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Quality Characteristics, *in vitro* Gas Production and Degradability of *Megathyrsus maximus* Ensiled with Different Parts of *Albizia saman*

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ABSTRACT

Background and Objective: Provision of affordable nutritious feeds throughout the year to ruminants are essential for improving the livestock systems productivity with methane mitigation potential. The study evaluated the effects of inclusion of *Albizia saman* parts (ASP) into *Megathyrsus maximus* silage on nutritive contents, production of *in vitro* gas and degradability for ruminants. **Materials and Methods:** The 5 silages with different parts of ASP (chaff, leaves, whole pods and seeds) and guinea grass were made into silage at a ratio of 25:75 (ASP: Grass), respectively with sole grass at 100% as control. The physical, fermentation characteristics and chemical quality of the silages were measured after 60 days of ensiling while degradability of the silage samples was carried out by incubating 200 mg DM for 24 hrs, using *in vitro* gas production method. **Results:** Increase in CP contents in silages with ASP parts over the control. Inclusion of ASP in grass silage increased in *in vitro* gas production with a corresponding decrease in relative methane gas volume. *In vitro*, dry matter digestibility and organic matter digestibility, short chain fatty acids and metabolizable energy increased by the addition of ASP to grass silage. **Conclusion:** The inclusion of ASP parts resulted in an increase in the nutritional quality of the silage, increased digestibility (total gas output) and reduced relative methane gas production. However, seeds and pods ensiled with the grass gave the highest quality and lowest net methane gas production when compared with other treatments.

KEYWORDS

Additives, anti-nutritional factors, browse parts, methane, nutritive quality, silage

INTRODUCTION

Feeding ruminants high nutritive feed is very essential for their growth and productivity. However, the forages which form the major feed of the animals become fibrous and lignified as they age and as they move towards dry season with reduced quality and quantity[1]. Feeding of fibrous and lignified forages in the tropics has been implicated in increased greenhouse gas (GHG) emissions of methane gas in the

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atmosphere when compared to developed countries. This has led to climate change, resulting in an imbalance of rainfall and temperature with the agricultural sector alone contributing roughly 10-20% of the total GHG emissions caused by human activity[2].

To fill the void left in provision of high-quality feed for ruminants due to darts supply of forage during off-season (dry), preservation of forages as silage or hay is regarded as a viable method of ensuring a consistent supply of feeds and maintaining the maximum performance of animals all year round[3]. However, the derived savanna zone of Nigeria with relatively high humidity may discourage the preservation of forages as hay[4], especially in high quantity. Instead, it is generally advised to store forages as silage in such circumstances[5]. Silage is a cheap way to conserve forage that results in feed that is largely stable and suitable for feeding livestock with little loss of forage quality[6].

Due to the low protein content, silages made solely from lignified tropical grasses are deficient in nutrients[7], suggesting the need for a rich protein source as an additive. The inclusion of high supplements is necessary to augment the quality of tropical grasses as well as aid in ensiling. Addition of lactic acid bacteria inoculation might not be affordable for poor resource farmers. McDonald *et al*.[8] stated that legumes typically have low water soluble concentrations with high levels of protein and buffering capacity. Oni *et al*.[9] reported that ruminants' production of methane gas can be decreased by using rumen modifiers, which are nutraceutical plants from trees and browse species with high nutritional value for ruminants, which will reduce the ruminants' contribution to the greenhouse effect. Yusuf *et al*.[10] have reported the feeding and methane mitigation potential of browse plant leaves, other parts of the browse trees are yet to find a definite use and often go into waste yearly, constituting significant environmental pollution. Arigbede *et al*.[11] reported that some of the indigenous multipurpose tree species are evergreen with a very high protein content. *Albizia saman* (Rain tree) is a tropical browse tree plant. The leaves and pods are valued as animal feed[12], while the ripened pods fall on the ground when mature.

There is need to determine the quality and digestibility of new feed before introduction to animals, as such, the *in vitro* gas production technique has been reported to be suitable in assessing how nutritious these feeds are[7]. According to Babayemi and Bamikole[13] the gas production technique is an efficient and less costly way to assess the value of feeds for ruminants. The procedure results also aid in a more accurate assessment of the feed's nutritional potential[14]. Gas production can also be used to predict volatile fatty acids (VFA), methane (CH_4) and each molar VFA[15].

In this study, it was hypothesized that *Albizia saman* parts (chaff, leaves, pods and seeds) ensiled with *Megathyrsus maximus* would improve better fermentation characteristics and increase the quality of the grass silage than is usually obtained with single species silage and mitigate CH_4 production due to the presence of phenolic compounds they contained, with the aim of using them in livestock rations.

