Evaluation of the physicochemical quality of milk from Djallonkè goats fed silage made from *Pennisetum pedicellatum Trin* in Burkina Faso

ABSTRACT

In order to assess the physical and chemical quality of milk from goats fed a diet of silage made from *Pennisetum pedicellatum Trin,* the second most common grass in Burkina Faso, the study compared four diets, two feeding practices, diet A (natural grazing) and diet B (natural grazing + corn bran), and two diets, C (silage + corn bran + peanut husks) and D (silage + corn bran), based on silage made from this grass. In a Latin square design with four experimental units or lots, the factors were the type of diet and the distribution of the goats into twelve (12) goats, with three (3) per lot. The bromatological values of samples of the pre-wilted and ensiled grass were analyzed. The amount of feed refused for diets A and B and the average ash, dry matter, fat, protein, and lactose content of the milk were determined for each batch. Analysis of the variance of the results using R revealed that pre-wilted *Pennisetum pedicellatum Trin* silage resulted in losses in nitrogen (-4%), total nitrogen (-20%) and digestibility (-12%). Feed conversion of the silage is better without weight gain with diet C. Unlike diet D, diet C reduces the fat and lactose content of milk obtained with diets A and B. The addition of additives to *Pennisetum pedicellatum* silage in barrels is essential to improve the nitrogen content of this forage grass for feeding Djallonkè dairy goats.

Keywords: Ensiled forage, feed, lactation, caprine, Burkina Faso.

INTRODUCTION

Milk plays a vital role in maintaining human health thanks to its high calcium and vitamin D content. Per capita milk consumption is low and is expected to increase from 20.2 kg in 2016 to 21.4 kg in 2026 in developed countries, and from 10.9 kg to 13.2 kg in developing countries (Fayama et al., 2024). Global milk production comes largely from cattle, buffalo, goats, sheep, and camels. Goat milk and products are increasingly preferred for their health and nutritional benefits, including greater digestibility and better lipid metabolism, in addition to their taste, compared to cow's milk (Desjeux, 1993). According to the FAO (Food and Agriculture Organization), the global goat population is estimated at 1,128,106,236 head in 2020, with Africa accounting for 43% and Asia ranking first in terms of numbers with 52% of the global herd. (FAOSTAT, 2022). The global population of dairy goats was estimated at 218 million in 2017 (FAOSTAT, 2022). In Burkina Faso, a country with an agricultural and pastoral vocation, goats represent a national asset in terms of the size of the herd, the number of people involved in their breeding, and the income they generate. Goat breeding is practiced throughout the country and by almost all ethnic communities (Kagoné, 2001). Goats play a very important social role within the Burkinabe population (Tchouamo et al*.,* 2005). Goat farming is an activity that is accessible to all social groups, particularly women, young people, and the elderly (Tekodjinan, 2011). The potential of goats for the sustainable supply of milk and meat for human consumption is undeniable, and their contribution to improving the nutrition of rural populations is likely to increase (Alexander and Wasike, 2019).However, they are prone to problems of quantitative and qualitative food shortages. Indeed, variability and fluctuations in rainfall, combined with extensive animal husbandry practices, expose them to recurrent nutritional deficiencies, especially during difficult seasons when grazing lands are almost desert-like (Sanon *et al.,* 2014).

To compensate for this, dairy farms, particularly in urban and semi-urban centers, supplement their goats' feed with agro-industrial by-products, hay, and green fodder (MRA, 2007). In recent years, farmers in the city of Bobo-Dioulass in Burkina Faso have been producing and marketing fodder. The most popular natural grasses are *Andropogon gayanus* (17%), *Echinochloa stagnina* (16%), *Pennisetum pedicellatum* (14%) and *Rottboellia exaltata* (13%). In addition, barrel silage made from *Pennisetum pedicellatum Trin* is developing and gaining momentum (Sanou et al., 2016; Sissao et al., 2024). Silage is a long-term forage preservation technique that ensures a stable and nutritious diet for livestock throughout the year. Several studies have shown that the composition of goat milk varies depending on many factors: season, diet, stage of lactation, physiological status, udder health, genetics, environment, and regions of production (Soryal et al., 2004). However, little information is available on the chemical composition of goat milk produced under the farming conditions in Burkina Faso. With this in mind, the present study aims to evaluate the physicochemical composition of milk from Djallonkè goats fed silage made from *Pennisetum pedicellatum Trin.*

STUDY ENVIRONMENT

The study was conducted from November 2021 to May 2022 in the province of Tuy, one of the three provinces of the Upper Basins region located in western Burkina Faso. The area is a Sudanian phytogeographic domain with a South Sudanian climate and rainfall of between 1,000 and 1,400 mm/year during a 5- to 6-month rainy season (Fonte and Guinko, 1995). It is one of the rainiest regions in the country. The experiment was conducted in Koumbia on the model farm, an area covered by the Appropriate Agricultural Mechanization (ASMC) project (Figure 1).

