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Evaluation of the Effects of the Addition of Salt, Type of Additive and the Shelf Life, on Chemical Composition of *Pennisetum purpureum* (Schumach) (Maralfalfa) Silages in Niger

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Abstract: Seasonal variations in the quantity and quality of fodder constitute an obstacle to the development of ruminant breeding in Niger. This is why this study was carried out to evaluate the effects of salt addition, shelf life, and type of additive on the chemical composition of *Pennisetum purpureum* Schumach (Maralfalfa) silages. These aspects were retained because salt, in addition to its preservative power, improves the palatability of the fodder. The duration of storage makes it possible to determine the optimum period for obtaining quality fodder. Additives, for their part, are retained, because, in this area, they are most commonly used as concentrates in ruminant feed. To do this, a completely randomized experimental design was used according to a 2×3×4 arrangement (2 levels of salt addition, 3 storage times, and 4 types of additive) giving 24 treatments repeated 4 times each, i.e. 96 repetitions in total. A comparison of means was carried out using the GLM (General Linear Model) procedure of the Statistical Package for Social Science (SPSS) software. DM, MM, OM, PB, CB, MG, and ENA were considered as dependent variables, while salt addition, shelf life, and additive type were used as fixed variables. Correlation tests were carried out to determine the different types of relationships between the variables and highlight the effects of the factors. The tests were carried out at the 5% threshold. The results obtained show that certain parameters of the chemical composition statistically ($p<0.05$) varied depending on the treatment, the addition of salt, the shelf life, and the type of additive. The results also show that there are different types of relationships between chemical composition parameters and that their connections are influenced by one or the combination of several factors. In summary, this study made it possible to draw the following conclusions: i) Considering the BP and CB couple and to a lesser extent MS and MG, the T5 and T6 treatments stood out. ii) 30-day silages seem to be the most successful; iii) the addition of salt improved most of the parameters of the chemical composition, but statistically reduced the level of Crude Protein (CP); iv) finally, the addition of rice bran made it possible to obtain the best results compared to other additives. However, despite these disparities between the different types of silage, their chemical composition is satisfactory overall. This study lays the foundations for the characterization of Maralfalfa silage in Niger.

Keywords: Silage, *Pennisetum purpureum*, Maralfalfa, Ruminant Feed, Chemical Composition, Niger

Introduction

In Niger, the animal feed problem manifests itself in a chronic fodder deficit. The latter was of the order of 15,269,916 TMS, or 46% of the needs for the 2021-2022 campaign (Oumarou *et al*., 2022). This situation results in a decline in the zootechnical performance of animals (Sourabie *et al*., 1995). Faced with this situation, the important question is: How to improve the diet of ruminants in Niger? The practice of highly productive and quality forage crops could well be a promising solution to meet the challenge (Latimer and George, 2023).

Thus, the cultivation of *Pennisetum purpureum* Schumach (Maralfalfa), which is a very important fodder in the tropics due to its high productivity, can play this role. Indeed, Maralfalfa is a grass that represents an obvious interest from a zootechnical point of view because it makes it possible to fill the energy and protein deficits that characterize tropical pastures during the dry season. Also, it is well suited for silage, which allows the breeder to preserve it and feed his livestock during difficult periods (Guido, 2003).

In areas with high potential, the annual dry matter yield of Maralfalfa is between 30 and 50 TMS/ha (Mtengeti *et al*., 2001). Most of this yield is generally achieved during the rainy season when grass is abundant and of good quality. The nitrogen value remains well above 100 g of MAD per kg of dry matter, which largely exceeds the values usually obtained for cultivated grasses (Roberge *et al*., 1985).

To prevent the fodder deficit during the lean season, grass must be mowed and preserved. Thus, the fodder can be preserved either in dry form (hay, dehydrated fodder) or in wet form (silage).

Silage refers to the technique of preserving food by controlled anaerobic acidification. It is a wet preservation technique, using anaerobiosis and a predominantly lactic acidifying fermentation in order to minimize losses of dry matter, and food value and to avoid the development of undesirable micro-organisms (Paragon *et al*., 2004). So silage is a technique for preserving fresh grass by fermentation.

Silage is an effective method of preserving forage.

