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Evaluation of silage quality of three sorghum varieties using in livestock systems of Burkina Faso

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ABSTRACT

This study aims to evaluate the physicochemical, microbiological and nutritional quality of silage from three improved sorghum varieties (Sariaso 14, Sariaso 15 and Sariaso 16) used in livestock farming systems in Burkina Faso. The sorghum stover were harvested after the grain harvest and ensiled with four treatments: without additives, with molasses, with salt, and with molasses + salt for 120 days. After 120 days, the fermentation parameters differed according to the varieties and additives. The pH of the silages ranged from 3.71 to 4.64, with the lowest values observed in Sariaso 16 ensiled with salt. The highest titratable acidity (18.36 g/kg DM) was obtained in the molasses + salt treatments, indicating more intense fermentation. From a microbiological perspective, the aerobic bacteria loads were lowest in molasses + salt silage (3.41×10^6 CFU/g DM) compared to the control (1×10^8 CFU/g FM). In addition, there was a reduction in yeasts and moulds, especially in the molasses + salt treatment (4.06×10^5 CFU/g FM). Bromatological analysis showed significant differences ($p<0.05$) between varieties and treatments. Sariaso 16 sorghum stalks treated with molasses/molasses + salt had the best nutritional values: high crude protein (3.33–3.41% DM), higher metabolisable energy (≈7.5 MJ/kg DM) and high digestibility (IVDOM > 51%). The results of the study show that improved varieties, particularly Sariaso 16, combined with the use of additives, are an effective strategy for producing high-quality silage. These results also demonstrate that variety selection, combined with the addition of additives, is a major lever for optimising the quality of sorghum silage and securing feed for ruminants during the dry season in Burkina Faso's livestock systems.

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INTRODUCTION

In Burkina Faso, sorghum (*Sorghum bicolor* (L.) Moench) is the second most important cereal after maize, with an estimated production of 2.8 million tons in 2020 (DGESS(CPSA)/MAAHM, 2021). Sorghum is a staple food for human consumption and a major forage crop for ruminants in tropical and semi-tropical Africa (Nebie, 2014; Neves *et al.,* 2015; Zhao *et al.,* 2019). This production relies mainly on local varieties, with improved varieties used only on a limited scale (Barro-Kondombo, 2010; Ouedraogo *et al.,* 2024). In recent years, research conducted by INERA in Burkina Faso has led to the development and dissemination of new sorghum varieties, such as Sariasso 14, Sariasso 15 and Sariasso 16.

Trials conducted under farm conditions have shown that these cultivars offer higher dry matter yields than local varieties and can be a valuable fodder resource during the dry season (Zampaligre *et al.,* 2021). However, before promoting these varieties on a large scale, it is necessary to obtain additional information on the quality of their ensiled forage. Thus, knowledge of the nutritional potential and biochemical characteristics of silage from these varieties could allow for the identification and availability of the best varieties to improve the nutritional potential of sorghum straw for animal feed. This study aimed to evaluate the physicochemical and microbiological qualities and nutritional value of Sariasso 14, Sariasso 15, and Sariasso 16 ensiled with additives (molasses and salt) as a dry-season feed for ruminants to ensure continuous and regular livestock nutrition, whether for maintaining growth, fattening, or milk production.

MATERIALS AND METHODS

Silage preparation

Three sorghum varieties were used in this study: Sariaso 14, Sariaso 15, and Sariaso 16. Sorghum stovers were harvested at the post-grain harvest stage at the research station of the Institute of Environment and Agricultural Research of Saria (INERA) and treated with two types of additives (salt and molasses). The harvested stovers were then ground using a chopper (130DX, ARS Co., Ltd., Osaka, Japan) to facilitate compaction and fermentation. The silage was made in cylindrical tubes 50 cm long and 10 cm in diameter, and for each variety, four treatment groups with three replicates per treatment were used: control (no additive), molasses 5% fresh weight, salt 5% fresh weight, and salt 5% + molasses 5% fresh weight. A total of thirty-six (36) silos (three varieties, three treatments, and three replicates) were used. The silos were stored at room temperature (25-38 °C) inside a building protected from light. After 120 d of ensiling, the silos were opened for analysis of chemical composition, fermentation quality, and microbial populations.

