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Evaluation of the Impact of the Formulation of Maralfalfa Hay (*Pennisetum sp.*) Associated with Molasses on the Average Daily Gain, Ingestion Rate and Carcass Yield of Small Ruminants

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Abstract

The evaluation of the impact of Maralfalfa hay (*Pennisetum sp.*) formulation combined with molasses on certain zootechnical parameters of small ruminants was conducted over a 45-day period at the experimental station of the Institute for Livestock Research for Development (Chad). A total of 18 goats were used, randomly divided into three diet groups. The animals in Diet Group A received a diet consisting of Maralfalfa hay without molasses, accompanied by concentrate (MH + 0% M + C), while Diet Groups B and C received Maralfalfa hay with 5% and 10% molasses, respectively, in addition to the concentrate (MH + 5% M + C and MH + 10% M + C). Physico-chemical analysis revealed that Maralfalfa is a potential source of protein (8.39% DM), fat (2.68% DM), carbohydrates (23.13% DM), and minerals (14.17% DM). The results of the average daily gain showed a significant increase ($P < 0.05$) in the average weight of animals in Diet Group B compared to Groups A and C. Similarly, the ingestion rate (356.975 ± 13.24 g) and carcass yield (44.55%) of the animals in Diet Group B were significantly improved with the addition of molasses to the ration. Given these results, Maralfalfa hay (*Pennisetum sp.*) could serve as an alternative forage source of energy and protein to supplement the diet of small ruminants. However, supplementation with molasses at a 5% rate is necessary to improve the zootechnical performance of small ruminants.

Keywords

Small Ruminants, Zootechnical Parameters, Molasses, Maralfalfa, CHAD

1. Introduction

In the African subtropical zone, livestock farming remains subject to a severe alternation between a biomass production period limited to three or four months and a long dry season, at the end of which herds face a marked energy and protein deficit [1]. The forage species that develop in these regions are predominantly grasses [2] [3], which have low nutritional value, as they are rich in cellulose but poor in nitrogen, minerals, and vitamins [4]. As a result, these forages do not meet the production needs of animals, making them more vulnerable to various diseases [5].

In Chad, livestock farming is a resource of crucial importance, with nearly 94 million heads, mainly ruminants. According to the General Livestock Census (RGE) conducted by the Ministry of Livestock and Animal Production, this activity represents the second-largest source of income after oil. It remains one of the pillars of the national economy and a significant source of revenue for the country's socio-economic development [6]. Thanks to its ability to thrive in restricted spaces or challenging agro-ecological environments, livestock farming offers opportunities to a wide range of social groups across almost all geographical regions. As such, it plays a crucial role in strengthening families' economic assets and social capital. It is a complex activity with multiple functions, offering both advantages and opportunities for farmers [7]. However, despite this multifunctionality, livestock farming in Chad faces numerous challenges related to nutrition and animal health.

Maralfalfa (*Pennisetum sp.*) is a grass species with high nutritional value (containing 12% more carbohydrates than other grasses) and is highly resistant to drought. Previous studies and trials have demonstrated that Maralfalfa is an excellent option for feeding cattle, horses, goats, and sheep [8]. Its combination with molasses helps increase ingestion rates and improve digestibility. In this regard, several authors have shown that treating coarse forages enhances their nutritional value, intake, and digestibility [4].

The addition of molasses to animal feed offers several nutritional and physiological benefits for ruminants. Rich in fermentable sugars, molasses promotes the proliferation of rumen microorganisms, thereby improving fiber digestion and nutrient assimilation [9] [10]. By enhancing the palatability of coarse forages, molasses stimulates feed intake, reducing the risk of energy deficiencies, especially during periods of forage scarcity [11]. Additionally, it helps balance rations by providing soluble carbohydrates, which are essential for optimizing protein utilization and improving the zootechnical performance of animals [4]. Thus, incorporating molasses into the diet of small ruminants is an effective strategy to increase average daily gain and carcass yield while reducing nutritional stress in challenging environments.

Given this situation, where animal nutrition poses a major challenge for farmers during forage deficit periods, the formulation of high-nutritional-value feed based on forages aligns with a broader goal of improving dietary supplementation. This approach aims to reduce nutritional stress and enhance livestock production.

2. Materials and Methods

2.1. Materials

2.1.1. Description of the Study Area

The experimental study on maralfalfa hay supplemented with molasses for feeding small ruminants was conducted at the Institute of Livestock Research and Development (IRED), specifically in its small ruminant experimental station.

