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Goat milk concentration of calcium, phosphorus, potassium and sodium

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Abstract
The objective of the study was to evaluate the impact of lactation stage on milk minerals of calcium, phosphorus, potassium and sodium content of Attappady Black goats and Malabari goats under Indian conditions. Thirty newly kidded does of Attappady Black and ten newly kidded does of Malabari goats were selected for this study. The overall milk sodium content differed significantly ($P<0.05$) between the Attappady black (274.96 ± 4.70) and Malabari goats (291.94 ± 6.36). No significant was observed in milk phosphorus and potassium content in between the breeds. But the milk calcium, phosphorus, sodium and potassium content was differed significantly in various stages of lactation in Attappady Black and Malabari goats. The milk calcium content was maximum ($P<0.01$) in Malabari goats (551.77 ± 10.93 ppm) compare than Attappady Black goats (445.20 ± 11.53 ppm). However phosphorus and potassium level in milk were higher in Attappady Black than the Malabari goats.

Keywords: Goat milk, mineral composition, stage of lactation, attappady black, malabari goats

Introduction
India is the highest goat milk producing country in the world with an annual milk production of 15.2 million metric tons during 2014-15 as per Basic Animal Husbandry and Fisheries Statistics (2015). This huge amount of goat milk production has been achieved by inhabiting world's second highest share of 135.17 million of goat population with 28 recognized breeds in India against the global goat population of 921 million. In Kerala, there are 12.3 lakhs heads of goats and they are the second major livestock species by population next to cattle with 14.1 lakh heads (B.H.S. 19th All India Livestock Census, 2012). The minerals is one of the required nutrient component of the food and it's necessary for human health (Elhardallou *et al*., 2016) [5] because of human body composed of 4 – 6% of the mineral content (Khan *et al*., 2014) [10] Among the other fluid, goat milk is a better food for peoples interest both in terms of mineral content and its effect of the health. (Matysek *et al*., 2013) [11]. The calcium content is mainly used for hardness of bone and teeth, maintain the regular heartbeat, muscle growth, muscle contraction, prevention of muscle cramp and the transmission of nerve impulses. The phosphorus content is important for maintain the acid base balance, cell membrane structure, energy metabolism of body and bone, teeth formation. (Kazi, 2015) [9]. The sodium content is mainly used for maintain the proper water balance, blood pH and also needed for function of muscle, stomach and nerve functions. The concentration of the mineral contents is mainly depending on the breed, feeding, lactation stage and the health condition of the udders. The potassium content is important for healthy nerves system, regular heart rhythm, and proper muscle contraction and interacts with sodium to maintain the acid base balance. The deficiencies of the mineral content as well as the toxicity levels are affect the whole physiological system of the body (Anderson *et al*., 2004) [3].

Materials and Methods
Location of the farm
The research was carried out in the ex-situ conservation units of Attappady black goats in Kerala Veterinary and Animal Sciences University. The units were, University Goat and Sheep farm, College of Veterinary and Animal Sciences, Mannuthy. The station is located at longitude of 76^{0}15′ E and latitude of 10^{0}31′ N and at altitude of 30 m above the sea level and Livestock Research Station, Thiruvazhamkunnu. The station is located at longitude of 76^{0}36' E and latitude of 11^{0}03'N and at altitude of 35 m above the sea level.

Experimental animal and period of study
Thirty newly kidded does of Attappady Black and ten Malabari goats negative for California Mastitis Test (CMT) were selected. The study was conducted for a period of seven months from October 2016 to April 2017 and the animals were maintained under the prevailing management conditions of the farms (KVASU, POP, 2016) [8].

Meteorological data
Climatological parameters such as air temperature and relative humidity of the area were obtained from the Centre for Animal adaptation to environmental and climate change studies (CAADECCS**)** College of veterinary and animal sciences, Mannuthy and Weather Station (World Meteorological Organization ID 43335), Palakkad.

Analysis of feed and fodder
Proximate analysis of feed and fodder of both farms were done as per the standard procedures (AOAC, 2012).

Sample analysis
The Milk samples (approximately 100 ml) were collected from all does in clean and sterile plastic container at first on seventh day of lactation and then every three weeks interval of the does till the end of lactation and was analysed for milk minerals *viz*., calcium, phosphorus, sodium and potassium content.