Fermentation modifies the nutritional components of the food and thus influences animal performance (Savoie and Tremblay, 1998). However, the nutritional value of silage depends on that of the original forage, the technique used, i.e. with or without additives, as well as the shelf life. This is why this study was carried out with the general objective of contributing to the improvement of ruminant feeding in Niger.

Specifically, this involves: i) determining the effects of the addition of salt, the shelf life, and the type of additive on the chemical composition of silage; ii) testing the different types of relationships between the variables of the chemical composition of silages.

Materials and Methods

Materials

Study Website

The test was conducted at the experimental station of the Regional Agricultural Research Center (CERRA) of Kollo, located in N'Dounga 7 km from the said center. This station is located between 13° 22' North latitude, and 02° 14' East longitude and is at an altitude of 192 m. It covers an area of 7 ha. The soil is sandy and suitable for several types of rainfed and irrigated crops.

The climate of the area is Sahelian type marked by a long dry season (October to June) characterized by the succession of a cold period (October to February) and a hot period (February to June) with temperatures up to 45°C in some places and a short rainy season (July to September) with an average annual rainfall of 500 mm. The rainiest months are July and August (Abdou *et al*., 2019).

Silage Preparation Equipment

Table 1 summarizes the equipment used for the preparation of the silages.

Methods

Plan of the Test

Three factors were evaluated. The addition of salt (with or without salt), the type of additive (wheat bran, cottonseed cake, rice bran, and without additive), and the shelf life (30, 45, and 60 days), thus giving a factorial plan of 2×4×3 = 24 treatments or types of silage. Indeed, each combination of the Addition of salt and type of additive (2*4 = 8 treatments) is repeated 3 times corresponding to the three-shelf life (30, 45, and 60 days).

Table 1: Material requirements for silage preparation

Item	Use	Units	Actual quantity	Increased quantity
Maralfalfa	Feed	Kg	434.4	500
Wheat bran	Additive	Bag of 50 kg	1	1
Cotton seed cake	Additive	Bag of 50 kg	1	1
Rice bran	Additive	Bag of 50 kg	1	1
Salt	Additive	Bag of 25 kg	1	1
Pot capacity 6 kg	Container	Unit	96	110
Plastic bags	Container	Unit	96	110
Roll of black plastic	Packaging	Unit	1	1
Adhesive tape	Packaging	Unit	4	4

Table 2: Chemical composition of treatments before ensilage

	Treatments							
Parameters (%)	T1	T2	T3	T4	T5	T6	T7	T8
DM	24.41	27.860	31.000	22.220	29.460	35.720	22.670	39.460
MM	15.07	20.720	24.600	27.390	19.040	25.720	18.630	23.510
OM	78.77	73.610	65.520	66.140	74.480	66.400	75.610	70.800
CP	3.21	8.426	5.599	5.964	9.374	7.149	6.219	5.216
CC	38.72	33.670	28.440	30.140	29.570	23.950	39.160	34.830
FM	1.08	1.280	2.040	1.880	5.540	5.780	2.200	1.680
NFE	35.75	30.240	29.440	28.160	30.000	29.520	28.030	29.070

T1: Silage of 100% Maralfalfa residues; T2: Silage of Maralfalfa residues +10% wheat bran; T3: Maralfalfa residue silage +10% wheat bran +4% salt; T4: Maralfalfa residue silage +4% salt; T5: Maralfalfa residue silage +10% rice bran; T6: Maralfalfa residue silage +10% rice bran +4% salt; T7: Silage of Maralfalfa residues +10% cottonseed cake; T8: Maralfalfa residue silage +10% cottonseed cake +4% salt; DM: Dry Matter; MM: Mineral Matter; OM: Organic Matter; CP: Crude Protein; CC: Crude Cellulose; FM: Fatty matter; NFE: Nitrogen-Free Extractive

Table 3: Chemical composition of the different types of additive

	Additive type		
Parameters (%)	Rice bran	Wheat bran	CSC
DM	93.820	94.420	94.620
MM	14.910	17.510	3.180
CP	15.028	13.296	6.803
CC	9.480	20.660	47.900