Food analysis using the NIRS method

To determine the nutritional value of the forage, samples of approximately 500 g were collected. The dried samples were ground and sieved for chemical analyses. The chemical contents of the different samples were determined using an NIRS FOSS DS 2500 F analyzer at the NIRS Laboratory (INERA-ILRI). The chemical analysis consisted of determining dry matter, mineral (ash) content, crude protein, and fiber (neutral detergent fiber). (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL), metabolizable energy (ME), and in vitro digestibility of organic matter (IVDOM).

Analysis of the physicochemical parameters of silage

The pH of the silage juice samples was measured according to the AFNOR standard (1970). Titratable acidity was determined according to the standard method (AFNOR, 1974).

Determination of the nutritional effect of the plants used

The enumeration of mesophilic aerobic flora, lactic acid bacteria, yeasts and molds, and total coliforms of fresh and ensiled sorghum was performed according to the methodology described by Cai *et al.* (2004). Mesophilic aerobic floras were enumerated on Plate Count Agar (PCA).

Lactic acid bacteria were enumerated on Man, Rogosa, and Sharpe (MRS) agar. Yeasts and molds were enumerated on Sabouraud's chloramphenicol agar. Coliforms were enumerated on crystal violet and neutral red (VRBL) lactose agar. Inoculated plates were incubated at 30 °C for 2–4 days under aerobic or anaerobic conditions, depending on the type of microorganism to be enumerated. Colonies were counted as the number of viable microorganisms in colony-forming units (CFU)/g of fresh mass (FM).

Statistical analysis of data

All the parameters collected were entered into a Microsoft Excel spreadsheet to constitute a database and analysed by using R software (R-Development-Core-Team, 2013). Analysis of variance (ANOVA) was performed. The Student Newman and Keuls test at a 5% threshold was used to separate variances when the analysis revealed a difference between the means.

RESULTS

Chemical composition before silage

The pH, lactic acid level, bromatological composition, and microbial population of the three sorghum varieties before ensiling are presented in Table 1. The results of the physicochemical analyses showed that before ensiling, all three varieties had very high pH levels, ranging from 6.85 to 8.12. Before ensiling, the results also showed that the average titratable acidity was low for the variety Sariaso 16, with a value of 7.51 and high 10.24 for Sariaso 15.

The values for crude protein and IVDOM were higher. for Sariaso 16 compared to the other two sorghum varieties, while the levels of dry matter, fiber (NDF, ADF, and ADL), and ash did not differ significantly between Sariaso 14 and Sariaso 15 compared to Sariaso 16. The microbial populations (aerobic bacteria, coliform bacteria, yeasts, and molds) present in the different sorghum varieties did not differ significantly before ensiling. However, mesophilic aerobic floras were dominant in the different sorghum varieties before ensiling.

Table 1. pH, chemical composition, microbial population of sorghum varieties before ensiling

	Sariaso 14	Sariaso 15	Sariass 16
pH	7.24	8.12	6.85
Titratable acidity (g/ kgFM)	9.98	10.24	7.51
DM (%)	44	46	40
Ash (% DM)	7.4	7.3	7.9
CP (% DM)	2,4	2,8	3,3
NDF (% DM)	68	69,9	66,5
ADF (% DM)	38,09	39,7	35,6
ADL (% DM)	4,23	4,4	4,1
ME (mJ kg^{-1} DM)	7,6	7,5	8,0
IVDOM	51,29	50,6	54,0
Microbial population (cfu g^{-1} FM)			
Aerobic bacteria	2,85 x10^{8}	2,54 x10^{8}	8.22 x 10^{7}
Lactic acid bacteria	2.39 x 10^{5}	8.95 x 10^{5}	1.01 x 10^{6}
Yeasts and molds	1.1 x 10^{6}	6.45 x 10^{4}	1.54 x 10^{6}
Coliforms	ND	ND	ND

FM: Fresh matter, DM: dry matter, lac acid: lactic acid, pH: potential of hydrogen. ADF = acid detergent fiber, ADL = acid detergent lignin, ME = metabolisable energy, NDF = neutral detergent fiber, CP = crude protein, IVDOM: *in vitro* digestibility of organic matter, CFU/g FM: colony-forming units per gram of fresh matter; ND: not detected

