

## **ENSILING PROPORTION AND DURATION EFFECTS ON FERMENTATION, NUTRITIONAL QUALITY AND METHANE CHARACTERISTICS OF MAIZE–DANIELLA SILAGE**

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### **ABSTRACT**

Seasonal fodder scarcity necessitates alternative silage strategies such as combining maize with *Daniella oliveri* which may enhance fermentation quality, nutritive value, digestibility, and methane mitigation in tropical ruminant systems. This study evaluated the effects of ensiling proportions and durations of maize (*Zea mays*) and *Daniella oliveri* on fermentation quality, nutrient composition, fibre fractions, *in vitro* digestibility, and methane production of mixed silages. Forage proportions comprising 100:0, 75:25, 50:50, 25:75, and 0:100 maize–Daniella ratios were ensiled in laboratory silos for 0, 2, 4, 8, and 12 weeks in a 5 × 5 factorial arrangement fitted into a completely randomized design. Physical characteristics, pH, organic acids, proximate composition, fibre fractions, forage quality indices, *in vitro* gas production, and methane emissions were determined. Sole maize silage exhibited superior fermentation quality, with lower pH, higher lactic acid, and reduced butyric acid levels, while sole *D. oliveri* silage consistently showed poor fermentation stability with elevated pH (>6.0) and high butyric acid. Inclusion of *D. oliveri* improved crude protein (up to 172 g/kg DM at 75M: 25D, 8 weeks) and ether extract content but also increased fibre fractions and reduced fermentation quality at higher proportions. *In vitro* assessments revealed greater energy efficiency and digestibility in maize-dominated silages, whereas sole *D. oliveri* produced the highest methane gas (17.3 ml/200 mg DM). Overall, 25% inclusion of *D. oliveri* with maize balanced nutritional enhancement and fermentation quality, while minimizing methane emissions. These results suggest maize–Daniella silage as a sustainable dry-season feed option for ruminant animal production in the tropics.

**Keywords:** *Daniella oliveri*; fodder; forage; *in vitro*; methane; *Zea mays*

### **INTRODUCTION**

In the tropics, livestock production faces significant challenges due to the shortage of fodder during the dry season. Regular availability of quality fodder is critical for cost-

effective ruminant production. However, extreme weather conditions restrict fodder supply during the dry season, creating a wide gap between availability and demand (Sarwar *et al.*, 2003). Conservation of forage pro-

duced during the rainy season through ensiling has therefore become a common practice among smallholder farmers.

Most tropical grasses and legumes are naturally poor silage materials due to their low water-soluble carbohydrate content, high buffering capacity, and susceptibility of protein to proteolysis (McDonald *et al.*, 1991; deFigueredo and Marais, 1994; Heinritz *et al.*, 2012; Alves *et al.*, 2025). Nevertheless, when crops with high nutritive value are ensiled, feed quality and animal performance can be sustained (Black *et al.*, 1995; Nkosi *et al.*, 2024). In Nigeria, maize (*Zea mays*) is the most widely used cereal for silage, followed by sorghum. Maize is particularly suited because of its high dry matter, low buffering capacity, and abundance of soluble carbohydrates that support lactic acid fermentation (Amodu and Abubakar, 2004; Staples, 2010).

In Nigeria, the seasonal fluctuations in pasture production lead to feed surpluses in the rainy season and scarcity in the dry season (Lamidi and Ologbose, 2018). Studies have reported that only 30–50% of available pasture is utilized, with the remaining wasted (Cowan *et al.*, 1993; USDA-NRCS, 2009). Ensiling the surplus has been proposed as a viable conservation method, as climatic conditions are often unsuitable for haymaking (Kaiser *et al.*, 1993; Ramos *et al.*, 2016; Sahoo, 2018). Research has shown that silages from maize, sorghum, elephant grass, and other tropical forages improve livestock productivity during feed-deficit periods (Umoh *et al.*, 1996; Khosravi *et al.*, 2018; Zhang *et al.*, 2024). Compared to hay, silage offers better nutrient preservation and longer storage when properly prepared (Tjandratmadja, 1989; Brockman, 1990; Ojo *et al.*, 2013).

Forage mixtures of cereals and legumes can provide a balanced substrate, where cereals supply fermentable carbohydrates and legumes increase protein content (Koljajic *et al.*, 1998; Dele *et al.*, 2022). Such combinations improve silage nutritive value, palatability, and digestibility (Assefa and Ledin, 2001; Nayigihugu *et al.*, 2002).

Maize is the third most important crop globally, after wheat and rice, and the most popular cereal conserved as silage (McDonald *et al.*, 1991; Bilal *et al.*, 2005).

African Copaiba Balsam tree, also known as West African Copal tree (*Daniella oliveri*) is an indigenous leguminous tree. It is a species of tree in the family Fabaceae. In Nigeria, it is abundant in the Guinea and Savanna zones and serves as a traditional medicine and livestock feed source (Dalziel, 1955; Keay *et al.*, 1964; Osuntoki *et al.*, 2016; Muhammad *et al.*, 2022; Balogun *et al.*, 2023).

Given the wide availability and suitability of maize for ensiling, combining it with *D. oliveri* could improve protein content, enhance fermentation, and produce high-quality silage for ruminants. This study therefore evaluated the physical properties, fermentative characteristics and chemical quality of maize–*Daniella* mixtures under varying ensiling durations.

## MATERIALS AND METHODS

### *Experimental sites*

The experiment was conducted in the Pasture Unit, Directorate of University Farms. Laboratory analysis was carried out at the Department of Pasture and Range Management, Federal University of Agriculture, Abeokuta. The area falls within the transitional rain forest vegetation zone of Southwest Nigeria; latitude 7° 13' 49.46" N, longitude 3° 26'

11.96° E, altitude of 76 m above sea level. The climate is humid with a mean annual rainfall of 1037 mm. Annual mean temperature is 34.7°C and relative humidity 82 %.

### **Sample collection and process of ensiling**

*Daniella oliveri* leaves were harvested from the Directorate of University Farms of the Federal University of Agriculture, Abeokuta; the whole maize stock (Suwan 1 variety) was harvested at the milky stage. Both Suwan 1 and *D. oliveri* were wilted overnight and chopped into pieces of  $\leq 2$  cm. The samples were mixed based on different proportions. Thereafter, the chopped forage samples were compacted into laboratory silo (960 ml) and were ensiled for various durations (0, 2, 4, 8, 12 weeks) at room temperature. After each ensiling duration, the silos were opened and 500 g samples were taken from each treatment and replicates. The 500 g samples were oven dried and used for further laboratory analysis.

