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Dry Matter Intake, Digestibility, and Growth Performance of Peulh Breed Lambs Fed Millet Silage Treated with NaCl

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ABSTRACT

Livestock feeding is a major challenge in Niger. The aim of this study conducted at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) experimental station in Sadoré, Niger, was to assess the effects of adding 1% NaCl to millet stover silage on the dry matter intake, digestibility, and weight performance of Peulh-bred lambs. Four treatments were tested, consisting of millet stover silages of two cultivars (Siaka Millet and Local Sadoré) with or without adding NaCl. The biological material included 32 lambs of Peulh breed Niger aged around 15 months with an average weight of 28.64 kg. They were divided into four blocks of homogeneous average weight and for each block, there were eight lambs. Each treatment was randomly assigned to a block. The trial lasted 75 days, including 15 days of adaptation and 60 days of data collection. Weight evaluation of animals was recorded, and bromatological analyses were carried out. Results indicated that there were significant differences between silages, according to NaCl addition and treatment, for some parameters of chemical composition, feed value, and zootechnical parameters of lambs. Depending on the treatment, moderately high significant differences were recorded for ash, organic matter, and crude fiber while low significant differences were recorded for digestibility coefficient and organic matter digestibility. Regarding NaCl addition, highly elevated significant differences were recorded for ash and organic matter. These differences were moderately significant for crude fiber and organic matter digestibility. Low significant differences were recorded for dry matter, nitrogen-free extract, digestibility coefficient, feed value, total weight gain, and average daily gain. It is concluded that the addition of 1% NaCl negatively affects the weight development of lambs although it improves the quality of silage parameters such as dry matter, ash, and digestibility coefficient.

Keywords: Millet residue, Salt, Sheep, Silage, Ruminant feed, Zootechnical performance.

INTRODUCTION

Livestock plays a key role in the economies of Sahelian countries and the food security of rural households (Cissé, 2015). In Niger, livestock is the second most important economic activity after agriculture and thus plays a key role in the country's economy. Livestock is practiced by 87% of the population and has contributed to 11-16% of the national Gross Domestic Product (GDP) and 25-40% of the agricultural Gross Domestic Product over the past decade (Rhissa, 2010; INS-Niger, 2019; MAG/EL-Niger, 2020). In the past, livestock was mainly concentrated in the north, in pastoral areas. However, it is now becoming increasingly important in agricultural areas in the southern parts of the country (Sourabie et al., 1995; Rhissa, 2010). The livestock population, including cattle, sheep, goats, horses, and donkeys was estimated at 59,809,696 heads in 2023. Small ruminants account for around 60.73% of this total, with 15,139,186 heads of sheep (MEL-Niger, 2022). Despite the numerical importance of small ruminants, the food shortage remains a major constraint limiting the development of their breeding in Niger. It is noteworthy that animal feed is essentially based on natural pastures. These are becoming increasingly scarce with the spread of crops, the disappearance of fallow land, and human pressure. This situation was further exacerbated by insufficient rainfall, leading to the disappearance of several palatable forage species (Alhassane et al., 2017). All these factors contribute to a decline in available fodder, which is estimated at 21,441,980 tonnes of dry matter in 2022, compared to the estimated needs of 33,873,786 tonnes of dry matter, giving a fodder deficit of around 36.70%, due to the decrease of pastures and the increase of need for food (MEL-Niger, 2022). Given these numerous constraints, which considerably reduce the productivity of livestock in Niger, other alternatives need to be found to feed animals properly (Dan Gomma et al., 2017). Millet is used as a dual-purpose crop (Moussa et al., 2017). Millet stovers are well appreciated by ruminants. Millet fodder could therefore be used as a basal diet for livestock such as sheep to boost their zootechnical performance (Umutoni et al., 2021). However, it has been

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observed that the main constraint of traditional storage of crop residues was the gradual loss of their nutrients, their level of ingestibility, and their digestion potential (Kanwé et al., 1997). To optimize the utilization of these residues, it is important to explore the technical possibilities for preserving or increasing their nutritional value, digestibility, and ingestibility. According to Rêgo et al. (2010), preserving fodder in the form of silage helps to preserve its initial quality. This initial quality could be improved by adding various additives. According to Masui et al. (1979) adding NaCl to forage during ensiling improved the nutritional value of the product.

The aim of this study was to assess the effects of adding NaCl to stover silages of two millet cultivars (Siaka Millet and Local Sadoré) on the zootechnical performance of lambs. Specifically, the study aimed to determine the chemical composition and feed value of the silages according to the treatments and the addition of NaCl. Additionally, it sought to compare parameters such as dry matter intake, apparent digestive utilization coefficient, feed conversion ratio, body weight, average daily gain, and total weight gain of the lambs. Furthermore, changes in average daily gain, dry matter intake, and refused dry matter over time were to be assessed in relation to the treatments and NaCl addition.

MATERIALS AND METHODS

Ethical approval

This study was conducted in accordance with the ethical rules relating to animal welfare. The experimental procedure was validated at the Faculty of Agronomy of the Abdou Moumouni University in Niamey, Niger and has received the approval of the Ministry of Agriculture and Livestock through the General Direction of Veterinary Services (DGSV) under authorization number MAG/EL/DGSV-002.

Experimental site

The study was carried out in Niger, at the Sadoré experimental station of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT Sahelian Centre) situated between 13° 14' N and 2° 16' E (Korombé et al., 2023a). The Sadoré station is characterized by a rainy season that starts late in June and ends in October. The dry season runs from November to May, with a hot dry period between March and May. Average annual rainfall is 562 mm and temperatures generally vary between 12°C and 44°C, with an average of 29.4°C (Umutoni et al., 2021).

Animals and trial duration

The trial was conducted from 25 December 2020 to 09 March 2021. It lasted 75 days, including 15 days of adaptation to the environment, conduct, treatments, and 60 days of data collection according to the previous study of Dan Gomma et al. (2017). The animals were bought at local livestock markets (Torodi and Balleyara). On arrival, they were identified (numbered ear tags), weighed (Pi) and their ages estimated. The trial was conducted with 32 young male Peulh-bred sheep with an average age of 15.56±1.03 months and an average initial weight of 28.64±1.66 kg (Table 1). The diet included wheat bran as a supplementary feed for all the animals at a rate of 300 g/day per lamb. This quantity was selected based on the findings of Chermiti (1999), who indicated that increasing the amount of wheat bran beyond this threshold could lead to a decrease in the voluntary intake of fodder by sheep. Therefore, in order to avoid any negative impact on the consumption of silages, this specific quantity was chosen. All the animals received the same quantities and types of wheat bran. The only thing that varied in the diet was the type of silage, which was distributed *ad libitum*, as the aim was to assess the ingestibility of these silages. The animals had free access to supplements of mineral salts.

