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Mineral Composition, Nitrogen Distribution of Goat's Milk Produced under Algerian Steppe Condition across Lactation Stage

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Abstract. Goat milk constitutes a well-priced source of minerals and proteins for a large rural population, particularly those living in the mountains and whose access to state-subsidized milk is very limited. This study aims at assessing the mineral composition and nitrogen distribution of goat milk produced by the Algerian Arabia breed and estimating how lactation stage affects these elements. Thirteen individual Arabia goat milks were collected and analyzed three times during the lactation period (early, mid, and late). Minerals were analyzed by atomic absorption spectrometry and nitrogen fractions using the Kjeldahl method. The findings of the research showed that casein, whey, and milk protein content had respective mean values of 2.95, 0.74, and 3.54 g 100 ml^{-1}, respectively. The highest levels of minerals were found for calcium (537 µg ml^{-1}), and sodium (336 µg ml^{-1}). The average trace mineral concentration was between 1.78 µg ml^{-1} (Fe) and 0.007 µg ml^{-1} (Cs). Heavy metal concentrations were assessed to be 0.057 µg ml^{-1} for Pb and 0.009 µg ml^{-1} for Cd. An important effect of stage of lactation ($p < 0.05$) was observed on only K, Fe, and Na mineral components, whereas nitrogen distribution was not affected. As the lactation period progressed, the variation of these components was not constant and fluctuated across lactation stages.
Key words: goat milk, lactation stage, minerals, protein, Algeria.

Introduction

The use of goats as a potential supply of protein (milk and meat) and a source of income (hide and skin) could improve the lives of people, particularly those in rural regions (Idamokoro, Muchenje, & Masika, 2017). In developing countries, goat milk can be considered a major source of food and, thus, the primary source of nutrients. Thus, goat farming for meat and milk is motivated by three main reasons: (i) they can better withstand higher temperatures and more difficult geological conditions, (ii) they are easier and cheaper to maintain, mainly by women and children, and (iii) compared to the milk of other domestic milk-producing mammals, their milk provides better nutritional and health benefits (Haenlein, 2017). The benefits of goat milk are observable at different levels: nutritional (Silanikove, Merin, & Leitner, 2014), therapeutic (Yangilar, 2013), and technological (Pazzola, 2019). Given that, Turkmen (2017) offers an elaborate discussion of the dietary value and health benefits of goat milk ingredients. Due to its non-allergenic qualities, digestive capacity, and contribution to lowering family-level poverty and dietary deficiency among small-scale producers as well as among consumers, goat milk is very common worldwide (Isidro-Requejo *et al.*, 2019).

Like the milk of other species, the quality of goat milk depends on several factors. According to Larson (1978), considerable intraspecies variation exists according to breed, nutrition, stage of lactation, environmental conditions, and other factors. Numerous research papers have focused on the impact of the lactation stage on goat milk composition (Chen *et al.*, 2018; Idamokoro, Muchenje, & Masika, 2017; Isidro-Requejo *et al.*, 2019; Marounek *et al.*, 2012; Michlova *et al.*, 2016; M.S. El-Tarabany, A.A. El-Tarabany, &

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Roushdy, 2018; Slyzius, Slyziene, & Lindziute, 2017; Tatar *et al.*, 2015; Turkmen, 2017).