2.1.2. Animal Materials

A total of eighteen (18) Sahelian goats, aged between 12 and 20 months and originating from the Bokoro area and its surroundings, were used in this study. The goats were divided into three groups, with six animals in each group. Their age was determined based on their dentition (Corcy, 1991). The animals were housed in a stable, with each having access to a feeder and a water trough (**Figures 1-3**).

Figure 1. Diet A (controls).

Figure 2. Diet B.

Figure 3. Diet C.

2.1.3. Plant Materials: Maralfalfa (*Pennisetum sp.*)

The Maralfalfa sample used in this study was harvested 45 days after reaching the developmental stage from the experimental plots at the Institute for Livestock Research and Development (IRED). The harvested forage was then cut using a motorized hay cutter to a length of approximately 2 to 4 cm, after which it was dried in the shade for ten days before being stored in bags for future use (Figures 4-5).

Figure 4. Harvest of Maralfalfa plant at 45 days.

Figure 5. Chopping of Maralfalfa.

2.1.4. Sugar Cane Molasses

The sugarcane molasses, produced by the Compagnie Sucrière du Tchad (C.S.T) in Sarh, was obtained through the ACCEPT project based at IRED, one week prior to the start of the trial (Figure 6).

Figure 6. Sugar can molasses.

2.2. Methods

2.2.1. Formulation of the Ration Based on Maralfalfa Hay Supplemented with Molasses

a) Experimental Protocol

Prior to offering 700 g of Maralfalfa hay per animal per day, molasses (relative to the weight of the hay) was first added to all rations. The liquid molasses was diluted with water (5% molasses for animals on Diet B and 10% molasses for animals on Diet C). The amount of water used for dilution was based on the quantity of Maralfalfa hay, with 250 ml of water for every 600 g of hay (Chenost *et al.*, 1997). Consequently, 292 ml of water was used to dilute the molasses before adding it to the daily ration (700 g of hay).

b) Experimental Device

Three experimental rations were prepared as follows:

- **Diet A**: 700 g of Maralfalfa hay with 0% molasses + 100 g of concentrate (peanut cake + corn bran);
- **Diet B**: 700 g of Maralfalfa hay with 5% molasses + 100 g of concentrate (peanut cake + corn bran);
- **Diet C**: 700 g of Maralfalfa hay with 10% molasses + 100 g of concentrate (peanut cake + corn bran).

The two ingredients (Maralfalfa hay and molasses) were thoroughly mixed before being provided to the animals. A representative sample of 100 g was collected from each ration for bromatological analysis.

2.2.2. Evaluation of Some Zootechnical Parameters (ADG, FI, and CAR)

a) Average Daily Gain (ADG)

The animals were weighed fasting at the start of the trial and then every ten (10) days, before the distribution of the daily ration (Figure 7). This allowed for the determination of the average daily gain (ADG). The ADG provides an indication of the growth rate of an animal over a specified period. ADG is expressed in kg and is determined using the following formula:

$$\textbf{ADG}: \frac{\text{weight at the end of the period-weight at the beginning of the period}}{\text{duration of the period}}$$

Figure 7. Weighing of the animal after ten (10) days of trial.

b) Ingestion Rate

The ingestion rate is obtained from measurements of the quantity of forage consumed compared to the reference feed. In this trial, the ingestions for each ration will be calculated by subtracting the amount served the previous day from the refusals collected the following day.

$$\text{IR} = \text{Quantity Served the Previous Day-Refusal}$$

c) Carcass Yield

To study carcass yield, the animals were slaughtered, skinned, and eviscerated before being weighed. Three (3) animals were randomly selected from the different diet groups, with one animal per group (Figures 8-9). The carcass yield was calculated by taking the ratio of the carcass weight obtained after evisceration to the live weight of the animal at slaughter, as follows:

$$\text{RC} = \frac{\text{PCE}}{\text{PVAA}} \times 100$$

PCE	Carcass weight after evisceration
PVAA	Live weight of the animal at slaughter

Figure 8. Skinning.

Figure 9. Carcass of animals from the three diets.

2.3. Statistical Data Analysis

Data on average daily gain, ingestion rate, and carcass weight were analyzed using Microsoft Excel for curve plotting, and the data were transformed using arcsin√(x/100) to normalize the distribution for both graphical and tabular representation. The transformed data were then subjected to Analysis of Variance (ANOVA) using the Statistical Package for the Social Sciences (SPSS v.17.0) for Windows software (SPSS Inc., Ltd., Statsoft). Tukey's post-hoc test was applied to separate the means at a 5% significance level to identify any significant differences between the groups.