Table 1. Weight before the adaptation period and age of Peulh breed lamb according to treatment and NaCl addition at the start of the 75-day trial

Factors	Modalities	Pi (kg)	Age (Month)
Treatment	T1	28.60 ± 1.44	16.25 ± 1.26
	T2	28.63 ± 1.35	15.00 ± 0.00
	T3	28.73 ± 2.38	16.00 ± 1.41
	T4	28.60 ± 2.05	15.00 ± 0.00
		1.00	0.179
NaCl	With NaCl	28.61 ± 1.61	15.00 ± 0.00
	Without NaCl	28.66 ± 1.82	16.12 ± 1.25
	Mean	28.64 ± 1.66	15.56 ± 1.03
	P-value	0.954	0.023

Pi: Initial weight before the adaptation period, T1: Siaka millet silage without NaCl, T2: Siaka millet silage with NaCl, T3: Local Sadoré silage without NaCl, and T4: Local Sadoré silage with NaCl.

Treatments and experimental design

The treatments consisted of silage from the stovers of two millet varieties, namely an improved variety (Siaka Millet) and a local variety (Local Sadoré). These varieties were chosen based on their favorable performance in initial trials, indicating their suitability for silage (Korombé et al., 2023a). Furthermore, the widespread geographical distribution of the local variety Sadoré in the study area and the high level of interest among farmers in the Siaka millet variety during participatory evaluations of millet varieties in the Torodi area were additional factors influencing their selection (ICRISAT, 2018). Thus, four treatments consisting of the combination of the 2 millet varieties and 2 levels of salt addition were tested. The treatments included T1 (Siaka millet silage without NaCl), T2 (siaka millet silage with NaCl), T3 (local Sadoré silage without NaCl), and T4 (local Sadoré silage with NaCl). In addition to this basic diet, each lamb received 300 g/day of wheat bran by supplementation and this quantity could not be increased. According to Chermiti (1999), the quantities of fodder voluntarily ingested by sheep decreased beyond this quantity of concentrated feed in the ration.

To allocate the animals to each treatment, four blocks of eight lambs (eight replicates) of homogenous weight ($p > 0.05$) were formed. Each block received one treatment at random (Table 1). It should be noted that the animals were kept in individual boxes measuring 1.5 m × 1m (1.5 m^2), throughout the trial.

Silage making

The stovers of the two millet cultivars (Siaka Millet and Local Sadoré) were produced at the Sadoré experimental station. They were cut at maturity after removing the ears and chopped into small pieces of 2 to 5 cm using a chopper (Morales et al., 2015; Trevisoli et al., 2017). Then, 30 kg of chopped millet stovers, according to the cultivar, were placed in plastic bags. This operation was carried out in compacted layers using a manual compactor with or without adding NaCl at a rate of 10 kg per tonne of stover depending on the type of treatment (Tamboura et al., 2005). The first bag of properly compacted chopped residues was placed into a second one to promote an anaerobic environment (Korombé et al., 2023a; 2023b). The bags were then hermetically sealed with string and tape and kept anaerobically at room temperature for at least 60 days before the start of the trial in a closed, well-ventilated building (de Pinho Costa et al., 2012; Lyimo, 2017). It should be noted that for each treatment, the quantities required to conduct the trial were produced.

Animals' management

On arrival, all animals were vaccinated against the three main diseases of small ruminants in the study area, namely pasteurellosis, small ruminant plague (SRP), and sheep and goat pox. The animals were also dewormed with Albendazole 300 (Manufacturing company was Lobs International Health, 121 Aguesseau Street, 92100 Boulogne-Billancourt, France) at a dosage of 7.5 mg per kg of body weight with a repeat dose one week later and ivermectin (Manufacturing company was Boehringer Ingelheim, Lyon and Reims, France) at a dose of 0.02 ml per kg of body weight). Albendazole 300 is administered by oral route and ivermectin by subcutaneous injection. In addition, the animals received multivitamins (Introvit-B-Complex manufactured in the Netherlands, contains vitamins B1, B2, B6, B12, and Nicotinamide, D panthenol, Ascorbic acid, Biotin, Choline chloride) at a dosage of 5ml/sheep. Regarding the vaccination, vaccine for pasteurellosis was Pastovac (Central Livestock Laboratory, Niamey, Niger). Vaccine for sheep and goat pox was Dermovac (Central Livestock Laboratory Niamey, Niger). The vaccine for the small ruminant plague was Perivac (Central Livestock Laboratory, Niamey, Niger).

The silage was distributed in two daily meals at fixed times, in the morning at 9 am and in the afternoon at 4 pm. The lamb also received 300g of wheat bran per day at 1.30 pm. Drinking water and lickstones (Yellow Rockies contains Sodium, Magnesium, Cobalt, Manganese, Selenium, Zinc, Iodine, and Iron) were available *ad libitum* to all animals throughout the trial.

Animals' weight and age determination

Animals were weighed before and after the adaptation period and every 10 days thereafter until the end of the trial. The age of animals was determined by examining their teeth (Landais and Bassewitz, 1982).

Feed offered and refused

After the adaptation period, the quantities of feed offered and refused were weighed daily throughout the trial. The silages were distributed in such a way as to constitute at least 10% refusals because, according to Cinq-Mars (2008), refusals can easily reach 10 to 15% with good forage. Samples of 100 g of the different silages were taken at each distribution and placed in an oven at a temperature of 65°C for 72 hours to determine the Dry Matter (DM) content (Trevisoli et al., 2017). The rejects were put in cotton bags and air-dried for 5 or 7 days to determine the DM content. All samples were crushed through a 1 mm sieve and kept in well-sealed plastic bags for later analysis.

Faeces collection

Two periods of feces collection of 5 continuous days were considered during the trial. The first collection was carried out 25 days after the start of the trial, including a three-day period of adaptation to fecal bags, and the second 25 days after the end of the first still including three days of adaptation to the fecal bags. A period of adaptation to the fecal bags of 3 days was observed before the start of each collection. Collections were made in the morning and evening. The fresh feces collected were weighed per animal and a mixed sample of 100 g was taken and put in a cotton bag then air-dried for 5 to 7 days to determine the DM content (Umutoni et al., 2021). Samples were also crushed through a 1 mm sieve and kept in well-sealed plastic bags for later analysis at the animal production Laboratory in the Faculty of Agronomy at Abdou Moumouni University in Niamey, Niger.

