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Full Length Research Article

CHEMICAL COMPOSITION, FERMENTATION CHARACTERISTICS AND ANTI-NUTRITIONAL CONTENT OF ENSILED MAIZE COB - SWEET POTATO VINE MIXTURE

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ABSTRACT
The study was conducted to assess the effect of dry matter levels on silage characteristics of maize cob and sweet potatoes vine mixtures. Maize cob (MC) and sweet potato vine (SPV) were chopped and mixed to provide dry matter levels of 70 %, 65 %, 60 % and 55 %, thus each level was considered as treatment T_1, T_2, T_3 and T_4, respectively. The materials were ensiled for 45 days in Ziploc polyethene bags, which were placed inside black plastic containers. Each container carried one treatment with five replicates. There was a significant ($p < 0.05$) difference in dry matter (902.40±0.40 – 975.55±2.74 g/kg), crude protein (39.70±5.25 – 69.40±1.44 g/kg), neutral detergent fibre (525.55±1.07 – 661.70±30.48 g/kg), and hemicellulose (163.45±2.34 – 302.30±4.04 g/kg) across the treatments. A linear decrease ($p < 0.05$) was observed in crude protein (CP) content, but dry matter (DM) and neutral detergent fibre (NDF) increased ($p<0.05$) across the treatments. Similarly, total volatile fatty acids (8.00±0.58 – 10.67±1.33 µmol/L) showed a numerical decrease at lower DM levels. However, pH (4.22±0.13 – 4.73±0.06) increased ($p<0.05$) linearly across the treatments. No significant difference ($p>0.05$) was observed in alkaloid and tannin contents across all the treatments. Invariably, flavonoid content increased ($p<0.05$) inversely with dry matter levels. Presentation of treatment diets (silage) to sheep and goats received different responses. Goats preferred T_1 while sheep showed a total preference to T_4 after spending little time on T_2 and T_3 silages. It was concluded that low dry matter levels encourage the formation of high-quality silage. It was further deduced that microbial activities increased with a decrease in dry matter levels. Hence, for good-quality silage using maize cob and sweet potato vine, 55 % DM level is recommended.

Keywords: fermentation, silage material, rumen ammonia-nitrogen, volatile fatty acids, nutrients.

INTRODUCTION
Maize (*Zea mays.* L) is the World's 3rd staple crop after wheat (*Triticum durum*) and rice (*Oryza sativa*) (Erenstein *et al.*, 2021). Maize is extensively grown in all the continents of the world. In Nigeria, maize is grown in all the savannah zones of the country; thus, it is accessible for utilization as animal feed. Maize is used as a silage material in many regions of the world (Ali *et al.*, 2016), owing to its relatively high dry matter content, low buffering capacity and high water-soluble carbohydrate for fermentation to lactic acid, which is responsible for decreasing pH to the expected level (Karnatam *et al.*, 2023). In Nigeria, processing maize to silage is not common due to the high demand of maize grain by consumers and the poultry feed industry. Hence, maize cob with a nearly zero completion, except where it is used as a source of fuel for cooking, can be processed to ruminant feedstuff (Adebayo *et al.*, 2018).
Sweet potato (*Ipomoea batatas*) is a dry land crop which is tolerant to diverse edaphic and climatic conditions and is typically a smallholder's crop grown on marginal soils with partial inputs (Ezin *et al.*, 2018). The root and vine can be fed to ruminant and monogastric animals (Sudarman *et al.,* 2016). Sweet potato root is rich in carbohydrates. However, it is low in protein and fats; meanwhile, its vine can serve as a source of nutrients such as protein and vitamins, having over 20 % crude protein with about 70 % digestibility and a DM yield of about 4-6 tons per hectare (Ezin *et al.*, 2018). Sweet potato vines can serve as valuable animal feedstuff. However, the availability of the vines is for a short period, because sweet potato vines could deteriorate within 2 to 3 days post-harvest. Besides, the leaves rapidly and easily shattered. Hence, ensiling vines during the period of surplus production could be a possible solution to overcome the wasting of sweet potato vines (Kuttu *et al.*, 2024) and improve the quality of silage materials (Li *et al.,* 2017).
In the savannah grasslands, ruminants have little access to forage during the dry season. Hence, feed shortages could be alleviated by ensiling dry and green feedstuff. Maize cob and sweet potato vine ensiled together have little research information; thus, the need for the current research. The study was aimed at determining the chemical content and fermentation characteristics of mixed maize cob and sweet potato vine silage (Li *et al.,* 2017).