3. Results and Discussion

3.1. Effect of the Experimental Ration on Some Zootechnical Parameters

3.1.1. Average Daily Gain

According to the data presented in Table 1, the average daily gain values observed for the different diets during the first and second weeks did not show significant differences ($P > 0.05$). However, a significant difference ($P < 0.001$) was observed during the third and fourth weeks of the study. Specifically, the average daily gain increased significantly with the progressive addition of molasses to the ration, with the highest value recorded for the FM + 5% M ration in Diet B.

The curve representing the weight gain evolution of animals on Diet A is shown in Figure 10. This figure illustrates the individual weight changes of each animal in the control group (Diet A). It was observed that animals A1 and A6 experienced weight gain starting in the first week, followed by a decrease in weight during the second and third weeks of the trial. A similar pattern was observed in animal A2, which gained weight during the first three weeks, followed by weight loss in the final week. In contrast, animals A3, A4, and A5 initially lost weight during the first week, regained weight during the second and third weeks (S2 and S3), and then experienced another weight loss during the fourth week (S4).

Table 1. Average daily gain of animals in different groups by week.

	Average Daily Gain (ADG)					
Ration	**Week 0**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	***F***
Diet A	14.98 ± 0.45^{aA}	14.96 ± 0.73^{aA}	14.99 ± 0.44^{aA}	14.90 ± 0.45^{aA}	14.70 ± 0.31^{aA}	/
Diet B	15.44 ± 1.08^{aA}	15.70 ± 0.44^{aA}	15.43 ± 0.94^{aA}	15.36 ± 0.82^{cC}	15.02 ± 0.76^{cC}	1,35
Diet C	14.53 ± 1.09^{aA}	14.23 ± 0.31^{aA}	14.55 ± 0.64^{aA}	14.45 ± 0.26^{abA}	14.39 ± 0.76^{Ab}	/
F	/	0.02*	1.81*	4.26***	6.19***	/

(n = 3). Values with the same lowercase letter in the same column and the same uppercase letter in the same row do not differ significantly according to Tukey's test at the 5% level. *: P > 0.05 (not significant); ***: P < 0.001 (highly significant); /: F-values were not determined due to lack of variance between means.

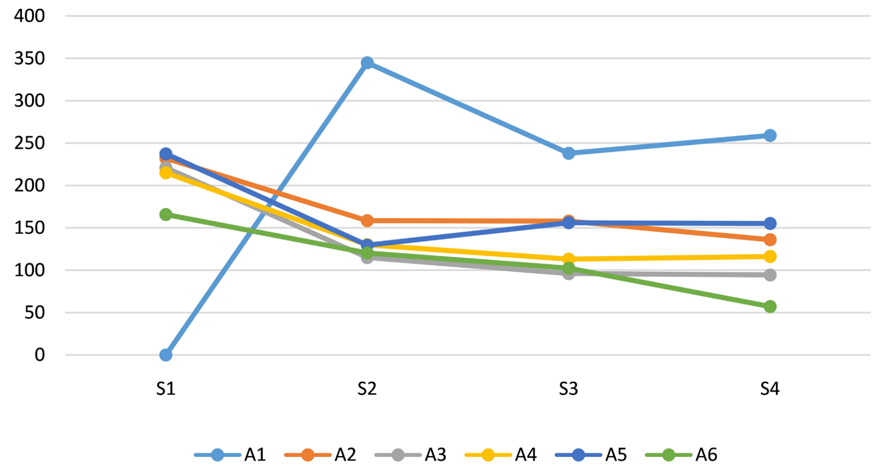

Figure 10. Evolution curve of weight gain for Diet A.

Figure 11 shows the curve of weight gain evolution for animals on Diet B. It illustrates the weight gain progression for each animal in the group treated with 5% molasses in their feed (Diet B) over the entire trial period. From the first week, it was observed that the weight gain curve for animals A7, A10, A11, and A12 followed an upward trend over time. In contrast, animals A8 and A9 maintained their initial weight. This stability persisted throughout the trial (up to four weeks) for animals A7, A8, A11, and A12. Animal A9 maintained a constant weight during the first three weeks before showing a weight increase in the final week of the experiment. As for animal A8, after keeping its starting weight at the beginning of the trial, a slight increase was observed between the second and third weeks (S2 and S3), before its weight stabilized by the end of the trial. Overall, the weight gain curve showed a general upward trend at all levels throughout the experiment.