Physico-chemical parameters of silage

The fermentation characteristics of the silage produced in this study were not affected ($p > 0.05$) by the variety, additive, or variety × additive combination (Table 2). Regarding fermentation characteristics, the three sorghum varieties had statistically similar pH values (4.09, 4.8, and 4.72 for Sariaso 14, Sariaso 15, and Sariaso 16, respectively). Sariaso 14 had a higher titratable acidity (16.9 g/kg), whereas Sariaso 15 and Sariaso 16 had statistically similar and lower titratable acidity values (15.67 and 14.77 g/kg, respectively) (Table 2).

Furthermore, the Sariaso 16 sorghum stems showed significantly higher DM (33%DM) than the other sorghum varieties (Sariaso 14 and Sariaso 15) ($p < 0.05$). Sorghum stover of the Sariaso 14 variety ensiled with salt had the highest dry matter content (43%). The lowest dry matter content was obtained in Sariaso 15 ensiled with molasses. Overall, the stovers of the different sorghum varieties ensiled (molasses, molasses plus salt) had a better dry matter content than sorghum stovers.

Table 2. Fermentation characteristics of sorghum varieties ensiled after 120 days

Silage		DM (%)	Titratable acidity	pH
Average interaction of varieties × additives				
Sariaso 14	Control	39^c	15.23^b	3.98^c
	Molasses	41^b	14.31^c	4.29^b
	Salt	43^a	15.62^b	4.20^b
	Molasses+Salt	40^b	18.09^a	4.64^a
Sariaso 15	Control	37.42^c	19.2^a	4.05^b
	Molasses	32.82^d	16.44^c	4.44^a
	Salt	42.11^b	19.43^a	3.89^c
	Molasses+Salt	40.11^a	18.90^b	4.35^a
Sariaso 16	Control	34.96^b	$15{,}23^b$	3.95^b
	Molasses	38.92^a	14.31^c	4.54^a
	Salt	39.06^a	15.62^b	3.71^c
	Molasses + Salt	39.89^a	18.09^a	4.63^a
Average of varieties				
Sariaso 14		37^a	16.9^a	4.09^b
Sariaso 15		36^a	15.67^a	4.8^a
Sariaso 16		33^b	14.77^b	4.72^a
Average of additives				
Control		38.21^c	16.84^a	4.97^a
Molasses		37.58^b	16.26^a	4.74^a
Salt		41.39^a	16.89^a	3.96^c
Molasses + Salt		40^a	18.36^b	4.42^b
Significance of main effects and interactions				
Additive (A)		<0.05	<0.05	<0.05
Variety (V)		0,038	0,93	0,86
A×V		<0.05	<0.001	<0.001

$^{a-d}$Different lowercase letters within a column among exposure days indicate significant differences at $p < .05$. DM: dry matter pH: potential of hydrogen.

Regarding the use of additives for silage, silages treated simultaneously with molasses and salt exhibited the best fermentation profile (pH 4.42 and lactic acid 18.36 g/kg). The least desirable fermentation characteristics were obtained in the control silage (untreated), which were characterized by the lowest lactic acid levels. low 16.84 g/kg for a higher pH value (4.97) (Table 2). Comparing the different samples of the same variety after ensiling with different additives, it appears that Sariaso 16 ensiled with salt was more acidic with a pH of 3.71, and the least acidic were Sariaso 14 ensiled with molasses + salt and Sariaso 16 with molasses + salt with respective pH levels of 4.64 and 4.63.

Comparing the average value of the varieties shows that Sarioso 14 was more acidic and that the most suitable additive was salt, because when mixed with sorghum it gives a more acidic pH than other additives mixed with sorghum, namely 3.96, with an acidity of 16.89 g/kg.

Microbiological population of silage

The microbial populations after 120 days are presented in Table 3. The total mesophilic aerobic flora and yeast and mold counts were significantly different among the different forage groups ($p < 0.05$).

After fermentation for 120 days, the microbial load in FAMT decreased considerably, but the lactic acid bacteria increased.