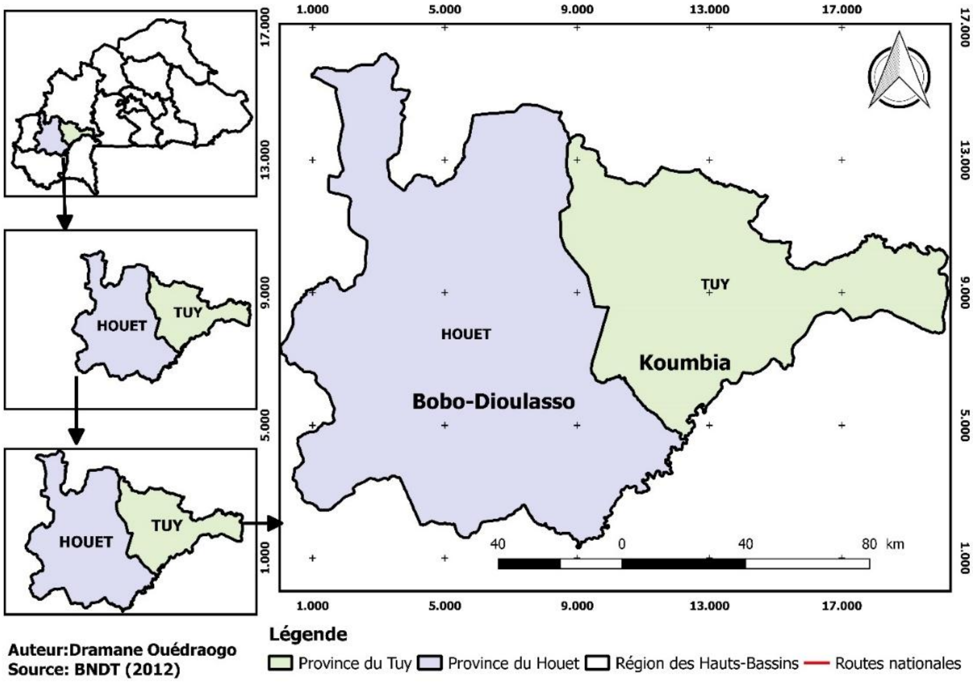


Figure1 : Location of the study area and site

MATERIAL AND METHODS

Setting up the experimental design

A Latin square experimental design with four experimental units or lots was used, with the factors being the type of diet and the distribution of goats (Figure 2). The trial was conducted with twelve (12) Djallonké goats, six (6) of which were between the firstand secondweeks of lactation and the other six (6) were pregnant. The goats were randomly divided into four (04) batches of three (03) goats per batch. Four types of diet were tested. Batch 1, or the control batch, was fed on natural pastures. Group 2 was fed natural pastures supplemented with corn bran. For group 3, the diet was , consisting of corn bran combined with silage and peanut husks. Group 4 was fed silage and corn bran. Unlike the animals in groups 3 and 4, which were kept in stalls throughout the experiment, the animals in groups 1 and 2 were allowed to roam freely in search of natural forage. To ensure the study was conducted properly, at the start of the trial, all goats underwent bleaching using Bolumisole M1 internal deworming, an injection of trypanocide (Veriben), and a vitamin and mineral supplement (CMV) called Boluvit.

Group 1	Group 2
Goat 10	Goat 7
Goat 11	Goat 8
Goat 12	Goat 9
Lot 3	**Lot 4**
Goat 1	Goat 4
Goat 2	Goat 5
Goat 3	Goat 6

Figure2: **Experimental setup**

Production and nutritional quality analysis of silage made from Pennisetum pedicellatum in barrels

For the production of silage in barrels made from *Pennisetum pedicellatum,*the amount of fodder was collected taking into account the fodder requirements for a goat based on live weight (PEP caprin, 2013) and the volume of silos in barrels with an average capacity of 96.51 ± 1.55 kg of fodder (Koudougou, 2018). The silage was produced according to the methodology of Sissao et al. (2024). Samples of 500 g were selected and nutritional analyses were performed using near-infrared spectroscopy (NIRS) in the animal production laboratory of the Institute for the Environment and Agricultural Research (INERA) in Bobo Dioulasso.