MATERIALS AND METHODS

Experimental site: The experiment was conducted during the 2019-2020 growing season at the Pasture Unit and Laboratory of the Department of Pasture and Range Management, Federal University of Agriculture, Abeokuta (FUNAAB) Nigeria, West Africa. The site lies within the savanna agro-ecological zone of South-Western Nigeria (Latitude 7°15'N, Longitude 3°21'E and 348 m above sea level with an average annual rainfall of 1037 mm). Mean annual temperature and humidity are 30.5°C and 82%, respectively[16].

Sourcing and harvesting of the grass materials: *Megathyrsus maximus* a well-adapted tropical grass previously known as *Panicum maximum* was sourced from a previously established plot. The plot which measured 15×30 m had previously been sown with *M. maximus* with a spacing of 0.5×0.5 m in 2018 and fertilized with 5.0 ton/ha of dried layers' manure without wood shavings (approximately 150 kg N/ha

Table 1: Chemical composition of fresh *Megathyrsus maximus* and *Albizia saman* parts before ensiling

		Albizia saman			
Parameter (%)	*Megathyrsus maximus*	Chaff	Leaves	Pods	Seeds
Dry matter	95.31	92.15	93.69	88.44	83.50
Crude protein	8.64	6.84	12.59	14.48	18.79
Ether extract	2.46	4.32	4.57	4.94	6.83
Ash	7.32	10.32	9.99	9.62	9.30
Neutral detergent fibre	65.00	74.11	38.12	47.14	51.33
Tannin (mg/kg)	ND	0.86	2.08	0.71	9.86

ND: Not determined

applied in split dosage in May and in September). The grasses on the plots were cut back to a stubble height of 15 cm during the early rainy season (immediately after the first rain in April) and allowed a re-growth period of 8 weeks. The dry matter yield obtained from the entire plot area at 8 weeks was 5.02 ton/ha by harvesting the grasses at 15 cm above ground level. Sub sample of 200 g of fresh grass samples was collected to determine their chemical composition (Table 1).

Sourcing, harvesting and processing of the *Albizia saman* parts: Mature pods of *Albizia saman* were collected from the Federal University of Agriculture, Abeokuta, (FUNAAB) and were sundried for 48 hrs. The pods were divided into three sets, such that one set contained whole pods, while the other two sets were separated into seeds and chaff (whole pod without the seed). The whole pods, seeds and chaff were further dried for 72 hrs, milled using a hammer mill and passed through a 3 mm sieve screen. Sub sample of 300 g of fresh leaves of *A. saman* was also collected. Fresh samples of *A. saman* plant parts-leaves, chaff, leaves, whole pods and seeds) were collected to determine their chemical composition (Table 1).

Ensiling process: The harvested *M. maximus* and *A. saman* leaves were wilted for 4 hours. After wilting, *M. maximus* was chopped to a length of about 2 cm and mixed with the *A. saman* parts at 75:25 proportion (g/g on dry matter basis) following the recommendations of Ojo *et al.*[17] to create four composite treatment samples with a sole grass sample representing the control.

Structure of the treatments is as shown:

- 100% *Megathyrsus maximus* (control)
- 75% *Megathyrsus maximus*+25% *Albizia saman* chaff
- 75% *Megathyrsus maximus*+25% *Albizia saman* leaves
- 75% *Megathyrsus maximus*+25% *Albizia saman* whole pods
- 75% *Megathyrsus maximus*+25% *Albizia saman* seeds

The contents of each composite sample were thoroughly mixed manually to allow for a more consistent mixture. Following this, each treatment sample was quickly compressed into 960 mL capacity glass silos replicated five times. Since animal feeding trials were not planned for this study, small capacity silos were used. Each silo was filled with roughly 500±30 g of each treatment mixtures at a density of 0.52 g/mL. To prevent air from entering the silos again, eight layers of duct tape were used to seal each silo tightly. The silos were kept at a constant room temperature of 26°C for 60 days.

Experimental design: The experiment was laid out in a completely randomized design with five treatments replicated five times to make a total number of 25 treatment combinations.

Quality analyses

Silage analyses: The silos were opened and examined for physical analysis including colour, odour, moistness and presence of mould (Appendix 1) at the end of the ensiling period. A scoring sheet was used

Appendix 1: Silage physical evaluation sheet

Factors	Description	Possible score
Color	Desirable: Green to yellowish-green	9-12
	Acceptable: Yellow to brownish	5-8
	Undesirable: Deep brown or black indicating excessive heating or putrefaction	0-4
Odor	Desirable: Light, pleasant odor with no indication of putrefaction	24-28
	Acceptable: Fruity, yeasty, musty, which indicates a slightly improper fermentation Slight burnt odor, sharp vinegar odor	11-23
	Undesirable: Strong burnt odor indicating excessive heating. Putrid, indicating improper fermentation	0-10
Moistness	No free water when squeezed in hand. Well preserved	9-10
	Some moisture can be squeezed from silage or silage dry or musty	5-8
	Silage wet, slimy or soggy, water easily squeezed from sample. Silage too dry with a strong burnt odor	0-4
Moldiness	No mold	9-10
	Slightly moldy	5-8
	Highly moldy	0-4