MATERIALS AND METHODS
Experimental Site
The experiment was carried out at the Animal Science Laboratory, Department of Animal Science, Kaduna State University, Kafanchan Campus. Kafanchan is located in the southern part of Kaduna State, Nigeria. It serves as the headquarters for the Jama'a Local Government Area.

Experimental Materials
Sweet potato vines, maize cob, vacuum machine, zip-lock polyethene bags, plastic buckets, pH meter, distilled water, sulphuric acid, 60 ml sample bottles, blender, knife, sand, and oven.

Steps in silage making using Ziploc polyethene bags:
Step 1: Chopping
Maize cob (MC) and sweet potato vine (SPV) were chopped, according to the procedure described by Giang *et al.* (2004), to a size of about 2-5 cm using a chaff cutter. The chopping facilitate good compaction and reduces air retention, it also increases the surface area of the vine and ensures that the forage ferments evenly.

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Step 2: Wilting
Maize cob (MC) and sweet potato vine (SPV) were spread out in thin layers on a clean plastic sheet to be wilted under the sun for 12 hours and turned 10 times.

Step 3: Compaction
The wilted material was compressed in Ziplock polyethene bags to eliminate any air pockets. This creates an oxygen-free environment, which is crucial for the fermentation process. The dry matter at ensiling was approximately 70%, 65%, 60%, and 55%, thus each level was considered as treatment T1, T2, T3, and T_4, respectively. To achieve the dry matter level per treatment, 2.3, 1.9, 1.5 and 1.1 parts of maize cob were mixed with one part of sweet potato vine. Replicates were placed in Ziploc Polyethene Bags, then vacuumed to remove air. The process of ensiling was carried out according to the method suggested by Kung and Shaver (2001). The Ziploc Polyethene Bags were carefully arranged in 20 L black plastic containers, then covered with soil before placing the plastic cover and tightened. The ensiling period lasted for 45 days before sampling and feed-out. Under normal conditions, silage fermentation will reach a stable condition within 14 – 21 days (Kung *et al*., 2018), and it can remain under stable fermentation conditions for about three (3) years with proper storage (Weinberg & Chen, 2013). Silage samples from each replicate were analysed for proximate constituents, cell wall components, pH, ammonia-nitrogen, total volatile acids and anti-nutrient.

Experiment Design
Each treatment was replicated three (3) times in a completely randomised design (CRD). The replicates were 500 g of the respective treatments.

Chemical Analysis
Chemical analysis was carried out at the National Animal Production Research Institute, Shika. Absolute dry matter (DM) and ash contents of the silage samples were determined according to AOAC (1990), while the total nitrogen (N) was determined by the Kjeldahl method (AOAC, 1990) and crude protein (CP) was calculated as N x 6.25. The neutral detergent fibre (NDF), acid detergent fibre (ADF) were determined using the ANKOM Technology method (Van Soest *et al*., 1991).