Diet formulation and rationing

The goats in batches 1 and 2 were rationed on a natural pasture-only basis (diet A) or on a natural pasture basis supplemented with corn bran (diet B). Only the goats in batches 3 and 4 received feed diets based on *Pennisetum pedicellatum* silage*.* Based on the nutritional requirements of goats (CTA fact sheet, 2015), the nutritional values of feed (CIRAD, 1999), the availability of feed in the study area ( ), and local feeding practices, diets C and D were formulated for the goats in stalls in batches 3 and 4, respectively (Table 1). Barrel silage made from *Pennisetum pedicellatum* was the main energy source in both diets. The protein sources were corn bran and peanut hulls for dietC and corn bran alone for dietD. Every morning during the trial, the silage was fed to the six (06) goats in total housing according to the diet calculations for the two (02) groups. Peanut husks were brought in the afternoon to batch 3, then corn bran in the evenings to batches 3 and 4 respectively. Batch 2, which was grazing on natural pastures, was supplemented with corn bran on a weekly basis.

Table *1*.Diet composition

Ingredients	Diet C (in g)	Diet D (in g)
Silage	1880	1820
Peanut tops	115	0
Corn bran	99	197
Total	**2094**	**2017**

Monitoring and collection of silage acceptability data

The adaptation period was 14 days before measurements were taken. The experimental pre-test lasted five weeks. The study focused exclusively on measuring silage refusal. The unconsumed silage was weighed 24 hours after distribution to the animals. An electronic scale was used to weigh the six pregnant goats in total housing at the beginning and end of the trial. The refusal rate was determined as the percentage ratio of silage refusal to the amount served. The feed conversion ratio (FCR) measured the efficiency with which the animals converted feed into biomass or production, based on the formula: FCR = Amount of feed consumed / Weight gain (Laisse, 2018).

Sampling and analysis of the physical and chemical composition of goat milk

The study was conducted in a real-world setting, i.e., under the producer's farming conditions. Milking was carried out every two (02) weeks, followed by analysis at the Laboratory for Research and Teaching in Animal Health and Biotechnology (LARESBA) using farm milk analysis (Miris® FMA). Milking was done manually. The samples collected were placed in a water bath at a temperature of 40°C. Using a syringe, the raw milk was sampled and placed in the device, which measured the light intensity transmitted by each of the sample's constituents in the infrared range and converted it into a percentage of the total sample at room temperature before analyzing the raw milk. To ensure data reliability, the FMA was cleaned with liquid (water) and then the following samples.

Statistical Analyses

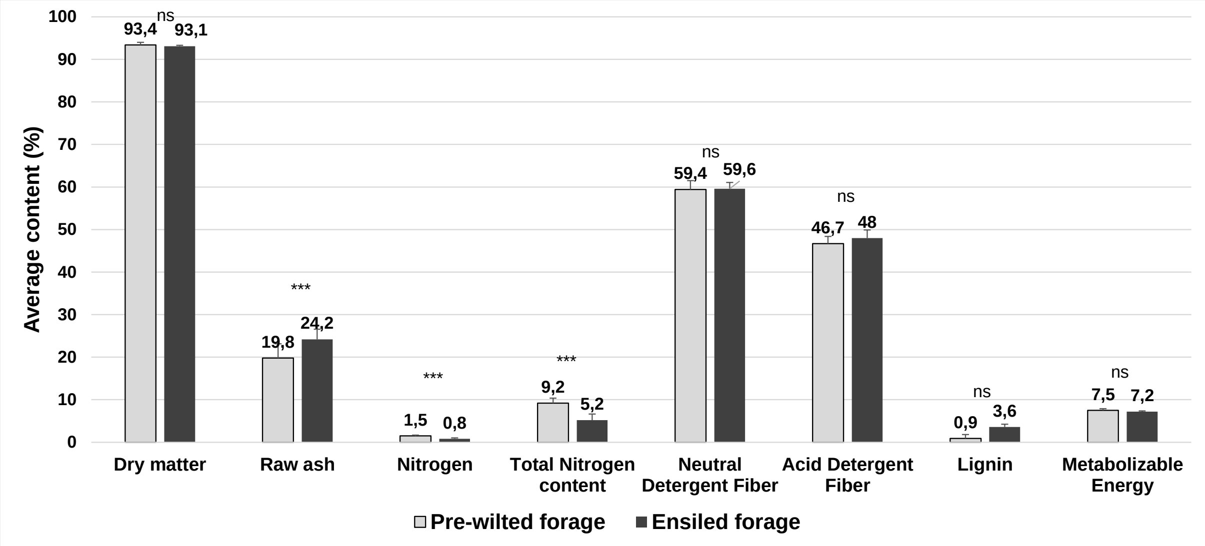
The measured densities over time were analyzed using a mixed linear model for longitudinal data, followed by an ANOVA to assess the effect of batches and blocks. The fat, protein, and lactose contents were analyzed using a Poisson-type generalized linear model with mixed effects, also supplemented by an ANOVA. The comparison of means was performed using Tukey's test at a 5% threshold.