In Algeria, the goat population is estimated at more than 5 million head in 2021 (FAO, 2021), of which the largest number is located in the steppe zone (Kadi *et al.*, 2014). Algerian steppe regions are characterized by shallow soils, poor in organic matter and sensitive to erosion and degradation; they are also marked by increasingly lower and irregular levels of rainfall that are coupled with an increase in temperatures and summer drought periods. Such factors make conditions for plant development more difficult with a deficit in water balance (Nedjimi & Guit, 2012). Goat farming is carried out extensively (Mouhous, Bouraine, & Bouaraba, 2013). Breeding is generally intended for meat production, and part of the milk can be consumed by the household (Yabrir *et al.*, 2016), with an average milk production estimated at 1.26 liters/goat/day (Mouhous, Bouraine, & Bouaraba, 2013). In Kabylia, goat milk, with its high nutritional value, has become the substitute for mothers' milk even at earlier stages of the child's development (Saidani *et al.*, 2019). Except for the research provided by Yabrir *et al.* (2016), there is a remarkable paucity of information about the chemical composition, minerals, and nitrogen fractions of goat milk produced in the Algerian steppe. Therefore, there is a pressing need to analyze mineral composition and nitrogen distribution of goat milk. The present study aims to address such a gap by analyzing the chemical composition of goat milk in the steppe area in Algeria, with particular reference to the impact of the lactation stage.

Materials and Methods

Sampling

Thirteen goats, kept in a semi-intensive dairy production system, were selected based on the following criteria: same breed (Arabia), same age (average age = 4 year) and all multiparous, at same parturition period (grouped farrowing's). The goats were kept in the same flock and received the same feed intake. At early and mid-lactating periods, the goats were fed with concentrate and straw. At later stages of lactation periods, the primary sources of nutrients are natural grazing that is supplemented with barley/wheat intake. Thirteen individual milk samples were collected periodically, at 3 different lactation stages (early, mid and late, once time per period), namely 20, 110 and 180 day (d) of lactation; during the experimental period. Milk samples were collected, from the Demonstration and Seed Production Farm (DSPF) of Ksar Chellala, Province of Tiaret (Algeria), into labeled plastic bottles at 4 **°C**, after washing udders with deionized water.

Nitrogen fraction determination

Nitrogen was determined by the Kjeldahl method (Schuck, Dolivet, & Jeanhet, 2012), following the steps described by Keys (1940). The first step, "digestion", was carried out on a digestion unit type Buchi K-435 (Flawil 1, Switzerland), and the second step, "distillation", on a distillation unit type Gerhardt Vapodest 10 (Königswinter, GB).

Raw milk was used for the total nitrogen (TN) analysis. Non-casein nitrogen (NCN), on the filtrate after acidification with 10% acetic acid at pH 4.6, and non-protein nitrogen (NPN), on the filtrate following the action of 15% trichloroacetic acid (Shahani & Sommer, 1951). Protein nitrogen (PN) = TN-NPN; casein nitrogen (CN) = NT-NCN; and soluble protein nitrogen (SPN) = NCN-NPN were the additional nitrogen fractions that were determined. The nitrogen contents of the different fractions analyzed are converted into protein contents using a conversion factor equal to 6.38, as recommended by Cerbulis & Farell (1975).

Mineral content analyses

The mineral contents of whole milk were measured, as well as the diffusible percentage for soluble elements. The soluble fraction was obtained by centrifugation at 10,000 rpm. Individual milk was dried for five hours at 103 ±2 °C and incinerated for nine hours at 525 ±25 °C in a muffle furnace (Yabrir *et al.*, 2016). The ash obtained was taken up by acid hydrolysis and treated successively with hydrochloric acid 50% and 10%, and deionized water, as described by Miles, Wilkinson, & Mcdowell (2001). After filtration, dilutions were carried out to the appropriate detection level according to the recommendations of the aforementioned authors.

Minerals content was determined by atomic absorption spectrometry (SAA, GC 107) (Yabrir *et al.*, 2016), equipped with a specific hollow cathode lamp for each element. The following wavelengths were used to determine minerals: Ca (623 nm), Mg (285.2 nm), Na (589 nm), K (768 nm), Cu (324.75 nm), Fe (248.3 nm), Mn (279.5 nm), Cr (357.9 nm), Pb (283.3 nm), Cd (228.8 nm), Cs (825.1 nm), and Co (460.7 nm). To create calibration curves, and for each element, three solutions (0.01, 0.1, and 0.5 ppm) were performed from the ISO standard solution (1.000 ppm) as described by Yabrir *et al.* (2016); the samples and standard solutions were made using deionized water (resistivity, 18 mΩ cm). Results are expressed in ppm (µg ml^{-1} of milk). All analyses were repeated three times, both for nitrogen fractions and for mineral content.

