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COMPOSITION AND FREEZING POINT OF COLOSTRUM AND MILK FROM CROSSBRED GOATS IN AN INSTITUTIONAL HERD IN MUÑOZ, NUEVA ECIJA, PHILIPPINES

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ABSTRACT

This study compared the composition and freezing point of colostrum and milk from 33 crossbred goats (i.e., 19 two-way crosses and 14 three-way crosses) that have Anglo Nubian or Boer sires. A total of 120 colostrum and milk samples were evaluated for fat, protein, and lactose content, solids non-fat (SNF), total solids, and freezing point. Colostrum contained significantly (*P*<0.05) more protein (14.59% vs. 3.21–3.50%), fat (5.60% vs. 2.34–2.79%), SNF (18.67% vs. 8.14–8.90%), and total solids (26.05% vs. 10.54–11.55%), but less lactose (3.14% vs. 4.37–4.75%) and moisture (73.95% vs. 88.45–89.46) than goat milk obtained on the 30th, 60th, and 90th day of lactation. Freezing point was significantly (*P*<0.05) lower in colostrum (–0.532°C) than in goat milk (–0.479°C). The freezing point of goat milk was negatively correlated with percent lactose (r = -0.72) and percent SNF (r = -0.71). Milk composition and freezing point of colostrum and milk were similar for two-way and three-way crossbred goats. However, crossbred does with Anglo Nubian sires had significantly higher (*P*<0.05) protein, SNF, and total solids but lower moisture in colostrum than crossbred goats with Boer sires.

Key words: colostrum, crossbred goats, freezing point, milk components

INTRODUCTION

Of the more than 2000 mammalian species that produce milk, few have been domesticated by humans to satisfy our nutritional requirements (Faye and Konuspayeva, 2012). Based on FAO statistics (FAO, 2019), milk production from goats was only 2.25% of the 883 billion tons of milk consumed by humans and ranked third next to water buffalo (15.14%) and cattle (81.05%). This is because the world average milk production per goat in 2019 (92.5 kg) was way below that of cattle (2699 kg) and water buffalo (1913 kg). Global demand for goat milk, however, continues to increase due to the nutritional needs of the growing human population and the health/medical benefits for people afflicted with cow milk allergies and other gastro-intestinal ailments (Haenlein, 2004).

Compared to cow or human milk, goat milk has better digestibility, alkalinity,

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buffering capacity, and certain therapeutic values in medicine and human nutrition (Park *et al*. 2007). Goat milk composition, however, may vary depending on breed, age, body size and weight, udder size, diet, stage of lactation, season, length of dry period, and environmental temperature (Mohsin *et al*., 2019).

In the Philippines, the goat inventory in 2020 was about 3.81 million heads (PSA, 2020). The data available in 2015 showed that the dairy goat population was 2,118 heads, including 1,169 does on the milking line which produced 335,840 liters of milk (liquid milk equivalent) or 1.65 percent of the total dairy output of 20.39 million liters (PSA, 2016). Except for a few local pure breeding farms, crossbreeding between the imported and expensive breeds having high dairy potential (e.g., Anglo-Nubian, Boer, Saanen, Alpine, or Toggenburg) and the native breed owned by smallholder farmers is a common practice to improve local goat milk production.

While there has been an increased interest in dairy products from goat milk because of their high nutritional content and health benefits, local data on the composition and freezing point of colostrum and milk obtained from adapted purebred or crossbred goats are scarce. In this regard, the purpose of this study was to characterize and compare the composition and freezing point of colostrum and milk collected on the 30th, 60th, and 90th day of lactation from crossbred goats with Anglo Nubian and Boer sires in the institutional herd of the Small Ruminant Center inside the Central Luzon State University campus (SRC-CLSU), Muñoz, Nueva Ecija, Philippines.

MATERIALS AND METHODS

This study was conducted in the Institute of Animal Science (IAS), College of Agriculture and Food Science (CAFS), University of the Philippines Los Baños (UPLB) in collaboration with SRC-CLSU and in compliance with the requirements of the UPLB Institutional Animal Care and Use Committee with Assigned Protocol No. 2019-0034.