Marginal and conditional R^2 values were calculated using the Nakagawa and Schielzeth method with the r.squaredGLMM function from the MuMIn package. All analyses and graphical representations were performed using R 4.5.1.

RESULTS

Bromatological value of Pennisetum pedicellatum Trin silage

Barrel silage had no significant effect ($p > 0.05$) on the dry matter, fiber (NDF, ADF), and lignin content of pre-wilted *Pennisetum pedicellatum* (Figure 2).However, the crude ash content was significantly ($p < 0.05$) improved by 22%. As for the nitrogen and total nitrogen- dry matter contents, this technique reduced them by 4% and 20%, respectively. The organic digestibility of the organic matter was reduced by 12% (52.9% and 50.6% forpre-wilted and ensiled forage respectively).



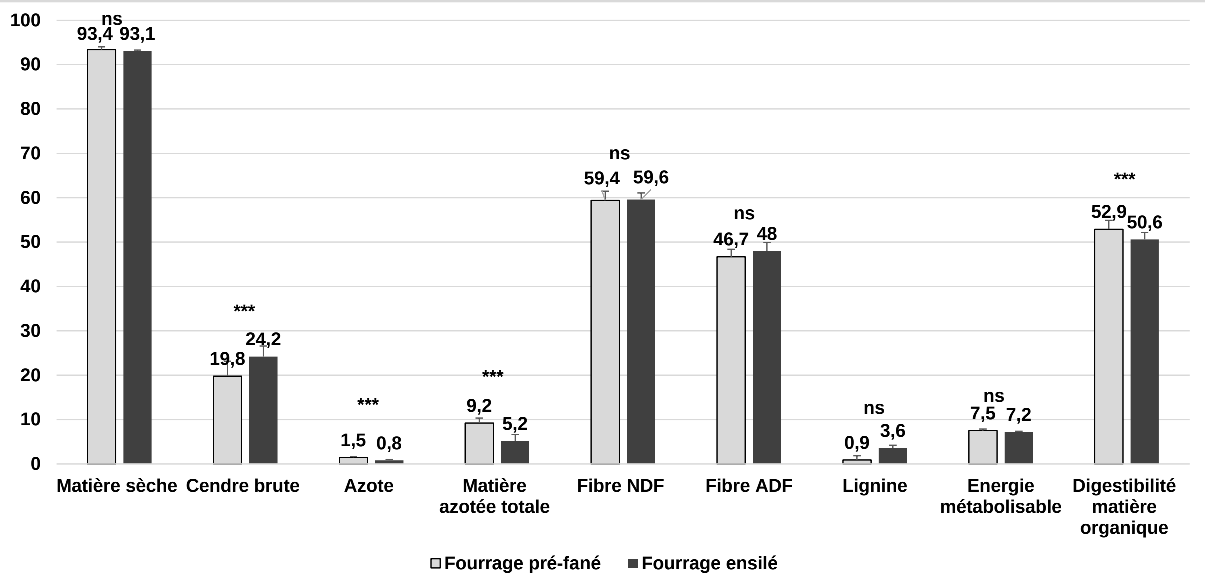


Figure2. Bromatological values of *pre-wilted and ensiled Pennisetum pedicellatum Trin* forage

N.B.: ns: values not significant, ***values highly significant at a probability threshold of 0.05.

Acceptability of Pennisetum pedicellatum Trin silage

During the 14-day adaptation period, the rejection rates for the two diets formulated with *Pennisetum pedicallatum Trin* gradually decreased over the first 10 days. The rejection rate was twice as high for dietC as for dietD during the first two days. This difference decreased and then reversed from the 7th day onwards, when the goats fully accepted diet C (Figure 3). Similarly, diets C and D did not cause the goats to gain weight, as diet C had a feed conversion ratio of 7-day, when the goats fully accepted dietC. Similarly, diets C and D did not cause the goats to gain weight, as dietC had a feed conversion ratio 73% higher than dietD (Table 2).