DM: Dry Matter; MM: Mineral Matter; CP: Crude Protein; CC: Crude Cellulose. CSC: Cotton Seed Cake

Table 4: Quantity of the different ingredients incorporated according to the treatment

	Ingredients					
Treat-ments	Mara lfalfa (kg)	Wheat bran (kg)	Rice bran (kg)	Cotton seed cake (kg)	Salt (kg)	Total (kg)
T1	5	0	0	0	0	5
T2	4.5	0.5	0	0	0	5
T3	4.3	0.5	0	0	0.2	5
T4	4.8	0	0	0	0.2	5
T5	4.5	0	0.5	0	0	5
T6	4.3	0	0.5	0	0.2	5
T7	4.5	0	0	0.5	0	5
T8	4.3	0	0	0.5	0.2	5

T1: Silage of 100% Maralfalfa residues; T2: Silage of Maralfalfa residues +10% wheat bran; T3: Maralfalfa residue silage +10% wheat bran +4% salt; T4: Maralfalfa residue silage +4% salt; T5: Maralfalfa residue silage +10% rice bran; T6: Maralfalfa residue silage +10% rice bran +4% salt; T7: Maralfalfa residue silage +10% cotton seed cake; T8: Silage of Maralfalfa residues +10% cotton seed cake +4% salt

It was considered, 4 repetitions for each of the 24 treatments, 96 repetitions in total. The different treatments are as follows:

- T1: Maralfalfa (stored for 30, 45 and 60 days)
- T2: Maralfalfa + wheat bran (stored for 30, 45 and 60 days)
- T3: Maralfalfa + wheat bran + salt (stored for 30, 45 and 60 days)
- T4: Maralfalfa + salt (stored for 30, 45 and 60 days)
- T5: Maralfalfa + rice bran (stored for 30, 45 and 60 days)
- T6: Maralfalfa + rice bran + salt (stored for 30, 45 and 60 days)
- T7: Maralfalfa + cotton seed cake + salt (stored for 30, 45 and 60 days)
- T8: Maralfalfa + cotton seed cake (stored for 30, 45 and 60 days)

Tables 2-3 respectively give the chemical composition of the treatments before ensiling and that of the additives.

Silage Preparation

Maralfalfa residues were produced at the CERRA Kollo experimental station in N'dounga and were cut at two months of regrowth as reported by Silva *et al.* (2014). The residues were then chopped into uniform strands of about 1 cm using an electric grinder. These chopped strands of Maralfalfa were used as a basic ingredient in the preparation of silage. For each type of silage. 4 repetitions of 5 kg each were considered. a total of 96 repetitions.

Wheat bran, Cotton seed cake, and rice bran were incorporated at 10% each and salt at 4% in the different silages. Thus, the various ingredients were weighed and mixed as follows depending on the treatment (Table 4).

Depending on the case, the mixture obtained was introduced into a plastic bag housed in a plastic jar. Then the plastic bag was hermetically sealed with adhesive tape, then the lid of the pot was placed and covered with a piece of black plastic so as to cover the edges of the pot, and after the assembly was completely sealed, with adhesive tape. The silages were kept for 30, 45, and 60 days.

Bromatological Analysis of Sample

When the silage was opened on the dates indicated, samples were taken and analyzed at the animal feed laboratory of the faculty of agronomy of Abdou Moumouni University in Niamey, according to the official de Bonville (1979).

The analyses focused on: the rate of Dry Matter (DM), Nitrogen (N), Crude Protein (CP), Crude Cellulose (CC), Ash or Mineral Matter (MM), Fatty Matter (FM), and Nitrogen-Free Extractives (NFE).

Statistical Analysis of Data

The data collected was entered into Excel. The latter was used for the design of figures and tables. A comparison of the means was carried out using the GLM (General Linear Model) procedure of the Statistical Package for Social Science (SPSS) software. DM, MM, OM, CP, CC, FM, and NFE were considered as dependent variables, while salt addition, shelf life, and type of additive were used as fixed variables.

Correlation tests were carried out to determine the different types of relationships between the variables and to highlight the effects of the factors.

Results and Discussion

Results

Effects of the Type of Treatment on the Chemical Composition of Silages

Analysis of the chemical composition of the silages revealed significant differences ($p<0.05$) depending on the treatment (Table 5) for all the parameters studied with the exception of the Nitrogen-Free Extractive (NFE).