A total of 120 milk samples were collected from 33 randomly-selected crossbred does with Anglo Nubian or Boer sires (i.e., 19 two-way crosses – “Anglo Nubian × Native” and “Boer × Native”, and 14 three-way crosses – “Anglo Nubian × Boer × Native”, “Boer × Saanen × Native”, and “Boer × Alpine × Native”) that gave birth from 01 November 2019 to 01 March 2021 at the SRC institutional herd, CLSU, Muñoz, Nueva Ecija (Table 1). The average parity number and age at kidding were 2.63 ± 1.45 (ranging from 1 – 6) and 4.27 ± 1.29 years (ranging from 2.32 – 6.62 years), respectively.

Goats were maintained in a complete confinement production system, wherein does and bucks are raised in separate pens and hand mated throughout the year. The crossbred does (also called “improved native”) were fed with roughage, commercial concentrate (300 g/day/animal) and supplemented with vitamins and minerals all year round. Cultivated forages comprised of Napier (*Pennisetum purpureum*) and para grass (*Brachiaria mutica*) and leguminous species such as “ipil-ipil” (*Leucaena leucocephala*), “kakawate” or “madre de cacao” (*Gliricidia sepium*), Centrosema (*Centrosema pubescens*), Rensonii (*Desmodium cineria*) and “balabalatong” (*Indigofera zollingeriana*) under a cut and carry system. The nutritional content of the lactating feeds was analyzed at the Animal Nutrition Division, IAS, CAFS, UPLB and found to contain 16.14% crude protein, 6.00% crude fat, 11.30% crude fiber, 7.78% moisture, 8.82% ash, 1.12% calcium, and 0.58% phosphorus using the Semi-micro Kjeldahl distillation, Soxhlet extraction, Weende method, oven drying, ashing

Table 1. Number and distribution of goats and milk samples (by milk type, sire breed, and breed combination).

	No. of goats	Milk Type				No. of samples
		Colostrum	30-d Milk	60-d Milk	90-d Milk	
Sire breed						
Anglo Nubian	21	19	21	20	19	79
Boer	12	6	12	12	11	41
Breed combination						
Two-way cross*	19	18	22	21	20	81
Three-way cross**	14	7	11	11	10	39
Total	33	25	33	32	30	120

*Two-way crosses include "Anglo Nubian (75%, 87.5%, 93.75%, 96.87%) × Native" and "Boer (75%, 87.5%, 93.75%) × Native".

**Three-way crosses include "50% Anglo Nubian × Boer (37.5%, 43.75%) × Native" and "50% Boer × 25% Anglo Nubian (or Alpine or Saanen) × 25% Native".

at 600°C, Titrimetric, and Colorimetric-UV-Vis method, respectively.

At least 50 mL samples of colostrum (day 1) and raw milk on the 30th, 60th, and 90th day of lactation were collected by hand, placed in plastic bottles, and immediately frozen at –20°C until further analysis. The MilkoScan Mars (FOSS Analytical A/S, Hillerod, Denmark) using the Fourier-transform infrared spectroscopy (FTIR) technology was used to determine percent fat, percent protein, percent lactose, percent solids non-fat (SNF), percent total solids, and freezing point (°C).

Pearson product-moment correlation coefficients among the proportion of milk components (moisture, fat, protein, lactose, solids non-fat, and total solids) and freezing point, were initially determined separately for colostrum and milk samples using the CORR procedure (SAS, 2009).

The general least squares procedures for unbalanced data (SAS, 2009) were used to examine the principal sources of variation affecting each colostrum/milk component and freezing point. Statistical significance was set at $P<0.05$. The mathematical model was: $y_{ijklm} = \mu + MType_i + BComb_i\ (MType_i) + SBreed_k\ (MType_i) + NKidd_l + e_{ijklm}$, where y_{ijklm} is the proportion of components and freezing point of all colostrum and milk samples, μ is the overall mean, $MType_i$ is the fixed effect for the j_{th} type of milk (i.e., colostrum and milk collected on the 30th, 60th, and 90th day of lactation), BCombi ($MType_i$) is the fixed effect of the j^{th} breed combination (i.e., two-way and three-way crosses) nested within the type of milk, $SBreed_k$ ($MType_i$) is the fixed effect of the kth sire breed (i.e., Anglo Nubian and Boer) nested within the type of milk, $NKidd_l$ is the l^{th} covariate effect of parity (number of kidding), and e_{ijklm} is the error term assumed to be normally distributed with the variance of errors as constant across observations.

