-Rodríguez (2012) who studied the effect of lactation period (over 14 weeks) on the characteristics of plain yoghurt. In countries like New Zealand deer have been farmed only for meat or velvet production, but in recent years the potential for developing dairy farms is increasing and producers' expectations about the milk use are promising (Ha et al., 2014).

Although knowledge on the characteristics of red deer milk is limited, several studies have focused in the influence that lactation stage, breed (Landete-Castillejos, García, Gómez, Molina, & Gallego, 2003b), birth date (Landete-Castillejos et al., 2000; Landete-Castillejos, García, Gomez, Berruga, & Gallego, 2005a), induced calving delays (Landete-Castillejos, Garcia, Gómez, Berruga, & Gallego, 2004), calving sex (Landete-Castillejos, García, López-Serrano, & Gallego, 2005b) or feeding (Landete-Castillejos, García, Gomez, & Gallego, 2003a) have on milk yield and/or composition. As for other cervid species, red deer milk is characterised by a high concentration of dry matter (26.7%), proteins (7.6%) and fat (11.5%) (Landete-Castillejos et al., 2000), presenting it as a good nutritious candidate for dairy industry.

When launching a new product of animal origin, it needs to be ensured that the product fulfils the quality and hygiene requirements expected by consumers and established by authorities. In this sense, it is of significant importance to establish the main physicochemical properties of red deer milk and compare this with those of the most important commercial dairy species because variations in milk properties modify the technological features of the milk. Besides milk composition, other parameters as

density or viscosity, as well as colour, conductivity or pH may provide interesting information about the suitability of deer milk for the production of some specific dairy products.

In this way, ethanol stability is frequently used in several countries as a milk freshness indicator in ruminants and also provides information about the heat stability of milk for dairy processes (Chen, Lewis, & Grandison, 2014; Horne, 2016; Molina, González, Brito, Carrillo, & Pinto, 2001). Ethanol stability is defined as the minimum concentration of added aqueous ethanol that gives rise to milk coagulation, and differs from one to another species (Chavez, Negri, Taverna, & Cuatrín, 2004; Chen, Grandison & Lewis, 2012; Guo et al., 1998; Horne, 2016). The aim of this work was to study the ethanol stability and other physicochemical and hygienic-sanitary properties of red deer milk for a potential use in making dairy products. A second objective was to compare the properties of this milk with that of other commercial dairy species (cow, goat and sheep) in the Mediterranean area.

2. Materials and methods

2.1. Milk Sampling

During 2016, raw milk from a herd of 26 red deer hinds of the Iberian subspecies *Cervus elaphus hispanicus* was sampled in the middle of the lactation period (weeks 6 to 10). Animals were housed in an outdoor enclosure (5000 m²) located at the Experimental Farm of the University of Castilla-La Mancha (Spain), and milking was conducted according to Landete-Castillejos et al. (2000). Due to the seasonality in the milk production of hinds (May–September), and the difficulties in milking these semi-

wild animals, the sampling was planned over the weeks of the lactation peak (from 6th to 10th weeks of lactation), of the total number of hinds milked at that time. Milk was kept at 4 °C until analysis (not longer than 12 h) at the Dairy Quality Laboratory of the University of Castilla-La Mancha (Albacete, Spain). Furthermore, bulk tank milk from Holstein cows, Manchega ewes and Murciano-Granadina goats was analysed in this study. For each one of the target species three different commercial farms of Castilla-La Mancha region were sampled over three different periods (4-month intervals), obtaining nine samples from each species. All samples were collected from bulk tanks after 10 min of milk agitation, immediately kept under refrigeration (around 4 °C) and transported to the laboratory for analysis (less than 2 h after collection).

2.2. *Chemical, microbial and physical analysis*

Gross composition (protein, fat, lactose and total solids) was determined with an infrared spectrophotometer MilkoScanTM Minor Type 78100 (Foss Electric, Hillerød, Denmark). Additional information on somatic cell counts (SCC) and total bacterial count (TBC) were obtained using a DeLaval Cell Counter DCC (DeLaval, Tumba, Sweden) and a MicroFossTM 32 system (Foss Electric), respectively. Both parameters, total viable count and SCC, were normalised and converted to log₁₀ TBC and log₁₀ SCC, respectively. The pH was measured using a Crison model GLP 22 pH meter (Crison, Barcelona, Spain) with a 5223 probe (Crison) and the titratable acidity was determined in milk by Dornic method using 0.111 M NaOH, with 100 µL phenolphthalein as an indicator, and expressed in g of lactic acid per 100 mL. The conductivity of the different milk samples was measured using a conductivity meter Crison model Basic 30, with a EC 5293 probe (Crison). To determine the density of raw