Bromatological analyses

Bromatological analyses were performed at the animal production laboratory of the Faculty of Agronomy at the Abdou Moumouni University in Niamey, Niger using AOAC (1990) procedures. The analysis was used to measure the levels of DM, Nitrogen (N), crude protein (CP), crude fiber (CF), ash, ether extract (EE), and nitrogen free extract (NFE).

Parameter determination

The variables were calculated according to the mathematical formulas developed by Rivière (1991). They were as follows, quantity of dry matter ingested (QDMI), quantity of dry matter refused (QDMR), apparent digestive utilization coefficient (ADUC), average daily gain (ADG), feed conversion ratio (FCR), fodder value (FV), digestibility coefficient (DC), digestible organic matter (DOM), digestible nitrogen matter (DNM). The formulas were as follows:

QDMI = QDMD – QDMR (Formula 1)

Where, QMSD is the quantity of dry matter distributed and QMSR denotes the quantity of dry matter refused.

$$\text{ADUC}(\%) = \frac{[\text{I}-\text{F}]}{\text{I}} \text{ X } 100$$ (Formula 2)

Where, I determines the quantity of feed ingested and F signifies the quantity of feces.

$$\text{ADG (g/d)} = \frac{\text{Body weight 2} - \text{Body weigth 1}}{\text{Age 2} - \text{Age 1}}$$ (Formula 3)

Where, g/d is gram per day

$$\text{FCR (Kg of DM/Kg of body weight)} = \frac{\text{QDMI during a period}}{\text{Weight gain over the same period}}$$ (Formula 4)

FV (FU) = (DOM (% of DM)X K)/100

Where, FU defines the fodder unit, DOM is digestible organic matter, % of DM denotes the percentage of dry matter, K determines the coefficient calculated on the basis of DC, fat content in % of DM, and the table for calculating the fodder value of feed (Rivière, 1991). The digestibility coefficient was determined as a function of the crude cellulose content in % of DM and the table for calculating the fodder value of feed (Rivière, 1991).

DOM (%) = (OM (% of DM)X DC)/100 (Formula 5)

Where, OM is organic matter, DOM denotes digestible OM, DC signifies digestibility coefficient determined as a function of the crude cellulose content in % of DM, and the table for calculating the fodder value of feed (Rivière, 1991).

DNM (%) = (CP (%)X DC)/100 (Formula 6)

Where, CP is the crude protein and DC shows a digestible coefficient.

Data analysis

The SPSS 20.0 software (United States of America) was used to analyze the data, using the general linear model (GLM) method with the least significant difference (LSD) test to compare the means of the various parameters at the 5% significance level. The parameters studied were considered as dependent variables and treatment and NaCl addition were used as fixed factors for all analyses.

RESULTS

Silage chemical composition

The chemical composition of silages varied according to treatment and within each cultivar according to the addition of NaCl (Table 2). Thus, depending on the treatment, only Ash, OM, and CF varied significantly ($p < 0.05$). Treatments T2 and T4 were characterized by higher levels of Ash, while the opposite results were recorded for OM and CF. Analysis based on the NaCl addition indicated significant differences ($p < 0.05$) between the means of DM, Ash, OM, and NFE for Siaka's millet stover silages. Silages with NaCl were characterized by higher DM and Ash, while the opposite results were obtained with CF and NFE. For the Local Sadoré variety, the Ash, OM, CF, and NFE rates varied significantly ($p < 0.05$) according to the addition of NaCl. The addition of NaCl resulted in silages with higher levels of ash and lower levels of OM, CF, and NFE. Overall, the addition of NaCl significantly ($p < 0.05$) increased DM and Ash levels, while OM, CF, and NFE levels decreased significantly ($p < 0.05$), compared to silages without NaCl (Table 2).

Table 2. Comparison of the chemical composition of silages offered to Peulh breed lambs according to treatment and the addition of NaCl in a trial lasting 75 days

Factors	Modalities	DM (%)	Ash (% DM)	OM (% DM)	CP (% DM)	CF (% DM)	EE (% DM)	NFE (%DM)
Treatment	T1	32.76 ± 1.24^{bA}	7.87 ± 1.24^{bB}	88.08 ± 1.54^{aA}	4.18 ± 0.73^{aA}	39.37 ± 2.09^{aB}	2.16 ± 1.01^{aA}	42.38 ± 0.45^{aA}
	T2	35.67 ± 1.08^{aA}	12.97 ± 0.82^{aA}	82.13 ± 0.48^{bB}	3.78 ± 0.80^{aA}	38.60 ± 1.04^{aB}	2.02 ± 1.08^{aA}	37.73 ± 2.59^{bA}
	T3	34.39 ± 1.29^{aA}	7.22 ± 1.83^{bB}	90.05 ± 3.03^{aA}	3.72 ± 0.65^{aA}	42.71 ± 0.53^{aA}	1.52 ± 0.42^{aA}	42.09 ± 3.48^{aA}
	T4	35.25 ± 1.73^{aA}	12.39 ± 0.51^{aA}	82.36 ± 2.04^{bB}	4.07 ± 0.60^{aA}	37.62 ± 0.20^{bB}	1.17 ± 0.49^{aA}	39.49 ± 1.92^{bA}
	p-value	0.116	0.001	0.002	0.825	0.004	0.460	0.126
NaCl	without NaCl	33.57 ± 1.44^{b}	7.54 ± 1.44^{b}	89.07 ± 2.40^{a}	3.95 ± 0.67^{a}	41.04 ± 2.28^{a}	1.84 ± 0.77^{a}	42.23 ± 2.23^{a}
	With NaCl	35.46 ± 1.31^{a}	12.68 ± 0.69^{a}	82.24 ± 1.33^{b}	3.92 ± 0.65^{a}	38.11 ± 0.86^{b}	1.60 ± 0.88^{a}	38.61 ± 2.26^{b}
	p-value	0.043	0.000	0.000	0.946	0.003	0.616	0.030

In each column, depending on the treatment, the averages with at least the same superscript capital letter are not significantly different between them. In each column, depending on the cultivar, the means with the same lower-case superscript letter are not statistically different from each other. T1: Siaka millet silage without NaCl, T2: Siaka millet silage with NaCl, T3: Local Sadoré silage without NaCl and T4: Local Sadoré silage with NaCl, DM: Dry matter, OM: Organic matter, CP: Crude protein, CF: Crude Fiber, EE: Ether extract, NFE: Nitrogen free extract, SEM: Standard error of mean, % DM: Percentage of DM.