Depending on the equality between the means, statistically homogeneous subsets are formed by parameter. Thus, there are 3, 3, 3, 4, 5, and 4 groups of statistically homogeneous averages respectively for Dry Matter (DM), Mineral Matter (MM), Organic Matter (OM), Fatty Matter (FM), Crude Cellulose (CC) and Crude Protein (CP) (Table 5). The high contents of DM, MM, OM, FM, CC, and CP were recorded with treatments T3, T4, T7, T5, T7, and T5 respectively. Furthermore, the lowest levels were obtained with treatments T1 for DM, T7 for MM, T4 for OM, T8 for FM, T6 for CC, and T4 for CP.

Effects of Shelf Life on the Chemical Composition of Silages

Table 6 presents the chemical composition of silages according to their shelf life. Analysis of the results showed significant differences ($p<0.05$) between the means for DM, MM, OM, and NFE. Thus, the DM was more abundant in the 45-day silages, the average of which is statistically higher than the others, while its lowest levels were obtained in the 60- and 30-day silages with statistically equal averages.

Regarding the MM, the high levels were recorded in the 60- and 45-day silages with statistically equal averages, while the lowest average statistically different from the others was obtained with the 30-day silages.

The best OM contents were recorded with the 30- and 60-day silages, which have statistically equal averages. Whereas, the lowest OM content statistically different from the others was obtained with the 45-day silages.

For NFE, the average obtained in 30-day silage is statistically equal to that found in 60-day silage but higher than that recorded in 45-day silage.

The latter has an NFE content statistically equal to that of 60-day-old silages (Table 6).

Effects of Salt Addition on the Chemical Composition of Silages

The chemical composition of the silages according to the addition of salt is presented in Table 7. The comparison of the means revealed significant differences for all the parameters studied, with the exception of the NFE. Higher contents of DM and MM were obtained in the silages with salt, while the opposite result was recorded for OM, FM, CC, and CP.

Table 5: Chemical composition of silage according to treatment

	Treatments									
Parameters (%)	T1	T2	T3	T4	T5	T6	T7	T8	SEM	P-value
DM	20.41^{c}	27.80^{ab}	31.99^{a}	26.22^{b}	27.17^{ab}	31.25^{ab}	27.19^{ab}	31.87^{a}	1.138	0.000
MM	12.01^{c}	15.44^{bc}	23.76^{a}	25.56^{a}	10.48^{c}	21.43^{ab}	9.18^{c}	19.51^{ab}	1.491	0.000
OM	83.26^{a}	80.02^{ab}	71.00^{c}	70.09^{c}	85.60^{a}	72.73^{c}	86.08^{a}	75.94^{bc}	1.443	0.000
FM	1.76^{d}	2.68^{c}	2.83^{c}	1.73^{d}	8.46^{a}	7.38^{b}	1.82^{d}	1.40^{d}	0.116	0.000
CC	44.06^{ab}	31.83^{cde}	28.49^{cde}	34.25^{bcd}	27.61^{de}	22.01^{e}	46.54^{a}	39.23^{abc}	2.416	0.000
CP	5.12^{d}	8.54^{ab}	7.47^{c}	4.85^{d}	9.27^{a}	8.18^{bc}	5.50^{d}	5.09^{d}	0.170	0.000
NFE	32.68^{a}	36.97^{a}	32.22^{a}	29.26^{a}	40.26^{a}	35.17^{a}	32.23^{a}	30.21^{a}	2.851	0.149

NB: For each row, the averages bearing at least one identical letter by exposing them are not statistically different from each other at the 5% level

T1: Silage of 100% Maralfalfa residues; T2: Silage of Maralfalfa residues +10% wheat bran; T3: Maralfalfa residue silage +10% wheat bran +4% salt; T4: Maralfalfa residue silage +4% salt; T5: Maralfalfa residue silage +10% rice bran; T6: Maralfalfa residue silage +10% rice bran +4% salt; T7: Silage of Maralfalfa residues +10% cotton seed cake; T8: Maralfalfa residue silage +10% cotton seed cake +4% salt; DM: Dry Matter; MM: Mineral Matter; OM: Organic Matter; FM: Fatty Matter; CC: Crude Cellulose; CP: Crude Protein; NFE: Nitrogen-Free Extractive. SEM: Standard Error of the Mean

Effects of the Type of Additive on the Chemical Composition of Silages

Table 8 provides information on the chemical composition of silage according to the type of additive. It appears from the analysis of this table that there are significant differences between the means for DM, MM, OM, FM, CC, and PC. Subsets of statistically homogeneous means stand out (Table 8).