The curve showing the weight gain evolution for animals on Diet C is presented in **Figure 12**. Analysis of this figure reveals that the average weight of animals A16 and A18 slightly decreased between the first and third weeks, before showing a marked increase in the final week. In contrast, animals A13, A17, A14, and A15 experienced weight gain between the first and second weeks of the trial, followed by a decrease between weeks 2 and 3 (S2 and S3). The average weight gain curve for the animals showed weight loss between the first and third weeks, followed by a slight increase towards the end of the trial.

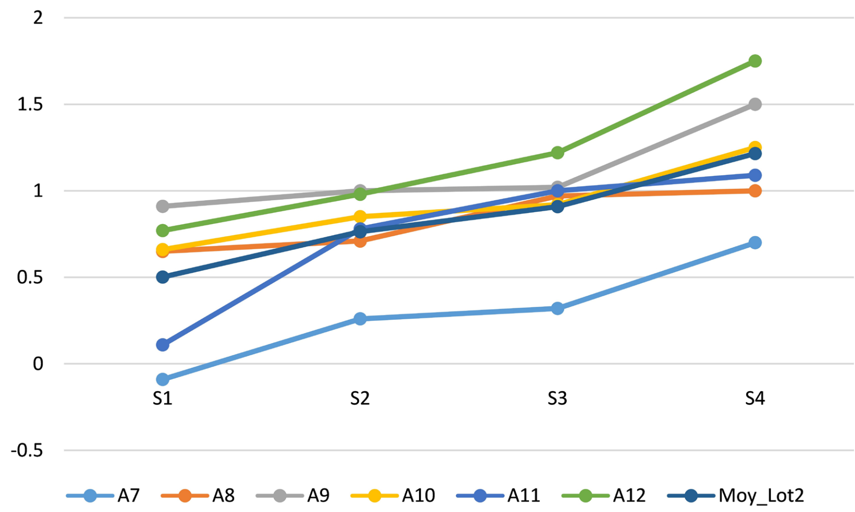

Figure 11. Evolution curve of weight gain for Diet B.

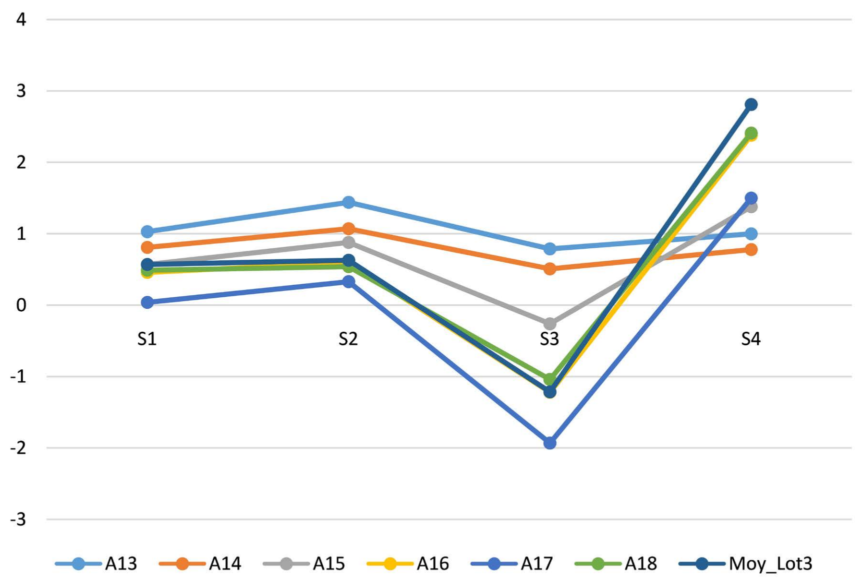

Figure 12. Evolution curve of weight gain for Diet C.

The analysis of this figure compares the evolution of the average weights of animals across different diets at the end of the experiment. Animals on Diet A (control group) showed a decrease in weight between the second and fourth weeks. Similarly, animals on Diet C experienced weight loss between the second and third weeks, followed by a slight weight increase toward the end of the trial. In contrast, animals on Diet B demonstrated a significant weight gain starting from the first week, which continued throughout the duration of the experiment

(**Figure 13**).