Sorghum stovers of the Sariaso variety 16 Silage ensiled after 120 d showed the lowest level of total mesophilic aerobic flora (4E+07 CFU/g FM). Conversely, the highest total microbial population was obtained in the control silage of the Sariaso 14 sorghum stems (8.84E+07 CFU/ g FM).

In general, the additives used significantly affected the evolution of the total mesophilic aerobic microbial population. Sorghum varieties ensiled with molasses plus salt exhibited the lowest total mesophilic aerobic microbial population (3.41E+06 CFU/ g FM) compared to the control (1E+08 CFU/ g FM) population.

Regarding the number of yeasts and molds (Table 3), all treated silage groups showed reduced yeast and mold counts compared with the control silages (untreated). Sorghum stovers ensiled simultaneously with molasses plus salt had the lowest yeast and mold population (4.06E +05 CFU/ g FM) compared with the high yeast and mold population in the untreated silage groups (1.79E +06 CFU/ g FM).

The results did not reveal a significant difference between the varieties and additives used for silage on the number of lactic acid bacteria, yeasts, molds, and coliforms (p>0.05); however, the results revealed that lactic acid bacteria dominated all groups of ensiled sorghum.

Table 3. Microbial population of ensiled sorghum varieties after 120 days of fermentation

Silage		Microbial population (cfu g^{-1} FM)			
		Aerobic bacteria	Lactic acid bacteria	Coliforms	Yeasts and molds
Average interaction of varieties × additives					
Sariaso 14	Control	8.84 x 10^{5}	3,97 x10^{6ab}	ND	3,57 x10^{5a}
	Molasses	7,23 x10^{5}	1,12 x10^{8ab}	1,97 x10^{6b}	3,55 x10^{6b}
	Salt	9,31 x10^{4}	1,27 x10^{6ab}	5,45 x10^{4c}	6,70 x10^{5a}
	Molasses+Salt	4,84 x10^{4}	5,67 x10^{7ab}	1,14 x10^{5a}	5,37 x10^{5}
Sariaso 15	Control	7,07 x10^{5}	6,30 x10^{7ab}	ND	5,91 x10^{5a}
	Molasses	3,92 x10^{5}	6,04 x10^{7ab}	4 x10^{4}	2,02 x10^{5a}
	Salt	2,80 x10^{5}	1,07 x10^{6a}	1,2 x10^{5}	4,17 x10^{8b}
	Molasses+Salt	2,29 x10^{5}	3,68 x10^{7ab}	3,5 x10^{4}	3,68 x10^{5a}
Sariaso 16	Control	2,78 x10^{5}	5,94 x10^{6b}	ND	1,95 x10^{5}
	Molasses	4,23 x10^{5}	6,55 x10^{8a}	ND	6,39 x10^{5}
	Salt	1,40 x10^{5}	5,32 x10^{8a}	ND	1,08 x10^{6}
	Molasses+Salt	2,43 x10^{5}	1,15 x10^{7b}	3,36 x10^{5}	2,30 x10^{5}
Average of varieties					
Sariaso 14		2.87 x 10^{5}	3.07 x 10^{7}	2.05 x 10^{3}	5.35x10^{5}
Sariaso 15		7 x 10^{5}	2 x 10^{8}	4 x 10^{4}	4 x 10^{5}
Sariaso 16		4 x 10^{5}	6. x10^{8}	7.08 x 10^{4}	6 x 10^{5}
Average of additives					
Control		1 x10^{6}	8. x10^{6}	8 x10^{4}	4 x10^{5}
Molasses		5 x10^{5}	7 x10^{8}	7 x10^{3}	6 x10^{5}
Salt		3,37 x10^{5}	6,87x 10^{7}	8x10^{4}	2,16x 10^{5}
Molasses+Salt		3,41x 10^{5}	5,1x 10^{7}	2,33x 10^{4}	4,06x 10^{5}
Significance of main effects and interactions					
Additive (A)		<0.001	<0.001	<0.001	<0.001
Variety (V)		<0.001	<0.001	<0.001	<0.001
A×V		<0.001	<0.001	<0.001	<0.001

$^{a–d}$Different lowercase letters within a column among exposure days indicate significant differences at $p < .05$. CFU/g FM: colony-forming unit per gram of fresh mater; ND: not detected