Oyaniran *et al.*[18], SEM: Standard error of mean and ND: Not determined

by six qualified silage experts to evaluate all treatments[18]. After the silos were opened, 200 g of silage were measured into 500 mL beakers. Based on the silage's outward appearance, scores for color and moldiness were given. Assessors' reactions to the smell of a silage sample were used to determine the odour score. The assessors, who were wearing latex gloves, extracted moisture from the silage and gave it a score based on how much free water was present (Appendix 1). According to AOAC[19] and Ojo *et al.*[20] procedures, respectively, the concentrations of ammonia and volatile fatty acids (acetic, propionic, butyric and lactic acid concentrations) in the silages were measured. The 10 g samples of silage from each silo were taken right away after the silos were opened and immersed in 100 mL of distilled water for 12 hrs. The mixtures were then filtered and the supernatant was divided into 4 equal aliquots for pH measurements with a pH meter (Hanna instruments, pH 211, microprocessor pH meter, K012818, Portugal)[21].

Chemical analyses: Sub samples of 300 g of fresh materials before ensiling as well as silage at the end of the ensiling period were dried in the oven to a fixed weight at 65°C and then grind through a 1.0 mm sieve screen. Proximate composition of the fresh and silages were determined according to the standard methods of Horwitz and AOACI[22], non-fibre carbohydrate (NFC g/kg) was calculated as: 1000-NDF-CP-EE-ash while neutral detergent fibre concentrations were determined according to van Soest *et al.*[23].

The concentrations of Ca and P were determined using atomic absorption spectrophotometer after wet digestion in nitric acid and hydrochloric acid[24].

The tannin and saponin contents were also determined following the procedures of Palacios *et al.*[25] and Obdoni and Ochuko[26], respectively.

***In vitro* gas production:** The process of determining *in vitro* gas production was according to the procedure of Anele *et al.*[27]. The 200±0.05 mg of the milled samples were weighed into 100 mL glass syringe fitted with silicon tubes as the only substrate (n = 5). Five syringes of incubation solution without substrate were also included as blanks to assist in estimating the net gas volume. Suction tube was used to collect rumen contents from three White Fulani cattle with an average weight of 140 kg at Cattle Production Venture FUNAAB.

The cattle were grazed on pasture consisting of grass and legumes and supplemented with concentrate. Concentrate supplement maize (13%), groundnut cake (7%), palm kernel cake (20%), wheat offal (54%), oyster shell (4%) and salt (2%) was made available to the animals in stall feeding prior and after grazing periods. The rumen contents were mixed and sieved with 4 layers of cheesecloth under a continuous flushing with carbon dioxide (CO_2). Macro and micro elements, reduction and resazurin dye solutions were mixed with distilled water. These solutions were mixed in the ratio 2:1 with the rumen fluid. This served as a source of inoculum. Then, 30 mL of the inoculum was drawn into each syringes. Air in the inoculum was eliminated by tapping and pushing the piston in the syringes upward. Controls (blanks) containing 30 mL buffered rumen fluid only were included in triplicates for correction of gas produced from rumen fluid due to the presence of small particles in the fluid. The syringes were placed in a refrigerated incubator (Refrigeration Compressor QD52H, Hangzhou Qianjiang Refrigeration Group Co. Ltd.,) with temperature regulated to 39°C. Each syringe's gas production was recorded at 3, 6, 9, 12, 18 and 24 hrs of incubation. Each incubation time's gas volume was expressed as mL/200 mg of incubated dry matter (DM).

Methane gas volume determination: The volume of methane (CH_4) gas produced was estimated 24 hrs post-incubation following the procedure of Fievez *et al.*[15]. This was done with the use of 5 mL syringe to infuse 4.0 mL of 10 M NaOH into three of the incubated contents in the syringes via the silicon tube just above the metal clip for methane production estimation per treatment. A pop sound was heard immediately the NaOH was introduced connoting absorption of CO_2 such that the left-over gas was considered as CH_4. The volume of CH_4 gas produced was also expressed in mL/200 mg DM.

***In vitro* post incubation parameters:** After 24 hrs of incubation, *in vitro* dry matter digestibility (IVDMD) was assessed. The syringe's contents were empty into crucibles that had already been weighed, then dried in an oven at 105°C until the weight remained constant. The dried residues were weighed and the following equation was used to determine digestibility:

$$\text{IVDMD (\%)} = \frac{\text{Initial DM input - DM residue - blank}}{\text{Intial DM input}} \times 100$$

- Organic matter digestibility (OMD) was calculated as: 14.88+0.889 GV+0.45 CP+0.651 Ash[26]
- Short-chain fatty acid (SCFA) was calculated as 0.0239 GV-0.0601[28]
- Metabolizable energy (ME) was calculated as 2.20+0.1357 GV+0.0057 CP+0.0002859 EE^2 [26]:

$$\text{Relative methane gas volume (\%)} = \frac{\text{Methane}}{\text{Total gas}} \times 100$$

Where, GP is 24 hrs sour's net gas production (mL 200 mg/DM):

CP = Crude protein content of substrate
Ash = Ash content of substrate
EE = Ether extract

Statistical analysis: The collected data were pooled and put through standard procedures to check for normality and variance. An analysis of variance with one way was performed on all data. The definition of significance was ($p<0.05$). The Tukey's HSD test was employed to determine which pairs of treatments differed significantly when the ANOVA results showed a significant difference between the treatments. The R statistical package was used for all analysis[29].

