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Technological properties of Saanen goat's milk in the context of mountain farming in Kabylia

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Abstract. The technological properties of milk are largely determined by its protein and mineral composition, which influence coagulation suitability and curd yield. This study examined the relationships between the composition of Saanen goat's milk produced in mountainous pastoral conditions and technological indicators. Monthly milk samples collected from March to May were analyzed to determine their chemical composition, mineral profile, and coagulation aptitude. Casein content was identified as the main determinant of technological performance, demonstrating strong positive correlations with curd yield efficiency, daily curd yield, and solid recovery, as well as negative correlations with water retention in the curd. Conversely, the casein number showed limited predictive value. Milk fat also significantly contributed to technological ability by enhancing solid recovery and curd yield through its interaction with the protein matrix. Colloidal calcium exhibited moderate associations with coagulation properties. Seasonal effects were observed with improved curd structuring and moisture control from March to May. Overall, the technological aptitude of Saanen milk was moderate, mainly due to relatively low casein content. These findings highlight the importance of milk components in determining processing performance and provide practical insights for improving feeding strategies and milk utilization in similar agro-climatic conditions.

Key words: Saanen goat milk, milk composition, nutrient recovery, curd yield, technological indicators.

INTRODUCTION

The Saanen goat is a dairy breed originating from Switzerland, widely recognized for its high milk yield and its ability to adapt to diverse environmental conditions (Zeljić Stojiljković et al., 2025). It is currently reared in a wide range of production systems, from temperate regions in Northern Europe to Mediterranean and arid environments (Teissier et al., 2024). Under intensive management and optimal conditions, lactation may extend over 300 days, with milk yields reaching 1,000 kg per lactation (Varlyakov et al., 2018).

In Algeria, particularly in the mountainous region of Kabylia, the Saanen breed is increasingly introduced into local farming systems to diversify dairy production and meet the growing demand for goat milk and derived products (Tefiel et al., 2014; Boumediene et al., 2025). However, these systems are predominantly extensive, characterized by limited concentrate supplementation and strong dependence on seasonal forage availability (Kadi et al., 2016). Under such conditions, milk production remains below the genetic potential of the breed, generally not exceeding 2 kg per day (Mouhous et al., 2015).

Beyond milk yield, the technological quality of milk is a key factor determining its suitability for processing, particularly for cheese production. This quality depends largely on milk composition, especially protein, fat, and mineral fractions, which are known to be influenced by feeding conditions, climate, and herd management practices (Inglingstad et al., 2014; Barłowska et al., 2018; Bouderka et al., 2025). In mountain pastoral systems, these factors may lead to specific compositional profiles that directly affect coagulation behavior, curd formation, and nutrient recovery, which in turn can influence the overall quality and yield of cheese produced from this milk.

While previous studies in Algeria have mainly focused on the reproductive performance and adaptation of Saanen goats to local conditions (Mouhous, 2021), limited information is available on the technological properties of their milk and its suitability for dairy processing. The connections between the composition of milk and how well it coagulates are not well understood in large-scale production systems. Addressing this knowledge ga*p* is essential for improving the valorization of goat milk in these regions. A better understanding of the factors affecting curd yield and nutrient recovery could hel*p* to optimize feeding strategies, milk selection, and processing conditions in small-scale and artisanal dairy systems.

Therefore, the objective of this study was to evaluate the technological properties of Saanen goat milk produced in a mountainous agroclimatic context by analyzing its physicochemical composition, mineral profile, and coagulation behavior. In addition, the study aimed to quantify curd yield and nutrient recovery and to assess the relationships between milk composition and technological performance.

MATERIALS AND METHODS

Experimental design and sampling

The study was conducted over a period of three months (January to March) at a private artisanal cheese factory. This period was chosen to coincide with the early to mid-lactation stage of Saanen goats, when the milk composition is relatively stable. Additionally, feeding conditions in the mountainous agroclimatic context of Kabylia are relatively homogenous during winter, helping to limit variability related to seasonal fluctuations.

Three cheese-making trials were carried out each month, at regular intervals, using Saanen goat's milk collected from three family farms in Kabylia (Afir, Makouda, and Mizrana). The herds (60 to 90 head) graze on mountain pastures at an altitude of 300–900 meters. Milk from the evening milking on each farm was collected the next morning by tanker and then mixed. Upon receipt at the cheese factory, a milk sample was taken from the bulk tank, refrigerated at 4 °C, and sent immediately to the laboratory for composition analyses.

Cheese making process

The process is based on a standardized protocol intended for producing uncooked pressed goat cheese without prolonged ripening. This was chosen to enable the rapid technological evaluation of milk clotting ability, independently of maturation. A total of 9 manufacturing tests were carried out (three per month over three consecutive months). For each test, 10 L of pasteurized milk (75 °C for 30 s) was used. The milk was inoculated with a freeze-dried mesophilic culture (FD-DVS R-707, Chr. Hansen, Denmark) at 8 times the recommended dose and maintained at 34 °C. Once the pH had stabilized, commercial rennet (recombinant bovine chymosin, 1,400 IMCU mL^{-1}, Chr. Hansen) was added at a rate of 25%. After coagulation, the curds were cut into cubes (~6 cm^3), stirred to encourage drainage, and then placed in hanging molds. Draining was carried out by gravity before unmolding, salting in brine, and refining in a ventilated chamber (13 °C, 80% H). The study was limited to analyzing the milk, curd, and whey from each test in order to establish a material balance and calculate curd yield and component recoveries (Cipolat-Gotet et al., 2015a).