Statistical analyses

The Statistica software was used for data analysis. The obtained results were subjected to a univariate descriptive analysis that consisted of means and standard error of mean value calculations. The Tukey range test and one-way Analysis of Variance (ANOVA) were performed to determine statistically significant differences. The factor being evaluated was the lactation stage, and the probability level was 95%.

Results

Nitrogen distribution and mineral composition

Table 1 illustrates the goat milk nitrogen distribution. The range TP content is 1.96-5.06 g 100 ml^{-1} with a mean value of 3.54 g 100 ml^{-1}. The analyzed goat milk has an average TN content of 4.00 g 100 ml^{-1}. The TP/TN ratio is 90% on average. In Algerian goat milk, the average value of caseins is 2.95 g 100 ml^{-1} and contains on average 0.74 g 100 ml^{-1} whey proteins (WP). Casein represents 83% of TP, and WP represents 21% of TP.

Table 2 lists the mineral contents of goat milk. Mineral elements are found in varied concentrations in the entire milk, ranging from 0.007 µg ml^{-1} (Cs) to 536.98 µg ml^{-1} (Ca). The highest values are seen for calcium and sodium, followed by potassium and magnesium, with average contents of 536.98 µg ml^{-1}, 336.29 µg ml^{-1}, 155.13 µg ml^{-1}, 76.73 µg ml^{-1}. Among the trace minerals, iron content is the highest (1.78 µg ml^{-1}) followed by copper (0.24 µg ml^{-1}). The presence of the other trace elements is detected to be between 0.108 µg ml^{-1} (Cr) and 0.007 µg ml^{-1} (Cs), and that of the heavy (toxic) metals to be between 0.009 µg ml^{-1} (Cd) and 0.057 µg ml^{-1} (Pb).

Effect of lactation stage

Table 3 shows that, only the minerals K, Fe, and Na are significantly affected by the lactation stage ($p < 0.05$). The amount of potassium decreases from 160 ppm at early lactation to 102 µg ml^{-1} in mid-lactation and increases again to reach a value of 203 µg ml^{-1} in late lactation. The content of Fe decreases significantly

Table 1

Nitrogen distribution of goat milk, g 100 ml^{-1}

Nitrogen fractions	Average (n=39)	Standard error	Minimum	Maximum
TN	4.00	0.29	2.13	5.54
TP	3.54	0.25	1.96	5.06
CAS	2.95	0.22	1.56	4.05
WP	0.74	0.05	0.4	1.02
TP/TN	0.88	0.03	0.55	0.92
CAS/TP	0.83	0.04	0.79	1.34
WP/TP	0.21	0.01	0.20	0.30

TN = total nitrogen; TP = total proteins; CAS = caseins; WP = whey proteins

Table 2

Goat milk mineral content, µg ml^{-1}

Element	Average (n=39)	Standard error	Minimum	Maximum
Ca	536.98	198.514	101	2542
Na	336.29	51.579	90	770
K	155.13	19.025	20.9	335
Mg	76.73	29.417	16.82	394
Fe	1.78	0.409	0.01	4.69
Cu	0.24	0.097	0.006	1.49
Mn	0.06	0.018	0.005	0.26
Cr	0.108	0.018	0.02	0.28
Co	0.009	0.003	0	0.05
Cs	0.007	0.003	0	0.04
Pb	0.057	0.008	0.005	0.12
Cd	0.009	0.001	0.003	0.02

Table 3

Milk mineral composition in goat milk at different lactation stages, µg ml^{-1} of milk