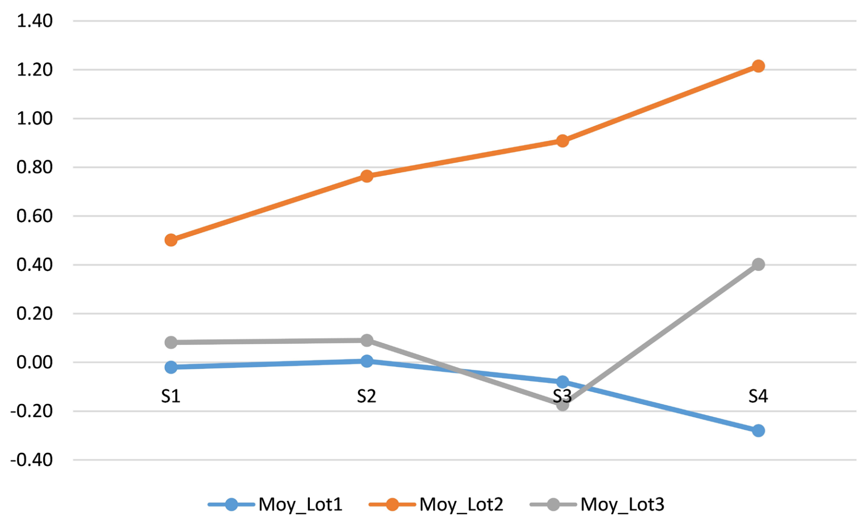

Figure 13. Comparative curve of weight gain by diet

3.1.2. Rate of Ingestion

Table 2 shows that the ingestion rates for the different diets during the first and second weeks did not exhibit significant differences (P > 0.05). However, a significant difference was observed during the third week of the study (P < 0.001). Specifically, the ingestion rate increased significantly with the level of molasses added to the ration, with the highest value recorded for the FM + 5% M ration of Diet B.

Table 2. Ingestion rates of animals on different diets by week.

	Ingestion Rate				
Feed Ration	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**F**
Diet A	214.198 ± 3.73^{aA}	166.35 ±5.53^{aA}	143.93 ± 25.34^{aA}	136.33 ± 19.43^{aA}	/
Diet B	372.68 ± 39.78^{cC}	397.95 ± 32.16^{cC}	376.53 ± 49.53^{bB}	356.975 ± 13.24^{cC}	1,6
Diet C	285.84 ± 17.72^{bB}	302.4 ± 63.36^{bB}	341.14 ± 29.98^{bB}	316.97 ± 13.24^{bB}	/
F	29.67	24.00	0.01	170.86	

(n = 3). Values marked with the same lowercase letter within the same column and the same uppercase letter across the same row do not show significant differences according to the Tukey test at the 5% level. *: P > 0.05 (not significant); P < 0.001 (highly significant); /: F-values were not determined due to no variance among means.

Figure 14 illustrates the ration intake rate for animals on Diet A. The results show that for animals A2, A3, A4, A5, and A6, the intake rate of the Diet A ration decreased starting from the first week. In contrast, animal A1 had a high intake in the first week, followed by a decline in food consumption from the second week until the end of the trial.

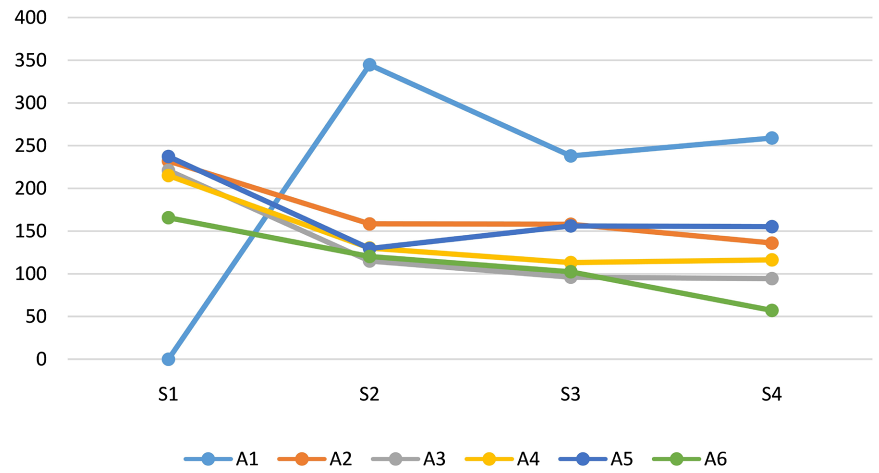

Figure 14. Ingestion rate of Diet A.