RESULTS

Percent protein in goat colostrum was positively correlated (P<0.01) with percent SNF (r = 0.99) and percent total solids (r = 0.78); negatively correlated with percent moisture (r = -0.78) and percent lactose (r = -0.74); and not correlated (P>0.05) with percent fat (Table 2). On the other hand, percent protein in the milk of crossbred goats was positively correlated (P<0.01) with percent SNF (r = 0.75) and percent total solids (r = 0.60), but not correlated with percent fat and percent lactose (P>0.05).

Percent fat in goat colostrum was positively correlated (P<0.01) with total solids (r = 0.57), negatively correlated (P<0.05) with percent lactose (r = -0.40), and not related to percent SNF (P>0.05). On the other hand, percent fat in goat milk was positively correlated (P<0.01) with total solids (r = 0.72) and not related to percent lactose and percent SNF (P>0.05).

Percent lactose in goat colostrum was negatively correlated (P<0.01) with percent SNF (r = -0.63) and percent total solids (r = -0.81). On the other hand, percent lactose in milk from crossbred goats was positively correlated (P<0.01) with percent SNF (r = 0.72), and not related to percent total solids (P>0.05).

Percent SNF in goat colostrum was also positively correlated (P<0.01) with percent total solids (r = 0.72). On the other hand, percent SNF in goat milk was positively correlated (P<0.01) with percent total solids (r = 0.64).

The freezing point of colostrum was positively correlated (P<0.01) with percent fat (r = 0.78). Freezing point was not related to percent moisture, percent protein, percent lactose, percent SNF, and percent total solids (P>0.05). On the other hand, the freezing point of goat milk was positively correlated (P<0.01) with percent fat (r = 0.27) but negatively correlated with percent lactose (r = -0.72) and percent SNF (r = -0.71). Freezing point was not related to percent moisture, percent protein, and percent total solids (P>0.05).

Percent fat was the most variable of the components of both colostrum and milk with a coefficient variation (CV) of 71.81%, followed by percent protein (CV= 40.12%), percent lactose (CV= 15.99%), and percent moisture (CV= 3.70%), see Table 3.

All composition parameters and freezing points were significantly affected (P<0.01) by the type of milk but not affected by the breed combination (i.e., two-way and three-way crosses) within the type of milk (P>0.05). Significant effects of sire breed (i.e., Anglo Nubian and Boer) within the type of milk were also found for percent moisture, protein, SNF, and total solids. Parity had significant (P<0.05) effects on percent moisture ($b_{\text{Parity.\% Moisture}}$ = -0.41) and percent total solids ($b_{\text{Parity.\% Totals solids}}$ = 0.41). This suggests that crossbred goats at higher parity had 0.41% higher total solids (lower moisture content) of colostrum or milk.

Percent protein, fat, SNF, and total solids were higher *(P*<0.05) in colostrum (14.59%, 5.60%, 18.67%, and 26.05%, respectively) than in milk (3.21–3.50%, 2.34–2.79%, 8.14–8.90%, and 10.54–11.55%, respectively), see Table 4. On the other hand, percent lactose and percent moisture were significantly (P<0.05) lower in colostrum (3.14% and73.95%, respectively) than in milk (4.37–4.75% and 88.45–89.46%, respectively).

For colostrum, crossbred goats with Anglo Nubian sires had significantly higher (P<0.05) percent protein, percent SNF, and percent total solids but lower percent moisture (i.e., 17.13%, 21.12%, 28.84%, and 71.16%, respectively) than crossbred goats with Boer sires (i.e., 12.05%, 16.22%, 23.26%, and 76.74%, respectively), see Table 5.