Statistical Analysis
Data obtained were subjected to analysis of variance (ANOVA) using a General Linear Model (GLM) of Statistical Analysis System (SAS) software version 9.4 (SAS, 2011). The model of the analysis was $Y_{ij} = \mu + t_i + e_{ij}$. Where: Y_{ij}= dependent variable/observation, μ = overall population mean, t_i = effect of i^{th} treatment (1=1, 2, 3, 4) and e_{ij} = random error/residual. Means were separated using Duncan multiple range tests (Duncan, 1955)

RESULTS AND DISCUSSION
Chemical content of maize cob- sweet potato vine silage
Proximate and fibre fractions of sweet potato vine and maize cob mixture ensiled at different dry matter levels are presented in Table 1. The results showed there was a significant difference (p<0.05) across the treatments in dry matter, ash, CP, NDF and hemicelluloses (HC). From Table 1, ether extract (EE), crude fibre (CF) and acid detergent fibre (ADF) showed no significant difference across the treatments. The increase in dry matter across the treatments may be as a result of the proportion of maize cob to sweet potato vine in the silage. It may also be due to the portion of soluble plant materials fermented by the anaerobic microbes present in the silage process. The difference observed in CP across the treatments may be a result of the sweet potato vine proportion in the silage, sweet potato vine recorded higher CP in the proximate analysis compared to the maize cob. In a similar silage experiment conducted using *Luecaena* and sorghum, CP content of the silage was high, ranging from 7.2 to 23.6 % with the inclusion of *Leucaena* (Andrade *et al*., 2019). The amount of NDF in the present study increased across the treatments. The increase could be associated with microbial activities which ferment soluble carbohydrates and crude protein before hemicellulose and cellulose. Previous research reported that NDF and ADF were less affected by ensiling (Panyasak & Tumwasorn, 2015). Nevertheless, in an experiment conducted on maize waste, NDF increased from 789.8 g/kg DM to 825.2 g/kg DM (Panyasak & Tumwasorn, 2015). The present work deduced that the increase in NDF across the treatments was probably due to high fermentation activities at higher moisture levels across the treatments.

Table 1: Proximate and fibre fraction (g/kg) of maize cob and sweet potato vine mixture ensiled at different dry matter levels

	Treatment				
Nutrient	T_1	T_2	T_3	T_4	p-value
Dry matter	902.4±0.40^c	933.9512.79^b	974.05±6.09^a	974.55±2.74^a	0.0003
Ash	41.2±1.79^b	56.00±5.77^a	34.50±0.64^b	32.70±2.31b	0.0037
Ether extract	36.5±0.40	35.55±2.34	49.70±6.64	32.70±15.07	0.5150
Crude fibre	314.45±0.20	306.45±3.84	322.65±9.67	332.70±11.26	0.1719
Crude protein	66.55±0.89^a	69.40±1.44^a	40.95±5.57^b	39.70±5.25^b	0.0008
NDF	525.55±1.07^b	636.45±8.23^a	626.30±5.60^a	661.70±30.48^a	0.0015
ADF	362.1±1.27	334.15±4.19	391.75±22.31	371.60±35.91	0.3487
Hemicellulose	163.45±2.34^b	302.30±4.04^a	234.55±27.91^a	290.10±5.42^a	0.0005

Values are presented as means ± SEM. $^{a\ b\ c}$ were different (p<0.05) within the same row. T_1= 70 % DM, T_2= 65 % DM, T_3= 60 % DM and T_4= 55 % DM. NDF= neutral detergent fibre, ADF= acid detergent fibre

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Fermentation characteristics of maize cob and sweet potato vine mixture ensiled at different dry matter levels