Table 4. Nutritional values of sorghum varieties ensiled after 120 days of fermentation

Silage	Chemical composition (% DM)							Energy (mJ kg^{-1} DM)
	DM	Ash	CP	ADF	ADL	NDF	IVDOM	ME
Sariasso 14								
Control	93.68^{a}	9.07^{b}	2.81^{c}	41.16 ^{a}	4.99^{b}	73,23^{b}	49,43^{a}	7.23^{a}
Molasses	93.79^{a}	9.13^{b}	2.19^{d}	44,41^{c}	5.53^{a}	75.82^{a}	46.97^{c}	6.84^{c}
Salt	92.82^{b}	11^{a}	3.15^{b}	42.98^{b}	5.01^{b}	72,24^{c}	46.85^{c}	6.79^{c}
Molasses+Salt	92.64^{b}	11.3^{a}	3.70^{a}	41.28^{c}	4.82^{c}	69.55^{d}	47.91^{b}	6.94^{b}
Sariasso 15								
Control	94.13^{a}	8.62^{d}	2.42^{d}	42.09^{a}	5.02^{a}	73.89^{a}	48.88^{c}	7.15^{b}
Molasses	93.69^{b}	9.22^{c}	2.98^{c}	39.81^{c}	4.82^{c}	69.70^{c}	50.68^{b}	7.42^{a}
Salt	93.46^{b}	10.67^{b}	3.77^{b}	40.68^{b}	4.83^{c}	70.42^{b}	48.12^{d}	6.96^{c}
Molasses+Salt	93.17^{c}	11.27^{a}	4.41^{a}	38.03^{d}	4.86^{b}	66.30^{d}	51.05^{a}	7.39^{a}
Sariasso 16								
Control	93.97^{b}	8.78^{b}	2.76^{b}	41.98 ^{a}	5.43^{a}	73.79^{a}	49.08^{b}	7.17
Molasses	93.48^{c}	8.65^{b}	2.52^{c}	38.74^{b}	4.74^{b}	68.64^{c}	51.39^{a}	7.56
Salt	93.15^{a}	10.52^{a}	3.33^{a}	38.86^{b}	4.95^{b}	69.63^{b}	49.83^{b}	7.25
Molasses+Salt	93.17^{a}	10.53^{a}	3.41^{a}	37.77^{c}	5.25^{a}	65.78^{d}	51.09^{a}	7.46
Average of varieties								
Sariasso 14	93.37	9.83	2.9^{c}	42.28^{a}	5.11	72.87^{a}	48.1^{b}	7
Sariasso 15	93.34	9.45	3,70^{a}	39.83^{b}	4.80	70.08^{b}	50.12^{a}	7.31
Sariasso 16	93.21	9.29	3.53^{b}	38.79^{c}	4.91	69.24^{c}	50.12^{a}	7.74
Average of additives								
Control	93.93^{a}	8.82^{d}	2.66^{c}	41.74^{b}	5.15	73.64 ^{a}	49.13^{c}	7.18^{b}
Molasses	93.65^{a}	9.00^{c}	2.56^{d}	40.99^{c}	5.03	71.39^{b}	49.68^{b}	7.27^{a}
Salt	92.95^{b}	10,92^{b}	2,76^{b}	44,16^{a}	5,17	73,60^{a}	45,22^{d}	6,54^{c}
Molasses+Salt	92,99^{b}	11,03^{a}	3,84^{a}	39,03^{d}	4,98	67,21^{c}	50,02^{a}	7,26^{a}
Significance of main effects and interactions								
Additive (A)	<0.001	0,9	0,84	<0.001	<0.001	<0.001	<0.001	<0.001
Variety (V)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
A×V	<0.001	<0.05	<0.05	<0.001	<0.001	<0.001	<0.001	<0.001

Evaluation of the nutritional value of silage

Analysis of variance revealed a significant difference ($p<0.05$) between forage treatments and forage type for the bromatological composition of forages at the 5% threshold.

Sariaso 16 sorghum stovers ensiled with molasses and molasses and salt exhibited the highest levels of crude protein (CP), metabolizable energy (ME), and in vitro digestibility of organic matter (IVDOM) against reduced NDF, ADF, and ADL (Table 4). The lowest nutritional value was obtained with ensiled Sariaso 14, characterized by reduced levels of CP, ME, IVDOM, and ash against high cell wall integrity (NDF, ADF, and ADL) (Table 4).