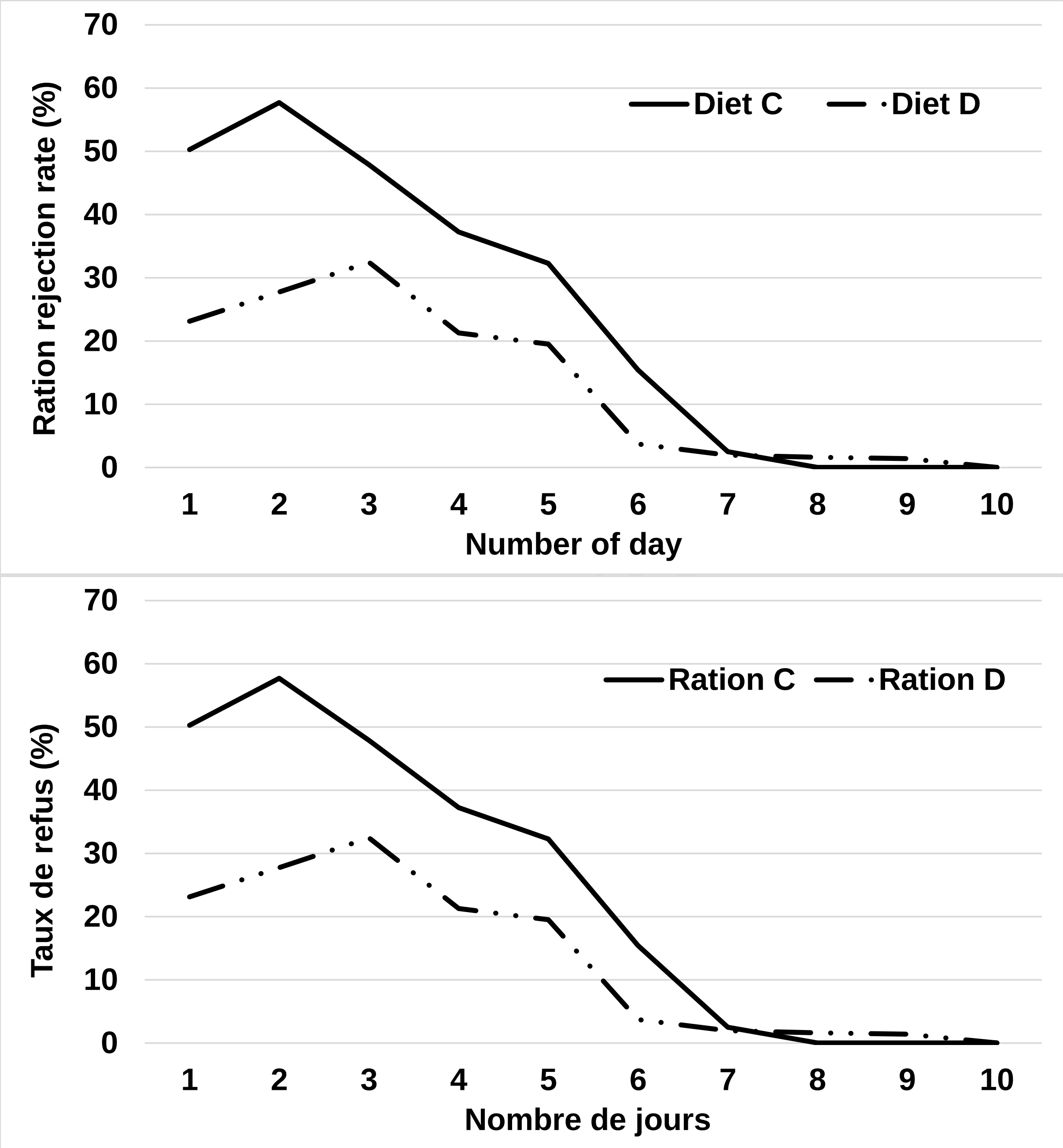


Figure 3. Variation in diet rejection rate during the adaptation period

Table 2: Feed conversion ratio of formulated diets

Diet	Weight gain	Average amount of forage ingested	Feed conversion ratio
Diet C	-0.33	68.7	13

DietD	-0.33	68.5	3.5

Effect of silage made from Pennisetum pedicellatum on the physical quality of raw milk

The density and dry matter content of raw milk did not vary significantly ($p > 0.05$) over the course of the days. They varied significantly ($p < 0.05$) depending on the diet (Table 3). The density of raw milk obtained when goats were fed diets based on *Pennisetum pedicellatum* was estimated at 0.69 ± 0.05 and 1.03 ± 0.01 for diets C and D, respectively. The dry matter content was 8.5 ± 1.4% and 14.5 ± 1.1% for diets C and D, respectively. The addition of peanut leaves (diet C) to the silage significantly ($p < 0.05$) reduced the density and dry matter content of the milk by 71% and 87%, respectively.The density and dry matter content of raw milk obtained when the goat was fed dietD were significantly ($p < 0.05$) similar to those obtained when it was fed on natural pastures with (1.03 ± 0 and 14.5 ± 1.1%) or without supplementation (1.06 ± 0.1 and 14.6 ± 1.5%). (Figure 4)