Figure 15 presents the intake rate of the ration for animals on Diet B over the four-week trial period. The data indicates that all animals consumed more than 300 g of the 700 g ration provided. Animals A7 and A8 had the highest intake rates, consuming 502 g and 522 g of the ration, respectively. In contrast, animals A9, A10, A11, and A12 showed a gradual decrease in their intake rate from the first to the third week, followed by a notable increase in consumption during the final week of the trial. This pattern suggests fluctuations in their feeding behavior, with a rise in intake towards the end of the experiment.

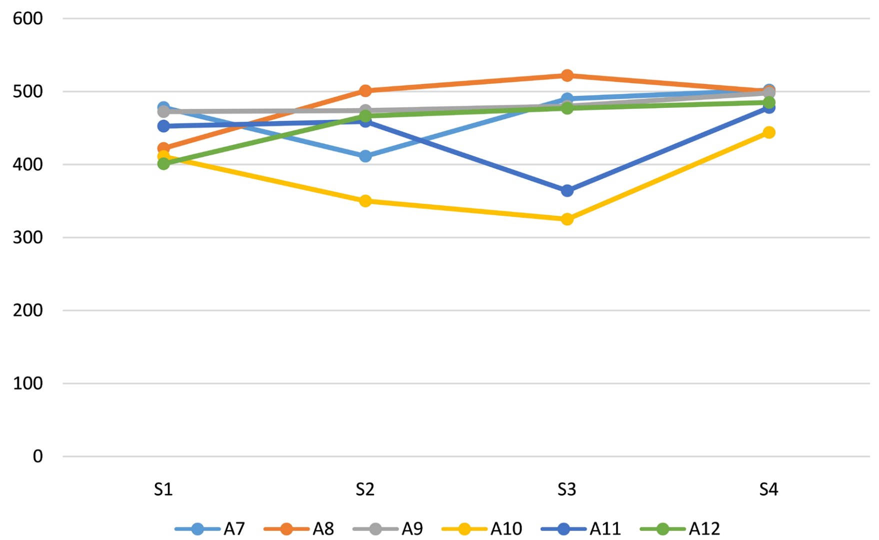

Figure 15. Ingestion rate of animals on Diet B.

Figure 16 illustrates the intake rate of animals on Diet C throughout the trial period. The figure shows the progression of the intake rate over time. It is observed that animals A13, A14, and A17 exhibited a decrease in their intake rate between the first and second weeks, followed by a slight increase during the third week, and then a further decline in the fourth week. In contrast, animals A15, A16, and A18 demonstrated a significant increase in their intake rate starting from the very first week of the experiment, with their consumption continuing to rise as the trial progressed.

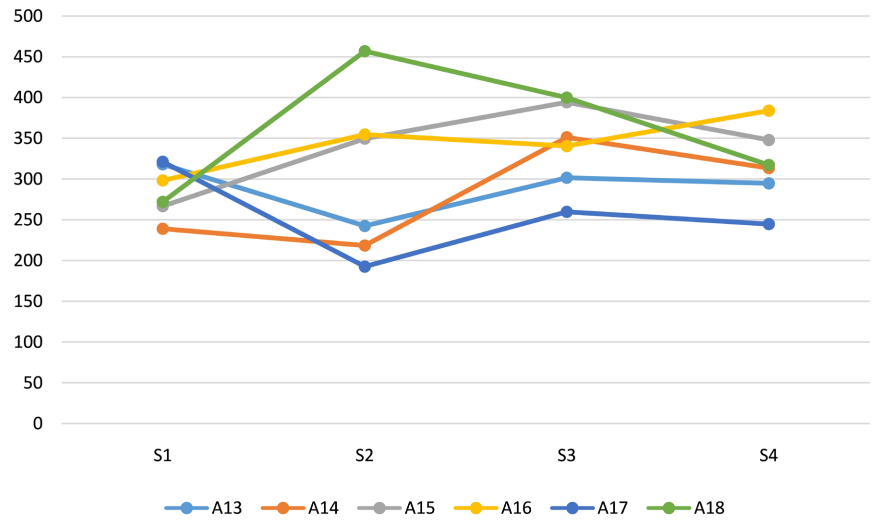

Figure 16. Ingestion rate of animals on Diet C.

3.1.3. Carcass Yield

Table 3 and **Figure 17** present the results of carcass yield (%) according to the different diets. Following slaughter, de-boning, and weighing, it was observed that animals on Diet B exhibited the highest carcass yield, reaching 44.55%. This suggests that the animals on Diet B had the most efficient conversion of feed into usable body mass. In contrast, animals from Batch 1, which were fed a different diet, showed the lowest carcass yield at 39.54%. This lower yield highlights a less efficient conversion compared to the animals on Diet B. These findings suggest notable differences in carcass yield across the three dietary groups, with Diet B resulting in the highest yield and Batch 1 showing the least efficient outcome among the three diets.