Fermentation characteristics of sweet potato vine and maize cob mixture ensiled at different dry matter levels are presented in Table 2. The results showed that there was a significant difference (p<0.05) across the treatments in pH due to lactic acid production. Silage is a product of anaerobic fermentation of plant materials. It is a way of preserving the organic matter content of a silage material. Lactic acid (LA) is the main preservative acid in silage; the higher the LA, the better the silage quality. However, butyric acid (BA) has a negative correlation to silage quality. Other important organic acids that ensure the quality of silage are acetic acid (AA) and propionic acid (PA) (Scherer *et al.*, 2015). A good silage has a low pH due to lactic acid production by lactic acid bacteria. The values of pH recorded in the present study were within an acceptable range of 4.2 – 5.5 (Kung *et al.*, 2018) for grass and legume silages. The concentration of ammonia nitrogen (NH_3-N) was not affected by dry matter levels. Although individual short-chain fatty acids were not determined in the present study, the increase in pH across treatments could be associated to butyrate concentration due to the presence of clostridia. It means that further lowering of dry matter level would increase moisture level thus leading to silage contamination. The TVFA recorded in this work was within the normal range of 7.6% – 14.1% reported for grass silage (Kung *et al*., 2018). Ammonia nitrogen (NH_3-N) in silage indicates decomposition of protein by clostridia, which thrives well in higher moisture silage. An NH_3-N level of 0.2% - 11% was recorded to have a negative effect on dry matter intake; higher level of NH_3-N in a silage decreases intake and milk production in cows (Jezequel *et al*., 2025). In the present study, NH_3-N varied across the treatments, with values lower than the concentration reported for alfalfa silage (Hu *et al.,* 2020).

Table 2: Fermentation characteristics of maize cob and sweet potato vine mixture ensiled at different dry matter levels

	Treatment				
Parameter	T_1	T_2	T_3	T_4	p-value
pH	$4.22±0.13^c$	$4.46±0.01^{bc}$	$4.73±0.06^a$	$4.67±0.05^{ab}$	0.0053
NH_3-N (%)	$0.03±0.00^b$	$0.05±0.01^a$	$0.03±0.00^b$	$0.03±0.00^b$	0.0059
TVFA (µmol/L)	10.67±1.33	9.00±0.58	9.33±0.67	8.00±0.58	0.2477

Values are presented as means ± SEM. $^{a\,b\,c}$ were different (p<0.05) within the same row. TVFA= total volatile fatty acid. T1= 70 % DM, T2= 65 % DM, T3= 60 % DM and T4= 55 % DM

Antinutrient content of maize cob and sweet potato vine mixture ensiled at different dry matter levels

Results on antinutrient contents (Table 3) showed significant differences (p < 0.05) in flavonoid contents. Flavonoid content increased linearly across the treatments, with T_4 recording the highest content. The result of alkaloid concentration observed in the present study was within a range reported by Khan *et al.* (2015). Nutritionally, alkaloids at higher levels are considered toxic, because they affect foetal development and even death in sheep (Khan *et al*., 2015). In humans, glycoalkaloids can cause haemolysis in human, and some alkaloids may cause infertility (Khan et al., 2015). Ensiling can reduce some alkaloids such as pyrrolizidine alkaloids (PAs), but the concentration of certain alkaloids may increase under anaerobic conditions. Factors that affect alkaloid concentration during the silage process include the type/nature of alkaloid, silage moisture content and temperature, ensiling period, and microbial inoculants (Khan *et al*., 2015). From the results in this study, alkaloid contents did not vary significantly (p>0.05) across all the treatment groups. The range of alkaloid concentration (1.16 – 1.48 mg/kg) was far below the toxic range of 3–10 mg/g (Amagloh *et al.*, 2022). Similarly, tannin content (1.28 – 1.35 mg/kg) was within the acceptable range of 2 - 4 % and < 2 % for both condensed tannins and hydrolysable tannins, respectively (Besharati *et al*., 2022). A tannin content > 50 g kg DM is known to reduce feed intake in ruminant animals (Besharati *et al*., 2022). The absence of a significant difference in alkaloid and tannin contents could be related to the moisture levels in the present study (Jayanegara *et al.*, 2019). Depending on the type of tannin (condensed or hydrolysable) and species of ruminant, tannin concentration of >5 % can reduce feed intake, feed digestibility, and milk yield (Jayanegara *et al.*, 2019). However, low and moderate concentrations of tannin (20 – 45 g/kg) can protect dietary protein from excessive microbial degradation in the rumen, thus increasing bypass protein, which increases the availability of essential amino acids in the small intestine. Moderate tannin content is also known to reduce greenhouse gas (GHG) emissions (Besharati *et al.,* 2022; Jayanegara *et al.*, 2019). Flavonoid content in the present study increased inversely with dry matter levels. The result was consistent with the fact that sweet potato's leaves and stems contain a higher concentration of flavonoids, which can be well preserved in silage (Liu *et al.*, 2020; Nguyen *et al.*, 2021).