Table 2. Pearson correlation coefficients among composition and freezing point of colostrum (upper right off-diagonals) and milk (lower left off-diagonals) from crossbred goats.

	% Moisture	**% Protein**	**% Fat**	**% Lactose**	**% Solids Non-fat**	**% Total Solids**	**Freezing point**
% Moisture	-	-0.78**	-0.57**	-0.81**	-0.72**	-1.00**	ns
% Protein	-0.60**	-	ns	-0.74**	0.99**	0.78	ns
% Fat	-0.71**	ns	-	-0.40*	ns	0.57**	0.78**
% Lactose	ns	ns	ns	-	-0.63**	-0.81**	ns
% Solids non-fat	-0.64**	0.75**	ns	0.50**	-	0.72**	ns
% Total solids	-1.00**	0.60**	0.72**	ns	0.64**	-	ns
Freezing point	ns	ns	0.27**	-0.72**	-0.71**	ns	-

ns - correlation coefficient (r) is not significantly different from zero (P>0.05).
*Correlation coefficient (r) is significantly different from zero (P<0.05).
**Correlation coefficient (r) is highly significantly different from zero (P<0.01).

For milk obtained on different days in lactation, crossbred goats with Anglo Nubian sires had significantly lower (*P*<0.05) percent total solids in 60-d and 90-d milk (i.e., 8.01% and 7.86%, respectively) than crossbred goats with Boer sires (i.e., 8.27% and 8.53%, respectively).

Table 3. Mean square F test results for the effects of milk type, "breed combination within milk type", "sire breed within milk type", and covariate effect of parity on the com position and freezing point of goat colostrum and milk.

	Milk type	Breed combination (within Milk type)	Sire breed (within Milk type)	Parity	Coeff. of Variation (%)
% Moisture	**	ns	*	*b = -0.41	3.70
% Protein	**	ns	**	ns	40.12
% Fat	**	ns	ns	ns	71.81
% Lactose	**	ns	ns	ns	15.99
% Solids non-fat	**	ns	**	ns	20.63
% Total solids	**	ns	*	*b = 0.41	22.12
Freezing point	**	ns	ns	ns	16.68

b is regression of parity on % moisture and % total solids.
ns - no significant effect of independent variable (*P*>0.05).
*highly significant effect of independent variable (*P*<0.05).
**highly significant effect of independent variable (*P*<0.01).

Table 4. Composition and freezing point of colostrum and of milk collected on different days of lactation.

	Colostrum	30-d Milk	60-d Milk	90-d Milk
% Moisture	73.95 ± 0.81^{b}	88.45 ± 0.60^{a}	89.46 ± 0.60^{a}	88.98 ± 0.63^{a}
% Protein	14.59 ± 0.60^{a}	3.50 ± 0.44^{b}	3.21 ± 0.45^{b}	3.25 ± 0.47^{b}
% Fat	5.60 ± 0.57^{a}	2.57 ± 0.42^{b}	2.34 ± 0.43^{b}	2.79 ± 0.45^{b}
% Lactose	3.14 ± 0.17^{c}	4.75 ± 0.13^{a}	4.37 ± 0.13^{b}	4.41 ± 0.13^{b}
% Solids non-fat	18.67 ± 0.57^{a}	8.90 ± 0.42^{b}	8.14 ± 0.42^{b}	8.20 ± 0.44^{b}
% Total solids	26.05 ± 0.81^{a}	11.55 ± 0.60^{b}	10.54 ± 0.60^{b}	11.02 ± 0.63^{b}
Freezing point, °C	-0.532 ± 0.021^{b}	-0.509 ± 0.016^{b}	-0.468 ± 0.016^{a}	-0.461 ± 0.016^{a}

Least square means in the same row without common letter superscripts are significantly different (*P*<0.05).

Table 5. Composition and freezing point of colostrum and of milk collected on different days of lactation from crossbred does with different sire breeds.