milk a lactodensimeter (Gerber Instruments AG, Effretikon, Switzerland) tuned from 1.020 to 1.040 g cm⁻³ was used and measurements were carried out at 20 ± 1 °C. Milk viscosity analysis was performed using a digital rotational viscometer model Visco Basic Plus L (Fungilab, Barcelona, Spain), with a Low Viscosity Adapter LCP/B (Fungilab). The measurements were performed at 25±0.5 °C, with spindle rotation ranging from 200 to 250 rpm(10 rpm intervals) every 30 s. The viscosity value was set by the average of 2 measures.

Milk colour was measured using a Minolta CR-400 colorimeter (Minolta Camera Co., Osaka, Japan) with a CR-a33f cone and a calibrated white plate (Minolta 11333110) with Y = 93.1, x = 0.3160 and y = 0.3323. D65 illuminant and a 10° angle of vision were used. CIE L*, a* and b* coordinates were obtained, where L* corresponds to brightness, a* value to the red-green component and b* value represents the yellow-blue component. The colour measurement was made according to Licón, Carmona, Rubio, Molina, and Berruga (2012) using transparent polystyrene 60 mL bottles (Deltalab, Barcelona, Spain) that contained 50 mL of the sample, by introducing the colorimeter 2 mm in the liquid and using a white background. Duplicate measurements for every sample at each sampling time were taken.

Ethanol stability (ES) was measured by mixing equal volumes (2 mL) of a milk sample and an ethanol solution (water/ethanol ranging from 10 to 100%, v/v, at 2% intervals) at room temperature. The minimum concentration (% v/v) of the ethanol solution required to coagulate an equal volume of milk sample was defined as the ethanol stability of milk. Each sample was evaluated by three observers using a visual scale, identifying clot formation as positive according to Chen et al. (2012). The effect of pH on ethanol stability was also determined by adjusting the pH of the milk samples

in the range 5.7–7.1 at intervals of 0.2 pH units by adding HCl or NaOH (0.1, 1 or 2 M) before addition of the ethanol solutions.

2.3. Statistical analysis

Statistical analyses were performed with SPSS 24.0 statistical software package (SPSS Inc., Chicago, IL, USA). Numerical data presented in this study are expressed as mean value for each parameter $\pm$ the corresponding standard deviation of the mean. One-way analysis of variance (ANOVA) was applied to test the significance of differences between groups mean values for each parameter, declaring statistical significance at $P \leq 0.05$. Tukey's post hoc tests were then conducted to compare the magnitude of the difference between mean values for each of the groups.

3. Results and discussion

3.1. Red deer milk and species-specific differences in the properties of milk

The mean values obtained for composition, hygienic and sanitary parameters in milk samples collected from the species studied are given in Table 1. Red deer milk contains higher total solids than milk from the other species at a significant level ($P < 0.001$), whereas cow milk showed the lowest concentrations in all components. A moderate variability in composition of red deer milk has been found in literature (Arman, Kay, Goodall, & Sharman, 1974; Krzywinski et al., 1980); however, values obtained in this study are similar to those reported by Landete-Castillejos et al. (2000) for this breed. Milk from ewes and goats showed intermediate mean values, with the

former richer in fat and protein. Of note is the high fat concentration observed in goat milk samples that is associated with Murciano-Granadina breeds, as reported in similar studies (Ceballos et al., 2009; Vara Martínez et al., 2018). As for milk composition, our results evidence remarkable disparity between species; nevertheless other factors such as diet, breed, environmental, stage of lactation and health status of the udder might have a significant impact on the composition of major and minor components of the milk (Park, Juárez, Ramos, & Haenlein, 2007).