Compositional analysis of milk, whey and curd

The main components of milk, whey, and curd, including fat, protein, lactose, and ash, were expressed in g kg^{-1} of fresh matter. Total solids content of milk and whey samples were determined by drying 3 g of each sample at 102 °C until a constant weight was reached. Ash content was determined by weighing after combusting each sample at 550 °C for 6 h. The fat content of milk and whey was analyzed using the Gerber method (ISO 19662, 2018). Fatty acid composition of milk was analyzed using gas chromatography (GC-FID) after methylation of fatty acids to fatty acid methyl esters (FAMEs). Separation was performed using a CP-Sil 88 CB capillary column (100 m × 0.25 mm × 0.20 µm; Agilent Technologies). The results were expressed as a percentage of total fatty acids identified. Total nitrogen, non-casein nitrogen, and non-protein nitrogen were determined using the Kjeldahl method. Nitrogen fractions of milk were prepared according to Rowland (1938) by precipitating the casein at pH 4.2 (the isoelectric point of caprine casein). Crude protein content was calculated as total nitrogen content × 6.38. Casein content was determined by difference, and the casein number was calculated as the ratio of casein to protein multiplied by 100. The fat/protein ratio was calculated as the ratio of milk fat content to total protein content. Lactose content was measured using an infrared analyzer (MilkoScan™ Mars, FOSS, Denmark) according to the IDF method (IDF 141B, 1996). Calcium content was estimated by flame emission spectrometry and phosphorus content by spectrophotometry. Soluble fractions were obtained after appropriate separation, and colloidal calcium and phosphorus were estimated by the difference between total and soluble contents, according to Remeuf et al. (1989). Concerning curd samples, fat, protein, lactose, and total solids were determined using a FoodScanTM analyzer (Foss, Denmark), which is based on near-infrared spectroscopy (NIRS). The pH of milk, whey, and curd samples was determined using a pH meter (Hanna Instruments, model HI 2210). Titratable acidity was only determined for milk samples by titration with N/9 NaOH using phenolphthalein as an indicator and expressed in Dornic degrees (°D).

Evaluation of yield and technological efficiency

In addition to physicochemical analyses, several technological indicators were calculated to evaluate coagulation performance (Vacca et al., 2018). For the nutrient recovery (REC, %), the proportion of each nutrient (protein or fat) recovered in the curd relative to its concentration in the initial milk. For curd yield (CY, %), the mass of curd obtained per 100 kg of processed milk. The theoretical curd yield (Th-CY) is calculated based on the initial concentrations of useful substances in the milk (standard formula). Regarding curd yield efficiency (Eff, %), the ratio of CY to Th-CY expresses the real performance relative to the expected yield. For daily curd yield (dCY), the total mass of curd obtained per day of production. These parameters were analyzed in each trial to assess the stability of technological performance over time and its relationshi*p* with the characteristics of the milk used.

Statistical analysis

Descriptive statistics (means and standard deviations [SD]) were performed, and the results are presented as means and coefficients of variation (CV). The effect of the month on the physicochemical composition of the milk was evaluated using one-way analysis of variance (ANOVA). Multiple comparison tests were performed to identify any significant differences between the sampling periods. A Pearson's correlation analysis was performed to examine the relationships between the physicochemical characteristics of milk, curd, and whey. A linear regression model was used to analyze the correlations between milk components (fat, protein, casein, casein number, and calcium) and technological parameters (nutrient components, curd yield, yield efficiency, and daily yield). In this model, milk components were considered as explanatory variables, while technological indicators were treated as dependent variables. Month was included as a fixed effect to account for seasonal variation. The general form of the model was: $Y = \beta_0 + \beta_1 \times + \varepsilon$. Where Y represents the dependent variable, $\times$ the explanatory variable, β_1 the regression coefficient, and ε the residual error. The regression coefficient (β) indicates the magnitude and direction of the relationshi*p* between variables. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using the R software.

RESULTS AND DISCUSSION

Physicochemical characteristics of Saanen goat's milk

The average chemical composition of Saanen goat's milk produced through a traditional, extensive breeding system in the mountainous Kabylia region is characterized by an average fat content of 39.6 g kg^{-1}, total protein content of 30.3 g kg^{-1}, lactose content of 49.9 g kg^{-1}, and ash content of 9.0 g kg^{-1}. The total solids content ranged from 121.1 to 130.5 g kg^{-1}, with an average value of 125.8 g kg^{-1}. Analysis of the main physicochemical characteristics of the samples reveals significant variations depending on the sampling month (Table 1). In particular, titratable acidity showed a highly significant difference ($p < 0.001$), with values increasing from 17°D in March to 18°D in May. The pH of the milk also decreased significantly ($p < 0.001$) in May (to 6.50), compared to previous months (6.56 in March and 6.59 in April), reflecting more pronounced natural acidification. The casein number increased slightly in May (73.03%), constituting a significant difference compared to March (72.41%), reflecting relative variations between casein and total protein rather than a change in overall protein composition. Ash content also varied significantly ($p < 0.05$) from 8.1 g kg^{-1} in March to 9.9 g kg^{-1} in May, potentially indicating greater mineralization towards the end of the season. Similarly, a significant decrease in colloidal calcium was observed ($p < 0.05$), with slightly lower levels in April. Regarding the major constituents of milk's chemical composition, there has been a gradual increase in total solids, rising from 121.1 g kg^{-1} in March to 130.5 g kg^{-1} in May. Similar trends are evident for lactose and protein contents, increasing from 46.3 g kg^{-1} to 51.7 g kg^{-1} and from 29 g kg^{-1} to 33 g kg^{-1}, respectively, during this period. The fat content remained relatively stable. However, descriptive analysis of the monthly averages shows that the differences observed for these main components are not statistically significant ($p > 0.05$). These results illustrate that the chemical composition of Saanen goat's milk produced within an extensive, pastoral, mountain farming system improved in May for most primary constituents. Although the coefficient of variation (CV) was low for most parameters, greater dispersion was observed for ash (CV = 10.06) and casein (CV = 8.01). This variation is linked to the consistency of local pastoral practices and minor changes in diet.