	Colostrum		30-d Milk		60-d Milk		90-d Milk	
	Anglo Nubian sire	Boer sire	Anglo Nubian sire	Boer sire	Anglo Nubian sire	Boer sire	Anglo Nubian sire	Boer sire
% Moisture	71.16 ± 0.85^{c}	76.74 ± 1.44^{b}	89.20 ± 0.80^{a}	87.69 ± 0.98^{a}	89.72 ± 0.82^{a}	89.20 ± 0.98^{a}	89.61 ± 1.02^{a}	89.35 ± 1.02^{a}
% Protein	17.13 ± 0.63^{a}	12.05 ± 1.06^{b}	3.14 ± 0.60^{c}	3.87 ± 0.72^{c}	2.95 ± 0.60^{c}	3.46 ± 0.72^{c}	2.92 ± 0.61^{c}	3.59 ± 0.75^{c}
% Fat	5.58 ± 0.60^{a}	5.61 ± 1.02^{a}	2.40 ± 0.57^{b}	2.75 ± 0.69^{b}	2.24 ± 0.58^{b}	2.44 ± 0.69^{b}	2.53 ± 0.59^{b}	3.05 ± 0.72^{b}
% Lactose	2.78 ± 0.18^{d}	3.50 ± 0.31^{c}	4.59 ± 0.17^{a}	4.90 ± 0.21^{a}	4.49 ± 0.18^{a}	4.26 ± 0.22^{b}	4.40 ± 0.18^{b}	4.42 ± 0.22^{b}
% Solids non-fat	21.12 ± 0.60^{a}	16.22 ± 1.00^{b}	8.32 ± 0.56^{cd}	9.48 ± 0.68^{c}	8.01 ± 0.57^{d}	8.27 ± 0.68^{c}	7.86 ± 0.58^{d}	8.53 ± 0.71^{c}
% Total solids	28.84 ± 0.85^{a}	23.26 ± 1.44^{b}	10.80 ± 0.80^{cd}	12.31 ± 0.98^{c}	10.28 ± 0.82^{d}	10.80 ± 0.98^{cd}	10.39 ± 0.83^{cd}	11.65 ± 1.02^{cd}
Freezing point (°C)	-0.525 ± 0.022^{b}	-0.539 ± 0.037^{b}	-0.521 ± 0.021^{b}	-0.497 ± 0.027	-0.482 ± 0.021^{a}	-0.454 ± 0.025^{a}	-0.454 ± 0.021^{a}	-0.468 ± 0.026^{a}

Least square means in the same row without common letter superscripts are significantly different ($P<0.05$).

DISCUSSION

Proteins in goat milk are not only less allergenic than cow milk (Lara-Villoslada *et al.*, 2004) but also known for their healing effect on cow milk allergy – the most common food allergy which causes many deaths in infants. The protein of goat milk is also more digestible than cow milk (Lopez-Aliaga *et al.*, 2003). Turkmen (2017) explained that the β-casein/αs1-casein ratio (70%/30%) of goat milk proteins is similar to human milk, which results in more digestibility compared to cow milk in relation to higher sensitivity of β-casein to the protease enzymes. Furthermore, goat milk contains bigger protein micelles than cows' milk, making it ideal for cheese processing (Haenlein, 2004).

For crossbred goats used in this study, percent protein was about 4.39 times higher in colostrum than in milk. Percent protein was not significantly different in goat milk collected on the 30th, 60th, and 90th day of lactation.

In colostrum, percent protein was higher for crossbred does with Anglo Nubian sires (17.16%) than for crossbred does with Boer sires (12.05%). By comparison, slightly lower values for percent protein in colostrum were reported by Kessler *et al*. (2018) for Anglo Nubian (16.36%), Boer (17.13%), Saanen (13.99%), and Toggenburg (13.22%) in Switzerland and Germany. A lower percent protein in colostrum was reported by Romero *et al*. (2013) for Murciano-Granadina goats in Spain (7.86–9.10%). Both Romero *et al*. (2013) and Kessler *et al*. (2018) showed that litter size was associated with changes in colostrum composition (especially protein) as a minimum colostrum quantity is required by the kids to meet their energy demands and to obtain adequate passive immunization. However, it is for this reason (i.e., high protein and total IgG concentrations) that makes goat colostrum an interesting product for uses beyond the traditional ones (Ruiz *et al*., 2014).