Table 3. Comparison of the nutritional value of silages offered to Peulh breed lambs according to treatments and salt addition in a trial lasting 75 days

Factors	Modalities	DC (% DM)	DNM (% DM)	DOM (% DM)	FV (FU)
Treatment	T1	48.23 ± 0.90^{aAB}	2.02 ± 0.39^{aA}	42.48 ± 0.13^{aA}	0.33 ± 0.01^{aA}
	T2	48.43 ± 0.46^{aAB}	1.83 ± 0.39^{aA}	39.78 ± 0.37^{bB}	0.31 ± 0.00^{bA}
	T3	47.17 ± 0.12^{bB}	1.76 ± 0.31^{aA}	42.48 ± 1.45^{aA}	0.32 ± 0.01^{aA}
	T4	48.83 ± 0.23^{aA}	1.99 ± 0.29^{aA}	40.22 ± 1.17^{aAB}	0.31 ± 0.01^{aA}
	p-value	0.023	0.764	0.013	0.126
NaCl	without NaCl	47.70 ± 0.82^{b}	1.89 ± 0.34^{a}	42.48 ± 0.92^{a}	0.33 ± 0.01^{a}
	With NaCl	48.63 ± 0.39^{a}	1.91 ± 0.32^{a}	40.00 ± 0.81^{b}	0.31 ± 0.01^{b}
	p-value	0.015	0.921	0.002	0.038

In each column, depending on the treatment, the averages with at least the same superscript capital letter are not significantly different ($p > 0.05$). In each column, depending on the cultivar, the means with the same lower-case superscript letter are not significantly different from each other ($p > 0.05$). T1: Siaka millet silage without NaCl, T2: Siaka millet silage with NaCl, T3: Local Sadoré silage without NaCl and T4: Local Sadoré silage with NaCl, DC: Digestibility coefficient, DNM: Digestible nitrogen matter, DOM: Digestible organic matter, FV: Fodder value, SEM: Standard error of mean, % DM: Percentage of DM, FU: Fodder unit.

Silage feed value

The feed value components studied varied between treatments and within the same cultivar as a function of NaCl addition (Table 3). Analysis by treatment indicated lower significant differences ($p < 0.05$) in the means of the DC and DOM. Treatment T4 had the highest DC, while treatments T1 and T3 gave the highest DOM values. For the Siaka's Millet variety, the DOM and FV averages decreased significantly with the addition of NaCl ($p < 0.05$). On the other hand, in the Local Sadoré variety, only DC increased significantly with the addition of NaCl, compared to silages without NaCl ($p < 0.05$). In general, the addition of NaCl to silage significantly reduced ($p < 0.05$) the values for DOM and VF, while significantly improving CD, compared to silages without NaCl ($p < 0.05$).

Zootechnical performance

The zootechnical performance of lambs was evaluated according to treatment and NaCl addition (Table 4). Analysis of Table 4 indicated that there were no significant differences between treatments for any of the parameters studied ($p > 0.05$). For silages of Siaka's Millet variety, only the final weight (Pf) decreased significantly ($p < 0.05$) with the addition of NaCl. As for the local Sadoré variety, no significant difference was noted depending on the addition of NaCl ($p > 0.05$). Overall, the addition of NaCl to silage resulted in a significant decrease ($p < 0.05$) in total weight gain (TWG) and average daily gain (ADG), compared to silages without NaCl.

Evolution over time of average daily gain

The variations in average daily gain (ADG) over time, as a function of treatment (Figure 1a) and NaCl addition (Figure 1b), indicated a sawtooth evolution. For the treatments, only the ADG means for the first decade varied significantly ($p < 0.05$), T1 gave the best ADG. Within each treatment, the evolution of the ADG as a function of trial duration indicated significant variations ($p < 0.05$) only in treatments T1 and T3. In both cases, the best ADG were recorded in order during the first, fifth, and sixth decades. On the other hand, the lowest ADG was recorded in the second and fourth decades for T1 and T3 respectively. Analysis according to the addition of NaCl revealed significant variations ($p < 0.05$) in ADG during the first and sixth decades. The silages without NaCl recorded the best ADG. For the silages without NaCl, a significant variation ($p < 0.05$) between the ADG means was also noted according to the duration of the trial. Thus, the ADG obtained during the first decade was higher than those of the other periods (Table 5).

Evolution over time of the total quantity of ingested dry matter

Analysis of the total quantity of dry matter intake (TQDMI) over time, as a function of treatment (Figure 2a) and NaCl addition (Figure 2b), indicated an overall upward trend. However, there was a slight fall in the quantities ingested in the fourth and sixth decades for all treatments (Figure 2a) and for silages with and without NaCl (Figure 2b). It should be noted that there was no significant difference among the groups for treatments and for NaCl addition. Similarly, on the one hand, for each treatment (Figure 2a) there were no significant differences between the averages according to the duration of the trial and, on the other hand, in silages with or without NaCl ($p > 0.05$; Figure 2b) the differences were also non-significant according to the duration of the trial ($p > 0.05$; Table 6).

Evolution over time of refused dry matter rates

The rates of dry matter refused (RDMR) as a function of treatment (Figure 3a) and NaCl addition (Figure 3b) indicated a general downward trend. However, a slight increase in RDMR was recorded in the fourth decade for treatments T1, T3, and T4 (Figure 3a) and as a function of NaCl addition (Figure 3b). There was no significant difference ($p > 0.05$) between the groups for the treatments or for the addition of NaCl. Also, within each treatment (Figure 3a) and within silages with and without NaCl (Figure 3b), there were no significant differences between the means according to the duration of the trial ($p > 0.05$; Table 7).