In general, the varieties of silage sorghum with molasses+salt showed better levels of MAT, CP, IVDOM, and EM and high ash values against reduced levels of NDF, ADF, and ADL (Table 4) compared to the control silage sorghum varieties.

Sariaso 16/molasses +salt and Sariaso 15/molasses +salt exhibited reduced levels of fiber (NDF, ADF, and ADL) (Table 4) against high levels of CP, IVDOM, EM, and ash compared with other silage groups (Table 4).

DISCUSSION

Feeds chemical composition

Regarding pre-ensilage values, our results were similar to those reported by Zampaligre *et al.* (2021) and Cai *et al.* (2020a, b).

Regarding the effect of silage on physicochemical parameters, our results are similar to those reported by Mfoukou *et al.* (2009), who found a pH of 3.8 to 4.02 with an acidity of 12.6 to 13.65 g/kg. The pH levels obtained after ensiling were low. This decrease in pH is due to fermentation, where lactic acid bacteria consume soluble sugars present in the forage and produce lactic acid, which lowers the pH.

High pH and low acidity promote the growth of microorganisms. Low pH and high acidity are unfavorable for the growth of certain bacteria (Cai *et al.,* 2020a). pH is one of the major factors in assessing silage quality. If the pH is within the acceptable range (3.5 to 4.5), it can be concluded that the silage is of good quality in the tropics (Bennani *et al.,* 2022). All samples analysed after fermentation had an acidic pH, which allowed us to conclude that our ensiled forages were of good quality.

Silage treated simultaneously with molasses and salt exhibited the lowest pH and highest acidity levels compared to the control silage, in contrast to silage that received no additives. Our results are consistent with Mahala and Khalifa (2007); Handriati *et al.* (2019); Lukkananukool *et al.* (2019); Hartutik *et al.* (2021) and Luo *et al.* (2021) found that molasses is rich in nutrients (total carbohydrates, carbohydrates non-fibrous, with total digestible nutrients, easily fermentable by lactic acid bacteria, improving the quality of the fermentation of forage by stimulating the activities of lactic acid bacteria, thus preventing dry matter losses and those of Mclaughlin *et al.* (2002) and Korombe *et al.* (2023) who found that salt-treated silages tended to exhibit high levels of significant lactic acid against reduced pH values compared to control silages, reflecting an improvement in the fermentation process following the addition of salt.

All sorghum varieties showed high values of significant dry matter. Our results corroborate those reported by Cai *et al.* (2020b), Terler *et al.* (2021), and Korombe *et al.* (2023), who found that the dry matter level was a function of the harvest stage. The high dry matter content of sorghum varieties ensiled after 120 d is linked to cell wall growth and the decrease in plant material moisture content due to maturity. However, the use of additives had a significant effect on the dry matter content during the preservation process. High dry matter levels were obtained with forages treated simultaneously with molasses and salt. According to McLaughlin *et al.* (2002) and Korombe *et al.* (2023), the addition of salt (NaCl) reduces dry matter losses during storage by reducing the activity of undesirable microorganisms. Furthermore, previous studies by Mahala and Khalifa (2007); Naeini *et al.* (2014); Lukkananukool *et al.* (2019); Luo *et al.* (2021), and Bennani *et al.* (2022), have shown that most of the nutrients in plant material are preserved with the addition of molasses following the stimulation of the fermentation process.

Microbiological population of silage

First, adding molasses to silage increases the number of aerobic bacteria, including lactic acid bacteria; therefore, the degradation of NDF and ADF in silage increases (Cussen *et al.,* 1995). Second, the decrease was due to the lower ADF content of the additives (Davies *et al.*, 1998).

In this study, sorghum variety and the use of additives had a significant effect on total flora colonies and molds and yeasts (p<0.05). Our results are similar to those of Cai *et al.* (2020b).

The number of yeast and mold growth was less significant in the ensiled sorghum stovers. This is consistent with the results of Cai *et al.* (2020a), who found that the development of these microorganisms was affected by the maturity of the plant material.