In goat milk, percent protein was higher in crossbred does with Boer sires (3.46–3.87%) than crossbred does with Anglo Nubian sires (2.92–3.14%). By comparison, Turkmen (2017) in their summary of goat milk from different breeds worldwide reported higher values for protein (3.6%). Mestawet *et al*. (2012) noted that despite a lower milk yield, indigenous goats in Ethiopia had higher percent protein (4.34% for Somali goats and 4.80% for Arsi-Bale goats) than the Boer breed (4.05%). Higher milk protein percentages were also reported by Mohsin *et al*. (2019) for British Alpine (4.31%), Jamnapari (5.80%), Saanen (4.83%), and Toggenburg (4.53%) in Malaysia.

Milk fats from goat are known to provide positive effects on the physical (i.e., softer texture) and sensory characteristics of dairy products (Silanikove *et al*., 2010), at the same time, allow better digestibility for humans because of the small fat globule size (Alferez *et al*., 2001; Park and Haenlein, 2006) and high short- and medium-chain fatty acids content (Turkmen, 2017). Goat milk also contains higher amounts of conjugated linoleic acids playing important roles in immune stimulation, growth promotion, and disease prevention (Turkmen, 2017).

In this study, percent fat was about 2.16 times higher in colostrum than in milk from crossbred goats. Percent fat was not significantly different in goat milk collected on the 30th, 60th, and 90th day of lactation.

In colostrum, percent fat was similar for crossbred does with Anglo Nubian sires (5.58%) and crossbred does with Boer sires contained lower protein (5.61%). By comparison, higher values for percent fat in colostrum were reported by Kessler *et al*. (2018) for Anglo Nubian (4.00%), Boer (4.38%), Saanen (6.57%), and Toggenburg (7.00%) in Switzerland

and Germany. Higher percent fat in colostrum was also reported by Romero *et al*. (2013) for Murciano-Granadina goats in Spain (8.19–8.36%).

In goat milk, percent fat was similar for crossbred does with Anglo Nubian sires (2.24–2.53%) and crossbred does with Boer sires (2.44–3.05%). By comparison, Turkmen (2017) reported higher average values for milk fat (4.5%) from different goat breeds in the world. A higher fat percentage in goat milk was also reported by Mestawet *et al*. (2012) for both indigenous breeds (i.e., 4.90% for Somali goats and 5.15 for Arsi-Bale goats) and the Boer breed (4.70%) in Ethiopia. Likewise, Mohsin *et al*. (2019) reported higher percent milk fat for British Alpine (3.70% fat,), Jamnapari (4.20%), and Saanen (3.93%) but lower fat percent for Toggenburg (3.08%) in Malaysia.

Lactose is the main carbohydrate found in varying concentrations in the milk of all mammals. Lactose is important for the intestinal absorption of calcium, magnesium and phosphorus, and the utilization of Vitamin D (Park *et al*., 2006). In this study, milk from crossbred goats contained 1.47 times more lactose than in colostrum. Percent lactose was significantly higher in 30-d milk (4.75%) than in 60-d milk (4.37%) and 90-d milk (4.41%). Percent lactose was not significantly different in 60-d and 90-d milk (P>0.05). On the contrary, Park *et al*. (2006) reported that lactose content decreases towards the end of the lactation.

In colostrum, percent lactose was lower for crossbred does with Anglo Nubian sires (2.78%) than for crossbred does with Boer sires (3.50%). By comparison, higher percent lactose in colostrum was reported by Romero *et al*. (2013) for Murciano-Granadina goats in Spain (3.57–3.92%). Kessler *et al*. (2018) also reported slightly higher percent lactose in colostrum for Anglo Nubian (3.19%), Boer (3.55%), Saanen (3.61%), and Toggenburg (3.61%) in Switzerland and Germany.