Overall, higher levels of OM and CC were recorded in silages with the addition of cotton seed cake (CSC). While FM and PC were more abundant in silages with the addition of rice bran.

As for the addition of wheat bran, it made it possible to obtain silage with higher rates of DM and MM. Also, compared to the control silages (without additive), an increase in the contents of DM, FM, and CP was observed regardless of the type of additive used except for the CSC (Table 8).

Different Types of Relationships between Variables

The different types of relationships between the variables were tested through correlations (Tables 9-10). The analysis of Table 9 shows that there are gross negative or positive correlations between certain variables.

Table 6: Chemical composition of silage according to the duration of storage

	Duration of the conversation				
Parameters (%)	30 Days	45 Days	60 Days	SEM	P-value
DM	25.80^{b}	32.55^{a}	25.61^{b}	0.70	0.000
MM	14.22^{b}	18.54^{a}	18.75^{a}	0.91	0.001
OM	80.48^{a}	75.58^{b}	78.16^{ab}	0.88	0.001
FM	3.51^{a}	3.44^{a}	3.57^{a}	0.07	0.458
CC	33.10^{a}	35.55^{a}	33.93^{a}	1.48	0.499
CP	6.74^{a}	6.79^{a}	6.73^{a}	0.10	0.908
NFE	37.13^{a}	29.81^{b}	33.94^{ab}	1.75	0.017

NB: For each row, the averages bearing at least one identical letter by exposing them are not statistically different from each other at the 5% level

DM: Dry Matter; MM: Mineral Matter; OM: Organic Matter; FM: Fatty Matter; CC: Crude Cellulose; CP: Crude Protein; NFE: Nitrogen-Free Extractive; SEM: Standard Error of the Mean

Table 7: Chemical composition of silage according to the addition of salt

	Adding salt			
Parameters (%)	With salt	Without salt	SEM	P-value
DM	30.33^{a}	25.64^{b}	0.5750	0.000
MM	22.56^{a}	11.78^{b}	0.7535	0.000
OM	72.44^{b}	83.71^{a}	0.7290	0.000
FM	3.33^{b}	3.68^{a}	0.0585	0.000
CC	31.00^{b}	37.39^{a}	1.2205	0.001
CP	6.40^{b}	7.11^{a}	0.0860	0.000
NFE	31.71^{a}	35.53^{a}	1.4405	0.067

NB: For each line, the averages bearing an identical letter by exposing them are not statistically different from each other at the 5% level

DM: Dry Matter; MM: Mineral Matter; MO: Organic Matter; FM: Fatty Matter; CC: Crude Cellulose; CP: Crude Protein; NFE: Nitrogen-Free Extractive; SEM: Standard Error of the Mean

Table 8: Chemical composition of silage according to the type of additive

	Additive Type					
Parameters (%)	Without additive	Wheat bran	Rice bran	CSC	SRM	P-value
DM	23.32^{b}	29.90^{a}	29.21^{a}	29.53^{a}	0.805	0.000
MM	19.05^{a}	19.60^{a}	15.95^{ab}	14.34^{b}	1.054	0.003
OM	76.29^{b}	75.51^{b}	79.17^{ab}	81.01^{a}	1.020	0.002
FM	1.74^{c}	2.75^{b}	7.92^{a}	1.61^{c}	0.082	0.000
CC	38.91^{a}	30.16^{b}	24.81^{b}	42.89^{a}	1.708	0.000
CP	4.98^{c}	8.01^{b}	8.72^{a}	5.30^{c}	0.121	0.000
NFE	30.97^{a}	34.59^{a}	37.71^{a}	31.22^{a}	2.016	0.075