RESULTS

Physical characteristics of silage made from *Megathyrsus maximum* ensiled with *Albizia saman* parts: The physical characteristics of silage made from *M. maximum* ensiled with *A. saman* parts (ASP) is presented in Table 2. The silage colour profile revealed the silages had desirable green to yellowish green

Table 2: Physical characteristics of silage made from *Megathyrsus maximum* ensiled with *Albizia saman* parts

	Silage treatment				
Physical characteristics	Sole *Megathyrsus maximus*	*Megathyrsus maximus*+ chaff	*Megathyrsus maximus*+ leaves	*Megathyrsus maximus*+ whole pods	*Megathyrsus maximus*+ seeds
Colour	Yellowish green	Brownish	Yellowish green	Brownish	Brownish
Odour	Fruity	Pleasant	Pleasant	Pleasant	Pleasant
Moistness	Some moisture	No free water	No free water	No free water	No free water
Moldiness	No mold	No mold	No mold	No mold	No mold

Table 3: pH and fermentation characteristics of silage made from *Megathyrsus maximus* ensiled with *Albizia saman* parts

	Silage treatment					
Parameter	Sole *Megathyrsus maximus*	*Megathyrsus maximus*+ chaff	*Megathyrsus maximus*+ leaves	*Megathyrsus maximus*+ whole pods	*Megathyrsus maximus*+ seeds	SEM
pH	4.90^{ab}	4.88^{ab}	5.19^{a}	4.61^{b}	4.99^{a}	0.11
NH_3- N (g/kg)	8.76^{d}	9.01^{c}	9.82^{b}	10.02^{a}	9.05^{c}	0.13
Lactic (g/kg DM)	3.69^{e}	7.26^{d}	9.78^{a}	9.22^{c}	9.40^{b}	0.61
Acetic (g/kg DM)	1.14^{c}	2.21^{b}	2.55^{a}	2.18^{b}	2.31^{ab}	0.09
Propionic (g/kg DM)	0.91^{b}	1.52^{a}	1.77^{a}	1.53^{a}	1.62^{a}	0.1
Butyric (g/kg DM)	0.15^{c}	0.29^{b}	0.33^{a}	0.29^{b}	0.31^{ab}	0.01

^{abc}Means on the same row with different superscript differ significantly ($p<0.05$), SEM: Standard error of mean and ND: Not determined

colour. The pure ensiled grass and silage made from the grass and *A. saman* leaves were yellowish green in colour, while the other silage treatments were brownish in colour. The odour of the silage were generally pleasant and fruity. Only the pure ensiled grass had a fruity smell. The moisture of the silage shows that the pure ensiled grass had little moisture while the other silage treatments are without moisture. None of the evaluated silage treatments showed presence of mould.

pH and fermentation characteristics of silage made from *Megathyrsus maximum* ensiled with *Albizia saman* parts: There was significant ($p<0.05$) difference in pH values of the grass silage due to the inclusion of the *A. saman* parts (Table 3). The pH values recorded for grass ensiled with *A. saman* pods was significantly ($p<0.05$) lower than values recorded for silage containing *A. saman* seeds and those containing *A. saman* leaves. The sole grass silage had the least NH_3-N value, while other treatments had comparable higher NH_3-N values. Significantly higher lactic, acetic and butyric acids values were recorded for silage containing *A. saman* leaves, while the least of the acid values were recorded for the sole grass silage.

Ensiling *Megathyrsus maximum* with *Albizia saman* parts improved silage chemical composition: The results showed that ensiling *M. maximum* with *A. saman* parts significantly improved the silage crude protein content (Table 4). Crude protein improvement was in the order seeds>pods>leaf>chaff. Ensiling *M. maximum* with *A. saman* chaff and sole grass silage caused no significant ($p>0.05$) improvement in the silage EE content, however, higher EE content were recorded in silages containing seeds, leaves and pods of *A. saman*. Improvements in silage EE content was higher with *A. saman* seeds than with its leaves or whole pods. Increase in ash content was also recorded as a result of ensiling *M. maximum* with ASP. The highest ($p<0.05$) improvement in ash content recorded for silage containing *A. saman* chaff. The non-fibre carbohydrate content of the silage declined with the inclusion of the *A. saman* chaff, pods and seeds in the silage and lastly in silage containing *A. saman* leaves.