For SCC, the lowest value was observed in deer milk (Table 1). Little attention has been given to the sanitary aspects of red deer milk production and no further information has been found in literature regarding the SCC in milk from this species. The values obtained in deer milk are similar to those observed in reindeer bulk raw milk (Kurki, Pitkälä, & Nieminen, 2004), and reveals a good overall health of the herd during the research period. When comparing with the other commercial species, significant differences were found between red deer and cow milk compared with sheep or goat milk ($P < 0.001$). As expected, the SCC were about 0.5–1 log units higher in milk from goats and sheep (Table 1) due to the presence of higher basal levels than in dairy cows, among other factors related to herd management (Leitner et al., 2016; Silanikove, Leitner, Merin, & Prosser, 2010). These physiological differences in the process of milk secretion established a lack of justification for applying cow milk regulatory standards to milk from small ruminants, and this contributed to the legislation of a specific regulation for sheep and goat (EU, 2004; PMO, 2015). The low SCC found in deer milk indicates its good quality from safety perspectives (this milk complies with EU regulations for cow milk). SCC is considered a sensitive marker of udder health condition in ruminants (Raynal-Ljutovac, Pirisi, de Crémoux, & Gonzalo,

2007; Souza et al., 2012) and is widely used for evaluating milk quality and ranking milk prices in dairy cattle (EU, 2004; PMO, 2015).

Under our conditions, TBC of red deer milk was similar to that found in sheep and goats' milk, but significantly higher than the counts observed in cows' milk ($P < 0.01$). This parameter is known to be dependent on the hygiene in milking and handling of milk, so these values do indeed reflect the level of modernisation and technology of installations in dairy farms. As for SCC, specific requirements for TBC of raw milk destined for human consumption are laid down in EU and American legislation (EU, 2004; PMO, 2015). Values obtained in milk from small ruminants meets the criteria established by legislation for milk intended for the manufacture of products involving heat treatments. There is, however, a need for improvement of the hygienic conditions under which milk is obtained in these farms, to reach similar levels as present in bovine holdings.

It has been widely reported that the physical properties of milk are related to its composition and animal species (Park et al., 2007). The values obtained in the study of the physical parameters are shown in Table 2. Thereby, the fat content in combination with the concentration of total solids in milk has a determining influence on its density, as other authors have already described (Gabas, Alexandre, Cabral, Fernandes De Oliveira, & Telis-Romero, 2011). Our results clearly show that the two species that produce the more concentrated milks, red deer and sheep, are those that have the highest density values ($P < 0.001$). Compared with the other dairy species mean pH of red deer milk was similar to that of sheep milk but lower than that of cows' or goats' milk ($P < 0.01$). The lower pH of red deer milk has been previously reported by Opatha Vithana et al. (2012) and Wang, Bekhit, Morton, and Mason (2018) and highlighted a significantly greater buffering capacity than any of the other milks, attributable to the higher protein

and mineral contents (Gallego, Landete-Castillejos, García, & Sánchez, 2006; Wang et al., 2018). These differences were also appreciated when the titratable acidity was evaluated (Table 2). Along with pH, titratable acidity provides information about total solids content of the milk as well as freshness, making it a very important feature when defining quality.

Taking into account that all milks were sampling and analysed in a very short period we can assume that acidity parameters express mainly the natural acidity and not developed acidity. Acidity of red deer milk is comparable with that of sheep milk, both being much higher than those of goat and cow milk ($P < 0.001$). Previous studies with milk deer did not provide information about this parameter; however, the values obtained in the cow, goat and sheep species are in accordance with those suggested by other authors (Machado, Fischer, Stumpf, Stivanin, 2017; Mahmood & Usman, 2010; Park et al., 2007).

Regarding the electrical conductivity of milk (EC), the lowest value was obtained for the red deer milk (Table 2). This value, together with that obtained in sheep milk were significantly lower ($P < 0.001$) than those observed in cows' and goats' milk (4.68 and 5.30 mS cm⁻¹, respectively). The results obtained in this study were similar to those described in the literature for sheep, cow and goat, which ranged from 4.00 to 5.50, 5.04 to 5.65 and 5.01 to 5.67 mS cm⁻¹, respectively (Diaz et al., 2011; Park et al., 2007; Yoganandi, Mehta, Wadhwani, Darji, & Aparnathi, 2014); however, no previous studies of conductivity in red deer milk were found. The differences among species in the mineral composition may be the possible origin of these disparities, as electrical conductivity in milk is mainly attributed to its salt content; however, other factors could also come into play, such as stage of lactation, season or feed (Mabrook & Petty, 2003).

The importance of electrical conductivity in milk lies in its practical application.