Table 3. carcass yield of the various batches.

Parameters	PAAB	PC	RC (%)
Diet A	13.2	5.22	39.54
Diet B	13.4	5.97	44.55
Diet C	11.75	5.1	43.4

PAAB: Slaughter Weight; **PC**: Carcass Weight; **RC**: Carcass Yield.

Figure 18 illustrates the difference between the pre-slaughter weight and the carcass weight across the different diet groups. The animals were weighed both before and after slaughter, allowing for a comparison of their weight changes. It is evident that the animals in Batch 2 showed the highest values, with a pre-slaughter weight of 13.40 kg and a carcass weight of 5.97 kg. These values suggest that the animals in Batch 2 had a higher overall body mass before slaughter and retained a relatively higher proportion of that weight as carcass weight. In contrast, animals on Diets A and C exhibited both pre-slaughter and carcass weights lower than those observed in Diet B. This indicates that the animals on these diets had less body mass before slaughter and showed a lower yield in terms of carcass weight compared to the animals on Diet B, further highlighting the differences in weight gain and carcass efficiency across the diet groups.

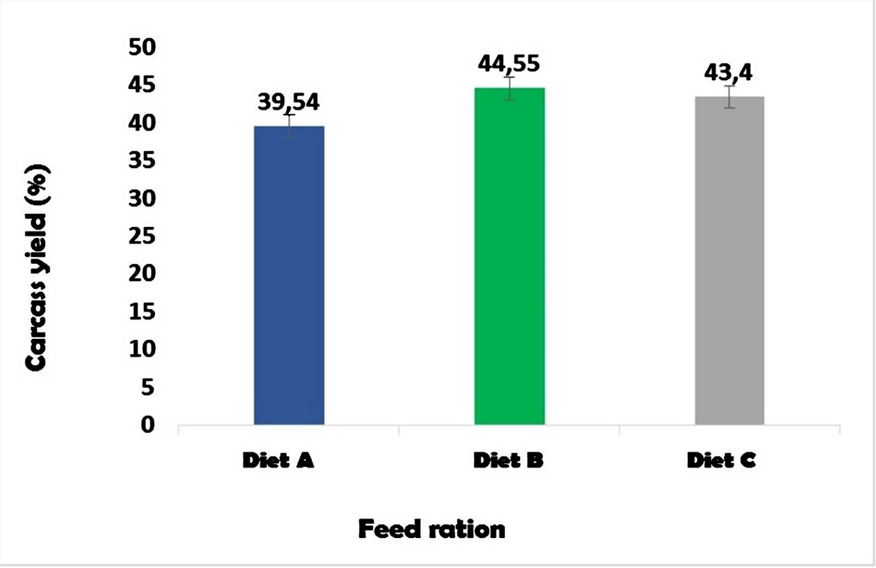

Figure 17. Carcass yield based on feed ration.

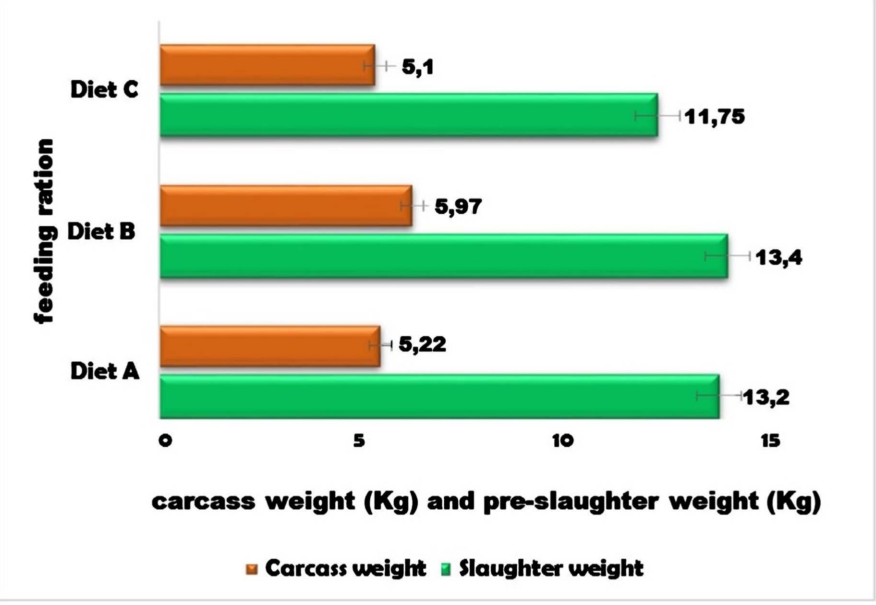

Figure 18. Difference between pre-slaughter weight and carcass weight.