Table 3: Effect of feed type on dry matter and density of raw milk

Variable	Factor	NumDF	DenDF	F statistic	Prob(>F)	R^2 marginal	R^2 conditional
Density	(Intercept)	1	22	15860.73	<0.0001***	0.9765	0.9765
	Day	2	22	107.26	0.2684		
	Lot	3	22	137.15	<0.0001***		
	Day:Lot	6	22	137.71	0.437		
		DF		**Chisq**	**Pr(>Chisq)**		
Dry matter content (%)	Day	3		2.06	0.5609	0.9731	0.9988
	Lot	4		3.46	0.0374*		
	Day:Lot	6		4.03	0.6724		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1; **DF:** Degree of freedom; **NumDF:** Degrees of freedom of the numerator related to fixed factors; **DenDF:** Degrees of freedom of the denominator related to the overall variation of the model

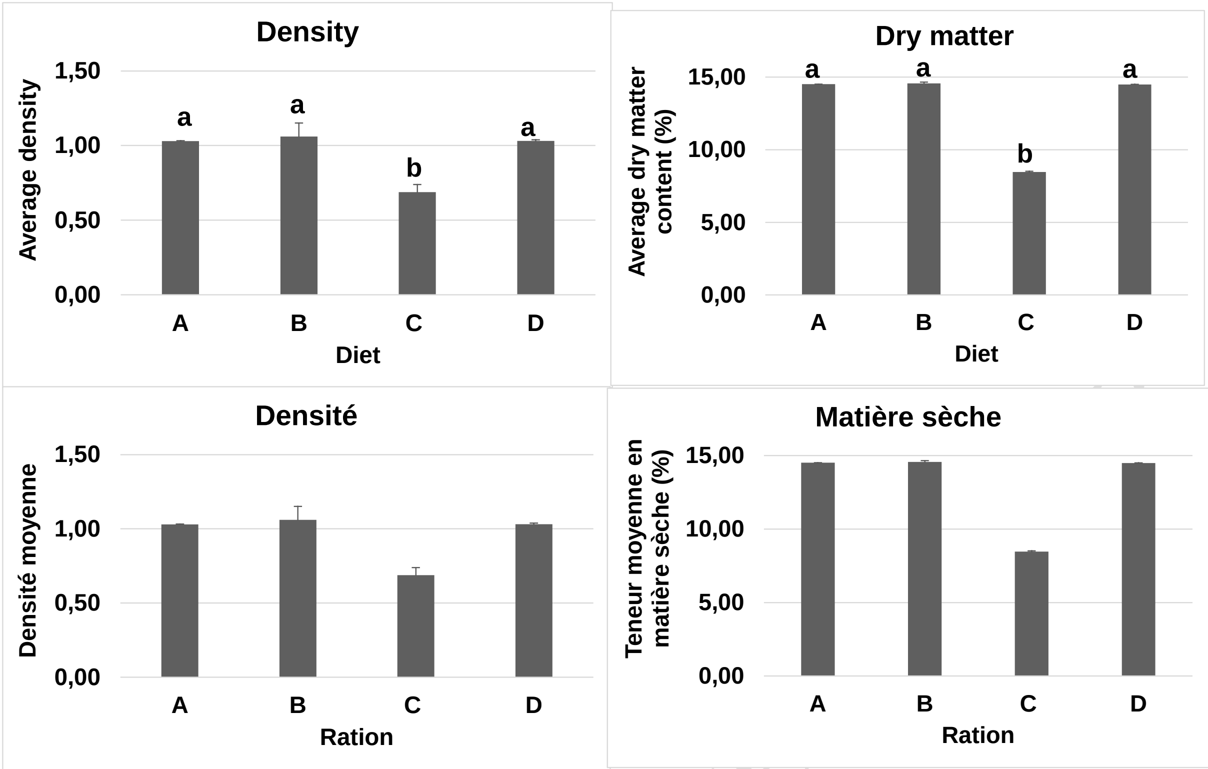


Figure 4. Effect of treatments on the average density and dry matter content of raw milk[GM1]

Significance codes: treatments with different letters a or b were significantly different at the 5% level

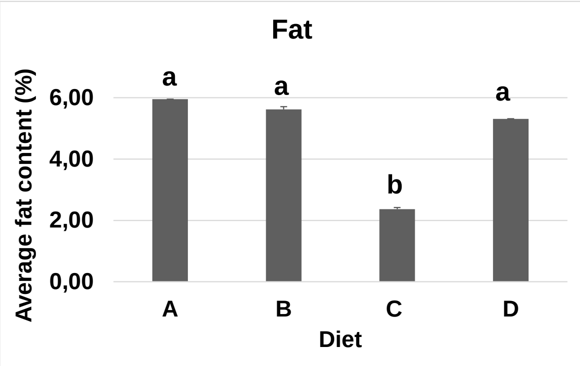
***Effect of silage made from Pennisetum pedicellatum* on the chemical quality of raw milk**