	Traits	Stage of lactation			Average
		Early	Mid	Late	
Macroelements	Ca	345.70±19.93[a]	593.40±270.56[a]	671.83±234.56[a]	536.98
	Na	198.80±18.21[a]	397.58±56.86[b]	412.48±53.33[b]	336.29
	K	160.13±6.49[a]	101.84±14.52[b]	203.43±22.28[a]	155.13
	Mg	46.30±3.31[a]	82.71±33.97[a]	101.17±40.41[a]	76.73
Microelements	Fe	2.71±0.41[a]	1.95±0.43[b]	0.68±0.15[b]	1.78
	Cu	0.16±0.04[a]	0.37±0.16[a]	0.18±0.05[a]	0.24
	Mn	0.04±0.008[a]	0.08±0.02[a]	0.05±0.02[a]	0.06
	Cr	0.123±0.02[a]	0.112±0.02[a]	0.090±0.01[a]	0.108
	Co	0.007±0.002[a]	0.005±0.002[a]	0.015±0.005[a]	0.009
	Cs	0.004±0.001[a]	0.014±0.004[a]	0.003±0.001[a]	0.007
	Pb	0.060±0.008[a]	0.046±0.006[a]	0.066±0.011[a]	0.057
	Cd	0.009±0.001[a]	0.010±0.001[a]	0.009±0.001[a]	0.009

[a,b] significant difference at 5% level are marked with different superscript letters in a same line

Table 4

Nitrogen distribution in goat milk at different lactation stages, g 100 ml^{-1}

Nitrogen fractions	Stage of lactation			Average
	Early	Mid	Late	
TN	4.18±0.19[a]	3.96±0.31[a]	3.85±0.39[a]	4.00
TP	3.83±0.17[a]	3.28±0.20[a]	3.53±0.36[a]	3.54
CAS	3.19±0.14[a]	2.89±0.22[a]	2.82±0.29[a]	2.95
WP	0.78±0.03[a]	0.73±0.06[a]	0.71±0.07[a]	0.74
TP/TN	0.92±0.001[a]	0.85±0.04[a]	0.92±0.001[a]	0.90
CAS/TP	0.80±0.001[a]	0.89±0.06[a]	0.80±0.00[a]	0.83
WP/TP	0.20±0.00[a]	0.22±0.01[a]	0.20±0.00[a]	0.21

TN=total nitrogen; TP=total proteins; CAS=caseins; WP= whey proteins

[a,a] : difference not significant at 5% level

and gradually from 2.71 to 0.68 µg ml^{-1} with the advancement of lactation, whereas Na increases significantly from 198 ppm at early lactation up to 397 µg ml^{-1} at mid-lactation to reach 412 µg ml^{-1} in late lactation. The other elements fluctuate from one stage to another in a non-significant way. These elements can be classified into four groups according to their variation along the lactation stage. The first group includes Ca and Mg, which are shown to gradually increase from the early to the late lactation stage. The second group includes Cr, which gradually decreases from early to late lactation. The third one comprises Cu, Mn, Cd, and Cs; these elements increase from early lactation to mid-lactation and decrease again in late lactation. The fourth group includes Co and Pb, which are inversely correlated with elements in the third group as they decrease from early lactation to mid-lactation and increase in late lactation.

The nitrogen distribution was higher at the early lactation stage in comparison to the late and mid-lactation phases (Table 4). The differing nitrogen fractions are not significantly affected by the lactation stage as shown in the following table:

Discussion

In the current study, all protein fractions are higher than those reported by Rafiq *et al.* (2015). The range of TP is slightly lower than those reported by Stocco *et al.* (2018) and higher than those reported by Ibrahim *et al.* (2020) and Michlova *et al.* (2016). Ceballos *et* *al.* (2009), who analyzed a sample of 30 Spanish goat milks, report a value close to the ones reported in the present study (estimated at 3.48%), while Park (2017) reports a value of 3.50% of protein in goat milk. In Estonian goat milk, the average protein content was found to be 3.41% by Tatar *et al.* (2015). Zazharska, Boyko, & Brygadyrenko (2018) reveal that protein content in goat milk refers to economically important characteristics and is more influenced by goats' food intake than by breed. The TP/TN ratio is concomitant with Grappin *et al.* (1981) in French goat milk. Concerning total nitrogen, Vierling (2008) indicates a value of 3.2 g 100 ml^{-1} of the same type of milk. The value indicated in the present study is slightly lower than that found by Turkmen (2017) with 4 g 100 ml^{-1}. However, it is greater than the value found by Guo *et al.* (2001) with 3.64 g 100 ml^{-1}.