Ensiling *Megathyrsus maximus* with *Albizia saman* parts caused a significant declined in the silage neutral detergent fibre (NDF) content. The decline in the NDF content was more pronounced with *A. saman* seeds than with the other plant parts. Ensiling *M. maximum* with the plant parts also increased

Table 4: Chemical composition of silage made from *Megathyrsus maximus* and *Albizia saman* parts

Chemical composition (g/kg DM)	Silage treatment					
	Sole *Megathyrsus maximus*	*Megathyrsus maximus*+ chaff	*Megathyrsus maximus*+ leaves	*Megathyrsus maximus*+ whole pods	*Megathyrsus maximus*+ seeds	SEM
Dry matter	928.62^{b}	933.02^{a}	923.19^{c}	931.67^{ab}	924.21^{c}	1.15
Crude protein	88.95^{e}	98.19^{d}	112.07^{c}	141.58^{b}	163.24^{a}	1.73
Ether extract	37.42^{c}	42.6^{bc}	44.01^{b}	43.92^{b}	52.48^{a}	1.56
Ash	72.27^{e}	170.58^{a}	111.09^{d}	122.38^{c}	136.85^{b}	2.15
Non-fibre carbohydrate	155.68^{a}	44.81^{e}	92.89^{b}	58.11^{d}	62.21^{c}	10.62
Neutral detergent fibre	645.68^{a}	643.81^{b}	639.94^{c}	634.00^{d}	585.23^{e}	6.05
Calcium	1.11^{e}	3.23^{b}	2.31^{c}	2.23^{d}	5.87^{a}	0.02
Phosphorus	1.13^{e}	1.87^{c}	1.25^{d}	2.15^{a}	1.92^{b}	0.03
Tannin (mg/kg DM)	ND	0.58^{d}	1.10^{c}	1.27^{b}	2.08^{a}	0.03
Saponin (mg/kg DM)	ND	5.68^{b}	5.51^{b}	5.41^{b}	6.83^{a}	0.1

^{abcde}Means on the same row with different superscript differ significantly ($p<0.05$)

Table 5: Dry matter digestibility, organic matter digestibility and metabolizable energy of silage made from *Megathyrsus maximus* and *Albizia saman* parts.

Post incubation parameter	Silage treatment					
	Sole *Megathyrsus maximus*	*Megathyrsus maximus*+ chaff	*Megathyrsus maximus*+ leaves	*Megathyrsus maximus*+ whole pods	*Megathyrsus maximus*+ seeds	SEM
In vitro dry matter digestibility (%)	42.56^{c}	60.16^{a}	53.73^{b}	57.85^{ab}	61.17^{a}	1.15
Organic matter digestibility (%)	32.73^{d}	44.77^{c}	57.77^{b}	68.48^{a}	61.16^{a}	1.73
Short chain fatty acids (µmol g DM)	0.19^{d}	0.33^{d}	0.76^{c}	1.00^{b}	1.28^{a}	1.56
Metabolizable energy (MJ kg DM)	3.65^{c}	4.45^{c}	6.94^{b}	8.28^{a}	9.94^{a}	2.15

SEM: Standard error of mean, ^{abcd}Means on the same row with different superscript differ significantly ($p<0.05$)

the Ca and P contents relative to the sole *M. maximum* silage, with silage containing the *A. saman* seeds having the highest calcium content. Silage containing *A. saman* whole pods had the highest phosphorus content, while the sole *M. maximum* silage had the least phosphorus content. The tannin content followed the order leaves>seeds>pods>chaff, while silage containing *A. saman* seeds had the highest saponin content.

Ensiling *Megathyrsus maximum* with *Albizia saman* parts resulted in higher *in vitro* gas volume (mL/200mg DM) and lower relative CH_4 gas volume than the sole *Megathyrsus maximum* silage: Ensiling *M. maximum* with *A. saman* leaves, whole pods and seeds caused a significant ($p<0.05$) increase in the final *in vitro* gas volume when compared with the sole *M. maximum* silage (Fig. 1). Final *in vitro* gas volume readings recorded for silage containing *A. saman* chaff and the sole *M. maximum* silage did not differ significantly ($p>0.05$) from each other. Silage containing *A. saman* seeds produced the highest final *in vitro* gas volume (56.27 mL/200 mg DM).

However, the grass silage produced the highest CH_4 gas relative to the total rumen gas volume (53.99%) (Fig. 2). Silage containing *A. saman* chaff and whole pods, produced comparable lower relative CH_4 gas volumes (27.10 and 25.88%, respectively).