Silage treated with molasses and/or salt contained the lowest total flora, mold, and yeast counts compared to the control silage. This is explained by the fact that the mold and yeast growth was inhibited by salt, and rapid acidification of the medium followed the addition of molasses, which improved the fermentation process (Vu *et al.,* 2019). Mclaughlin *et al* (2002), found that the total mesophilic aerobic flora, molds and yeasts had These microorganisms tend to be lower in salted corn silage. This indicates that salting forage reduces the growth of undesirable microorganisms during fermentation.

Regarding total and thermotolerant coliforms, a comparison of our study with that of Khota (2017) showed that both varieties of ensiled sorghum were of good quality.

Evaluation of the nutritional value of silage

The use of additives and sorghum variety also significantly affected the bromatological composition of the forage sorghum (p<0.05).

Adding salt to sorghum silage significantly increased the crude protein content (p<0.01). This result is similar to that reported by Bolsen. *et al.* (1996) and Keskin Singh *et al.* (2005) reported that adding salt to sorghum silage increases acetic acid concentration. The non-saturated fiber (NDF) content of all sorghum silages significantly decreased (p<0.01) in the salt and molasses+salt groups. Adding molasses decreased the unsaturated fiber (ADF) content of silages in general, and the NDF and ADF content of sorghum silages ensiled with salt and molasses decreased. The researchers proposed two reasons for this decrease.

The reduction in metabolizable energy levels in silage is likely linked to a decrease in substrate levels due to the use of plant material constituents by microorganisms during fermentation, as well as a higher content of fiber fractions (NDF, ADF, and ADL) and ash compared to fresh fodder (Terler *et al.,* 2021).

The addition of molasses or molasses + salt to ensiled sorghum stems improved crude protein (CP) and energy (EM) levels and increased ash levels (p<0.05), while decreasing fiber levels (NDF, ADF, ADL) (p <0.01) compared to control silages. Our results corroborate those reported by Thomas *et al.* (2013), Handriati *et al.* (2019), Lukkananukool *et al.* (2019), Hartutik *et al.* (2021), and Luo *et al.* (2021), who found that molasses, by stimulating lactic acid bacteria activity, best preserves the nutrient levels of the plant material, and those of McLaughlin *et al.* (2002) and Korombe. *et al.* (2023) who observed a significant level of nutrients in salted silage compared to control forages.

The drop in fiber level (NDF, ADF, and ADL) in silage due to the addition of molasses and/or salt results, in part, from the lower fiber concentration in molasses (Bennani *et al.,* 2022) and salt.

Silage treated with molasses or molasses plus salt showed satisfactory levels of in vitro digestibility of organic matter and metabolizable energy compared with control silage or silage treated with salt alone. This is explained by the fact that the addition of molasses stimulated cell wall hydrolysis, making it more digestible than the other treatments. Furthermore, molasses is primarily a source of energy (soluble sugar), which explains the improved energy level of silage following its addition (Mahala and Khalifa, 2007).

CONCLUSION

This study evaluated the influence of sorghum varieties (Sariaso 14, Sariaso 15, and Sariaso 16) and additives (molasses and salt) on the physicochemical, microbiological, and nutritional quality of silage after 120 days of storage. The results show that the additives, particularly the molasses and salt combination, significantly improved fermentation, leading to a decrease in pH, an increase in titratable acidity, and a reduction in undesirable microorganisms (mesophilic aerobic flora, yeasts, and molds).

From a nutritional point of view, silages treated with molasses and/or salt showed the best levels of organic matter, crude protein, metabolizable energy and in vitro digestibility, associated with a decrease in fibrous fractions (NDF, ADF, ADL).

Among the varieties tested, Sariaso 16, ensiled with molasses + salt, showed the best fermentation and nutritional profile, confirming its potential as a dual-use variety (grain and fodder) adapted to the livestock systems of Burkina Faso.

Thus, the combined use of molasses and salt is an effective strategy to improve the preservation quality and nutritional value of sorghum silage, helping to secure ruminant feed during the dry season.

This study thus provides a solid basis for varietal selection and improvement of sorghum silage practices in Burkina Faso, strengthening the sustainable use of sorghum in animal feed.

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