The average casein content of goat milk from Algeria is significantly higher than those reported by Larson (1978); Michlova *et al.* (2016), and Turkmen (2017) but it is lower than that reported by Stocco *et al.* (2018). According to Stocco *et al.* (2018), goat milk casein not only increases curd firmness traits but also affects considerably the properties of the final gel network at the rennet coagulation time.

The content of whey proteins (WP) found in the present study is higher than that cited by Hejtmánková *et al.* (2012), Larson (1978), and Turkmen (2017), but it is lower than that declared by Veinoglou *et al.* (1982). The proteins that remain in the solution after precipitation are whey proteins (McSweeney, 2003), many of these proteins (α-lactalbumin, β-lactoglobulin, immunoglobulins, and serum albumin, inter alia) have interesting functional, nutritional, and physiological properties (Fox, 2001), and they are marketed as food and nutritional ingredients, such as whey protein isolate, whey protein concentrate, and whey powder (Patel & Patel, 2015). According to Svanborg *et al.* (2015), whey protein concentrate (WPC) or isolate (WPI) are often made from cheese whey; however, WPC can also be made by fractionating skim milk. Buttermilk (BM) is another possible source for WPC, which has remarkable composition and solubility characteristics.

The values of caseins found in the present study are similar to those reported by Kindstedt, Duthie, & Nilsok (1983). Moreover, the ratio WP/TP is similar to the result of Jaubert (1997). Hejtmánková *et al.* (2012) found that the average whey to total protein ratio in goat milk was 15.8% and varied from 13.0 to 20.4%.

According to Guo (2003), goat milk has a larger total protein and non-protein nitrogen content when compared to cow milk, whereas the nitrogen content of casein is lower.

Generally, major and trace mineral values are low in comparison to the various results obtained elsewhere, such as those of Curro *et al.* (2019), Michlova *et al.* (2016), Park *et al.* (2007), Turkmen (2017), and Pan *et al.* (2023). In some cases, however, Mg and Na are higher (Curro *et al.*, 2019). It is widely known that goat milk has higher concentrations of some significant minerals in comparison to cow milk; several of these substances are more accessible in goat milk (Turkmen, 2017).

Ca, P, and Mg are the most documented elements in the literature. This is probably due to the technological importance that these elements play in the structure and organization of the casein micelle (Croguennec, Jeanter, & Brulé, 2008). Another plausible rationale for such studies comes from a nutritional point of view as Ca, P and Mg are components of body tissues and fluids (Campos *et al.*, 2003).

Among the trace minerals, lower contents of Fe in goat milk and higher values of Cu and Mn were observed by Curro *et al.* (2019), Park *et al.* (2007), and Turkmen (2017) when compared to our findings. Regarding toxic elements, their presence in goat milk are higher than indicated by Antunovic *et al.* (2012) and Rahimi (2013). However, they have low values in goat milk and they are considered the most toxic (Dana, 2014) and an indication of milk contamination (Dhanalakshmi & Gawdaman, 2013). The FAO/WHO expert committee limits a provisional tolerable weekly intake (PTWI) at 7 μg kg^{-1} Cd, and 25 μg kg^{-1} Pb, bodyweight (FAO/WHO, 1993).