Microwave digestion of milk samples
Equipment
The equipment used was PerkinElmer Titan MPS and standard 100 mL digestion vessel

Reagents
HNO_3 (70%) 7.5 mL
H_2O_2 (30%) 1.5 mL

Procedure
Weighed 3.5 mL of the milk sample into the digestion vessel and added 7.5 mL of HNO_3 and 1.5 mL of H_2O_2. The mixture was shaken carefully and stirred with a clean glass bar. Waited for 10 min before closing the vessel and heated in the microwave with the following program.

Table 1: Temperature programme for microwave digestion of milk

Step	Target temperature (°C)	Pressure max (bar)	Ramp time (min)	Hold time (min)	Power (%)
1	165	30	5	10	50
2	190	30	5	20	80
3	30	30	1	10	0

Waited until the vessels were cooled to room temperature to avoid foaming and splashing. Carefully opened the digestion vessel in a fume hood wearing hand, eye and body protection since a large amount of gas was produced during the digestion process. A clear solution was obtained. The milk was digested in an acid solution with a PerkinElmer Titan MPS.
The digested samples were filtered using Whatman No. 40 ashless filter paper and stored in high density poly ethylene (HDPE) bottles for mineral estimation after making into 50 ml using de-ionized water. Then the samples were used for the analysis of calcium, phosphorus sodium and potassium content by using Atomic Absorption Spectrophotometer as per Ojoawo and Akinsoyinu (2014).

Statistical analysis
Data obtained on the experiment were subjected to statistical analysis as per Snedecor and Cochran (1994) and results were interpreted.

Result and Discussion
Meterological data
The microclimate variables considered for the study were air temperature (℃) and relative humidity (%) of Mannuthy and Palakkad regions and the values are represented in Table 2. Air temperature was not significantly different between the locations but the Mannuthy region had significantly (P<0.01) higher relative humidity in per cent (76.96) than Palakkad (64.58) region.

Table 2: Meteorological data on Mannuthy and Palakkad regions

Parameters	Mannuthy	Palakkad	t-value	*p*-value
Air temperature (℃)	28.94 ± 0.10	29.16 ± 0.12	1.837	0.176
Relative humidity (%)	76.96 ± 0.90	64.58 ± 0.78	107.50**	<0.001

**Significant at 1% level

Proximate composition of feeds and fodder
The proximate composition (per cent) of feed and fodder are presented in table 3. The crude protein (per cent) content of feed on Mannuthy and Thiruvazhamkunnu farms were 20.47 and 20.10 respectively and crude protein content fodder on Mannuthy and Thiruvazhamkunnu farms were 8.06 and 8.03 respectively.

Table 3: Proximate composition of feed and fodder

Parameters (%)	Feed		Fodder	
	Mannuthy	Thiruvazhamkunnu	Mannuthy	Thiruvazhamkunnu
Moisture	6.06 ± 0.05	6.04 ± 0.04	78.24 ± 1.88	78.63 ± 2.01
Crude protein	20.47 ± 0.52	20.10 ± 0.54	8.06 ± 0.57	8.03 ± 0.54
Crude fibre	11.21 ± 0.68	11.14 ± 0.71	35.35 ± 0.17	35.10 ± 0.14
Ether extract	3.18 ± 0.15	3.12 ± 0.08	2.88 ± 0.14	3.06 ± 0.13
Total ash	8.99 ± 0.05	8.80 ± 0.08	11.10 ± 0.16	10.57 ± 0.06
Nitrogen free extract	56.14 ± 1.40	56.83 ± 1.42	42.61 ± 0.88	43.22 ± 0.47

Milk mineral composition
Calcium
The calcium content of milk in goats was recorded and summarized in Table 4. The overall milk calcium content had significant (P<0.01) difference between the Attappady Black and Malabari goats. Also, it differed significantly (P<0.01)

within the both breeds during various lactation stages and between the two breeds, calcium content was significantly (P<0.01) higher in Malabari goats on weeks 4 and 7 but not in 1st and 10th weeks of lactation stages. The highest calcium content (ppm) was observed in 1st (571.18 ± 20.10) and 4th week (638.56 ± 16.21) of lactation in Attappady Black and Malabari goats respectively.