Ensiling *Megathyrsus maximum* with *Albizia saman* parts improved silage dry matter digestibility, organic matter digestibility, short chain fatty acids and metabolizable energy: Ensiling *M. maximum* with the ASP significantly ($p<0.05$) increased the *in vitro* dry matter digestibility (IVDMD) when compared with the sole *M. maximum* silage Table 5). Higher ($p<0.05$) IVDMD values were recorded for silage containing *A. saman* seeds, whole pods and chaff than silage containing its leaves. Silage containing *A. saman* seeds and whole pods had comparable higher ($p<0.05$) organic matter digestibility (OMD) values

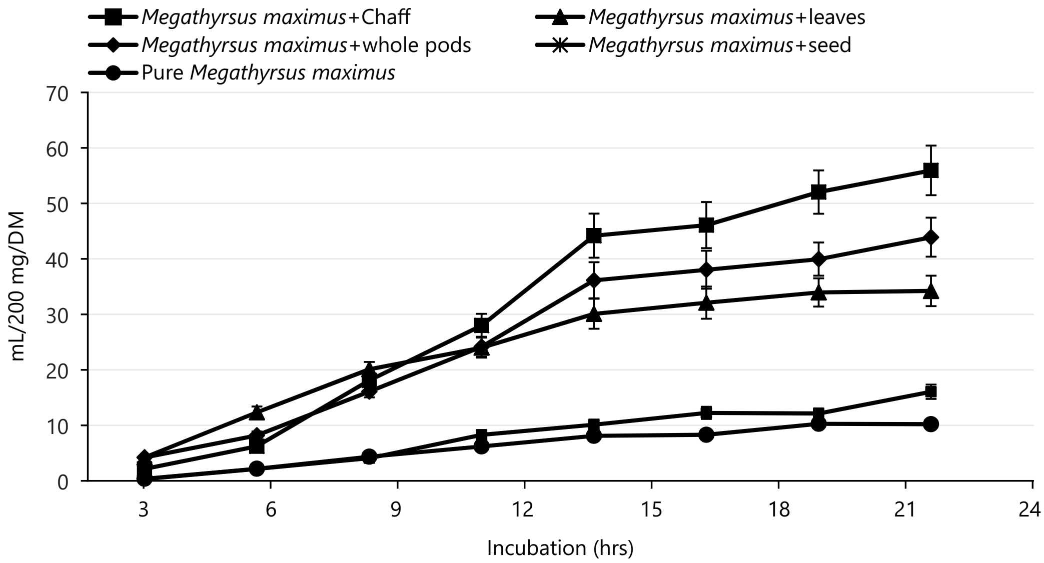

Fig. 1: *In vitro* gas volume readings of silage made from *Megathyrsus maximus* and *Albizia saman* parts

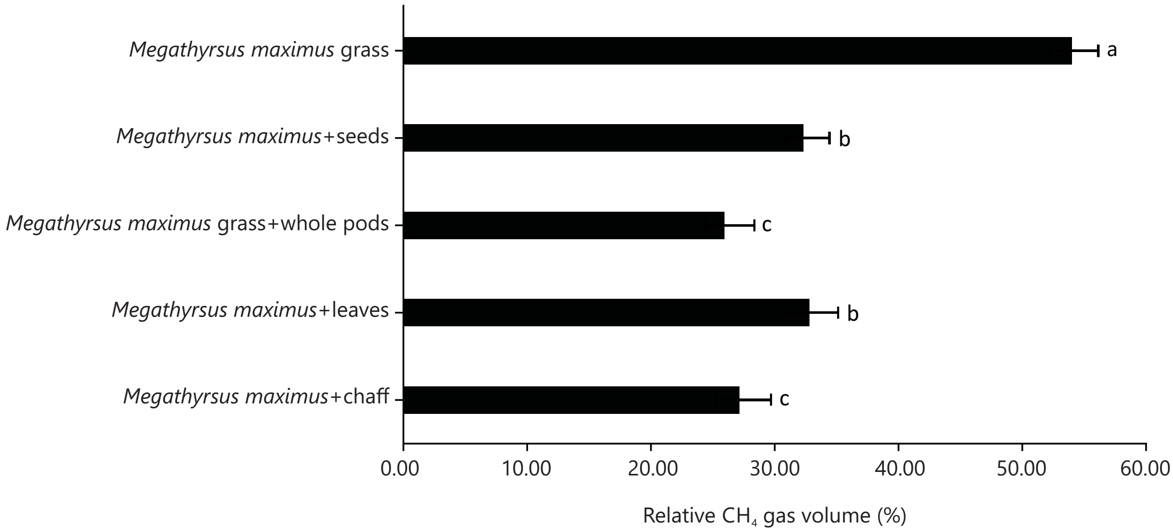

Fig. 2: Relative CH_4 gas volume readings of silage made from *Megathyrsus maximus* and *Albizia saman* parts

that the other silage treatments. Although OMD values recorded for the sole *M. maximum* silage was lower ($p<0.05$) than values recorded for silage containing *A. saman* leaves and chaff. The sole *M. maximum* silage and silage containing *A. saman* chaff had comparable lower ($p<0.05$) short chain fatty acids (SCFA) and metabolizable energy (ME) values. For the other treatments, improvements in SCFA was in the order *A. saman* seeds>*A. saman* whole pods>*A. saman* leaves, while silage containing *A. saman* leaves had a significantly lower ME value than the comparable higher values recorded for silage containing *A. saman* seeds and whole pods.