NB: For each row, the averages bearing at least one identical letter by exposing them are not statistically different from each other at the 5% level

DM: Dry Matter; MM: Mineral Matter; OM: Organic Matter; FM: Fatty Matter; CC: Crude Cellulose; CP: Crude Protein; NFE: Nitrogen-Free Extractive

Table 9: Correlation matrix of raw relationships between variables

Variables	DM	MM	FM	CC	CP	OM	NFR	Tr	DS	AoS	TA
DM	1										
MM	0.326**	1									
FM	0.103	-0.103	1								
CC	-0.190	-0.290*	-0.557**	1							
CP	0.171	-0.100	0.749**	-0.569**	1						
OM	-0.388**	-0.977**	0.100	0.298*	0.102	1					
NFE	-0.181	-0.463**	0.294*	-0.632**	0.335**	0.475**	1				
Tr	0.101	0.228	-0.229	0.165	-0.510**	-0.247*	-0.241*	1			
DS	0.014	0.253*	0.021	0.024	0.015	-0.133	-0.153	0.011	1		
AoS	0.400**	0.712**	-0.076	-0.303*	-0.219	-0.726**	-0.214	0.432**	0.018	1	
TA	-0.363**	-0.053	-0.388**	0.474**	-0.793**	0.065	-0.226	0.409**	-0.024	0.019	1

NB: **. The correlation is significant at the 0.01 level (two-sided); *. The correlation is significant at the 0.05 level (two-sided)
DM: Dry Matter; MM: Mineral Matter; OM: Organic Matter; FM: Fatty Matter; CC: Crude Cellulose; CP: Crude Protein; NFE: Nitrogen-Free Extractive; Tr: Treatment; DS: Duration of Storage; AoS: Addition of Salt; TA: Type of Additive

Table 10: Correlation matrix of relationships between variables, without the effects of processing, addition of salt, shelf life, and type of additive

Variables	DM	MM	FM	CC	CP	OM	NFE
DM	1						
MM	0.042	1					
FM	-0.007	-0.136	1				
CC	0.144	-0.082	-0.521***	1			
CP	-0.048	-0.013	0.818***	-0.529***	1		
OM	-0.130	-0.966***	0.129	0.072	0.029	1	
NFE	-0.220	-0.480***	0.222	-0.756***	0.199	0.513***	1

NB: ***. The correlation is significant at the 0.001 level (two-sided)
DM: Dry Matter; MM: Mineral Matter; OM: Organic Matter; FM: Fatty Matter; CC: Crude Cellulose; CP: Crude Protein; NFE: Nitrogen-Free Extractive

Table 11: Characteristics of the different types of links between variables

Links	Correlation type	Dependency factor
DM-MM	Positive	AoS
DM-OM	Négative	AoS
MM-CC	Négative	AoS
FM-NFE	Positive	TA
CC-OM	Positive	AoS
CP-NFE	Positive	TA-AoS
Tr-NFE	Négative	AoS-Tr-TA
Tr-CP	Négative	Tr
Tr-OM	Négative	AoS-Tr
Tr-TA	Positive	
DS-MM	Positive	DS
AoS-DM	Positive	AoS
AoS-MM	Positive	AoS
AoS-CC	Négative	AoS
AoS-OM	Négative	AoS
AoS-Tr	Positive	
TA-DM	Négative	TA
TA-FM	Négative	TA
TA-CC	Positive	TA
TA-CP	Négative	TA
TA-Tr	Positive	