The *Zea mays* and *D. oliveri* mixtures (1000 g) were as follows:

100% *Z. mays* + 0% *D. oliveri*

75% *Z. mays* + 25% *D. oliveri*

50% *Z. mays* + 50% *D. oliveri*

25% *Z. mays* + 75% *D. oliveri*

0% *Z. mays* + 100% *D. oliveri*

### **Experimental design**

The experiment was laid in a  $5 \times 5$  factorial arrangement in a Completely Randomized Design (CRD) with five (5) proportions of maize (M) and *Daniella oliveri* (D) mixtures (100M:0D, 75M:25D, 50M:50D, 25M:75D, 0M:100D) and five ensiling period (0, 2, 4, 8, 12 weeks) making a total of twenty-five (25) treatment combinations with three (3) replicates.

### **Physical characteristics, pH, lactic acid and volatile fatty acids**

At the expiration of each ensiling duration, the silos were opened and seven (7) trained panelists observed and evaluated the physical characteristics of the silage such as grain content, colour, odour, and moisture, using the procedure of Bates (1998). Silage colour was scored on a 12-point scale. Green to yellowish-green coloration indicated desirable preservation (9-12), yellow to brownish coloration was considered acceptable (5-8), while deep brown/black or predominantly white/gray coloration indicated undesirable preservation (0-4) according to the procedure of Bates (1998). A 20-gram of silage sample was added to 180 ml of distilled water, blended for 120 seconds and allowed to stand on the bench at room temperature for one hour. The blended silage samples were filtered via four layers of cheesecloth. A portion of the filtrate was used for pH determination of the silage at liquid state with the use of a pH meter. A second portion of the filtered liquid (filtrate) was used to determine the lactic acid content according to Taylor (1996). The third portion of the filtrate was used to determine propionic, acetic, butyric acids according to Kostulak-Zielińska and Potkański (2001) and Gašior (2002) using High Performance Liquid Chromatography (HPLC).

### **Chemical analysis**

Samples of experimental silages (500 g) were oven dried at 65°C until constant weight was obtained, milled and analyzed for dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE), ash and Nitrogen free extract (NFE) according to the methods of AOAC (2002). The neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid

detergent lignin (ADL) were determined as described by Van Soest *et al.* (1991). Percentage hemicellulose content was obtained by finding the difference between NDF and ADF values (Church, 1979), while cellulose was calculated by taking the difference between ADF and ADL.

### **Forage quality indices**

Fleish points =  $220 + (2 \times \text{DM \%} - 15) - (40 \times \text{pH})$ ; Where fleish points denote values between 85 and 100 as very good quality; 60 and 80 as good quality; 55 and 60 as moderate quality; 25 and 40 as, satisfying quality; < 20 as worthless (Kilic, 1986).

Relative feed value (RFV) of the silage was calculated from the estimates of dry matter digestibility (DMD) and dry matter intake (DMI) according to Rohweder *et al.* (1978).

Followings were the equations used:

Dry matter digestibility (% DM) =

$88.9 - 0.779 \times \text{ADF (\% DM)}$

Dry matter intake (% Body weight) =

$120/\text{NDF (\% DM)}$

Relative feed value =  $(\text{DDM} \times \text{DMI})/1.29$

$\text{TDN} = 87.84 - (\text{ADF\%} \times 0.7)$

### **In vitro gas and methane determination**

The *in vitro* gas production of the samples was determined using the procedure of Menke and Steingass (1988). 200 mg of each of the samples was weighed with a sensitive scale and sextuplicated (three for dry matter digestibility and another three for methane determination) and placed in fibre bags before introducing the bags in 100 ml calibrated glass syringe. Rumen fluid (inoculum) was collected inside a pre-warmed flask (39 °C) from cattle at an abattoir in Abeokuta. The inoculum was filtered through two layers of cheesecloth and mixed with sodium and ammonia bicarbonate buffer (35 g NaHCO<sub>3</sub> plus 4 g NH<sub>4</sub>HCO<sub>3</sub> per litre) at a ratio of 1:2 (v/v) to prevent lowering the pH of the rumen

fluid which could result in decreased activities of the microbes. 30 ml of the buffered inoculum was then added to each syringe containing the milled samples and the gas released was read directly on the graduated syringe. The syringes were positioned vertically in a water bath with shaker kept at 39 °C. A blank syringe containing 30 ml of the buffered inoculum only was included as the control. Gas production was recorded at 24 and 48 hours of incubation.

Organic matter digestibility (OMD) was estimated as

$\text{OMD (\%)} = 14.88 + 0.889\text{GV} + 0.45\text{CP} + 0.651 \text{ash}$  (Menke and Steingass, 1988).

Short chain fatty acids (SCFA) was estimated as

$\text{SCFA} = 0.0239\text{GV} - 0.0601$  (Getachew *et al.*, 2000).

Metabolizable energy (ME) was be calculated as

$\text{ME} = 2.20 + 0.136\text{GV} + 0.057\text{CP} + 0.029\text{CP}^2$  (Menke and Steingass, 1988).

Total gas volume (GV) was expressed as ml/200mgDM, CP and ash as g/kg DM, ME as MJ/kg DM and SCFA as μmol/g DM.

After 48 hours of incubation, 4ml NaOH (10M) was introduced into the syringe to estimate the amount of methane produced. Average volume of gas produced from the blanks was deducted from the volume of gas produced per sample (Fievez *et al.*, 2005).

### **In vitro dry matter digestibility (IVDMD)**

After 48 hours of incubation, three syringes were used to determine the dry matter digestibility by decanting the fluid and the bags were washed thoroughly and oven-dried at 105 °C for 24 hours. The dry residue was weighed and digestibility calculated using the following equation:

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

**Statistical analysis**

All data collected were subjected to analysis of variance (ANOVA) and significant difference between individual means was separated using the Duncan's multiple range test according to SAS (2002). Significant difference was tested at 5% probability level.

**Statistical model**

$$Y_{ijk} = \mu + M_i + E_j + (ME)_{ij} + \Sigma_{ijk}$$

Where;

$Y_{ijk}$ ; represented the Observed value of dependent variables;  $\mu$  : Population mean;  $M_i$ : Proportion of Maize-Daniella mixtures,  $E_j$  : Effect of ensiling duration;  $(ME)_{ij}$  : Interaction effect Proportion of Maize-Daniella mixtures and ensiling period;  $\Sigma_{ijk}$ : Random residual error.

**RESULTS****Physical characteristics of silage**

Grain contents were higher for silage with whole maize and 75 % maize over the period except when stored for two weeks. The grain content ranged from 8.56% of 0M:100D to 34.11% of 100M: 0D silage at four weeks of ensiling. Mixtures of 100M: 0D silage and 25M: 75D and at two and eight weeks of ensiling, respectively had the highest value (10.00) for colour. Only the pure Daniella stored for two weeks putrid (8.44) in odour. Mixture of 25M: 75D at twelve weeks of ensiling had the highest value (9.00) of moisture whereas 100M: 0D ensiled for six weeks had the least moisture (6.78) value (Table 1).