Table 1. Monthly variations in the physicochemical characteristics of Saanen goat's milk from extensive traditional breeding in Kabylia

Milk Traits	March	April	May	Mean ± SD	CV	*p*-value
Acidity (°D)	17.0^{b}	16.0^{a}	18.0^{c}	17.0 ± 0.82	5.88	***
pH	6.56^{b}	6.59^{b}	6.50^{a}	6.55 ± 0.06	0.69	***
Total solids (g kg^{-1})	121.1	125.7	130.5	125.8 ± 0.34	3.74	-
Fat (g kg^{-1})	39.0	39.5	40.3	39.6 ± 0.29	1.65	-
Protein (g kg^{-1})	29.0	29.0	33.0	30.3 ± 0.17	7.61	-
Serum Protein (g kg^{-1})	8.0	7.9	8.0	7.96 ± 0.02	0.72	-
Casein (g kg^{-1})	21.0	21.1	24.1	22.07 ± 0.13	8.01	-
Casein number (%)	72.41^{a}	72.76^{ab}	73.03^{b}	72.73 ± 0.63	0.43	*
Fat / protien ratio	1.34	1.36	1.22	1.30 ± 0.07	5.75	-
Lactose (g kg^{-1})	46.3	51.8	51.7	49.93 ± 0.39	6.30	-
Ash (g kg^{-1})	8.1^{a}	8.9^{ab}	9.9^{b}	8.96 ± 0.01	10.06	*
Total Calcium (g kg^{-1})	1.09	1.08	1.09	1.09 ± 0.01	0.53	-
Colloïdal Calcium (g kg^{-1})	0.95^{b}	0.92^{ab}	0.93^{a}	0.93 ± 0.002	1.64	*
Total Phosphorus (g kg^{-1})	1.05	1.01	1.03	1.03 ± 0.003	1.94	-
Colloïdal Phosphorus (g kg^{-1})	0.77	0.79	0.85	0.80 ± 0.006	5.18	-

Means followed by different letters (a,b, c) within a row indicate significant differences between months according to Tukey's post-hoc test ($p < 0.05$). Significance levels are indicated as follows: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; ns: not significant.

The compositional profile of Saanen goat milk produced in Kabylie differs from that observed in intensive grazing systems in temperate, mountainous regions. As well as having a relatively high fat content and a lower casein content (with a casein index below the international average for this breed, according to Vacca et al. (2018)), it has an above-average colloidal mineral fraction and, more specifically, an above-average colloidal calcium content. The farming system significantly impacts milk composition, consequently affecting its suitability for cheese production, as demonstrated by Pazzola et al. (2018). The mountainous environment of Kabylie, with altitudes ranging from 300 to 900 meters, and extensive resource management appear to induce physiological adaptation in Saanen goats, resulting in an unusual chemical composition that could affect the structure of the curd during coagulation (Fox et al., 2017). In addition to these physiological factors, seasonal factors must also be monitored to ensure the technological quality of milk intended for processing.

Table 2. Fatty acid composition (sum of fatty acids (% of total fatty acids) and nutritional indices of extracted fat from Saanen goat's milk collected during the spring season and analyzed by gas chromatography

Main fatty acids	Mean ± SD
C4 :0 (Butyric Acid)	0.96 ± 0.43
C6 :0 (Caproic Acid)	1.02 ± 0.32
C8 :0 (Caprylic Acid)	1.10 ± 0.28
C10 :0 (Capric Acid)	3.65 ± 0.61
C12 :0 (Lauric Acid)	1.59 ± 0.454
C14 :0 (Myristic Acid)	5.13 ± 0.31
C15 :0 (Pentadécanoic Acid)	0.36 ± 0.025
C16 :0 (Palmitic Acid)	28.15 ± 0.82
C17:0 (Margaric acid)	0.29 ± 0.08
C18 :0 (Stearic acid)	24.19 ± 0.447
C20:0 (Arachidic acid)	0.07 ± 0.085
C14 :1 (Myristoleic Acid)	0.07 ± 0.015
C16 :1 (Palmitoleic acidic)	1.24 ± 0.115
C17 :1 (Heptadecenoic acid)	0.17 ± 0.04
C18 : 1ω9 (Oleic Acid)	24.00 ± 2.03
C20:1n-9 (Gondoic Acid)	0.07 ± 0.035
C18 : 2ω6 (Linoleic acid)	2.21 ± 0.135
C18:3ω3 (α-Linolenic Acid)	1.92 ± 0.39
Sums of fatty acids	
Σ Polyunsaturated Fatty Acids (PUFA)	4.13 ± 0.52
Σ Monounsaturated Fatty Acids (MUFA)	25.57 ± 1.45
Σ Unsaturated Fatty Acids (UFA)	29.70 ± 1.007
Σ Saturated Fatty Acids (SFA)	65.86 ± 0.22
ω-6	2.28 ± 0.025
Ratios of fatty acids	
PUFA/ SFA	0.063 ± 0.004
ω-6/ω-3	1.19 ± 0.38
AI	1.69 ± 0.24
DI14	0.014 ± 0.004
DI16	0.044 ± 0.003
DI18	0.99 ± 0.938