Percent lactose in goat milk was similar for crossbred does with Anglo Nubian sires (4.40–4.59%) and crossbred does with Boer sires (4.26–4.90%). By comparison, Turkmen (2017) reported similar average percent lactose (4.4%) from different breeds worldwide. Mestawet *et al*. (2012) reported higher percent lactose for both indigenous breeds in Ethiopia (i.e., 4.93% lactose for Somali goats and 4.97% lactose for Arsi-Bale goats) and the Boer breed (i.e., 4.96% lactose). In contrast, Mohsin *et al*. (2019) reported lower percent lactose for British Alpine (2.40%), Jamnapari (2.00%), Saanen (2.95%), and Toggenburg (2.26%) in Malaysia.

The freezing point was significantly lower in colostrum (–0.532°C) than in milk (–0.479°C). Freezing point of goat milk was significantly lower in 30-d milk (–0.509°C) than in 60-d milk (–0.468°C) and 90-d milk (–0.461°C). The differences in freezing point in 60-d milk and 90-d milk were not significant (P>0.05).

The freezing point of milk of crossbred goats in this study was higher than those reported by Janstova *et al*. (2007) for White Shorthaired goats in the Czech Republic (–0.545 to – 0.557°C). According to Janstova *et al*. (2007), freezing point is affected by major milk constituents, mainly lactose and chlorides and other milk constituents (calcium, magnesium, lactates, phosphates, citrates, urea, etc.). Milk fat globules, casein micelles and whey proteins also play a negligible role in the reduction of freezing point.

In practice, an increase in the freezing point of milk (a shift towards zero) indicates adulteration of milk with water added either intentionally or accidentally during the production, handling, and processing of milk. Heat treatment may change the milk constituents and so may also affect the freezing point (Janstova *et al*., 2007). In buffalo milk, freezing point is now widely used not only to indicate adulteration but also as a quality criterion for calculating the price of raw milk purchased and processed into dairy products (Pesce *et al*., 2016).

For goat milk in this study, we found a negative correlation of freezing point with percent lactose (r = -0.72) and percent SNF (r = -0.71), and a low positive correlation between the freezing point and percent fat (r = 0.27). Freezing point was not correlated with percent protein and total solids. Similarly, Janstova *et al*. (2007) reported that the variation in the freezing point values was caused by a higher SNF in goat milk (i.e., the correlation coefficient between the freezing point and percent SNF is r = -0.94). The variation in freezing point may be a result of the variability of the milk contents (especially lactose and fat) and not necessarily total solids, depending on the stage of lactation, nutrition or feeding regimes, breed, and animal health status (Park *et al*., 2006; Morand-Fehr *et al*., 2007; Mestawet *et al*., 2012).

Colostrum had a higher nutritional value in terms of percent protein than goat milk. Colostrum was 94.5% fat-free while goat milk was 97.1–97.3% fat-free. However, the production of colostrum in commercial quantities will be difficult as the amount of colostrum produced by a goat is only less than 1% of the total milk that may be produced in one lactation period. In managing the local dairy goat farms, the focus should thus be to increase milk yield. The sire breed to produce crossbred goats may be considered in making breeding decisions to improve the composition of colostrum and milk.

Besides its contribution to the establishment of quality standards for goat milk producers, the knowledge on the composition of goat colostrum and milk can be used to update the local “Food Composition Tables” and “Food Exchange Lists”. The extent of variations in the freezing point of milk from crossbred goats may also serve to set the upper tolerance limit of determining milk adulteration of goat milk. Such information will benefit both consumers for a better understanding of goat colostrum and milk as healthy or functional food, and the dairy processors engaged in the development of dairy milk products from goats.

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REFERENCES

Alferez MJM, Barrionuevo M, Lopez-Aliaga I, Sanz Sampelayo MR, Lisbona F, Robles JC and Campos MS. 2001. Digestive utilization of goat and cow milk fat in malabsorption syndrome. *J Dairy Sci* 64:451-461.

Faye B and Konuspayeva G. 2012. The sustainability challenge to the dairy sector - the growing importance of non-cattle milk production worldwide. *Int Dairy J* 24:50-56.