**pH and fermentative characteristics of silage**

The effects of ensiling duration and proportion on the pH and fermentative characteristics of silage were significant (Table 2). Silage dry matter (DM) content ranged from 29.06 to 37.71%. pH values of the sole Daniella silage for all ensiling durations

were  $\geq 6.0$  while sole maize silage across all the ensiling durations recorded  $\text{pH} \leq 4.15$ . Sole maize ensiled for 8 weeks had the highest value of lactic acid of 96.21 g/kg and the least lactic acid (7.6 g/kg) value was recorded for sole Daniella ensiled for 2 weeks. The butyric (14.03 g/kg) value of sole Daniella ensiled for 8 weeks was the highest; the least of 0.70 g/kg butyric acid was recorded for sole maize ensiled for 2 weeks.

**Proximate and fibre composition of Maize- Daniella silages**

There were significant differences in the DM, CP, Ash, EE, CF, NFE contents of silage at different plant proportions as influenced by ensiling duration (Table 3). The DM content of pure maize ensiled for twelve weeks (969.70 g/kg) was the highest; 75% M : 25% D recorded the least DM (870.10 g/kg) value. Mixture of 75 % M: 25% D had the highest CP content value (172.33 g/kg DM) in silage stored for eight weeks while fresh un-ensiled pure maize had the least CP content value (90.93 g/kg DM). The ash content value ranged from 85.03 g/kg DM for 25 % M: 75 % D ensiled for twelve weeks to 127.07g/kg DM for fresh 25 % un-ensiled maize. 100 % ensiled Daniella stored for twelve weeks had the highest value (116.20 g/kg DM) of EE and fresh un-ensiled pure maize had the least value of 10.10 g/kg DM (Table 3).

There were significant differences in the fibre composition across the parameters (Table 4). The NDF contents of the silages ranged from 626.92 g/kg DM to 471.09 g/kg DM for 50% M:50% D silage ensiled for 2 weeks and 0% M:100% D ensiled for 8 weeks, respectively. The ADF values ranged from 203.73 g/kg DM of pure ensiled maize stored for eight weeks to 462.64 g/kg DM of fresh 25M% :75% D. The ADL content of 75% M:25% D ensiled for 12 weeks was the

**Table 1: Effect of ensiling duration and plant proportion on the physical characteristics of silage produced from Maize-Daniella mixtures.**

Duration (weeks)	Plant Proportion (%)	Grain%	Colour	Odour	Moisture
2	100M:0D	33.00 <sup>ab</sup>	10.00 <sup>a</sup>	21.67 <sup>ab</sup>	8.22 <sup>a-d</sup>
	75M:25D	24.56 <sup>def</sup>	9.00 <sup>ab</sup>	12.89 <sup>cde</sup>	8.78 <sup>abc</sup>
	50M:50D	16.67 <sup>h</sup>	9.00 <sup>ab</sup>	12.22 <sup>de</sup>	8.44 <sup>a-d</sup>
	25M:75D	17.78 <sup>gh</sup>	9.44 <sup>ab</sup>	13.22 <sup>cde</sup>	8.78 <sup>abc</sup>
	0M:100D	9.33 <sup>i</sup>	8.33 <sup>ab</sup>	8.44 <sup>e</sup>	8.33 <sup>a-d</sup>
4	100M:0D	34.11 <sup>a</sup>	8.67 <sup>ab</sup>	19.44 <sup>abc</sup>	7.11 <sup>cd</sup>
	75M:25D	31.22 <sup>abc</sup>	7.56 <sup>ab</sup>	18.78 <sup>a-d</sup>	7.11 <sup>cd</sup>
	50M:50D	27.67 <sup>bcd</sup>	7.89 <sup>ab</sup>	16.00 <sup>bcd</sup>	7.56 <sup>a-d</sup>
	25M:75D	24.00 <sup>def</sup>	8.67 <sup>ab</sup>	22.22 <sup>ab</sup>	8.44 <sup>a-d</sup>
	0M:100D	21.22 <sup>fgh</sup>	7.67 <sup>ab</sup>	15.89 <sup>bcd</sup>	8.78 <sup>abc</sup>
8	100M:0D	30.67 <sup>abc</sup>	7.11 <sup>b</sup>	25.11 <sup>a</sup>	6.78 <sup>d</sup>
	75M:25D	26.89 <sup>cde</sup>	9.89 <sup>a</sup>	23.44 <sup>a</sup>	7.56 <sup>a-d</sup>
	50M:50D	21.56 <sup>e-h</sup>	9.67 <sup>ab</sup>	21.56 <sup>ab</sup>	7.44 <sup>a-d</sup>
	25M:75D	20.33 <sup>fgh</sup>	10.00 <sup>a</sup>	24.11 <sup>a</sup>	8.89 <sup>ab</sup>
	0M:100D	8.56 <sup>i</sup>	8.78 <sup>ab</sup>	20.44 <sup>ab</sup>	8.67 <sup>abc</sup>
12	100M:0D	32.22 <sup>abc</sup>	8.00 <sup>ab</sup>	24.11 <sup>a</sup>	7.22 <sup>bcd</sup>
	75M:25D	27.11 <sup>cd</sup>	7.22 <sup>b</sup>	22.78 <sup>ab</sup>	8.67 <sup>abc</sup>
	50M:50D	22.56 <sup>d-g</sup>	7.67 <sup>ab</sup>	22.00 <sup>ab</sup>	7.11 <sup>cd</sup>
	25M:75D	19.67 <sup>fgh</sup>	7.89 <sup>ab</sup>	25.67 <sup>a</sup>	9.00 <sup>a</sup>
	0M:100D	11.00 <sup>i</sup>	8.44 <sup>ab</sup>	23.22 <sup>a</sup>	7.89 <sup>a-d</sup>
SEM		0.06	0.13	0.46	0.09

abcdefgh means on the same column with different superscripts are significantly ( $p < 0.05$ ) different

M- Maize, D- Daniella, SEM- Standard error of mean

highest though similar to that recorded for 25M:75D ensiled for 8 weeks and the sole maize ensiled for 8 weeks recorded the least ADL (77.78 g/kg) content (Table 4).