Saanen milk fatty acids profile

Analysis of the fatty acid profile of Saanen goat's milk (Table 2) shows that saturated fatty acids dominate, accounting for 65.86% of the total. By comparison, monounsaturated fatty acids account for 25.6%, while polyunsaturated fatty acids account for just 4.1%. The main fatty acids are palmitic acid (C16:0) at 28.15%, stearic acid (C18:0) at 24.19%, and oleic acid (C18:1 ω9) at 24%. These proportions are consistent with those reported by Yurchenko et al. (2018) for Saanen goat's milk, confirming the predominance of palmitic and oleic acids among the major lipid constituents. Caproic acid (C6:0), caprylic acid (C8:0), and capric acid (C10:0) contribute to the characteristic aroma of goat's milk, representing around 6% of the total fatty acid content. The atherogenicity index (AI), calculated according to the Ulbricht & Southgate (1991) method, and was estimated at 1.69, indicating moderate cardiovascular risk.

The lipid profile observed in this study is consistent with that reported by López et al. (2019) for goats raised on an extensive diet with a high intake of long-chain fatty acids (FAs) of dietary origin, particularly palmitic, stearic, and oleic acids. The lower proportions of medium-chain fatty acids (C10:0, C12:0, and C14:0) observed in this study compared with the values reported for stall-fed goats (Šlyžius et al., 2023) suggest reduced de novo fatty acid synthesis in the mammary gland and an increased contribution from preformed fatty acids derived from dietary intake. The C14:1/C14:0 ratio, which is an indirect indicator of stearoyl-CoA desaturase (SCD) activity, was low at 0.0136, which suggests that endogenous desaturation is limited. This value is comparable to that reported by Tudisco et al. (2014) under summer feeding conditions, when the nutritional quality of forage tends to decline. The presence of oleiferous plants, such as mastic (*Pistacia lentiscus*) and oleaster (*Olea europaea* var. *sylvestris*), in the goats' grazing areas could potentially cause reduced SCD activity. This is consistent with the inhibitory effect observed when diets are supplemented with vegetable oils rich in polyunsaturated fatty acids (Bernard et al., 2009). Finally, the atherogenicity index (AI) obtained in this study fell within or slightly below the range reported by Kasapidou et al. (2023) for goats fed buriti oil (AI = 2.20 - 1.47), suggesting a potentially more favorable fatty acid profile from a cardiovascular health perspective.

Clotting ability of Saanen goat's milk

Material balance: impact of the physicochemical characteristics of milk on those of curd and whey

Clotting Saanen goat's milk (with a dry matter content of 125.8 g kg^{-1}) yielded a curd with a dry matter content of 442.2 g kg^{-1} (based on fresh matter), which mainly contained 166.2 g kg^{-1} and 230.5 g kg^{-1} of protein and fat, respectively. The whey obtained during draining primarily composed lactose, accounting for around half of its dry matter content (37.9 g kg^{-1}). In terms of the coefficient of variation (CV), most parameters showed moderate variation, except for lactose in the curd, which exhibited a higher CV (19%) (Table 3). This indicates relatively low variability among samples. This may be explained by the use of bulk milk from farms operating under similar extensive feeding conditions, resulting in relatively stable milk composition.

A linear regression analysis revealed several significant relationships between milk composition and curd and whey characteristics. Milk fat ($\beta = 2.35$, $p < 0.001$) and protein ($\beta = 1.72$, $p < 0.001$) showed strong positive correlations with their respective concentrations in the curd. This is consistent with the well-established role of caseins in forming a three-dimensional protein network that retains fat and water during coagulation. Similar relationships between milk composition and curd dry matter have been identified using multiple linear regression approaches in dairy systems (Kern et al., 2019), supporting the relevance of relationships observed in the present study. Although these mechanisms have been extensively described in bovine milk, comparable coagulation principles are generally applicable to goat milk, despite differences in casein micelle size and mineralization (Clark & Sherbon, 2000; Park et al., 2007). In contrast, lactose showed a stronger correlation with whey ($\beta = 0.81$; $p = 0.001$) than with curd ($\beta = 0.45$; $p = 0.049$), confirming its preferential partitioning into the liquid phase during coagulation. A significant relationshi*p* was also observed between milk pH and pH of both curd ($\beta = 0.28$, $p = 0.026$) and whey ($\beta = 0.15$, $p = 0.048$), suggesting the influence of initial milk acidity on coagulation behavior and acid–base balance of the resulting products. The presence of residual lactose in the curd (23.9 g kg^{-1}), combined with a relatively high curd pH (~ 6.15), may influence coagulation kinetics. Similar observations have been reported by Pazzola et al. (2018), who showed that elevated pH and residual lactose can slow coagulation and curd firming in small ruminant milk.