Table 4. Comparison of zootechnical parameters of Peulh breed lambs fed NaCl-treated silages according to the treatments and NaCl addition in a trial lasting 75 days

Factors	Modalities	$Pi_{2\ (kg)}$	Pf (kg)	TWG (kg)	ADG (g/d)	TQDMI (g/d)	FCR	ADUC (%)
Treatments	T1	28.04±1.41^{aA}	31.60±0.58^{aA}	3.56±1.83^{aA}	59.38±35.82^{aA}	682.28±33.30^{aA}	11.49±14.64^{aA}	88.45±0.87^{aA}
	T2	27.49±1.73^{aA}	28.59±1.89^{bA}	1.10±1.38^{aA}	18.33±27.04^{aA}	601.88±128.84^{aA}	32.83±14.45^{aA}	88.22±1.22^{aA}
	T3	27.90±2.16^{aA}	30.13±2.06^{aA}	2.23±0.73^{aA}	37.08±14.24^{aA}	675.64±68.13^{aA}	18.22±13.87^{aA}	89.47±1.57^{aA}
	T4	29.30±2.63^{aA}	30.43±2.63^{aA}	1.13±1.27^{aA}	18.75±24.99^{aA}	664.29±29.38^{aA}	35.43±10.85^{aA}	89.26±0.39^{aA}
	p-value	0.577	0.120	0.302	0.100	0.112	0.345	0.112
NaCl	Without NaCl	27.97±1.37^{a}	30.86±1.21^{a}	2.89±1.71^{a}	48.23±38.05^{a}	678.96±30.05^{a}	14.08±14.51^{a}	88.96±1.27^{a}
	With NaCl	28.39±2.43^{a}	29.51±2.44^{a}	1.11±1.28^{b}	18.54±26.16^{b}	633.09±99.08^{a}	34.14±14.76^{a}	88.74±1.07^{a}
	p-value	0.669	0.178	0.022	0.022	0.266	0.319	0.695

In each column, depending on the treatment, the averages with at least the same superscript capital letter are not significantly different ($p > 0.05$). In each column, depending on the cultivar, the means with the same lower-case superscript letter are not statistically different from each other ($p > 0.05$). T1: Siaka millet silage without NaCl, T2: Siaka millet silage with NaCl, T3: Local Sadoré silage without NaCl, and T4: Local Sadoré silage with NaCl, Pi_2: Initial weight after the adaptation period, Pf: Final weight; TWG: Total weight gain, ADG: Average daily gain, TQDMI: Total quantity of dry matter ingested, FCR: Feed conversion ratio, ADUC: Apparent digestive utilization coefficient; SEM: Standard error mean.

Table 5. Comparison of average daily gain of Peulh breed lambs fed NaCl-treated silages as a function of treatment and addition of NaCl according to the duration of the trial

Factors / Number of days	Modalities	10	20	30	40	50	60	p-value
Treatments	T1	194.50±136.62^{aA}	14.25±12.61^{bA}	46.43±34.26^{abA}	19.20±39.54^{bA}	125.89±93.92^{abA}	69.85±35.82^{abA}	0.018
	T2	30.63±55.58^{aB}	15.62±53.83^{aA}	39.29±37.12^{aA}	11.61±60.57^{aA}	57.14±57.74^{aA}	21.57±27.04^{aA}	0.803
	T3	153.13±50.06^{aAB}	7.62±10.12^{bA}	-1.07±4979^{bA}	21.43±26.88^{bA}	62.50±41.80^{bA}	43.63±14.24^{bA}	0.000
	T4	62.25±38.86^{aB}	63.75±58.37^{aA}	0.36±81.65^{aA}	-1.79±61.20^{aA}	-1.79±95.19^{aA}	22.06±24.99^{aA}	0.475
	p-value	0.045	0.235	0.486	0.907	0.184	0.077	
NaCl	Without salt	173.81±97.80^{aA}	10.94±11.18^{bA}	22.68±47.01^{bA}	20.31±31.32^{bA}	94.20±75.35^{abA}	56.74±28.87^{bA}	0.000
	With salt	46.44±47.48^{aB}	39.69±58.03^{aA}	19.82±62.30^{aA}	4.91±56.82^{aA}	27.68±79.40^{aA}	21.81±24.10^{aB}	0.744
	p-value	0.008	0.182	0.918	0.543	0.105	0.022	

In the rows, within each treatment according to the trial period, the means which have at least one lowercase letter in common as a superscript are not significantly different at the 5% threshold. In the columns, for each trial period, the means with at least one capital letter in common are not significantly different at the 5% threshold. T1: Siaka millet silage without NaCl, T2: Siaka millet silage with NaCl, T3: Local Sadoré silage without NaCl and T4: Local Sadoré silage with NaCl.

Table 6. Comparison of total quantity of dry matter ingested averages of Peulh breed lambs fed NaCl-treated silages as a function of treatment and addition of NaCl according to the duration of the trial

Factors \ Number of days	Modalities	10	20	30	40	50	60	p-value
Treatments	T1	659.65±23.61[aA]	676.5±38.02[aA]	698.95±51.31[aA]	654.65±27.76[aA]	709.13±34.90[aA]	694.8±49.32[aA]	0.305
	T2	556.44±138.53[aA]	575.11±109.49[aA]	606.84±137.10[aA]	620.58±135.17[aA]	627.59±133.50[aA]	624.74±187.03[aA]	0.97
	T3	622.15±71.14[aA]	668.65±77.07[aA]	685.5±77.60[aA]	680.9±61.62[aA]	694.00±58.71[aA]	702.68±46.87[aA]	0.601
	T4	643.05±49.69[aA]	669.15±22.42[aA]	674.30±36.47[aA]	660.55±32.29[aA]	671.35±19.97[aA]	667.33±17.74[aA]	0.763
	p-value	0.351	0.187	0.455	0.742	0.478	0.692	
NaCl	Without salt	640.90±53.01[aA]	672.58±56.42[aA]	692.23±61.33[aA]	667.78±46.42[aA]	701.56±45.44[aA]	698.74±44.74[aA]	0.252
	With salt	599.75±106.90[aA]	622.13±88.77[aA]	640.57±99.63[aA]	640.57±93.45[aA]	649.47±91.41[aA]	646.04±125.08[aA]	0.942
	p-value	0.339	0.178	0.247	0.495	0.194	0.312	

In the rows, within each treatment according to the trial period, the means which have at least one lowercase letter in common as a superscript are not significantly different at the 5% threshold. In the columns, for each trial period, the means with at least one capital letter in common are not significantly different at the 5% threshold. T1: Siaka millet silage without NaCl, T2: Siaka millet silage with NaCl, T3: Local Sadoré silage without NaCl, and T4: Local Sadoré silage with NaCl.