#### ***Fleish point and forage quality indices***

The effects of ensiling duration and proportion on the parameters were significant on Fleish point, TDN, RFV and DDM but not on DMI (Table 5). Highest Fleish point (107.37) was recorded from silage with proportion of 25M: 75D ensiled for 4 weeks;

prolonged ensiling to 12 weeks reduced Fleish points, especially for sole maize silage (56.29). Total Digestible Nutrients (TDN) increased with ensiling duration in maize-dominant silages; the highest was recorded from sole maize ensiled for 8 weeks (73.54 %); the least (56.25 %) value was recorded from sole Daniella silage ensiled for 2 weeks. Dry Matter Digestibility (DDM) was significantly improved by longer ensiling in maize-rich silages, with maximum DDM recorded at 8 weeks across all proportions, with sole

maize ensiled for 8 weeks recording the highest DDM (73.03 %) and the sole Daniella ensiled for 2 weeks recording the least DDM (53.79 %) value. Relative Feed Value (RFV) followed a similar pattern with TDN and DDM. The highest RFV values were observed in 100% maize silage at 2 and 8 weeks. Proportions of 75M:25D maintained acceptable RFV (>100) up to 8 weeks, while

**Table 2: Effects of ensiling duration and plant proportion on the pH and fermentative characteristics (g/kg) of silage produced from Maize-Daniella mixtures.**

Duration (weeks)	Plant Proportion (%)	DM-silage (%)	pH	Lactic	Acetic	Propionic	Butyric
0	100M:0D	29.06 <sup>l</sup>	nd	nd	nd	nd	nd
	75M:25D	29.99 <sup>kl</sup>	nd	nd	nd	nd	nd
	50M:50D	31.24 <sup>ijk</sup>	nd	nd	nd	nd	nd
	25M:75D	33.89 <sup>def</sup>	nd	nd	nd	nd	nd
	0M:100D	34.63 <sup>de</sup>	nd	nd	nd	nd	nd
2	100M:0D	29.20 <sup>l</sup>	4.15 <sup>n</sup>	86.40 <sup>c</sup>	13.63 <sup>n</sup>	1.01 <sup>m</sup>	0.57 <sup>n</sup>
	75M:25D	31.38 <sup>hij</sup>	4.31 <sup>j</sup>	71.63 <sup>e</sup>	17.83 <sup>l</sup>	1.52 <sup>k</sup>	1.18 <sup>m</sup>
	50M:50D	33.32 <sup>efg</sup>	4.77 <sup>g</sup>	48.18 <sup>g</sup>	23.87 <sup>i</sup>	2.43 <sup>i</sup>	3.51 <sup>j</sup>
	25M:75D	34.26 <sup>def</sup>	5.37 <sup>d</sup>	29.25 <sup>i</sup>	30.61 <sup>f</sup>	3.53 <sup>f</sup>	6.25 <sup>g</sup>
	0M:100D	36.02 <sup>bc</sup>	6.15 <sup>a</sup>	7.67 <sup>k</sup>	41.21 <sup>c</sup>	4.65 <sup>c</sup>	12.05 <sup>d</sup>
4	100M:0D	30.35 <sup>ijkl</sup>	4.06 <sup>o</sup>	91.61 <sup>b</sup>	14.81 <sup>mn</sup>	1.08 <sup>lm</sup>	0.63 <sup>n</sup>
	75M:25D	32.38 <sup>ghi</sup>	4.23 <sup>l</sup>	73.63 <sup>e</sup>	19.47 <sup>k</sup>	1.58 <sup>k</sup>	1.27 <sup>lm</sup>
	50M:50D	33.08 <sup>fgh</sup>	4.71 <sup>h</sup>	50.61 <sup>g</sup>	26.01 <sup>h</sup>	2.66 <sup>h</sup>	3.78 <sup>i</sup>
	25M:75D	34.65 <sup>de</sup>	5.30 <sup>e</sup>	31.27 <sup>i</sup>	33.43 <sup>e</sup>	3.78 <sup>e</sup>	6.65 <sup>f</sup>
	0M:100D	36.73 <sup>ab</sup>	6.09 <sup>b</sup>	8.61 <sup>k</sup>	45.20 <sup>b</sup>	5.00 <sup>b</sup>	13.02 <sup>c</sup>
8	100M:0D	31.58 <sup>ij</sup>	3.99 <sup>p</sup>	96.21 <sup>a</sup>	17.29 <sup>l</sup>	1.23 <sup>l</sup>	0.70 <sup>n</sup>
	75M:25D	33.50 <sup>d-g</sup>	4.19 <sup>m</sup>	77.08 <sup>d</sup>	21.01 <sup>j</sup>	1.85 <sup>j</sup>	1.55 <sup>k</sup>
	50M:50D	34.86 <sup>cd</sup>	4.66 <sup>i</sup>	53.07 <sup>f</sup>	27.81 <sup>g</sup>	3.01 <sup>g</sup>	4.14 <sup>h</sup>
	25M:75D	36.46 <sup>ab</sup>	5.22 <sup>f</sup>	34.47 <sup>h</sup>	36.07 <sup>d</sup>	3.96 <sup>d</sup>	7.03 <sup>e</sup>
	0M:100D	37.25 <sup>ab</sup>	6.00 <sup>c</sup>	10.88 <sup>j</sup>	48.65 <sup>a</sup>	5.28 <sup>a</sup>	14.03 <sup>a</sup>
12	100M:0D	31.89 <sup>hi</sup>	4.06 <sup>o</sup>	90.83 <sup>b</sup>	15.67 <sup>m</sup>	1.13 <sup>lm</sup>	0.61 <sup>n</sup>
	75M:25D	33.19 <sup>efg</sup>	4.27 <sup>k</sup>	72.42 <sup>e</sup>	21.04 <sup>j</sup>	1.65 <sup>k</sup>	1.41 <sup>kl</sup>
	50M:50D	34.59 <sup>de</sup>	4.70 <sup>h</sup>	50.87 <sup>g</sup>	27.67 <sup>g</sup>	2.74 <sup>h</sup>	4.02 <sup>h</sup>
	25M:75D	36.34 <sup>b</sup>	5.32 <sup>e</sup>	31.22 <sup>i</sup>	33.27 <sup>e</sup>	3.80 <sup>e</sup>	6.54 <sup>f</sup>
	0M:100D	37.71 <sup>a</sup>	6.11 <sup>b</sup>	9.28 <sup>k</sup>	45.86 <sup>b</sup>	5.08 <sup>b</sup>	13.53 <sup>b</sup>
SEM		0.53	0.07	2.94	1.08	0.16	0.49

abcdefg means on the same column with different superscripts are significantly ( $p < 0.05$ ) different

M- Maize, D- Daniella, SEM- Standard Error of Mean, nd- Not determined

**Table 3: Effects of ensiling duration and plant proportion on the proximate composition (g/kg DM) of silage produced from Maize-Daniella mixtures.**