The change in mineral composition along the lactation stage showed variable results, as some minerals demonstrated patterns that were similar to those found in the previous studies, whereas others varied. According to Park & Chukwu (1989), the levels of Cu, Al, Fe, and Zn in goat milk of French-Alpine and Anglo-Nubian breeds were influenced by the stage of lactation, which has no statistically significant bearing on the manganese value change. Aganga, Amarteifio, & Nkile (2002) showed that there was a fluctuation in the contents of the major minerals in Tswana goat's milk as the lactation period advanced; fluctuation was not significant for P, Na, Cu, Fe, and Zn, but significant for Ca, Mg, K, and Mn.

According to Kondyli, Katsiari, & Voutsinas (2007) findings, Na, Mg, and Fe did not change significantly during lactation. However, the mineral concentrations of Ca, P, K, Cu, Zn, and Mn in Greek raw goat milk change significantly in relation to lactation stages. Michlova *et al.* (2016) observed that at the beginning of lactation, Ca and Cu contents were significantly higher but Mg, K, and Na were significantly lower, noting that Mg increased continuously during the entire lactation period. With the exception of the boron element, Curro *et al.* (2019) discovered recent changes in the mineral composition of milk in five local breeds and one mixed breed in Italy, with greater concentrations at the end of lactation than at the beginning for almost all major elements (Ca, Na, P, S, Mg, and K) and trace elements (Zn, Sr, Ba, and Fe). However, decreasing values of calcium in mature milk and late lactation milk of Laoshan goat milk are not significant (Chen *et al.*, 2018). Furthermore, Pan *et al.* (2023) reported that the concentrations of Mg, Ca, Na, K, Cu, and Fe in milk, collected from 15 healthy Laoshan goats with the same parity and lactation period, exhibited a decreasing trend during the lactation period 1–3 to 150 d, followed by an increase from 150 to 240 d, however, the concentrations of Cr, Ni, and Mo showed an increasing trend from 1–3 to 150 d of lactation, while the concentrations of Mn and Zn increased during the lactation period of 1–3 to 90 d and then decreased from 90 to 240 d. According to Idamokoro, Muchenje, & Masika (2017), the lactation stage had no influence on the potassium and iron levels in the milk of Nguni, Boer, and non-descript goats, but it did on the calcium, magnesium, and sodium levels.

The findings regarding the effect of the lactation stage do not align with those reported by Kapadiya *et al.* (2016) for nitrogen distribution; Noutfia *et al.* (2014) for total nitrogenous matter; Curro *et al.* (2019) and Kondyli, Katsiari, & Voutsinas (2007) for protein; and Aganga, Amarteifio, & Nkile (2002) for caseins. Nonetheless, the findings of the present study seem to align with those of Idamokoro, Muchenje, & Masika (2017) and M.S. El-Tarabany, A.A. El-Tarabany, & Roushdy (2018) for protein in Boer and non-descript South African goats milk and Baladi goats milk under Egyptian conditions, respectively.

According to Park (2017), the protein content of the milk is high in the first few months of lactation: it drops quickly to its lowest point during the second to third months, and then gradually rises as breastfeeding progresses. The yield and goat milk's protein content were found to be negatively correlated (Schmidt, 1971). Finally, Tatar *et al.* (2015) found a seasonal variation in the protein content of Estonian goat milk, which showed the lowest average protein content during the spring-summer season and a higher average in the summer-autumn season.

Conclusions

In conclusion, Algerian Arabia goat milk produced under steppe conditions showed a large difference in average values between lactation stages, but was not significant statistically, except for K, Fe, and Na. As the lactation period progressed, the variation of these components was not consistent between lactation stages and fluctuated remarkably. In view of that, milk quality is the result of many factors that can operate separately or in interactions. The present study, therefore, recommends future studies where there is a focus on the interaction of these factors affecting goat milk quality, chemical composition, and nutritional profile.

The findings of this study imply that the milk produced by goat breeds in the steppe area might be effective for increasing the value of goat milk produced under Algerian steppe conditions and contribute to supplying the national milk market. This milk can constitute a good source of minerals and proteins, especially for children from rural populations.

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