Table 4: Milk calcium content of attappady black and malabari goats during lactation

Stages of lactation (In weeks)	Ca (ppm)		t-value	*p*-value
	Attappady black (n = 30)	Malabari (n = 10)		
1	571.18 ± 20.10^{a}	619.66 ± 25.17^{ab}	1.280	0.208
4	502.15 ± 22.64^{b}	638.56 ± 16.21^{a}	3.360**	0.002
7	431.40 ± 17.94^{c}	552.68 ±14.53^{bcd}	3.743**	0.001
10	476.05 ± 24.30^{bc}	527.63 ± 17.00^{cd}	1.739	0.091
13		475.73 ± 17.27^{e}		
16		496.35 ± 26.94^{de}		
F-value	7.500**	11.897**		
p-value	<0.001	<0.001		
Mean	445.20 ± 11.53	551.77 ± 10.93	3.561**	0.002

**Significant at 1% level,*Significant at 5% level and means with same lower case as superscripts have no significant difference between the weeks

The mean milk calcium content (ppm) recorded during experimental period was 445.20 ± 11.53 and 551.77 ± 10.93 of Attappady Black and Malabari goats respectively. In both the breeds the obtained value of calcium was lower than the reference value of 1,200 mg L^{-1} suggested by Underwood (1981) [15]. In contrast to the present result, Guzeler *et al.* (2010) [7] reported the average calcium content in milk was 2220 mg L^{-1} in Sannan x kill's goats which was higher than the present findings and Singh *et al.* (2014) [13] reported the overall calcium content of Beetal breed was 344 mg L^{-1} which was lower than the present study.

The milk calcium content of Attappady Black and Malabari goats during various lactation stages are summarized in Table 4. The milk calcium content differed significantly (P<0.01) within the breeds of various lactation stages and between the breeds in weeks 4 and 7 (P<0.01) but not in weeks 1and 10. These results are in agreement with the conclusion of Antunac *et al.* (2001) [4] who found the calcium content had significant (P<0.01) difference between the lactation stages and the highest calcium content noticed in early lactation in alpine and Sannan goat breeds. Similarly, Ahamefula *et al*. (2012) [2] found the calcium content was significantly (P<0.05) different between the breeds in 1, 2, 4, 5, 8 and 9th weeks in red Sokoto and West African dwarf does. In contrast to the present result, Park and Chukwu (1988) [12] reported there is no significant difference between the calcium content and the lactation stage on French-alpine and Anglo-Nubian does. Similarly, Aganga *et al.* (2002) [1] observed the calcium content was not significantly (p>0.05) difference between the lactation stages. In the present study, the higher concentration of calcium content observed on early lactation is probably due to the higher amounts of casein, which acts as a calcium (Ca caseinate) carrier in milk.

Phosphorus

Data of milk phosphorus content of experimental animals are represented in Table 5. The overall milk phosphorus content was fairly comparable (p>0.05) between the Attappady Black and Malabari goats. No significant (p>0.05) difference was noticed between the two breeds on weeks 1, 4, 7 and 10 of lactation stages but the milk phosphorus content was differed significantly in various stages lactation in Attappady Black (P<0.05) and Malabari (P<0.01) goats. The Attappady Black had highest phosphorus content (ppm) in 1st week (530.61 ± 18.67) of lactation whereas in Malabari goats it was at 16th week (527.49 ± 20.80) of lactation.

The Mean milk phosphorus content (ppm) respectively in Attappady Black and Malabari goats were 523.97 ± 9.34 and 515.94 ± 7.53. This value of phosphorus was lower than the reference value of 1000 mg L^{-1} suggested by Underwood (1981) [15] in both the breeds. These results obtained in the present study Garcia *et al.* (2006) [6] who stated the average phosphorus content of canary Island goat milk was 510 mg L^{-1}. But, findings were contrary to Guzeler *et al.* (2010) [7] reported the average phosphorus content in milk (1080 mg L^{-1}) in Sannan x kills which was higher than the present findings and Singh *et al.* (2014) [13] reported the overall phosphorus content of Beetal breed was 355 mg L^{-1} which was lower than the present findings.

The average phosphorus content of Attappady Black and Malabari goats on various lactation stages are represented in Table 5. Milk phosphorus content differed significantly in various stages lactation in Attappady Black (P<0.05) and Malabari (P<0.01) goats and there is no significant difference between the breeds in weeks 1, 4, 7 and 10. The findings were similar to Ahamefula *et al*. (2012) [2] who found the phosphorus content had significant (P<0.05) difference between the breeds in 2, 4, 6, 9 and 10th weeks. Singh and Sharma (2016) [14] reported that stages of lactation had significant (5%) effect on phosphorus content in different stages of lactation. In contrast to the present result, Park and Chukwu (1988) [12] reported that there is no significant difference between the phosphorus content and the stages of lactation. Similarly, Guzeler *et al*. (2010) [7] and Matysek *et al*. (2013) [11] found that the phosphorus content of milk was not significantly different (P<0.05) during the stages of lactation. In the present study, the higher concentration of phosphorus content observed on early lactation is probably due to accumulation of casein, which acts as a calcium (colloidal calcium phosphate) carrier in milk.