Table 3. Effect of milk characteristics on curd and whey properties (β values ± significance; time reference: March)

Traits	Milk		Curd		Whey		Milk/Curd (β ± signif.)	Milk/*Whey (β ± signif.)	Seasonal effect (April/May)
	Mean	CV	Mean	CV	Mean	CV			
Total solids (g kg^{-1})	125.8	3.74	442.2	5.05	75.9	4.72	–	–	–
Fat (g kg^{-1})	39.6	1.65	230.5	7.88	10.5	7.13	2.35***	- 0.10 ns	April: ns May: ns
Protein (g kg^{-1})	30.3	7.61	166.2	6.36	8.0	4.80	1.72***	0.71**	May: +0.37*
Lactose (g kg^{-1})	49.93	6.30	23.9	19.01	37.9	6.28	0.45*	0.81***	May: +0.27*
pH	6.55	0.69	6.15	0.50	6.34	1.56	0.28*	0.15*	April: ns

β: regression coefficient obtained from the linear regression model. It indicates the magnitude and direction of the relationship between milk components (independent variables) and curd or whey characteristics (dependent variables). March was used as the reference level for estimation of seasonal effects. Significance levels are indicated as follows: $p < 0.05$, *$p < 0.01$, ***$p < 0.001$, and ns: not significant ($p > 0.05$).

Seasonal effects were also observed, with significant increases in curd protein (+0.37, $p = 0.022$) and whey lactose (+0.27, $p = 0.024$) in May compared to March. These variations likely reflect improvements in feeding conditions and animal physiological status during spring, which are known to influence milk synthesis. Seasonal changes in milk composition and their impact on technological properties have been widely reported in goat milk (Cipolat-Gotet et al., 2015b; Pereira et al., 2019).

Overall, these results confirm that the chemical composition of raw milk is closely associated with the physicochemical properties of curd and whey. This is consistent with previous studies reporting that variations in milk composition, whether intrinsic or seasonal, significantly influence coagulation behavior and technological properties of dairy products (Marcinkonienė & Ciprovica, 2020; Paschino et al., 2020).

Enzymatic coagulation efficiency: Curd yield and nutriments recovery

In uncooked pressed goat's cheese manufacture, cheese yield and moisture control depend on the ability of the casein network to entrap fat and expel whey. In the present study, seasonal changes in the composition of Saanen goat's milk were reflected in the evolution of the fat-to-protein ratio and the casein number (Table 1). Although both parameters remained within relatively narrow ranges (72 to 73% for casein number and 1.33 to 1.22 for fat/protein ratio), their seasonal trends may be associated with slight improvements in curd structuring and syneresis efficiency towards late spring. This is consistent with a previous study indicating that fat/protein ratio influences cheese yield and water retention through its effect on curd structure (Bojanić Rašović et al., 2013). Following coagulation and subsequent draining of the curd (Table 4), protein and fat recovery rates reached 73.05% and 71.87%, respectively, while total solids recovery remained lower (38.47%), reflecting losses of whey soluble components such as lactose. The average curd yield (CY = 12.26 kg per 100 kg of milk) was characterized by a relatively high proportion of water (55.5%), indicating a moist curd. This technological profile is consistent with the characteristics of enzymatic coagulation in goat milk, which typically leads to moderate solid recovery and higher moisture retention (Vacca et al., 2018; Pazzola et al., 2019; Marcinkonienė & Ciprovica, 2020).

Table 4. Relationships between the composition of Saanen goat's milk and the technological indicators of coagulation and cheese yield (β coefficients ± significance *p*)

Technological indicators	Mean	CV	Fat (β)	Protein (β)	Casein (β)	Casein number (β)	Ca (β)	Effect month (*p*)
Mean			39.6	30.3	22.07	72.73	1.09	
CV			1.65	7.61	8.01	0.43	0.53	
Nutrient recovery (REC, %)								
REC$_{\mathrm{FAT}}$	71.87	2.55	+0.84 ***	+0.42 **	+0.78 ***	ns	+0.38 **	*
REC$_{\mathrm{PROTEIN}}$	73.05	2.51	ns	+0.69 ***	+0.85 ***	+0.33 **	+0.34 **	**
REC$_{\mathrm{SOLIDS}}$	38.47	7.97	+0.76 ***	+0.48 **	+0.74 ***	ns	+0.36 **	*
REC$_{\mathrm{ENERGY}}$	59.414	4.38	+0.59 ***	ns	ns	ns	ns	**
Curd yield (CY, %)								
CY$_{\mathrm{CURD}}$	12.26	11.75	+0.91 ***	+0.55 ***	+0.80 ***	ns	+0.42 **	**
CY$_{\mathrm{SOLIDS}}$	5.91	12.18	+0.78 ***	+0.49 ***	+0.76 ***	ns	+0.31 **	**
CY$_{\mathrm{WATER}}$	6.25	12.39	ns	−0.36 **	−0.48 **	ns	ns	*
Theoretical curd yield (Th-CY, %)								
Th-CY$_{\mathrm{CURD}}$	11.14	14.62	+0.67 ***	+0.41 **	+0.70 ***	ns	+0.39 **	**
Th-CY$_{\mathrm{SOLIDS}}$	6.242	10.98	ns	+0.45 **	+0.69 ***	ns	ns	*
Curd yield efficiency (Eff, %)								
Eff-CY$_{\mathrm{CURD}}$	1.114	16.5	ns	ns	+0.37 **	+0.29 **	ns	*
Eff-CY$_{\mathrm{SOLIDS}}$	0.953	13.4	+0.38 **	ns	ns	ns	ns	*
Daily curd yield (dCY, kg d)$^{-1}$								
dCY $_{\mathrm{CURD}}$	0.184	11.66	+0.82 ***	+0.39 **	+0.75 ***	ns	+0.35 **	**
dCY $_{\mathrm{SOLIDS}}$	0.089	12.093	ns	+0.41 **	+0.71 ***	ns	ns	**
dCY $_{\mathrm{WATER}}$	0.094	12.26	ns	− 0.33 **	− 0.44 **	ns	ns	*