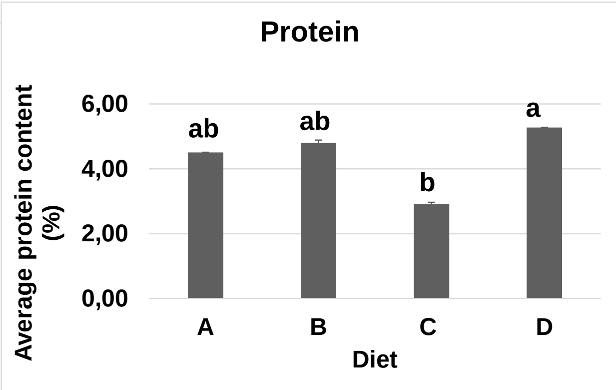
Goats fed on natural pastureswith or without supplements produced raw milk with higher fat (5.6 ± 1.2% and 6 ± 1.2% respectively), protein (4.8 ± 0.4% and 4.5 ± 0.4% respectively), and lactose (3.5 ± 0.21% and 3.5 ± 0.3% respectively) (Table 4). These values did not differ significantly ($p > 0.05$) from each other and were significantly ($p < 0.05$) similar to those obtained when the goats were fed silage made from *Pennisetum pedicellatum* supplemented with corn bran (diet D) (5.3 ± 1.3% fat; 2.9 ± 0.2% protein, 2.5 ± 0.9% fat). However, the fat and lactose contents of raw milk s were significantly ($p < 0.05$) lower than all these values when the goats were fed dietC. The protein content of raw milk was significantly ($p < 0.05$) reduced by 81% when the goats consumed dietD instead of dietC (Figure 5).

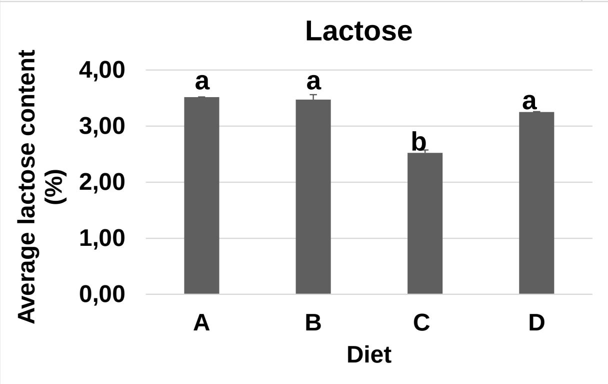
Table 4: Effect of feed type on the chemical quality of raw milk

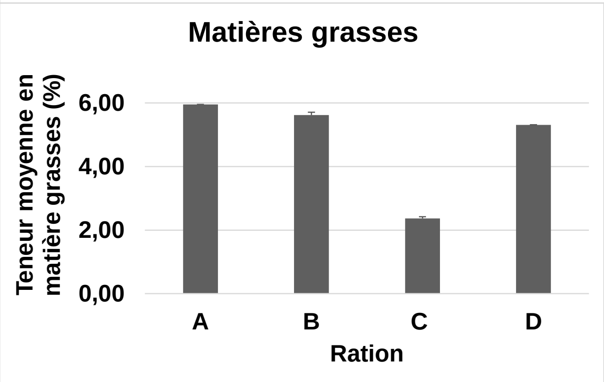
Variable	Factor	DF	Chisq	Pr(>Chisq)	R^2 marginal	R^2 conditional
	Day	3	5.77	0.1229		
Fat content (%)	Lot	4	2.99	0.03692*	0.9683	0.9964
	Day:Lot	6	3.12	0.7936		

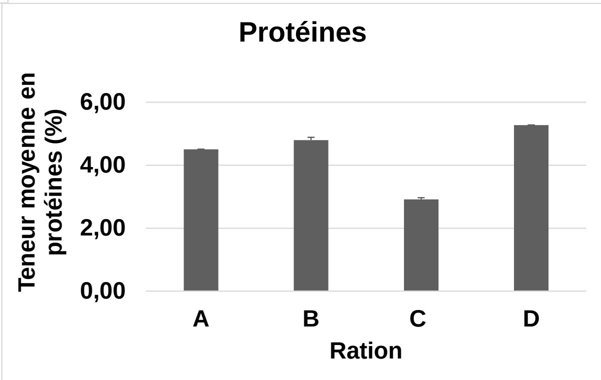
Protein content (%)	Day	3	1.17	0.7604	0.9677	0.9960
	Lot	4	1.72	0.04492*		
	Day:Lot	6	4.97	0.5479		
Lactose content (%)	Day	3	1.05	0.7897	0.9684	0.9949
	Lot	4	4.18	0.02961*		
	Day:Lot	6	0.69	0.9947		