Table 7. Comparison of refused dry matter rates fed NaCl-treated silages as a function of treatments and addition of NaCl in Peulh breed lambs according to trial duration

Factors \ Number of days	Modalities	10	20	30	40	50	60	p-value
Treatments	T1	25.54±4.60[aA]	22.26±7.41[aA]	17.88±10.00[aA]	26.52±5.41[aA]	16.80±5.94[aA]	22.74±4.61[aA]	0.265
	T2	49.67±25.02[aA]	46.30±19.78[aA]	40.57±24.76[aA]	38.09±24.41[aA]	36.82±24.11[aA]	37.34±33.77[aA]	0.970
	T3	36.00±13.22[aA]	27.36±14.32[aA]	24.22±14.42[aA]	25.08±11.45[aA]	22.64±10.91[aA]	21.03±8.71[aA]	0.601
	T4	26.76±9.96[aA]	21.52±4.49[aA]	20.49±7.31[aA]	23.25±6.47[aA]	21.08±4.00[aA]	21.89±3.56[aA]	0.763
	p-value	0.146	0.062	0.219	0.469	0.24	0.533	
NaCl	Without salt	30.77±10.73[aA]	24.81±10.90[aA]	21.05±11.98[aA]	25.80±8.33[aA]	19.72±8.71[aA]	21.89±6.52[aA]	0.176
	With salt	38.21±21.47[aA]	33.91±18.75[aA]	30.53±20.02[aA]	30.67±18.34[aA]	28.95±18.08[aA]	29.61±23.72[aA]	0.924
	p-value	0.346	0.185	0.248	0.504	0.203	0.399	

In the rows, within each treatment according to the trial period, the means which have at least one lowercase letter in common as a superscript are not significantly different at the 5% threshold. In the columns, for each trial period, the means with at least one capital letter in common are not significantly different at the 5% threshold. T1: Siaka millet silage without NaCl; T2: Siaka millet silage with NaCl, T3: Local Sadoré silage without NaCl and T4: Local Sadoré silage with NaCl.

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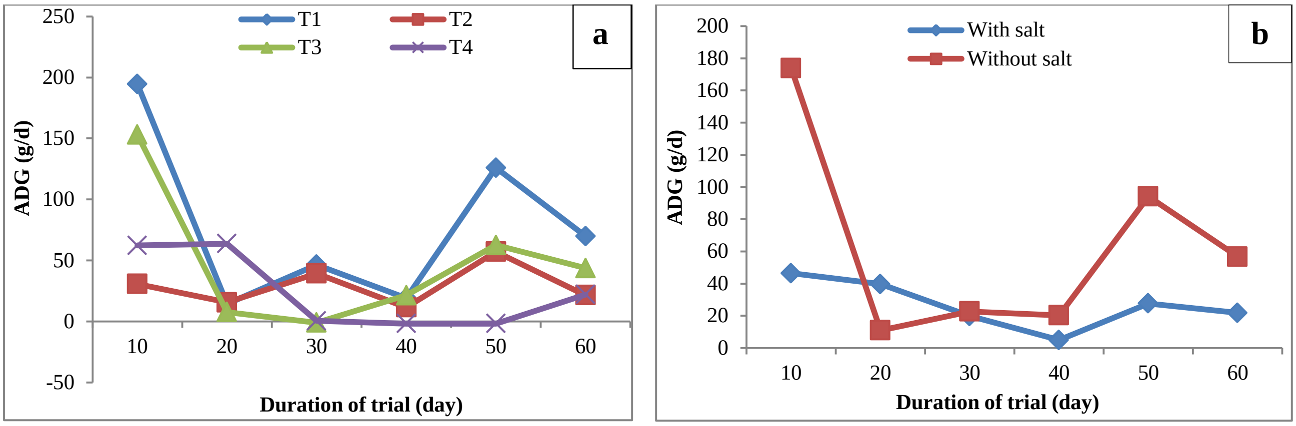

Figure 1. Evolution of average daily gain over time fed NaCl-treated silages, as a function of treatments (**a**) and NaCl addition (**b**) in Peulh breed lambs in a trial lasting 75 days

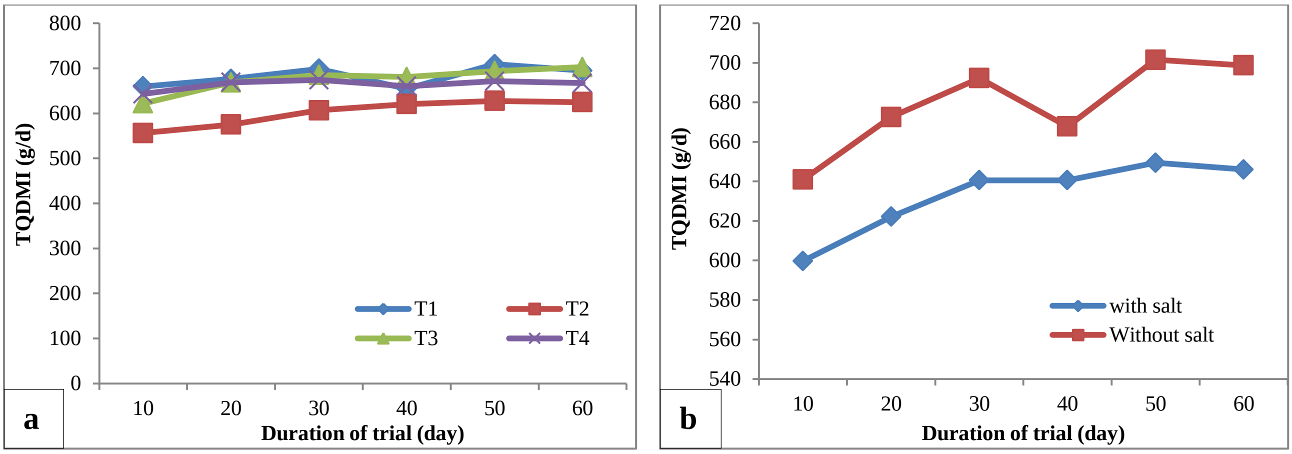

Figure 2. Evolution over time of total quantity of dry matter ingested fed NaCl-treated silages as a function of treatments (**a**) and NaCl addition (**b**) in Peulh breed lambs in a trial lasting 75 days. QMSTI: Total quantity of dry matter ingested