DISCUSSION

The physical characteristics (colour, odour, moistness and mouldiness) are indicative of silages of excellent qualities. Favorable scores for all the physical characteristics of the silages, indicated that potentially satisfactory silages were produced. The sole grass silage's yellowish green coloration was consistent with the findings of Oduguwa *et al.*[30] report, which states that green plant material that is ensiled produces a yellow color. Despite popular belief that silage's brownish color could be a physical sign of deterioration, in this study, all the grass silage produced with ASP inclusion, with the exception of the leaf part, were brownish in colour. This is mainly due to the colour of the plant parts used for ensiling. Lamidi and Ojo[31] recorded similar colour with ensilage of *Delonix regia* seeds with *Panicum grass*. This is an indication that mixtures of grasses with plant parts are complementary with each other and more than visual characteristic is required to determine rottenness of a silage. Better quality of the mixtures in terms of the physical characteristics of silages could be as a result of different chemical composition of the mixed forages. The colour of the silages fell within which are regarded as good to acceptable ranges for silage[7].

The odour of the silages also fell within the range classified as acceptable and desirable reported by Oyaniran *et al.*[18] which indicated they are good silage. This was in line with the report of McDonald *et al.*[32] that well-preserved silage must have an acceptance aroma.

The scores of no mould in all the silages showed that they are in good condition and that they were well preserved. Furthermore, lack of mould presence in the silages after supplementation of grass with ASP (additives) suggest that high-quality silage was obtained, which might considerably improve the dry matter intake of ruminants. This was in consonance with the report of Wan *et al.*[33] that obtained high quality sudangrass after wilting and addition of additive to sudangrass silage.

Wilting and inclusion of ASP to grass silage could have been responsible for little or no moistness recorded in this study. Reduction of the moisture of grass silage and inclusion of ASP that prevent effluent lose from the silage helps to concentrates the water soluble carbohydrates and improves the effectiveness of the lactic acid bacteria and the quality of silage[34]. The total score for the colour, odour, mouldiness and moistness of the silage in this study ranked as good silage[17].

A successful ensilage is indicated by it pH. The pH values recorded for the silages were within the range of 4.5–5.5 classified as good silage[35]. This fact suggests that activities of undesirable microorganism were slowed down by high temperature and low pH. This prevent the effluent from silage, which can reduce the quality of the silage. Ojo *et al.*[36] reported that increased breakdown of carbohydrate in the process of fermentation brought about the reduction in pH which characterizes the process of ensilage that makes sugar available to produce more lactic acid. Moreover, pH above 5.0 has also been reported in some studies with tropical forage species under tropical conditions[3].

The content of lactic acid in silages fall in the range and above 2.37-5.89% reported by Oduguwa *et al.*[30]. High concentrations of lactic acid in silage are a clear indication of good preservation, which invariably results in lower loss of DM and energy during storage. Inclusion of ASP enhanced the quality of silages in this study. This was consistent with the findings of Assefa and Ledin[37] that added additives to silage will increase its protein content while providing lactic acid bacteria with an adequate supply of fermentable carbohydrates. An essential marker of proteolytic activity during fermentation is ammonia nitrogen. The silage's ammonia concentrations were well below 12%, which was regarded as a sign of high quality and well-preserved forage[30]. Acetic acid concentrations were in the normal range for grass silage (0.5-3.0% DM)[29]. Sole grass silage also fell in line with the range of 0.74-1.53% DM for *Pennisetum* hybrid silage reported by Ojo *et al.*[38].

The range of CP recorded for the silages was well above the threshold of 70 g kg DM required by rumen microbes to build their body protein. Ruminant forage intake and rumen microbial activity would be negatively impacted below this threshold[39]. Typical of tropical species under tropical conditions, the lower concentration of nutrient in grass silage compared with the others recorded in this study suggest the need for addition of tropical grasses with supplements that are accessible and available to farmers prior to ensiling so as to improve fermentation and minimize DM loss.

The CP content of the ASP showed that they have the potential to contribute to ruminant feeding system as cheap protein supplement. The silage will also be adequate in providing high quality protein supplement for livestock production during the dry season. Similar report was provided by Usman *et al.*[3] with substantial increase in the CP content of silage of *Sorghum almum* harvested at maturity due to the grain fractions it contained, which helped to increase the forage's nutritional value[40]. Higher proportion of additives in forages have been reported to enables the microbial synthesis of enough water-soluble carbohydrates into organic acids during fermentation, protecting the CP content from proteolytic degradation[3]. Hence, the higher CP in this silage treatment.