Table 5: Milk phosphorus content of attappady black and malabari goats during lactation

Stages of lactation (In weeks)	P (ppm)		t-value	*p*-value
	Attappady black (n = 30)	Malabari (n = 10)		
1	530.61 ± 18.67^{a}	517.41 ± 18.02^{abc}	0.387	0.701
4	521.50 ± 18.83^{bc}	502.17 ± 18.00^{d}	0.561	0.578

7	516.72 ± 18.93^{c}	510.56 ± 18.49^{c}	0.178	0.860
10	527.02 ± 19.11^{b}	513.45 ±18.07^{bcd}	0.402	0.690
13		525.06 ± 20.71^{b}		
16		527.49 ± 20.80^{a}		
F-value	4.075*	5.885**		
p-value	0.009	<0.001		
Mean	523.97 ± 9.34	515.94 ± 7.53	0.563	0.574

**Significant at 1% level,*Significant at 5% level and means with same lower case as superscripts have no significant difference between the weeks

Sodium

The average sodium content in milk were recorded and summarized in Table 6. The overall milk sodium content differed significantly (P<0.05) between the Attappady Black and Malabari goats. Between the two breeds Malabari goats had significantly higher sodium content in weeks 1 and 4 (P<0.05) but not in 7th and 10th weeks of lactation stages and also it differed significantly (P<0.01) within the both breeds during lactation stages. The highest sodium content (ppm) was observed in 10th week of lactation in Attappady Black (307.72 ± 5.95) and Malabari (320.89 ± 12.06) goats.

Data of milk sodium content of experimental animals on various lactation stages were presented in Table 6. The average milk sodium content of Attappady black and Malabari goats were 274.95 ± 4.70 and 291.94 ± 6.36 ppm respectively. This value of Sodium content was lower than the reference value of 500 mg L^{-1} counseled by Underwood (1981) [15]. The results of present study was compared favorably with the value of 256 mg L^{-1} reported by Khan *et al*. (2014) [10] on milk from South Korean supermarket. In contrast to the present result, Guzeler *et al*. (2010) [7] reported the average sodium content in milk was 670 mg L^{-1} in Sannan x kill's goats which was higher than the present findings and Singh *et al*. (2014) [13] reported the overall sodium content of Beetal breed was 118 mg L^{-1} which was lower than the present findings.

Milk sodium content differed significantly (P<0.05) within the breeds of various lactation stages. Sodium content of milk (ppm) differed significantly between the breeds in weeks 1 and 4 (P<0.05) but not in 7th and 10th weeks. The findings were similar to Ahamefula *et al*. (2012) [2] who reported that the sodium content was significantly (P<0.05) different between the breeds at 1st, 2nd, 3rd, 5th, and 7th weeks and they observed the highest sodium content in 10th week of lactation. Matysek *et al*. (2013) [11] reported that the sodium content had a significant (P<0.01) difference between the stages of lactation and the highest sodium content was observed in end stage of lactation. In contrast to the present result, Park and Chukwu (1988) [12] and Aganga *et al*. (2002) [1] observed that the sodium value was not significantly (p>0.05) differ between the lactation stages. The decrease sodium concentration in early lactation might be due to high concentration of prostaglandins, which causes an increase in sodium content in milk.

Table 6: Milk sodium content of attappady black and malabari goats during lactation

Stages of lactation (In weeks)	Na (ppm)		t-value	*p*-value
	Attappady black (n = 30)	Malabari (n = 10)		
1	269.28 ± 12.29^{bc}	319.29 ± 12.72^{ab}	2.210*	0.033
4	249.98 ± 8.94^{c}	287.06 ± 12.07^{bc}	2.177*	0.036
7	272.86 ± 6.05^{b}	254.26 ± 13.85^{e}	1.417	0.165
10	307.72 ± 5.95^{a}	273.02 ± 17.11^{c}	1.915	0.081
13		301.12 ± 17.01^{abc}		
16		320.89 ± 12.06^{a}		
F-value	7.455**	7.084**		
p-value	<0.001	<0.001		
Mean	274.96 ± 4.70	291.94 ± 6.36	2.116*	0.04

**Significant at 1% level,*Significant at 5% level and means with same lower case as superscripts have no significant difference between the weeks

Potassium

Summarized data of milk potassium content of Attappady Black and Malabari does are listed in Table 7. There is no significant (p>0.05) difference between the overall potassium content of Attappady Black and Malabari goats and also between the two breeds (p>0.05) in weeks 1, 4, 7 and 10 of lactation stages. But it differed significantly (P<0.05) within the both breeds of various lactation stages. The highest potassium content (ppm) of Attappady Black and Malabari goats was noticed in 10th (849.93 ± 14.35) and 1st (857.60 ± 20.76) week of lactation respectively.