Duration (weeks)	Plant Proportion (%)	DM*	CP	ASH	EE	CF	NFE
0	100M:0D	910.83 <sup>f</sup>	90.93 <sup>g</sup>	85.47 <sup>d-h</sup>	10.10 <sup>l</sup>	177.53 <sup>e-j</sup>	635.97 <sup>a</sup>
	75M:25D	914.00 <sup>ef</sup>	130.10 <sup>f</sup>	115.87 <sup>ab</sup>	40.93 <sup>hij</sup>	265.70 <sup>a</sup>	447.40 <sup>g-i</sup>
	50M:50D	922.53 <sup>def</sup>	140.27 <sup>c-f</sup>	122.60 <sup>a</sup>	58.07 <sup>gh</sup>	262.10 <sup>ab</sup>	416.97 <sup>ij</sup>
	25M:75D	924.80 <sup>def</sup>	149.80 <sup>b-f</sup>	127.07 <sup>a</sup>	73.30 <sup>d-g</sup>	239.93 <sup>abc</sup>	409.90 <sup>j</sup>
	0M:100D	932.73 <sup>c-f</sup>	150.50 <sup>a-f</sup>	125.87 <sup>a</sup>	84.83 <sup>cde</sup>	210.40 <sup>c-f</sup>	428.40 <sup>ij</sup>
2	100M:0D	916.50 <sup>def</sup>	103.45 <sup>g</sup>	91.40 <sup>c-f</sup>	17.60 <sup>kl</sup>	160.50 <sup>ij</sup>	627.05 <sup>ab</sup>
	75M:25D	922.25 <sup>def</sup>	131.15 <sup>f</sup>	94.55 <sup>cde</sup>	46.65 <sup>hi</sup>	228.40 <sup>a-d</sup>	499.25 <sup>ef</sup>
	50M:50D	931.90 <sup>c-f</sup>	138.95 <sup>def</sup>	96.85 <sup>cde</sup>	70.20 <sup>efg</sup>	205.85 <sup>c-f</sup>	488.15 <sup>efg</sup>
	25M:75D	936.50 <sup>b-e</sup>	154.65 <sup>a-e</sup>	97.10 <sup>cde</sup>	77.50 <sup>c-f</sup>	212.40 <sup>c-f</sup>	458.35 <sup>f-i</sup>
	0M:100D	931.85 <sup>c-f</sup>	153.75 <sup>a-e</sup>	100.15 <sup>cd</sup>	86.75 <sup>b-e</sup>	222.80 <sup>bcd</sup>	436.55 <sup>ij</sup>
4	100M:0D	913.53 <sup>ef</sup>	128.97 <sup>f</sup>	89.07 <sup>d-g</sup>	24.07 <sup>jkl</sup>	172.73 <sup>f-j</sup>	585.17 <sup>bc</sup>
	75M:25D	924.27 <sup>def</sup>	141.57 <sup>c-f</sup>	91.80 <sup>c-f</sup>	45.33 <sup>hi</sup>	226.77 <sup>a-d</sup>	494.53 <sup>ef</sup>
	50M:50D	927.73 <sup>c-f</sup>	134.13 <sup>ef</sup>	94.03 <sup>cde</sup>	65.77 <sup>fg</sup>	214.87 <sup>cde</sup>	491.20 <sup>ef</sup>
	25M:75D	930.30 <sup>c-f</sup>	154.83 <sup>a-e</sup>	98.13 <sup>cde</sup>	79.40 <sup>c-f</sup>	208.07 <sup>c-f</sup>	459.57 <sup>f-i</sup>
	0M:100D	921.27 <sup>def</sup>	155.83 <sup>a-e</sup>	95.50 <sup>cde</sup>	84.27 <sup>cde</sup>	223.87 <sup>bcd</sup>	440.53 <sup>hij</sup>
8	100M:0D	932.20 <sup>c-f</sup>	142.87 <sup>b-f</sup>	76.30 <sup>gh</sup>	30.33 <sup>ijk</sup>	177.47 <sup>e-j</sup>	573.03 <sup>c</sup>
	75M:25D	937.13 <sup>b-e</sup>	172.33 <sup>a</sup>	85.97 <sup>d-h</sup>	46.60 <sup>hi</sup>	203.90 <sup>e-g</sup>	491.20 <sup>ef</sup>
	50M:50D	951.00 <sup>abc</sup>	155.17 <sup>a-e</sup>	85.50 <sup>d-h</sup>	79.47 <sup>c-f</sup>	162.97 <sup>hij</sup>	516.90 <sup>de</sup>
	25M:75D	958.30 <sup>ab</sup>	158.77 <sup>a-d</sup>	84.63 <sup>e-h</sup>	94.77 <sup>bc</sup>	152.77 <sup>ij</sup>	509.07 <sup>c</sup>
	0M:100D	957.83 <sup>ab</sup>	149.57 <sup>b-f</sup>	93.80 <sup>c-f</sup>	103.90 <sup>ab</sup>	172.70 <sup>f-j</sup>	480.03 <sup>e-h</sup>
12	100M:0D	929.13 <sup>c-f</sup>	136.57 <sup>def</sup>	73.57 <sup>h</sup>	25.50 <sup>jkl</sup>	190.77 <sup>e-i</sup>	573.60 <sup>c</sup>
	75M:25D	870.10 <sup>g</sup>	98.83 <sup>g</sup>	104.97 <sup>bc</sup>	37.43 <sup>ij</sup>	203.10 <sup>e-h</sup>	555.67 <sup>cd</sup>
	50M:50D	957.93 <sup>ab</sup>	164.27 <sup>a</sup>	74.80 <sup>gh</sup>	90.10 <sup>bcd</sup>	164.13 <sup>g-j</sup>	506.70 <sup>de</sup>
	25M:75D	938.53 <sup>bcd</sup>	139.00 <sup>def</sup>	85.03 <sup>e-h</sup>	75.83 <sup>d-g</sup>	181.43 <sup>e-j</sup>	518.70 <sup>de</sup>
	0M:100D	969.70 <sup>a</sup>	161.80 <sup>abc</sup>	79.33 <sup>fgh</sup>	116.20 <sup>a</sup>	144.13 <sup>i</sup>	498.53 <sup>ef</sup>
SEM		2.38	2.38	1.75	3.31	3.90	7.13

abcdefghijkl means on the same column with different superscripts are significantly ( $p < 0.05$ ) different

M- Maize, D- Daniella, DM\*- Dry matter (laboratory dry matter), CP- Crude protein, EE- Ether extract, CF- Crude fibre, NFE- Nitrogen free extract, SEM- Standard Error of Mean

**Table 4: Effects of ensiling duration and plant proportion on the fibre composition (g/kg DM) of silage produced from Maize-Daniella mixtures**