β: regression coefficient obtained from linear regression models, indicating the magnitude and direction of the relationshi*p* between milk components (independent variables) and a technological indicator (dependent variable). Positive β values indicate a positive correlation, whereas negative values indicate an inverse relationship. *p*: level of statistical significance: $p < 0.05$; * $p < 0.01$; *** $p < 0.001$; ns: not significant ($p > 0.05$). Month effect: *p*-value of the fixed effect of month included in the regression model.

Linear regression analysis (Table 4) identified casein content as the main factor associated with nutrient recovery and curd yield parameters. In particular, casein showed strong positive correlation with REC$_{\mathrm{PROTEIN}}$ (β = +0.85, $p < 0.001$), REC$_{\mathrm{FAT}}$ (β = +0.78, $p < 0.001$), CY$_{\mathrm{CURD}}$ (β = +0.80, $p < 0.001$), and dCY$_{\mathrm{CURD}}$ (β = +0.75, $p < 0.001$). These results confirm the central role of casein in forming the micellar network responsible for curd structure and solid retention, as widely reported in goat milk studies (Stocco et al., 2018; Marcinkonienė & Ciprovica, 2020). In contrast, casein number did not significantly explain the observed variability in curd yield and moisture retention, indicating that the absolute amount of casein is more relevant to coagulation efficiency than its relative proportion to total protein.

Fat emerged as the second most influential factor affecting technological performance. Significant positive correlations were observed between fat content and several technological indicators, including REC_{FAT} ($\beta = +0.84$, $p < 0.001$), REC_{SOLIDS} ($\beta = +0.76$, $p < 0.001$), REC_{ENERGY} ($\beta = +0.59$, $p < 0.001$) and CY_{CURD} ($\beta = +0.91$, $p < 0.001$). These results are consistent with previous studies showing that fat contributes substantially to curd formation through its incorporation into the protein matrix (Vacca et al., 2018; Pazzola et al., 2019). More generally, similar correlations between fat/protein balance and cheese yield have been reported in dairy matrices, where this ratio significantly influences curd composition, dry matter content, and water retention (Bojanić Rašović et al., 2013). However, when combined with moderate to low casein content, higher fat levels may increase water retention and reduce curd firmness. This reflects the limited capacity of a less dense casein network to effectively entra*p* fat globules and expel whey. The combined effect of relatively high fat content and moderate casein availability therefore explains the observed technological profile, characterized by satisfactory fat recovery but high moisture retention.

Daily curd yield (0.184 kg day^{-1}) confirmed this trend with comparable contributions from solids (0.089 kg day^{-1}) and water (0.094 kg day^{-1}). The relatively high proportion of retained water is consistent with the structural characteristics of goat milk, notably smaller and less aggregated casein micelles compared to cow milk (Clark & Sherbon, 2000; Park et al., 2007), which limit gel firmness and promote moisture retention. Colloidal calcium showed only a moderate contribution to technological parameters. This suggests that, in the presence of moderate to low casein content, calcium alone is insufficient to strengthen the micellar network, suggesting its secondary role compared to protein structure and organization.

Overall, these results indicate that casein primarily governs curd structure and moisture retention, while fat enhances curd yield and nutrient recovery through its interaction with the protein matrix. The combination of moderate casein content, relatively high fat levels, and intrinsic physicochemical characteristics of goat milk results in moist curd with moderate solid recovery. Progressive seasonal variations in milk composition, particularly toward spring, were associated with slight improvement in coagulation efficiency and curd structuring.

CONCLUSIONS

This study reveals that Saanen goat milk produced under an extensive mountain pastoral system in Kabylia presents specific technological properties linked to its composition and seasonal variability. Casein content was identified as the primary factor influencing curd yield and water retention, while fat content contributed to nutrient recovery through its interaction with the protein matrix. Seasonal changes in milk composition were associated with variations in coagulation suitability and technological performance. However, given the limited sample size and study duration, further investigations over longer periods and with larger datasets are required to confirm and extend these results.

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REFERENCES

Barłowska, J., Pastuszka, R., Rysiak, A., Król, J., Brodziak, A., Kędzierska-Matysek, M., Wolanciuk, A. & Litwińczuk, Z. 2018. Physicochemical and sensory properties of goat cheeses and their fatty acid profile in relation to the geographic region of production. *International Journal of Dairy Technology* **71**, 699–708. https://doi.org/10.1111/1471-0307.12506

Bernard, L., Shingfield, K.J., Rouel, J., Ferlay, A. & Chilliard, Y. 2009. Effect of plant oils in the diet on performance and milk fatty acid composition in goats fed diets based on grass hay or maize silage. *British Journal of Nutrition* **101**, 213–224. https://doi.org/10.1017/S0007114508006533

Bojanić Rašović, M., Nikolić, N., Martinović, A., Katić, V., Rašović, R., Walcer, M. & Domig, K. 2013. Correlation between protein to fat ratio of milk and chemical parameters and the yield of semi-hard cheese. *Biotechnology in Animal Husbandry* **29**(1), 145–159.