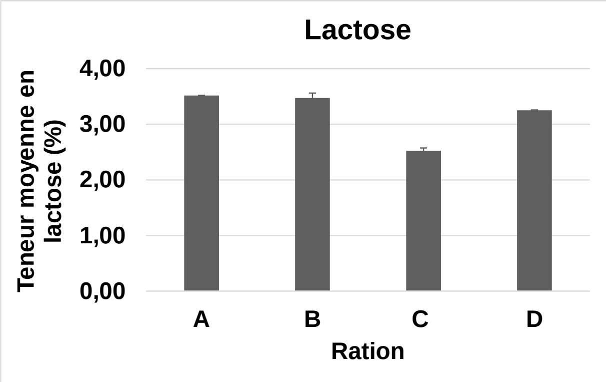


Figure 5. Effect of treatments on fat, protein, and lactose (C) in raw milk

Discussion

Nutritional quality and acceptability of Pennisetum pedicellatum Trin silage

The results show no significant difference ($p > 0.05$) in dry matter content, fiber content (NDF, ADF), and lignin between pre-wilted grass and silage. These results confirm that silage in *Pennisetum pedicellatum* barrels preserves the fibrous structure and are consistent with those of Ma et al. (2024), which indicate that lignin-rich tropical grasses retain their cell walls after silage due to their low degradability. They also agree with the observations of Maciel (2025), showing that when tropical grasses are ensiled without additives and fermentable substrates, the degradation of fiber walls remains limited.

The reduction in total nitrogen content (-4%) and total nitrogenous matter (-20%) indicates that silage leads to losses in organic matter, nitrogen, and digestibility, probably due to microbial deamination and the conversion of true protein into non-protein nitrogen (NPN), corroborating the results of Riyanti et al. (2024) on *Pennisetum purpureum*. These losses can be compensated for, as shown by Ma et al. (2024) on *Pennisetum giganteum* + rice straw, where the addition of additives (lactic acid bacteria + cellulase) improves in vitro digestibility and silage quality. Riyanti et al. (2024) also confirm that inoculation with microorganisms increases the digestibility and stability of silage.

The gradual decrease in refusals during the first ten days shows that goats normally adapt to the new diet. This phenomenon corresponds to the observations of Gomes et al. (2020) and Lopes et al. (2023), which highlight the influence of forage quality and feeding experience on the intake and selectivity.

Castillejos Rosa et al. (2022) add that goats adjust their selection and consumption based on digestibility, secondary compounds, and prior experience, illustrating their ability to adapt. Full acceptance of the diet after a few days illustrates this food learning phenomenon described by Gomes et al. (2020). The higher feed conversion ratio for diet A, despite the lack of weight gain, suggests better nutrient utilization in meeting the maintenance and production needs of goats. These results are consistent with the observations of Castillejos Rosa et al. (2022) and Lopes et al. (2023), which show that moderate-quality forage with suitable particle size can improve digestive efficiency without necessarily leading to rapid weight gain.

***Physicochemical quality of milk from a diet based on Pennisetum pedicellatum* on the chemical quality of raw milk**

The results on milk density and dry matter, which were stable over time but varied according to the diets, confirm that diet has a strong influence on milk composition (Morand-Fehr et al., 1980; Ramos et al., 2020). Several studies confirm this decisive role of the diet. Vicente et al. (2017) showed that milk composition varies according to the type of diet (silage, pasture, dry fodder), while De La Torre Santos et al. (2021) observed that the type of silage and the use of pasture alter the lipid profile and antioxidants in milk.DietC, which is more nutritious, leads to a marked decrease in dry matter (-71 to -87%), while dietD provides values close to those of the natural pasture.DietD, combining *P. pedicellatum* silage and corn bran, maintains normal levels of fat, protein, and lactose, while a more balanced diet, such as dietC, reduces the fat and lactose content, thereby improving milk quality. Thus, a well-formulated silage preserves or even improves the chemical quality of milk (Morand-Fehr et al., 1980; Ramos et al., 2020). Milk that is less dense and lower in fatty acids and protein is similar to skim milk. Thus, properly formulated silage that is balanced in energy and protein can support the production of milk with good chemical quality, maintaining total solids, fat, and protein at normal levels (Meethip et al., 2024;Sidibé-Anago et al., 2025).

CONCLUSION

The relevance of evaluating the effect of feed on the quality of raw goat milk is justified by the results obtained. *Pennisetum pedicellatum* grass ensiled in barrels requires the addition of additives to improve nitrogen content. A balanced diet based on *Pennisetum pedicellatum* silage in barrels must be dieted by combining different sources of nitrogen, such as corn bran and peanut husks, to make it more acceptable to Djallonké goats and produce high-quality milk.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

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