Duration (weeks)	Plant Proportion (%)	NDF	ADF	ADL	HEM	CELL
0	100M:0D	617.17 <sup>ab</sup>	273.01 <sup>def</sup>	129.34 <sup>a-d</sup>	344.16 <sup>a</sup>	143.67 <sup>i</sup>
	75M:25D	614.37 <sup>ab</sup>	349.75 <sup>a-e</sup>	166.61 <sup>a-d</sup>	264.61 <sup>a-e</sup>	183.14 <sup>gh</sup>
	50M:50D	607.21 <sup>b</sup>	346.79 <sup>a-e</sup>	151.79 <sup>a-d</sup>	260.42 <sup>a-f</sup>	195.00 <sup>g</sup>
	25M:75D	590.52 <sup>cd</sup>	462.64 <sup>a</sup>	176.70 <sup>abc</sup>	127.88 <sup>dfg</sup>	285.94 <sup>a</sup>
	0M:100D	585.20 <sup>d</sup>	444.46 <sup>ab</sup>	183.95 <sup>ab</sup>	140.74 <sup>c-g</sup>	260.51 <sup>b</sup>
2	100M:0D	512.69 <sup>ef</sup>	250.90 <sup>ef</sup>	109.04 <sup>bcd</sup>	261.79 <sup>a-d</sup>	141.86 <sup>i</sup>
	75M:25D	563.02 <sup>de</sup>	354.50 <sup>a-e</sup>	175.20 <sup>abc</sup>	208.52 <sup>a-g</sup>	179.30 <sup>gh</sup>
	50M:50D	626.92 <sup>a</sup>	393.17 <sup>a-d</sup>	165.50 <sup>a-d</sup>	233.75 <sup>a-g</sup>	227.67 <sup>de</sup>
	25M:75D	554.44 <sup>de</sup>	431.23 <sup>abc</sup>	169.09 <sup>a-d</sup>	123.21 <sup>efg</sup>	262.13 <sup>b</sup>
	0M:100D	558.02 <sup>de</sup>	450.70 <sup>a</sup>	197.07 <sup>ab</sup>	107.31 <sup>g</sup>	253.63 <sup>c</sup>
4	100M:0D	576.50 <sup>de</sup>	299.15 <sup>c-f</sup>	87.57 <sup>cd</sup>	277.35 <sup>a-d</sup>	211.58 <sup>f</sup>
	75M:25D	576.21 <sup>de</sup>	316.49 <sup>b-f</sup>	177.46 <sup>abc</sup>	259.72 <sup>a-f</sup>	139.03 <sup>j</sup>
	50M:50D	605.70 <sup>b</sup>	380.81 <sup>a-e</sup>	174.35 <sup>abc</sup>	224.89 <sup>a-g</sup>	206.46 <sup>fg</sup>
	25M:75D	547.63 <sup>e</sup>	386.04 <sup>a-d</sup>	168.60 <sup>a-d</sup>	161.59 <sup>c-g</sup>	217.44 <sup>ef</sup>
	0M:100D	577.84 <sup>de</sup>	408.87 <sup>abc</sup>	176.48 <sup>abc</sup>	168.97 <sup>b-g</sup>	232.40 <sup>d</sup>
8	100M:0D	547.81 <sup>e</sup>	203.73 <sup>f</sup>	77.78 <sup>d</sup>	344.09 <sup>a</sup>	125.94 <sup>k</sup>
	75M:25D	578.98 <sup>de</sup>	299.87 <sup>c-f</sup>	174.02 <sup>abc</sup>	279.11 <sup>abc</sup>	125.85 <sup>k</sup>
	50M:50D	546.25 <sup>e</sup>	339.17 <sup>a-e</sup>	180.14 <sup>ab</sup>	207.08 <sup>a-g</sup>	159.03 <sup>h</sup>
	25M:75D	604.45 <sup>b</sup>	391.13 <sup>a-d</sup>	209.01 <sup>a</sup>	213.33 <sup>a-g</sup>	182.12 <sup>gh</sup>
	0M:100D	471.09 <sup>f</sup>	361.63 <sup>a-e</sup>	180.49 <sup>ab</sup>	109.47 <sup>fg</sup>	181.14 <sup>gh</sup>
12	100M:0D	595.52 <sup>c</sup>	276.58 <sup>def</sup>	127.81 <sup>a-d</sup>	318.94 <sup>ab</sup>	148.77 <sup>i</sup>
	75M:25D	597.17 <sup>c</sup>	352.56 <sup>a-e</sup>	211.72 <sup>a</sup>	244.61 <sup>a-g</sup>	140.83 <sup>i</sup>
	50M:50D	614.85 <sup>ab</sup>	380.40 <sup>a-e</sup>	157.17 <sup>a-d</sup>	234.45 <sup>a-g</sup>	223.23 <sup>e</sup>
	25M:75D	596.68 <sup>c</sup>	390.71 <sup>a-d</sup>	184.12 <sup>ab</sup>	205.97 <sup>a-g</sup>	206.60 <sup>fg</sup>
	0M:100D	540.56 <sup>e</sup>	334.98 <sup>a-f</sup>	173.87 <sup>abc</sup>	205.58 <sup>a-g</sup>	161.12 <sup>h</sup>
SEM		2.55	8.32	4.69	8.98	3.15

ab, c, d, e, f, g, h, i, j, k means on the same column with different superscripts are significantly ( $p < 0.05$ ) different

M- Maize, D- Daniella, NDF- Neutral Detergent Fibre, ADF- Acid Detergent Fibre, ADL- Acid Detergent Lignin, HEM- Hemi-cellulose, CELL- Cellulose, SEM- Standard Error of Mean

higher Daniella inclusion ( $\geq 50\%$ ) significantly depressed RFV values. (Table 5).

#### **In-vitro gas production, methane production and dry matter digestibility**

The ensiling duration and proportion significantly influenced the volume of gas produced (Table 6). Pure maize silage stored for twelve weeks recorded the highest volume of gas produced for both 24 and 48 hours of incubation; recording 35.00 and 57.50 ml/200g DM, respectively. The un-ensiled 75M:25D recorded the least gas volume at 24 hours of incubation whereas at fourth week of ensiling, 25M:75D recorded the least volume of gas at 48 hours of incubation (14.00 ml/200g DM). The effect of ensiling duration and proportion was significant on DMD which value ranged from 33.95% of silage produced from 100% Daniella stored for twelve weeks to 61.40% of silage produced from 100% maize stored for eight weeks. SCFA ranged from 0.13  $\mu\text{mol}$  of un-ensiled 75% maize and 25% Daniella to 0.78  $\mu\text{mol}$  of pure maize silage produced at 12 weeks of ensiling. ME and OMD also followed similar trend after the order of SCFA. Methane ( $\text{CH}_4$ ) ranged from 2.00 ml/200mg DM of pure maize silage stored for two weeks to 17.33 ml/200mg DM of pure Daniella silage stored for twelve weeks (Table 6).