Bouderka, G., Nabi, M., Kebbal, S., Hadj-Omar, K., Salhi, O., Khelifi-Touhami, N.A. & Ouchene, N. 2025. Effects of goat breeds on the physicochemical properties of raw goat milk. *Journal of the Saudi Society of Agricultural Sciences* **24**(5), 39. https://doi.org/10.1007/s44447-025-00049-0

Boumediene, F., Meribai, A., Kahlouche, A., Bouchibane, M., Touzout, N. & Belbraouet, S. 2025. Effects of breed and lactation-stage of goat on the composition and lipid fraction of milk in Algeria. *Asian Journal of Dairy and Food Research* **44**(3), 505–510. https://doi.org/10.18805/ajdfr.DRF-446.

Cipolat-Gotet, C., Bittante, G. & Cecchinato, A. 2015a. Phenotypic analysis of cheese yields and nutrient recoveries in the curd of buffalo milk, as measured with an individual model cheese-manufacturing process. *Journal of Dairy Science* **98**(1), 633–645. https://doi.org/10.3168/jds.2014-8308

Cipolat-Gotet, C., Pazzola, M., Ferragina, A., Cecchinato, A., Dettori, M.L. & Vacca, G.M. 2015b. Technical note: Improving modeling of coagulation, curd firming and syneresis of shee*p* milk. *Journal of Dairy Science* **101**, 5832–5837. https://doi.org/10.3168/jds.2017-14256

Clark, S. & Sherbon, J.W. 2000. Alphas1-casein, milk composition and coagulation properties of goat milk. *Small Ruminant Research* **38**, 123–134. https://doi.org/10.1016/S0921-4488(00)00154-1

Fox, P.F., Guinee, T.P., Cogan, T.M. & McSweeney, P.L. 2017. Fundamentals of Cheese science. Springer New York, NY. P*p* **1**, 271. https://doi.org/10.1007/978-1-4899-7681-9

IDF standard 141B. 1996. Whole Milk: Determination of Milk Fat, Protein and lactose content. Guide for the operation of mid-infrared instruments. *International Dairy Federation*, Brussels.

Inglingstad, R.A., Steinshamn, H., Dagnachew, B.S., Valenti, B., Criscione, A., Rukke, E.O., Devold, T.G., Skeie, S.B. & Vegarud, G.E. 2014. Grazing season and forage type influence goat milk composition and rennet coagulation properties. *Journal of Dairy Science* **97**(6), 3800–3814. https://doi.org/10.3168/jds.2013-7542

ISO 19662. 2018. Milk — Determination of fat content — Acido-butyrometric (Gerber method. *International Organization for Standardization*, Switzerland

Kadi, S.A., Djellal, F., Hassini, F. & Mouhous, A. 2016. Pratiques alimentaires dans les élevages caprins dans la région montagneuse de Tizi-Ouzou en Algérie. In M. Napoléone, H. Ben Salem, J.P. Boutonnet, A, López-Francos, D. Gabiña (ed), The value chains of Mediterranean sheep and goat products: Organization of the industry, marketing strategies, feeding and production systems, *Options Méditerranéennes CIHEAM,* 249–252. http://om.ciheam.org/article.php?IDPDF=00007283

Kasapidou, E., Iliadis, I.V., Mitlianga, P., Papatzimos, G., Karatzia, M.A., Papadopoulos, V., Amanatidis, M., Tortoka, V., Tsiftsi, E., Aggou, A. & Basdagianni, Z. 2023. Variations in composition, antioxidant profile, and physical traits of goat milk within the semi–intensive production system in mountainous areas during the post–weaning to end of lactation period. *Animals* **13**(22), 1–19. https://doi.org/10.3390/ani13223505

Kern, C., Stefan, T. & Hinrichs, J. 2019. A Multiple linear regression modeling: Prediction of cheese curd dry matter during curd treatment. *Food Research International* **121**, 471–478. https://doi.org/10.1016/j.foodres.2018.11.061

López, A., Vasconi, M., Moretti, V.M. & Bellagamba, F. 2019. Fatty Acid Profile in Goat Milk from High- and Low-Input Conventional and Organic Systems. *Animals* **9**(7), 1–14. https://doi.org/10.3390/ani9070452

Marcinkonienė, L. & Ciprovica, I. 2020. The influence of milk quality and composition on goat milk suitability for cheese production. *Agronomy Research* **18**(S3), 1796–1703. https://doi.org/10.15159/AR.20.094

Mouhous, A., Kadi, S.A. & Brabez, F. 2015. Adaptation strategies of goat farmers in the mountainous region of Tizi-Ouzou, Algeria. *European Science Journal* **11**(2), 1857–7881 (in French).