Food and Agriculture Organization of the United Nations [FAO]. 2019. *FAOSTAT statistical database*. [Rome] :FAO.

Haenlein GFW. 2004. Goat milk in human nutrition. *Small Rumin Res* 51:155-163.

Janstova B, Drackova M, Navratilova P, Hadra L and Vorlova L. 2007. Freezing point of raw and heat-treated goat milk. *Czech J Anim Sci* 52:394-398.

Kessler EC, Bruckmaier RM and Gross JJ. 2018. Immunoglobulin G content and colostrum composition of different goat and sheep breeds in Switzerland and Germany. *J Dairy Sci* 102:5542-5549.

Lara-Villoslada F, Olivares M, Jimenez J, Boza J and Xaus J. 2004. Goat milk is less immunogenic than cow milk in a murine model of atopy. *J Pediatr Gastroenterol Nutr* 39:354-360.

Lopez-Aliaga I, Alferez MJM, Barrionuevo M, Nestares T, Sanz Sampelayo MR and Campos MS. 2003. Study of nutritive utilization of protein and magnesium in rats with resection on the distal small intestine. Beneficial effect of goat milk. *J Dairy Sci* 86:2958-2966.

Mestawet TA, Girma A, Adnoy T, Devold TG, Narvhus JA and Vegarud GE. 2012. Milk production, composition and variation at different lactation stages of four goat breeds in Ethiopia. *Small Rumin Res* 105:176-181.

Morand-Fehr P, Fedele V, Decandia M and Le Frileux Y. 2007. Influence of farming and feeding systems on composition and quality of goat and sheep milk. *Small Rumin Res* 68:20- 34.

Mohsin AZ, Sukor R, Selamat J, Hussin ASM and Ismail IH. 2019. Chemical and mineral composition of raw goat milk as affected by breed varieties available in Malaysia. *Int J Food Prop* 22:815-824.

Park YW and Haenlein GFW. 2006. *Therapeutic and hypo-allergenic values of goat milk and implication of food allergy*. In: Handbook of Milk of Non-Bovine Mammals (eds. Park YW and Haenlein GFW). Blackwell Publishing, Ames, Iowa, pp. 121-136.

Park YW, Juarez M, Ramos M and Haenlein GFW. 2007. Physico-chemical characteristics of goat and sheep milk. *Small Rumin Res* 68:88-113.

Pesce A, Salzano C, De Felice A, Garofalo F, Liguori S, De Santo A, Palermo P and Guarin A. 2016. Monitoring the freezing point of buffalo milk. *Ital J Food Saf* 5:5691 95-97.

Philippine Statistics Authority [PSA]. 2016. Dairy Industry Situation Report: January to December 2015. https://psa.gov.ph/sites/default/files/DAIRY%20Industry%20Performance%20Report%20-%20Jan%20-%20Dec%202015_1.pdf

Philippine Statistics Authority [PSA]. 2020. Goat Situation Report: January to December 2019. https://psa.gov.ph/sites/default/files/Goat%20Situation%20Report_signed.pdf.

Romero T, Beltran MC, Rodríguez M, Martí De Olives A and Molina. MP. 2013. Short communication: Goat colostrum quality: Litter size and lactation number effects. *J Dairy Sci* 92:7526-7531.

Ruiz P, Seseña S, Rieiro I and Llanos Palop M. 2014. Effect of postpartum time and season on the physicochemical characteristics of Murciano-Granadina goat colostrum. *Int J Dairy Technol* 68:88-96.

Silanikove N, Leitner G, Merin U and Prosser CG. 2010. Recent advances in exploiting goat's milk: quality, safety and production aspects. *Small Rumin Res* 89:110-124.

Statistical Analysis System (SAS). 2009. SAS/STAT ® 9.2 User's Guide. 2nd Ed. SAS Institute, Inc. Cary, NC USA.

Turkmen N. 2017. *The nutritional value and health benefits of goat milk components*. In: Nutrients in Dairy and Their Implications for Health and Disease. Elsevier Inc. Chapter 35, pp. 441-449.