#### **DISCUSSION**

The physical characteristics of grain content, colour, odour, moistness indicated silages of excellent quality. Favorable scores across these traits confirmed production of potential silages. The colour ranking, influenced by ensiling plant proportions and duration, aligned with Bates (1998) and Usman *et al.* (2021), who described desirable silage as one that preserves its original colour, and with t'Mannetje (1999), who noted

that good silage maintains the pasture's colour. Oduguwa *et al.* (2007) also emphasized that the greenish colour reflects well-preserved silage. The grain content in pure maize and higher maize proportion silages agreed with Bates (1998) rankings. The pleasant odour, with no sign of putrefaction, was consistent with McDonald *et al.* (1995), Bates (1998) and Usman *et al.* (2021), who highlighted aroma as an indicator of good silage. Moistness also reflected proper preservation, falling within Bates' (1998) description of slightly moist silage with no free water, supporting the findings of Dele (2012) and Ukankwo and Igwe (2012).

The pH for good silage as in this study is acidic and average of 4.60 which showed more stability with pure maize as reported by Gordon (1989) and Kung and Shaver (2002) but as the quantity of Daniella increased the quality reduced hence increase in pH towards alkalinity. The pH of silage recorded in this study showed an increasing trend with increase in the inclusion level of Daniella and was in contrast with the report of Azim *et al.* (2000) that reported decrease in the pH of a silage with increase in the inclusion level of cowpea, but in line with the reports of Kato *et al.* (2004) and Ozturk *et al.* (2006) when Gliricida and Alfalfa were ensiled with maize at increasing graded level of inclusion, respectively. The increase in the pH of the silage in this study with increasing ensiling duration is in line with the study of Ali *et al.* (2015) which reported that the pH change might be as a result of the silage and atmospheric temperature. The general decline in the pH value across all treatments across the ensiling duration is in line with the findings of Ouamba *et al.* (2022) and Lai *et al.* (2023) reporting that the decline is a signal of a well conserved silage because of the acidification of the silage against spoilage microorgan-

**Table 5: Effect of ensiling duration and plant proportion on Fleigh point, TDN, RFV (%) of silage produced from Maize-Daniella mixtures.**

Duration (Weeks)	Plant Proportion (%)	Fleigh	TDN	RFV	DDM	DMI
2	100M:0D	92.99 <sup>ab</sup>	70.24 <sup>ab</sup>	128.13 <sup>a</sup>	69.35 <sup>ab</sup>	2.37
	75M:25D	82.57 <sup>ab</sup>	62.98 <sup>b-e</sup>	101.90 <sup>c</sup>	61.28 <sup>b-e</sup>	2.14
	50M:50D	75.99 <sup>ab</sup>	60.28 <sup>cde</sup>	86.52 <sup>e</sup>	58.27 <sup>cde</sup>	1.91
	25M:75D	70.74 <sup>ab</sup>	57.61 <sup>de</sup>	92.88 <sup>d</sup>	55.31 <sup>de</sup>	2.17
	0M:100D	80.64 <sup>ab</sup>	56.25 <sup>e</sup>	89.82 <sup>de</sup>	53.79 <sup>e</sup>	2.15
4	100M:0D	90.51 <sup>ab</sup>	66.86 <sup>a-d</sup>	106.39 <sup>b</sup>	65.59 <sup>a-d</sup>	2.09
	75M:25D	98.38 <sup>ab</sup>	65.65 <sup>a-d</sup>	106.55 <sup>b</sup>	64.25 <sup>a-d</sup>	2.12
	50M:50D	94.46 <sup>ab</sup>	61.14 <sup>b-e</sup>	93.56 <sup>d</sup>	59.23 <sup>b-e</sup>	2.03
	25M:75D	107.37 <sup>a</sup>	60.78 <sup>cde</sup>	100.58 <sup>c</sup>	58.83 <sup>cde</sup>	2.20
	0M:100D	73.43 <sup>ab</sup>	59.18 <sup>cde</sup>	92.40 <sup>d</sup>	64.25 <sup>a-d</sup>	2.09
8	100M:0D	76.68 <sup>ab</sup>	73.54 <sup>a</sup>	125.69 <sup>a</sup>	73.03 <sup>a</sup>	2.21
	75M:25D	80.33 <sup>ab</sup>	66.81 <sup>a-d</sup>	105.50 <sup>b</sup>	65.54 <sup>a-d</sup>	2.08
	50M:50D	79.64 <sup>ab</sup>	64.06 <sup>b-e</sup>	106.69 <sup>b</sup>	62.48 <sup>b-e</sup>	2.20
	25M:75D	74.41 <sup>ab</sup>	60.42 <sup>cde</sup>	90.88 <sup>de</sup>	58.43 <sup>cde</sup>	2.00
	0M:100D	57.76 <sup>b</sup>	62.49 <sup>b-e</sup>	121.50 <sup>ab</sup>	60.73 <sup>b-e</sup>	2.57
12	100M:0D	56.29 <sup>b</sup>	68.44 <sup>abc</sup>	106.68 <sup>b</sup>	67.35 <sup>abc</sup>	2.03
	75M:25D	60.09 <sup>b</sup>	63.12 <sup>b-e</sup>	96.17 <sup>cd</sup>	61.44 <sup>b-e</sup>	2.02
	50M:50D	65.88 <sup>ab</sup>	60.28 <sup>cde</sup>	90.35 <sup>de</sup>	59.27 <sup>b-e</sup>	1.96
	25M:75D	69.52 <sup>ab</sup>	60.45 <sup>cde</sup>	91.15 <sup>de</sup>	58.46 <sup>cde</sup>	2.01
	0M:100D	64.31 <sup>b</sup>	64.35 <sup>a-e</sup>	109.38 <sup>b</sup>	62.80 <sup>a-e</sup>	2.24
SEM		2.30	0.64	2.21	0.71	0.03

<sup>abcdef</sup> means on the same column with different superscripts are significantly ( $P < 0.05$ ) different, M- Maize, D- Daniella, DM- Dry matter, TDN- Total Digestible Nutrients, RFV- Relative Feed Value, DDM- Dry matter digestibility, DMI- Dry matter intake, SEM- Standard Error of Mean

**Table 6: Effects of ensiling duration and plant proportion on *in vitro* gas production (ml/200mg DM), dry matter digestibility, methane (ml/200mg DM) and post incubation calculations of silage produced from Maize-Daniella mixtures**