In fact, this parameter has been widely studied in dairy cattle as a mastitis detection method, providing useful results in cows as well as moderate use in small ruminants (Lien, Wan, & Ting, 2016; Romero, Pantoja, Sendra, Peris, & Díaz, 2012; Romero, Roca, Alejandro, Muelas, & Díaz, 2017). Red deer milk showed SCC similar to that cow milk; however, its conductivity was closer to that sheep. Bearing in mind that the Na/K ratio described for these three species is very similar (Chavez et al., 2004; Gallego et al., 2006; Park et al., 2007), this greater similarity between red deer and sheep milk could be explained by its calcium content, which, according to literature, presents very similar levels (Gallego et al., 2006; Park et al., 2007).

The comparative study of colour was performed by determining the chromatic coordinates of the milk samples (Table 2). The colour of red deer milk was closer to that of sheep than the other species, both being brighter (L^* coordinate) than cows' or goats' milk ($P < 0.001$). As for the redness (a^* coordinate), significant differences were found between goats' milk and the other studies species ($P < 0.001$), while yellowness (b^* coordinate) was significantly higher in red deer milk, followed by sheep, and being lower in cows' and goats' milk ($P < 0.001$). Slight variations in colour from one species to another may be due to chemical differences in the milk of these species. In this regard, it has been reported that cows' milk has higher carotene content than sheep's milk (Balthazar et al., 2017), while, on the other hand, the absence of this compound in goats' milk may be due to its ability to convert β -carotene to vitamin A. This, together with the smaller diameter of fat globules may be the reason why goats' milk is generally whiter (Lucas, Rock, Agabriel, Chilliard, & Coulon, 2008; Park et al., 2007).

Viscosity differences among species was less noticeable but significant (Table 2). The results obtained revealed a higher viscosity in milk from deer and sheep in comparison with cows' and goats' milk at a highly significant level ($P < 0.001$). Other

authors proposed similar viscosity values for cow, goat and sheep milk (Park, 2007; Prajapati et al., 2017; Roman, Vojtech, Sarka, & Kvetoslava, 2015); however, no information about deer milk has been found. Since milk is an emulsion of fat globules dispersed in a fluid that contains dissolved carbohydrates and protein aggregates with minerals (Brans, Schroën, van der Sman, & Boom, 2004), the knowledge of its physical behaviour, specially flow behaviour, is important as it could help to optimise the processes of storage and transport of milk to reduce technical and economic losses in the dairy industry (Kumbár & Nedomová, 2015).

3.2. *Ethanol stability*

The results obtained in the ethanol stability test of raw milk from red deer, sheep, goat and cow (Table 2) confirm significant differences among species ($P < 0.001$). At a natural pH value, the average ES for red deer's milk closely resembles that of sheep's milk (62 and 63%, v/v, respectively), both being slightly but significantly higher than that of goats' milk (50%, v/v) but far lower compared with bovine milk (83%, v/v), which proved to be the most stable to high ethanol concentrations of the four species discussed. These data are consistent with previous studies carried out on sheep and goat milk (Fava et al., 2014; Guo et al., 1998) while, for bovine milk, values obtained were intermediate to those reported by other authors (Chavez et al., 2004; Chen, Lewis, & Grandison, 2014; Davies & White, 1958).

It is worth noting that all bovine samples were above 74% (v/v), which is the recommended threshold for UHT processing (Chen et al., 2014), also complying with limits set up by regulations of the countries that still use the alcohol test to measure the freshness and the microbiological quality of milk, such as Argentina or Spain (FIL-IDF,

1969; RD, 2008). Apart from the slight variation just mentioned, this research noted a remarkable difference in ES stability of goats' milk compared with that of cows' milk, which has been previously reported (Guo et al., 1998; Horne & Parker, 1982; Sánchez-Macías, Moreno-Indias, Castro, Morales-delaNuez, & Argüello, 2014).