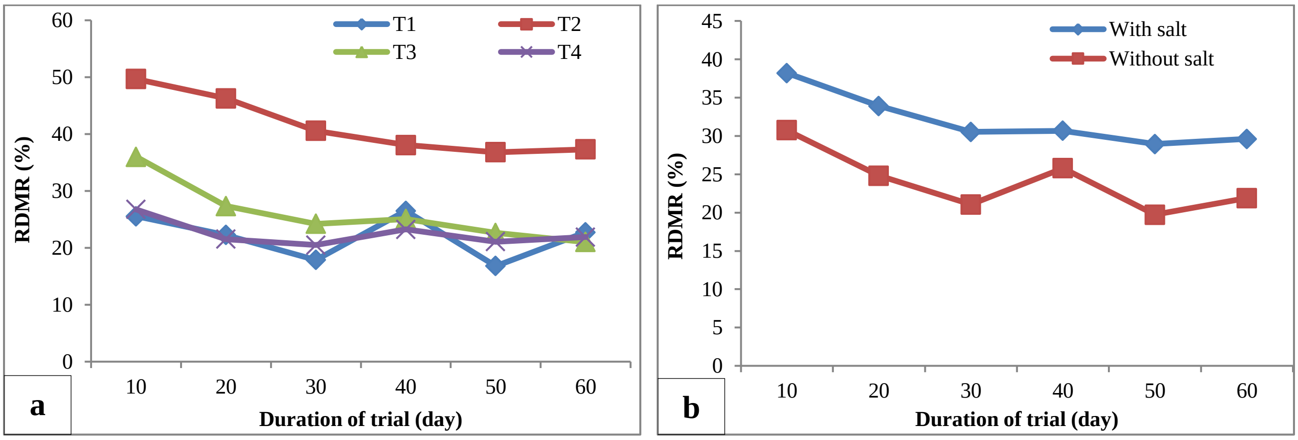

Figure 3. Evolution over time of refused dry matter rates fed NaCl-treated silages as a function of treatments (**a**) and NaCl addition (**b**) in Peulh breed lambs in a trial lasting 75 days

DISCUSSION

The chemical composition of silages

The addition of NaCl increased the DM and ash contents and decreased the OM, CF, and NFE contents. Silage additives can play several roles in the silage preservation process. Thus, a classification is made according to their properties, such as stimulants of fermentation, inhibitors of fermentation, inhibitors of aerobic deterioration, nutritional value improvers, and absorbents (Muck et al., 2018). NaCl can then be considered as a fermentation stimulant by limiting the spoilage of silage through the drop in pH (McLaughlin et al., 2002; Korombé et al., 2023a) and as a nutritive value improver and absorbent, in that it provides the minerals Na (39%) and Cl (61%) and absorbs the moisture from the

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stovers before silage by increasing the DM rate (Johansson, 2008; Korombé et al., 2023a). Ergin and Gumus (2020) also indicated that the ash content increased after the addition of NaCl to alfalfa silage, compared with the controls without NaCl.

The decrease in OM, CF, and NFE with the increase in DM and ash contents can be explained through the various relationships that exist between these parameters. According to Mahaman (2018), the DM percentage is calculated as the OM percentage to which the ash percentage has been added. It is also well known that CF and NFE were components of OM. From these relationships, it is clear that an increase in Ash content can lead to an increase in DM rate, a decrease in OM rate, and, indirectly, a decrease in CF and NFE contents. This decrease in CF content after the addition of NaCl was recorded by Ergin and Gumus (2020) on alfalfa silage. This can be explained by the fact that NaCl contributes to the solubilization of cellulose and the breaking of chemical bonds between cellulose and hemicellulose or lignin. So, when the chemical bonds are broken, the polymers are converted into monomers (Jiang et al., 2015). This is well confirmed by the results reported by Ergin and Gumus (2020), who noted high levels of hemicellulose in silages with NaCl.

In this study, the addition of NaCl had no effect on the CP content. This result supports that of Ergin and Gumus (2020) who recorded no significant difference for this parameter between alfalfa silage with NaCl and that without NaCl.

The nutritional value of silages

NaCl addition increased overall the value of the digestibility coefficient (DC). This situation was probably linked to the reduction in CF in silages with NaCl. According to Rivière's table (1991), when the CF value decreased, the DC value increased. The same type of relationship between CF content and DC was reported by Andrieu and Baumont (2000) and Peyrat et al. (2014) when studying maize silages. These results further confirm the role of NaCl in cellulose solubilization reported by Jiang et al. (2015).

The addition of NaCl globally decreased the OMD value. This was due to the significant decrease in OM content in silages with NaCl. Indeed, this decrease could not be compensated by the positive effect of NaCl on DC, since OMD was a function of these two parameters. Fodder value also decreased with the addition of NaCl to the silage. This parameter was closely linked to DOM, DC, and EE. The latter was higher in silages without NaCl. Digestible Nitrogen Matter (DNM) was not changed with the addition of NaCl. As this parameter was obtained from the CP and DC, this result can be explained by the fact that, on the one hand, a decrease in CP content was observed with the addition of NaCl and, on the other hand, an increase in DC with the addition of NaCl. It was as though there was compensation on both sides, i.e. in the silages with NaCl and without NaCl.

Weight performances

The means of live weights obtained for the lambs at 16.1 months (after the adaptation period) and 18.1 months (at the end of the trial) were 28.6 kg and 30.19 kg respectively. These results were within the range of 22.53 to 33.95 kg initial weight and 27.29 to 41.72 kg final weight reported by Tensaba et al. (2023) for lambs averaging 18 months old. The average initial weight of the animals in this study, however, is lower than that reported by Abdou et al. (2011), which is 27 kg for Oudah lambs aged 12 months on average.

In this study variations in ADG over time, as a function of treatments and NaCl addition, indicated a general trend with irregular patterns of the curves. This result was similar to that obtained by Simian (2017), who recorded irregular patterns of the curves for ADG evolution over time, with Djallonké sheep aged around 18 months and fed dual-purpose crop stovers. However, the shape of the curves differs according to the study.

According to Mahaman (2018), there was a positive correlation between the quantity of diet and the weight gains of the animals, so the evolution of the ADG of lambs in irregular trend could be explained through the quantities of diet which was a function of the state of health of the animals and the environmental conditions.

Furthermore, the results of this study indicated a variation in ADG from 18.33 to 59.38 g/d with an average of 33.39 g/d. These ADG values were lower than those obtained by (Abdou, 1997; Somda, 2001; Simian, 2017; Sana et al., 2020; Umutoni et al., 2021; Tensaba et al., 2023). Thus, on the one hand, it was observed that the minimum value of ADG (18.33 g/d) obtained in this study is higher than that reported by Amuda (2013), which was -19.05 g/d, but lower than that recorded by Ayano (2013) of the order of 30.56 g/d, and on the other hand that the opposite results were obtained for the maximum values of ADG.