DM-MM: Link between Dry Matter and Mineral Matter; DM-OM: Link between Dry Matter and Organic Matter; MM-CC: Bond between Mineral Matter and Crude Cellulose; FM-NFE: Bond between Fatty Matter and Nitrogen-Free Extractive; CC-OM: Bond between Crude Cellulose and Organic Matter; CP-NFE: Bond between Crude Protein and Nitrogen-Free Extractive; Tr-NFE: Link between Treatment and Nitrogen-Free Extractive; Tr-CP: Link between Treatment and Crude Protein; Tr-OM: Link between Treatment and Organic Matter; Tr-TA: Link between Treatment and Type of additive; DS-MM: Link between duration of storage and Mineral Material; AoS-DM: Link between Addition of Salt and Dry Matter; AoS-MM: Link between Addition of salt and Mineral Matter; AoS-CC: Link between Added Salt and Crude Cellulose; AoS-OM: Link between Addition of Salt and Organic Matter; Aos-Tr: Link between Salt addition and Treatment; TA-DM: Link between Type of Additive and Dry Matter; TA-FM: Link between Type of Additive and Fatty Matter; TA-CC: Link between Type of Additive and Crude Cellulose; TA-CP: Link between Type of Additive and Crude Protein; TA-Tr: Link between Type of Additive and Treatment; Tr: Treatment; DS: Duration of storage; AoS: Addition of Salt; TA: Type of Additive; TA-AoS: Association between Type of Additive and Addition of Salt; AoS-Tr-TA: Association between Addition of Salt. Treatment and Type of Additive; AoS-Tr: Association between Salt Addition and Treatment

Table 10 for its part, summarizes the correlations between the variables by canceling out the effects of the 4 factors (processing, shelf life, addition of salt, and Type of additive).

The analysis of this table shows the existence of natural links between certain variables. Thus, FM positively influences CP and negatively CC.

The latter evolves in the opposite direction with CP and NFE. As for the MM, it acts negatively on the OM and the NFE, while these two variables evolve in the same direction. The cross-analysis of the two Tables (9-10), as well as the partial correlations carried out by eliminating one by one the effects of the factors, made it possible to know those (factors), which influence each type of connection (Table 11).

Discussion

Analysis of the Chemical Composition of Silage According to the Treatment

The chemical composition of the silages varied statistically ($p<0.05$) according to the treatment for all the parameters except for the NFE. This result can be explained through the difference in composition between the ingredients that make up the treatments. Under the same conditions, Maralfalfa + 10% rice bran, the DM and PB contents obtained in the present study are higher than those reported by Monteiro *et al.* (2016), which are respectively 28.89 and 7.12%. This can be explained through the difference in composition between the ingredients (Maralfalfa residues and rice bran) used in the two trials.

Concerning the Maralfalfa +10% Cotton Seed Cake (CSC) treatment, the DM rate obtained in our study is included in the ranges 25.9-33.3% and 24.40-34.26% reported respectively by Viana *et al*. (2012); Dias *et al*. (2019) for additions of 7 and 14% Cotton seed Cake (CSC) in Maralfalfa silage. These results show an increase in the rate of MS with the level of incorporation of the CSC. Indeed, Lowilai *et al*. (1995) obtained an increase in CP and DM rates with the level of incorporation of wheat bran and rice bran in water hyacinth silage.

On the other hand, the OM and CP contents obtained in the present study are lower than those reported by Viana *et al*. (2012); Dias *et al*. (2019), while the opposite result was obtained for CC. This can be explained through differences in composition between the ingredients (Maralfalfa residues and CSC) used for the preparation of the silages in the different trials. Indeed, the residues of Maralfalfa and CSC used for the preparation of the silages in our study presented lower contents, in OM and CP, compared to those used by these authors and higher rates in MS and CC especially compared to the ingredients, used by Dias *et al*. (2019).

As for the Maralfalfa 100% and Maralfalfa +10% wheat bran treatments, Silva *et al*. (2014) reported lower rates of DM and higher OM and CP compared to those obtained in our study. These differences can be explained through the composition of the ingredients (Maralfalfa residues and wheat bran) used in the two trials. The increase in DM and CP levels observed in our study with the addition of 10% wheat bran is consistent with the result obtained by Gul *et al*. (2019) on rapeseed silage with the addition of the same rate of bran.

In short, the influence of the type of additive on the chemical composition of silage observed in this study corroborates the results reported by Saricicek and Kilic (2011) on alfalfa silage.