In this context, Guo et al. (1998) found that the lower stability of goats' milk compared with that of cows' milk may be due to sodium and potassium balance. They observed that Na/K ratio of goat milk is usually lower than that of cows', also noting that the addition of sodium to goat milk increases its Na/K ratio thus stabilising casein micelles. Although in this work the mineral content was not studied, based on previous research (Chavez et al., 2004; Gallego et al., 2006; Guo et al., 1998; Park et al., 2007; Vergara, Landete-Castillejos, Garcia, Molina, & Gallego, 2003) the calculated Na/K ratios in milk are 0.29 for deer, 0.32 for sheep, 0.23 for goat and 0.30 for cow. These values are consistent with ES obtained, revealing a clear relationship between ES and Na/K ratio for all species discussed and confirming, therefore, the observations of Guo et al. (1988). Also, the ionic calcium concentration in milk, that was superior in goats' milk and intermediate in sheep's milk (Lewis, 2011), could influence in its lower stability (Davies & White, 1958) and contribute to a poorest heat stability.

High values of TBC are also related to low milk stability, probably due to proteolysis and lactose degradation that result in lower pH and calcium phosphate values, further increase in ionic calcium concentration and micelle destabilisation (Machado et al., 2017). In this regard, the values obtained in the present work showed a weak-but statistically significant-correlation between ES and bacterial content (-0.48 ; $P < 0.01$, data not shown), converging with the above-mentioned findings. Nevertheless, milk stability is a complex matter and many other properties of milk have been associated with low ES, such as acidity, phosphate and citrate contents, ionic calcium

concentration and ionic strength (Chavez et al., 2004; Davies & White, 1958; Horne, 2016; Machado et al., 2017).

3.3. *Effect of pH on ethanol stability*

Early studies of ES were based on single-point assays at the natural pH of the milk; however, it has been found that the artificial adjustment of the pH of milk markedly alters the value of its stability towards ethanol-induced coagulation, providing a ES to pH profile characteristic of an individual milk (Horne & Muir, 1990). From a technological point of view, it is interesting to know how fast milk proteins are destabilised by acidification since it allows the establishment of the suitability of milk for the production of certain dairy products. To this end, a comparison of the typical ethanol stability/pH profiles of raw milk from red deer, sheep, goat and cow is shown in Fig. 1.

The ES/pH profile displays a distinctive sigmoidal shape with an inflexion point occurring over a narrow range of natural pH. At the alkaline arm of the pH profile ES increased substantially as the pH of milk rises while on the acid side of the natural pH the stability was less affected by pH variations. Both aspects of this behaviour can be observed in the four species studied. As expected, milk acidification reduce ethanol stability, which is consistent with the results of other reports (Davies & White, 1958; Guo et al., 1998; Horne, 2016; Tsioulpas, Lewis, & Grandison, 2007). These studies indicate that milk stability is negatively related to acidity since the reduction in pH of milk decreases calcium phosphate caseinate content and increases ionic calcium concentration, which reduces repulsion forces among caseins and favours coagulation of milk.

The results of our study indicated that no significant differences were found in ES mean values between red deer and sheep milk throughout the studied interval; however, the ES/pH pattern of these two species differs in shape. The ES in sheep's milk significantly increased in a sigmoidal curve as pH increases; however, deer milk showed a more linear shape at pH values higher than 5.9. As described by Guo et al. (1998), the ES/pH profile of goats' milk showed a shallow sigmoidal curve, similar to that observed in sheep's milk, but being goats' milk more unstable when pHs was higher than natural values. On the other hand, evolution of ethanol stability versus pH in cow milk was quite different compared with the others, showing a marked sigmoidal pattern that reached the highest ES values, which agrees with the results published by Horne (1992). It should further be noted that the differences between deer and sheep milks relative to goats' and cows' milk became clearly significant above their natural pHs.

Taking into account the effect of acidification on ethanol stability of milk it can be observed that cow milk is the most variable to changes in pH, especially over a narrow range of initial pH (6.76 ± 0.2 changes 30%, v/v), while goat milk turned out to be the most robust (6.72 ± 0.2 changes 10%, v/v).

4. Conclusions

The data presented in this study confirm that red deer milk is a rich source of nutrients with a content of total solids, fat, protein and lactose much higher than that observed for sheep, goat or cow milk. Furthermore, its particularly high percentages of fat and total protein, which are more similar to sheep than the other ruminants, suggest excellent cheesemaking suitability. The values obtained in the determination of the

physical parameters revealed noticeable differences in the milk of the four species; however, some similarities in conductivity, viscosity, colour and ethanol stability of milk from red deer and sheep were found, highlighting the similarity between these two species.