The deterioration of climatic conditions in the Sahelian countries over the past four decades has weakened their ecosystems and accelerated the degradation of natural resources, severely impacting the living conditions of local populations. Although climate change is widely blamed as the main factor, it is essential not to overlook the human dimension in the environmental dynamics [12]. In the Sahelian and Saharan regions of Chad, the persistence of drought has exacerbated the degradation of water resources, soil, and vegetation. To meet the nutritional needs of animals and hope for minimal production of small ruminants, particularly during the dry season, it is crucial to improve the nutritional value and palatability of certain forages, such as Maralfalfa (*Pennisetum sp*).

In this study, the chemical composition of Maralfalfa hay was influenced by the addition of molasses. The levels of physico-chemical constituents, such as crude fiber and ash, decreased with increasing levels of molasses incorporation into the rations. These results suggest that the addition of molasses has a diluting effect on the plant's bromatological composition [13]. The dry matter content of Maralfalfa hay mixed with 5% molasses was slightly higher compared to the control diet and the diet treated with 10%. These results are in line with those obtained by Bostomi *et al.* (2008) [14]. Indeed, the carbohydrate content observed in this study is lower than those reported by Christon in 1978 [15], while the protein content is significantly higher than the one found by the same author. According to H. Archimède *et al.* (2011) [16], this difference in chemical composition is often related to the location where the plant material, such as sugarcane, is harvested.

The addition of 5% molasses to the ration, rich in minerals and sugars, enhances the intake rate of animals. This finding is confirmed by Pathoummalangsy and Preston (2008) [17], who assert that to improve the nutritional value of poor forages, adding rapidly fermentable carbohydrates allows for better use of ammonia by rumen microorganisms. Furthermore, Rivière *et al.* (1991) [18] report that molasses is highly palatable for animals due to its sugars and mineral salts. The optimal level of molasses in ruminant feed is 4 to 5%, as it improves both the intake and digestibility of coarse forages, especially during the dry season [18]. This is because molasses, rich in carbohydrates and easily fermentable, provides a significant amount of energy to rumen microorganisms. The stimulation of microbial proliferation accelerates the breakdown of plant residues and facilitates the transfer of rumen digesta to the omasum [19].

The use of Maralfalfa (*Pennisetum sp.*) in ruminant feeding has been reported by Ramirez *et al.* (2003) [20], who indicate that in Colombia, Maralfalfa is used as a cut-and-carry pasture for dairy cows. However, this practice is often based on the producers' experience rather than technical data. Nonetheless, empirical data shows that Maralfalfa is a grass with a high capacity for producing high-quality forage [20]. In this study, Maralfalfa was used as the base diet for the experimental animals, and its combination with molasses resulted in a significant weight gain, especially during the dry season. This result is confirmed by Pedro Miguel (2011) [8], who reports that feeding Maralfalfa in Ecuador leads to a weight gain increase of at least 10% in the Creole livestock in the Pulpana region.

The intake rate of Maralfalfa hay observed in our study is high, a result comparable to that obtained by Pedro Miguel (2011) [8], who, in a comparative study between Maralfalfa and Elephant grass (Kikuyu), found that Maralfalfa had a higher intake rate compared to Kikuyu when fed simultaneously to dairy cows.

4. Conclusions

In conclusion, this study on the incorporation of molasses and Maralfalfa hay (*Pennisetum sp.*) into the diet of small ruminants has led to the following key findings:

- Maralfalfa hay, when combined with molasses, demonstrates a high rate of dry matter intake.
- Incorporating a 5% dose of molasses into the diet significantly impacts weight gain.
- The inclusion of molasses in the diet improves the carcass yield of animals on Diet B.

Based on the results, Maralfalfa hay (*Pennisetum sp.*) emerges as a valuable alternative energy- and protein-rich forage source to enhance the diet of small ruminants. However, supplementing with molasses at a rate of 5% is essential to improve ration intake rates and optimize the zootechnical performance of small ruminants.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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