The values recorded for EE and ash contents of the silages were high enough to provide energy to animals and mineral specifications for upkeep and other productive activities. The NFC's relationship with ammonia-N utilization in the rumen has also been shown to be favorable[41]. By encouraging better utilization of rumen ammonia released from feeds with high content of rumen degradable CP, adequate NFC contents in the plant parts may enable efficient microbial protein synthesis because nitrogen utilization by rumen microorganisms is correlated with the amount of fermentable energy[42].

The range of values for the fibre fractions of the silages indicated that they were diverse in terms of their cell wall contents. The range of NDF contents is below the 650 g kg DM suggested as the critical threshold above which ruminant efficiency in utilizing tropical forages would be compromised as a result of filling effect[43]. The lower fibre contents of silages containing ASP compared with sole grass silage is due to their inclusion to the grass[39]. Reduction of fibre content in silage is as a result of microbial activity-induced biological fibre degradation during silage fermentation[44].

Olanite *et al.*[45] reported that Ca and P minerals are necessary for improved animal performance due to their support for bone growth and the enzymatic activities of cell membranes. Minerals also help immune system to function properly. Generally, silages produced with inclusion of ASP had higher Ca contents than from sole grass. This was consistent with Furey and Tilman[46] report, which found that the levels of calcium in grasses and legumes differ noticeably. While P level in this study was above the mean value of 1.2 g/kg DM reported by Muhammad *et al.*[47], the range of values recorded for Ca in the present study was higher than the 0.7 to 0.9 g/kg DM reported by Muhammad *et al.*[47].

The results from the quality evaluation of grass with inclusion of ASP silages tend to be more nutrient dense than grass alone. This implied that the parts of the tree legumes can be used as supplement to poor quality grasses as silage in total mixed ration during the dry season. The result of this study was in line with the report of Stürm *et al.*[48] that the combination of grasses and legumes is very effective as high quality diet in ruminant feed.

The tannin content in the silages with inclusion of ASP was below 6.00% toxic level for small ruminants. Presence of phytochemicals in the silages with inclusion of plant parts can ameliorate the occurrences of climate change. Oni *et al.*[9] reported that ruminants' production of methane gas can be decreased by using rumen modifiers, which are nutraceutical plants derived from trees and browse species with high nutritional value for ruminants. This reduces the ruminants' contribution to the greenhouse effect. Babayemi *et al.*[49] also reported that anti-nutritional factors in feed are capable of reducing methane production.

A higher gas production in silages with inclusion of ASP showed that a higher content of digestible nutrients in the diets allowed rumen microbes to degrade them more quickly. According to Aderinboye *et al.*[50], higher gas production has been reported to produce short chain fatty acids that will increase the supply of carbohydrates. The results in this study corroborated reports of Oni *et al.*[9] with increased gas production with inclusion of *Chromolaena odorata* at varying levels to ruminants' diet. Andualem *et al*.[51] reported a positive correlation between CP and gas volumes while there was a negative correlation between NDF and gas volumes in diets[52].

Methane production has been reported to be both an energy loss to ruminants and a factor in global warming[13]. The reduction in methane content of the silage with inclusion of the ASP agreed with the report of Guo *et al*.[53] that noticed a decrease in methane production when goats were fed plants with a lot of tannins and saponins, like tea saponin. With the addition of ASP to grass silage, the amount of relative methane gas produced decreased significantly, which suggests that *A. saman* has the potential to reduce methane emissions.

The microbial population and activity during substrate fermentation can be estimated using *in vitro* dry matter digestibility (IVDMD)[54]. With higher IVDMD of silages with inclusion of ASP in this study above the sole grass silage, revealed the increase in number of advantageous microbes was encouraged through higher CP contents in the ASP. According to McDonald *et al*.[8], inclusion of protein in a diet may increase the rumen microorganisms' activity and improve feedstuffs' digestibility. This was in line with the current research. The positive correlation between SCFA, gas production, ME and IVDMD was a good indicator of volatile fatty acid production, which is directly related to microbial mass production.

CONCLUSION

This study concluded that *Albizia saman* parts ensiled with grass provided protein supplement in the grass silage as a result of higher nutritional contents above sole grass silage due to a more increased content of crude protein than in common grasses. Moreover, the lower relative methane gas production from ASP ensiled with *Megathyrsus maximus* gives indication that ASP has potential in mitigating methane gas production. The addition of *Albizia saman* parts in grass silage improved fermentation profile as well as higher nutritional quality contents.

SIGNIFICANCE STATEMENT

Evaluation of silage of *Megathyrsus maximus* enhanced with *Albizia saman* parts (chaff, leaves, whole pods and seeds) was carried out to determine the nutritive quality as well as the potential of the parts with grass to reduce the methane emission from animals. It was discovered from the study that the addition of the parts to grass increased the quality of the silage as well as reduced the relative methane gas production. Seed and pods parts were the best in improving the quality of the grass silage above other parts.

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