Due to their particular composition and physicochemical properties, red deer, goat and sheep milk have ES characteristic behaviours that clearly differentiate them from cow milk. When comparing the response with the ethanol stability test to pH variation there are also similarities between red deer and sheep milks, as no significant differences were found in ES mean values for the pH range 5.9 to 7.1. This proves that red deer milk is suitable for subjection to the same thermal processing and the manufacture of similar dairy products as sheep milk. Thus, red deer milk could be industrialised, and provide a suitable source for the production of cheese or fermented milks, so that this dairy orientation could become a production alternative in the Iberian deer farms that would improve its profitability. This work may be a promising basis for the study and exploitation of Iberian red deer milk. However, further studies are needed to complete the knowledge of the red deers' milk technological features, as well as to determine more precisely its nutritional and economic value.

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Table 1

Composition and properties of deer’s sheep’s goats’ and cows’ bulk tank milks. ^a

Variable	Species				<i>P</i> -value
	Deer (n = 9)	Ewe (n = 9)	Goat (n = 9)	Cow (n = 9)	
Fat (%)	9.43±1.24 ^d	7.46±0.45 ^c	5.42±1.05 ^b	3.30±0.40 ^a	***
Protein (%)	6.96±0.46 ^d	5.90±0.44 ^c	3.81±0.45 ^b	3.27±0.05 ^a	***
Lactose (%)	4.74±0.25 ^c	4.59±0.17 ^{bc}	4.29±0.11 ^a	4.51±0.05 ^b	***
Total solids (%)	21.85±1.75 ^d	18.54±0.70 ^c	14.31±1.43 ^b	12.12±0.37 ^a	***
SCC* (log cell mL ⁻¹)	4.89±0.63 ^a	5.88±0.11 ^b	6.12±0.16 ^b	5.30±0.43 ^a	***
TBC* (log cfu mL ⁻¹)	6.10±1.08 ^b	5.55±0.57 ^{ab}	5.73±0.84 ^{ab}	4.79±0.85 ^a	**

^a Abbreviations are: SCC, somatic cell count; TBC, total bacterial count. Values are means ± standard deviation; means within a row with different superscript letters are significantly different (*P* < 0.05). Significant differences between species are indicated by: ***P* < 0.01 and ****P* < 0.001.

Table 2Physical properties of deer's, sheep's, goats' and cows' bulk tank milks. ^a

Variable	Species				<i>P</i> -value
	Deer (n = 9)	Ewe (n = 9)	Goat (n = 9)	Cow (n = 9)	
Density (*)	1.038±0.002 ^c	1.036±0.002 ^b	1.030±0.002 ^a	1.031±0.001 ^a	***
pH	6.61±0.14 ^a	6.69±0.05 ^{ab}	6.72±0.07 ^b	6.76±0.05 ^b	**
Acidity (% lactic acid)	0.26 ±0.05 ^b	0.23±0.03 ^b	0.15±0.3 ^a	0.16±0.02 ^a	***
Conductivity (mS cm ⁻¹)	3.59±0.64 ^a	3.94±0.32 ^a	5.30±0.54 ^c	4.68±0.23 ^b	***
Coordinate L*	89.24±0.62 ^b	87.96±0.48 ^b	86.02±1.51 ^a	84.84±1.12 ^a	***
Coordinate a*	-3.05±0.50 ^a	-3.29±0.25 ^a	-2.13±0.22 ^b	-3.27±0.20 ^a	***
Coordinate b*	8.45±0.80 ^c	6.61±1.57 ^b	5.48±0.34 ^{ab}	5.14±0.59 ^a	***
Viscosity (cP)	3.01±0.35 ^b	2.75±0.39 ^b	2.18±0.37 ^a	2.00±0.02 ^a	***
Ethanol stability (% ethanol, v/v)	62±6 ^b	63±6 ^b	50±6 ^a	83±5 ^c	***

^a Values are means ± standard deviation; means within a row with different superscript letters are significantly different ($P < 0.05$). Significant differences between species are indicated by: ** $P < 0.01$ and *** $P < 0.001$.

Legend to figure

Fig. 1. Ethanol stability to pH profiles of bulk tank milk samples: —●—, deer; -△-, sheep;□...., goat; —×—, cow. Data points with different letters are significantly different; *P*-values are indicated by the asterisks below the pH value on the x-axis: *, *P* < 0.05; **, *P* < 0.01; ***, *P* < 0.001.

Figure 1 TC Edits

Fig. 1.