These differences and similarities between the results of this study and those of others can be explained by differences between the diets used, the characteristics of the sheep (breed, age, initial weight), and the duration of the trials.

Overall, NaCl addition reduced the ADG of lambs. This result can be explained by the fact that NaCl seems to have a negative effect on the digestibility of organic matter (White et al., 2019; Korombé et al., 2023b). White et al. (2019) concluded that high NaCl diets affect rumen performance. However, the results of this study are opposite to those reported by Rabelo et al. (2013) who recorded higher ADG than the control with NaCl doses of 0.5%, 1%, and 2%.

Average Daily Gain varied significantly over time, but at a lower rate only in silages without NaCl (T1 and T3). The highest ADG values were obtained in the first decade of the trial, after which they evolved overall without significant differences (T3). These results can be explained by the duration of the data collection (2 months) because, according to Simian (2017), sheep showed their best weight performance during the first 2 months. This would suggest that this duration is relatively short to produce significant differences in weight performance.

Ingested dry matter

The total quantities of dry matter ingested (TQDMI) varied in this study from 601.88 to 682.28 g/d, with an average of 656.03 g/d. These results were higher than those reported by Amuda (2013) and Ayano (2013), who recorded TQDMI ranging respectively from 242.26 to 592.41 g/d and from 459.28 to 530.01 g/d in West African dwarf lambs averaging 12 to 14 months of age and diet based on maize silage and mixed cassava haulm and panicum maximum grass silage. However, the results of this study were lower than those reported by de Carvalho et al. (2017), who recorded TQDMI between 740 and 1080 g/d in 6-month-old lambs fed 50% tropical forage silages and 50% a concentrate based on maize and soybean meal.

These differences with results of this study were due to differences in the characteristics of the sheep (initial weight, age, breed), in the nature of the diet, and in the duration of the trials. Overall, the analysis of TQDMI over time showed an upward trend. This result was reported by Keles et al. (2018), who observed a linear increase in TQDMI over time in lambs with an average weight of 21.6 kg, fed buckwheat silage or maize silage. This can be explained by the fact that feed intake capacity was linked to the weight or more to the size of the animals during their growth (Jarrige, 1988).

In this study, TQDMI did not vary significantly with NaCl addition, although there was a general downward trend with the addition of NaCl. The results of this study were contrary to those of Rabelo et al. (2013) who recorded significantly higher DM intake levels than the control (387 g/d) with NaCl doses of 0.5% (667 g/d) and 2% (516 g/d). It should be noted that feed refusal rates moved in the opposite direction to TQDMI, with a minimum of 16.80% and a maximum of 49.67%. Overall, for all the treatments concerned, the refusal rate was higher than 10%, which was the minimum feed refusal threshold to be allowed in the trials, especially for good forages. This feed refusal rate can reach 30 or 40% for some forage categories (Bougouma-Yameogo, 1995; Zoungrana et al., 1999; Kirilov et al., 2006; Cinq-Mars, 2008).

Feed conversion ratio

The feed conversion ratio (FCR) was in this study from 11.49 to 35.43 kg of feed per kg of weight gain, with an average of 24.11 kg of feed per kg of weight gain. The results of this study differ from those reported by Amuda (2013) and Ayano (2013) who recorded FCR ranging from -5.32 to 18.72 kg feed per kg weight gain and 12.96 to 16.04 kg of feed per kg of weight gain in West African dwarf lambs of an average age of 12 to 14 months, fed maize silage and mixed silage of cassava tops and panicum maximum grass. Variations in FCR between periods may be due to the stage of growth and the type of tissue deposited (Sangaré et al., 2005). The FCR did not significantly with the addition of NaCl, although there was a trend towards an increase in the FCR for lambs fed silage with NaCl. This can be explained by the negative effect of NaCl on digestibility mentioned by White et al. (2019); Korombé et al. (2023b). Diets with a high NaCl content alter the efficiency of digestion. Feed conversion ratio will therefore not be efficient.

Apparent digestive utilization coefficient

The apparent digestive utilization coefficient (ADUC) values recorded in this study ranged from 88.22% to 89.47%. These results were higher than those reported by Wilkins et al. (1971), who estimated that the apparent digestibility of silage dry matter for sheep ranged from 55.3% to 80.0%. The results of this study were also higher than those obtained by Mahaman (2018) who varied from 65 to 75% in lambs fed cowpea hay pellets. These differences with the results of this study can be explained by differences in the characteristics of the animals (age, breed, and initial weight), the type of diet (physical characteristics, chemical composition, Nutritive value), the duration of the trials and the fecal collection methods (Khan et al., 2003). The addition of NaCl did not significantly influence ADUC in this study. However, there was a general downward trend with the addition of NaCl. This result was in accordance with that reported by White et al. (2019) who concluded, that diets with high NaCl content alter rumen function.

CONCLUSION

The effects of millet stover silages, depending on NaCl addition, on the dry matter intake, digestibility, and growth performance of Peulh breed lamb of Niger, revealed differences in the chemical composition and feed value of the silages. Thus, overall, silages with NaCl were characterized by a high digestibility coefficient and high DM and ash contents and by low values for DOM, FV, OM, CF, and NFE compared with silages without NaCl. The evaluation also indicated that the treatments were equivalent in terms of zootechnical performance, but that the addition of NaCl reduced the total weight gain and ADG of the lambs. The results indicated that the addition of NaCl to millet stover silages, despite some differences in chemical composition and nutritional value such as dry matter, ash and digestibility coefficient, but did not positively change the zootechnical performance such as daily weight gains, feed conversion ratio, digestibility, feed intake of the lambs. NaCl seems to had a negative effect on average daily weight gain. However, further investigations are needed to assess the effects of different doses of NaCl in millet stover silages on the zootechnical performance of lambs or to extend the study to other ruminant species.

DECLARATIONS

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Ethical considerations

The authors declare that all ethical aspects of the publication of an original article have been considered in the preparation of this paper.

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Authors' contributions

All authors participated in protocol development, Hamza Seydou Korombé, Amadou Maman Manouga, Abdoussalam Ibrahima contributed to trial conduct and data collection. All authors participated in data analysis. Hamza Seydou Korombe has written the first draft of the manuscript. All authors have reviewed the draft of the manuscript. All authors checked and approved the final version of the manuscript.

Competing interests

The authors declare that no conflict of interest has been presented.

Availability of data and materials

The authors declare that they are willing to provide the data relating to this study if reasonably requested.

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