Analysis of Chemical Composition According to Shelf Life

The contents of MS, MM, OM, and NFE varied significantly ($p<0.05$) depending on the shelf life. A change in all nutrients was observed with increasing storage time per 15-day interval. Indeed, an increase of 26.16 and 7.40% was observed, respectively for DM and CC between the 30th and 45th day. Then, a decrease of 21.32% in DM and 4.56% in CC was recorded between the 45th and 60th day of storage. Saricicek *et al*. (2016a), reported the same patterns of fluctuation for DM and CC on maize silages with shelf lives spaced 14 days apart. These authors recorded an increase of 11.69% in DM and 3.99% in CC between the 90th and 104th day and a decrease of 14.45% in DM and 1.30% in CC between the 104th and 104th day, and 118th day of storage. The increase in DM and CC observed may be due to the evaporation of water in the silages, and the decrease in their contents which followed afterward, can be explained through a loss of DM caused by the microorganisms.

However, in our study fluctuations without and with significant differences were observed respectively for BP and NFE. These fluctuations consisted of an increase of 0.74% in CP and a decrease of 19.71% in NFE between the 30th and 45th day and a decrease of 0.88% in CP and an increase of 13.85% of NFE between the 45th and the 60th day of storage. These results are contrary to those obtained by Saricicek *et al*. (2016a) who recorded fluctuations in CP and ENA with significant differences. These fluctuations were reflected, first, in a decrease of 9.39% in CP and an increase of 2.46% in NFE, followed by an increase of 6.48% in CP and a decrease of 1.36% in NFE.

Our results are also contrary to those of Massaro Junior *et al*. (2020), who obtained with grape marc silage a 0.40% decrease in CP between the 36th and 48th day and an increase of 6.90% of CP between the 48th and the 60th day.

Also, Saricicek *et al*. (2016b) observed on maize silage, a linear decrease in cp between the 90th. 104th and 118th days of storage.

The discrepancies and similarities between our results and those of Saricicek *et al.* (2016a-b); Massaro Junior *et al.* (2020) can be explained through differences between the ensiled plant material and the storage times used in the different trials.

Analysis of the Chemical Composition According to the Addition of Salt

The different parameters of the chemical composition with the exception of NFE varied significantly (<0.05) depending on the addition of salt. This result is consistent with that reported by Rabelo *et al*. (2014) regarding DM indeed, these authors obtained significant differences between the silages treated with salt (1-2%) and the controls. This confirms the strong capacity of salt to absorb water from silage reported by Roberge and Toutain (1999). On the other hand, Rezende *et al*. (2011) reported on sugarcane silage, non-significant differences in DM between controls and those treated with 0.5.1 and 2% salt.

These authors linked this to the hygroscopic action of salt, which causes plant cells to retain more water thanks to a medium rich in solutes.

As for fibers (NDF, ADF, and Hemicellulose) and PB, Rabelo *et al*. (2014) did not record significant differences depending on the addition of salt. These differences between our results may be linked to differences in salt dose and plant material used in the two tests. In the majority of silage cases, we note an evolution in the opposite direction between the BP and the NDF rate.

Indeed, a reduction in BP in silages compared to products before ensiling would result in an increase in the ash and NDF levels of the silages, respectively. Reported the opposite relationship between BP and NDF content. According to a study by Morales *et al*. (2015), on millet silage, several factors can explain these variations including, in particular, the edapho-climatic conditions, the cutting stage, the variety used, the ensiling techniques used and the shelf life of the silages.

Conclusion

This study made it possible to understand the effects of certain factors on the chemical composition of Maralfalfa silage under the conditions of Niger. Thus, considering the couple CP and CC and to a lesser extent DM and FM, treatments T5 and T6 stood out. Concerning the shelf life, the best compromise seems to be found with 30-day silages even if the DM content is much better in those of 45 days.

As for the addition of salt, on the whole, it made it possible to obtain the best silages, however, it seems to have a negative influence on the CP. Regarding the type of additive, a marked improvement in certain parameters was observed compared to the control (without additive) with the addition of rice and wheat bran. Nevertheless, the best silages were obtained with rice bran considering all parameters except MM.

This study also made it possible to understand that there are natural relationships between certain variables and to know the specific effects of the factors on the different links between variables. Overall, all the silages presented a satisfactory chemical composition.

This study laid the groundwork for the characterization of Maralfalfa silage in Niger.

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Author’s Contributions

All authors equally contributed to this study.

Ethics

This article is original and has never been published before. The author has also confirmed to all authors involved in this study to read and agree to the contents of this article and that there are no ethical issues involved.

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