Data on mean milk phosphorus content recorded during experimental period was 825.83 ± 7.49 and 813.90 ± 9.63 ppm of Attappady Black and Malabari goats respectively. This value of potassium was lower than the reference value of 1500 mgL^{-1} suggested by Underwood (1981) [15] in both the breeds. The results of present study compared favorably with the value of 824.4 ± 0.56 mg L^{-1} reported by Khan *et al*. (2014) [10] on milk from South Korean supermarkets. In contrast to the present result, Guzeler *et al*. (2010) [7] who reported the average potassium content in milk was 1530 mg L^{-1} in Sannan x kills and also Kapadiya *et al*. (2016) [8] noted the average content of potassium (980 ± 190.89 mg L^{-1}) in Surti goats.

Table 7: Milk potassium content of attappady black and malabari goats during lactation

Stages of lactation (In weeks)	K (ppm)		t-value	*p*-value
	Attappady black (n = 30)	Malabari (n = 10)		
1	827.89 ± 16.04^{ab}	857.60 ± 20.76^{a}	0.979	0.334
4	800.56 ± 14.50^{c}	810.40 ± 25.46^{abd}	0.338	0.737
7	824.94 ± 13.96^{bc}	812.97 ± 18.30^{bcd}	0.453	0.653
10	849.93 ± 14.35^{a}	802.15 ± 23.78^{d}	1.682	0.101
13		788.27 ± 23.75^{d}		
16		805.96 ± 20.67^{bd}		
F-value	4.352*	3.337*		
p-value	0.007	0.012		
mean	825.83 ± 7.49	813.90 ± 9.63	1.047	0.296

**Significant at 1% level,*Significant at 5% level and means with same lower case as superscripts have no significant difference between the weeks

Summarized data of milk potassium content of Attappady Black and Malabari does on various lactation stages were listed in Table 7. Milk potassium content was differed significantly ($P<0.05$) within the breeds of various lactation stages and there is no significant difference between the breeds in weeks 1, 4, 7 and 10. These results of present studies are agreed with the findings of Mewstaw *et al.* (2012) who reported the stage of lactation had significant ($P<0.001$) difference on potassium content of Boer goats, Cross, Arsi – Bali and Somali and they found the potassium content were significantly higher ($P<0.001$) in the early and late lactation stage than the mid lactation. In contrast to the present result, Park and Chukwu (1988) [12] and Guzeler *et al.* (2010) [7] who observed that the potassium content of milk was not significantly ($P<0.05$) different during the stages of lactation. In the present study, the higher concentration of potassium content observed in goats is probably due to accumulation of high amounts of potassium content in the feed and fodder which are provided to the goats.

Correlation coefficient

The correlation between the investigated macro minerals in milk was negative and significant in K^+ and P and Na^+ and K^+. In contrary to present findings Ying *et al.* (2003) [16] who found that the positively correlation noticed between the potassium and phosphorus content. There is no correlation was noticed in other milk minerals of Attappady Black goats (Table 8) and none of the milk minerals are correlated in Malabari goats (Table 9).

Table 8: Correlation coefficients between the experimental parameters of attappady black goats

Components	Ca	P	K^+	Na^+
Ca	1			
P	0.099	1		
K^+	-0.011	-0.198*	1	
Na^+	0.173	0.158	-0.185*	1

**Significant at 1% level,*Significant at 5% level.

Table 9: Correlation coefficients between the experimental parameters of malabari goats

Components	Ca	P	K	Na
Ca	1			
P	0.211	1		
K^+	-0.008	0.104	1	
Na^+	0.031	0.069	0.071	1

**Significant at 1% level,*Significant at 5% level.

Conclusion

For small ruminants within breed or different breeds, the variability in blood and milk composition may arrive due to management and environment of the location of study. The Attappady black goats are medium sized animal and it well adapted to hilly regions. So animals arrived from a different habitat could leads to both physiological and nutritional threats because the new location had different diet in both form and composition, which could changes the milk composition, hence the variation in milk composition was observed. For Malabari goats, however differences in milk composition even with animals within same locality would tend to highlight the high genetic variability within the breeds.

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