Mouhous, A., Kadi, S.A., Guermah, H. & Djellal, F. 2021. The goat meat sector in an Algerian mountain region: analysis of its value chain. In López-Francos, A. (ed.), Jouven, M. (ed.), Porqueddu, C. (ed.), Ben Salem, H. (ed.), Keli, A. (ed.), Araba, A. (ed.), Chentouf, M. (ed.). Efficiency and resilience of forage resources and small ruminant production to cope with global challenges in Mediterranean areas *Options Méditerranéennes*, *CIHEAM* 115–118. http://om.ciheam.org/article.php?IDPDF=00007981

Park, Y.W., Juárez, M., Ramos, M.G.F.W. & Haenlein, G.F.W. 2007. Physico-chemical characteristics of goat and shee*p* milk. *Small Ruminant Research* **68**, 88–113. https://doi.org/10.1016/j.smallrumres.2006.09.013

Paschino, P., Stocco, G., Dettori, M.L., Pazzola, M., Marongiu, M.L., Pilo, C.E., Cipolat-Gotet, C. & Vacca, G.M. 2020. Characterization of milk composition, coagulation properties, and cheese-making ability of goats reared in extensive farms. *Journal of Dairy Science* **103**, 5830–5843. https://doi.org/10.3168/jds.2019-17805

Pazzola, M., Stocco, G., Dettori, M.L., Bittante, G. & Vacca, G.M. 2019. Effect of goat milk composition on cheese-making traits and daily cheese productions. *Journal of Dairy Sciences* **102**(5), 3947–3955. https://doi.org/10.3168/jds.2018-15397

Pazzola, M., Stocco, G., Paschino, P., Dettori, M.L., Cipolat-Gotet, C., Bittante, G. & Vacca, G.M. 2018. Modeling of coagulation, curd firming, and syneresis of goat milk. *Journal of Dairy Sciences* **101**(8), 7027–7039. https://doi.org/10.3168/jds.2018-14397

Pereira, T.C.J., Ribeiro, L.S.O., Pires, A.J.V., Pereira, M.L.A., Santos, A.B., Silva, H.D.O. & de Carvalho, G.G.P. 2019. Growth performance and apparent digestibility by goats fed diets with peach palm meal replacing maize. *Applied Animal Science* **35**(6), 563–569. https://doi.org/10.15232/aas.2019-01874

Remeuf, F., Lenoir, J. & Duby, C. 1989. Study of the relationshi*p* between the physicochemical characteristics of goat's milk and its ability to coagulate with rennet. *Dairy Science & Technology* **69**, 499–518.

Rowland, S.J. 1938. The determination of the nitrogen distribution in milk. *Journal of Dairy Research* **9**(1), 42–46. https://doi.org/10.1017/S0022029900002296

Šlyžius, E., Anskienė, L., Palubinskas, G., Juozaitienė, V., Šlyžienė, B., Juodžentytė, R. & Laučienė, L. 2023. Associations between somatic cell count and milk fatty acid and amino acid profile in Alpine and Saanen goat breeds. *Animals* **13**, 965. https://doi.org/10.3390/ani13060965

Stocco, G., Pazzola, M., Dettori, M.L., Paschino, P., Bittante, G. & Vacca, G.M. 2018. Effect of composition on coagulation, curdfirming and syneresis of goat milk. *Journal of Dairy Science* **101**(11), 9693–9702. https://doi.org/10.3168/jds.2018-15027

Tefiel, H., Ata, N., Chahbar, M., Benyarou, M., Fantazi, K., Yilmaz, O., Cemal, I., Karaca, O., Boudouma, D. & Gaouar, S.B.S. 2018. Genetic characterization of four Algerian goat breeds assessed by microsatellite markers. *Small Ruminant Research* **160**, 65–71. https://doi.org/10.1016/j.smallrumres.2018.01.021

Teissier, M., Brito, L.F., Schenkel, F.S., Bruni, G., Fresi, P., Bapst, B., Robert-Granie, C. & Larroque, H. 2024. Genetic parameters for milk production and type traits in North American and European Alpine and Saanen dairy goat populations. *JDS Communications* **5**(1), 28–32. https://doi.org/10.3168/jdsc.2023-0389

Tudisco, R., Grossi, M., Calabrò, S., Cutrignelli, M.I., Musco, N., Addi, L. & Infascelli, F. 2014. Influence of pasture on goat milk fatty acids and stearoyl-CoA desaturase expression in milk somatic cells. *Small Ruminant Research* **122**(1–3), 38–43. https://doi.org/10.1016/j.smallrumres.2014.07.016

Ulbricht, T.L.V. & Southgate, D.A.T. 1991. Coronary heart disease: seven dietary factors. *The Lancet* **338**(8773), 985–992. https://doi.org/10.1016/0140-6736(91)91846-M

Vacca, G.M., Stocco, G., Dettori, M.L., Summer, A., Cipolat-Gotet, C., Bittante, G. & Pazzola, M. 2018. Cheese yield, cheese-making efficiency, and daily production of 6 breeds of goats. *Journal of Dairy Sciences* **101**(9), 7817–7832. https://doi.org/10.3168/jds.2018-14450

Varlyakov, I., Slavov, T., Radev, V., Nedeva, I. & Nikolov, G. 2018. Milking behaviour of Saanen goats. *Bulgarian Journal of Agricultural Sciences* **24**(1), 109–118.

Yurchenko, S., Sats, A., Tatar, V., Kaart, T., Mootse, H. & Jõudu, I. 2018. Fatty acid profile of milk from Saanen and Swedish Landrace goats. *Food Chemistry* **254**(15), 326–332. https://doi.org/10.1016/j.foodchem.2018.02.041

Zeljić Stojiljković, K., Mićić, N., Bogdanović, V., Đedović, R., Pihler, I., Stojiljković, N. & Stanojević, D. 2025. Genetic evaluation of milk production traits in the Serbian Saanen goat population. *Animals* **15**(20), 3008. https://doi.org/10.3390/ani15203008