Table 3: Antinutrient content (mg/kg) of maize cob and sweet potato vine mixture ensiled at different dry matter levels

	Treatment				
Parameter	T1	T2	T3	T4	p-value
Alkaloid	1.16±0.33	1.26±0.22	1.33±0.27	1.48±0.36	0.0947
Tannin	1.35±0.06	1.28±0.07	1.35±0.14	1.30±0.23	0.9766
Flavonoid	$77.98±2.01^b$	$84.59±1.95^{ab}$	$89.92±3.04^a$	$83.08±1.73^{ab}$	0.0335

Values are presented as means ± SEM. $^{a\,b\,c}$ were different (p < 0.05) within the same row. T1 = 70 % DM, T2 = 65 % DM, T3 = 60 % DM and T4 = 55 % DM.

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Physical properties of maize cob and sweet potato vine mixture ensiled at different dry matter levels

Physical properties of maize cob – sweet potato vine silage (Table 4) indicate the unique characteristics of silage ensiled at different DM levels. All treatments exhibited greenish brown colour, intact vines, cob not rotten, and absence of mould. However, the leafy odour of T_1 was slightly different from T_2, T_3 and T_4, which had a slightly sourer smell.

Silage colour, smell and texture are important parameters in evaluating silage quality (Kung *et al.,* 2018). In the present study, all the treatments exhibited properties of a good silage. It was observed that when treatment diets (T_1, T_2, T_3 and T_4) were offered to sheep and goats, the animals exhibited different preferences for treatments (Shu'aibu *et al*., 2024). In Figure 1, goats preferred T_1, while sheep showed a preference to T_2, T_3 and T_4. However, sheep later concentrated on T_4 only (Figure 2).

Table 4: Physical properties of ensiled maize cob with sweet potato vines at different dry matter levels

Treatments	Colour	Mould	Structure	Odour	Visible water
T_1	Greenish brown	No mould	Intact vines and cob not rotten	Leafy	No water
T_2	Greenish brown	No mould	Intact vines and cob not rotten	Slightly sour	No water
T_3	Greenish brown	No mould	Intact vines and cob not rotten	Slightly sour	No water
T_4	Greenish brown	No mould	Intact vines and cob not rotten	Slightly sour	No water

T_1 = 70 % DM, T_2 = 65 % DM, T_3 = 60 % DM and T_4 = 55 % DM.

Figure 1: Goats and sheep preferences to maize cob and sweet potato vine mixture ensiled at different dry matter levels (from left – right = T1 –T4, respectively)

Figure 2: Sheep's final preference to T4 (maize cob and sweet potato vine mixture ensiled at 55 % DM level)

Conclusion

Ensiling of maize cob with sweet potato vine at different dry matter levels had no effect on the ether extract, crude fibre, acid detergent fibre and ammonia nitrogen. However, moisture levels influenced dry matter, crude protein, neutral detergent fibre, hemicellulose, pH, total volatile fatty acids and flavonoid. It was concluded that 55 % DM (45 % moisture) encourages the formation of high-quality silage from a mixture of maize cob and sweet potato vine.

Recommendation

It was deduced that microbial activities increased with a decrease in dry matter levels. Hence, for good-quality silage using maize cob and sweet potato vine, a 55 % dry matter level is recommended. Further research is also recommended at lower dry matter levels.

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