Dura- tion (weeks)	Plant propor- tion (%)	Gas 24	Gas 48	DMD (%)	SCFA ( $\mu$ mol)	ME (MJKg <sup>-1</sup> )	OMD (%)	CH <sub>4</sub>
0	100M:0D	20.00 <sup>bcde</sup>	20.00 <sup>fgh</sup>	48.28 <sup>cde</sup>	0.42 <sup>c</sup>	4.97 <sup>c</sup>	42.32 <sup>def</sup>	5.00 <sup>fg</sup>
	75M:25D	8.00 <sup>f</sup>	14.50 <sup>gh</sup>	47.53 <sup>c-f</sup>	0.13 <sup>f</sup>	3.36 <sup>f</sup>	35.39 <sup>g</sup>	8.67 <sup>cde</sup>
	50M:50D	26.00 <sup>a-d</sup>	40.00 <sup>bc</sup>	46.13 <sup>c-g</sup>	0.56 <sup>b</sup>	5.82 <sup>b</sup>	52.29 <sup>ab</sup>	15.00 <sup>ab</sup>
	25M:75D	15.00 <sup>ef</sup>	21.00 <sup>fgh</sup>	40.69 <sup>d-h</sup>	0.30 <sup>cde</sup>	4.34 <sup>cde</sup>	43.23 <sup>def</sup>	10.00 <sup>cd</sup>
	0M:100D	17.50 <sup>c-f</sup>	20.50 <sup>fgh</sup>	48.48 <sup>cd</sup>	0.36 <sup>cd</sup>	4.68 <sup>cd</sup>	45.40 <sup>dc</sup>	10.00 <sup>cd</sup>
2	100M:0D	14.00 <sup>ef</sup>	17.00 <sup>gh</sup>	61.40 <sup>a</sup>	0.27 <sup>c-f</sup>	4.16 <sup>cde</sup>	37.93 <sup>fg</sup>	2.00 <sup>h</sup>
	75M:25D	27.00 <sup>abc</sup>	38.50 <sup>bcd</sup>	51.65 <sup>bc</sup>	0.59 <sup>b</sup>	5.95 <sup>b</sup>	50.94 <sup>b</sup>	17.00 <sup>a</sup>
	50M:50D	15.00 <sup>ef</sup>	20.00 <sup>fgh</sup>	43.80 <sup>c-g</sup>	0.30 <sup>cde</sup>	4.33 <sup>cde</sup>	40.77 <sup>d-g</sup>	17.00 <sup>a</sup>
	25M:75D	18.00 <sup>c-f</sup>	25.00 <sup>e-h</sup>	39.33 <sup>fgh</sup>	0.37 <sup>cd</sup>	4.75 <sup>cd</sup>	44.16 <sup>de</sup>	11.00 <sup>c</sup>
	0M:100D	12.50 <sup>ef</sup>	22.50 <sup>e-h</sup>	45.66 <sup>c-g</sup>	0.24 <sup>def</sup>	4.01 <sup>def</sup>	39.43 <sup>efg</sup>	6.00 <sup>efg</sup>
4	100M:0D	28.50 <sup>ab</sup>	38.00 <sup>bcd</sup>	63.95 <sup>a</sup>	0.62 <sup>b</sup>	6.14 <sup>b</sup>	51.82 <sup>ab</sup>	11.00 <sup>c</sup>
	75M:25D	16.00 <sup>def</sup>	23.50 <sup>e-h</sup>	45.29 <sup>c-g</sup>	0.32 <sup>cde</sup>	4.46 <sup>cde</sup>	41.45 <sup>def</sup>	14.00 <sup>b</sup>
	50M:50D	18.00 <sup>c-f</sup>	23.00 <sup>e-h</sup>	40.82 <sup>d-h</sup>	0.37 <sup>cd</sup>	4.73 <sup>cd</sup>	43.04 <sup>def</sup>	7.00 <sup>ef</sup>
	25M:75D	10.50 <sup>ef</sup>	14.00 <sup>h</sup>	40.94 <sup>d-h</sup>	0.19 <sup>ef</sup>	3.73 <sup>ef</sup>	37.57 <sup>fg</sup>	2.33 <sup>h</sup>
	0M:100D	14.50 <sup>ef</sup>	18.50 <sup>fgh</sup>	38.69 <sup>gh</sup>	0.29 <sup>cde</sup>	4.28 <sup>cde</sup>	41.00 <sup>def</sup>	15.00 <sup>ab</sup>
8	100M:0D	30.00 <sup>ab</sup>	46.00 <sup>ab</sup>	60.59 <sup>a</sup>	0.66 <sup>ab</sup>	6.36 <sup>ab</sup>	52.95 <sup>ab</sup>	8.00 <sup>de</sup>
	75M:25D	17.50 <sup>c-f</sup>	30.00 <sup>c-f</sup>	59.03 <sup>ab</sup>	0.36 <sup>cd</sup>	4.68 <sup>cd</sup>	43.79 <sup>de</sup>	5.00 <sup>fg</sup>
	50M:50D	14.00 <sup>ef</sup>	17.00 <sup>gh</sup>	39.94 <sup>e-h</sup>	0.27 <sup>c-f</sup>	4.21 <sup>cde</sup>	39.88 <sup>d-g</sup>	7.00 <sup>ef</sup>
	25M:75D	14.50 <sup>ef</sup>	20.00 <sup>fgh</sup>	38.33 <sup>gh</sup>	0.29 <sup>cde</sup>	4.28 <sup>cde</sup>	40.43 <sup>d-g</sup>	17.00 <sup>a</sup>
	0M:100D	14.00 <sup>ef</sup>	20.50 <sup>fgh</sup>	38.31 <sup>gh</sup>	0.27 <sup>c-f</sup>	4.22 <sup>cde</sup>	40.16 <sup>d-g</sup>	3.67 <sup>gh</sup>
12	100M:0D	35.00 <sup>a</sup>	57.50 <sup>a</sup>	65.95 <sup>a</sup>	0.78 <sup>a</sup>	7.03 <sup>a</sup>	56.93 <sup>a</sup>	10.00 <sup>cd</sup>
	75M:25D	26.00 <sup>a-d</sup>	34.00 <sup>b-e</sup>	58.30 <sup>ab</sup>	0.56 <sup>b</sup>	5.79 <sup>b</sup>	49.28 <sup>bc</sup>	7.00 <sup>ef</sup>
	50M:50D	17.00 <sup>c-f</sup>	26.50 <sup>d-g</sup>	45.98 <sup>c-g</sup>	0.35 <sup>cd</sup>	4.62 <sup>cd</sup>	42.25 <sup>def</sup>	11.00 <sup>c</sup>
	25M:75D	17.00 <sup>c-f</sup>	24.00 <sup>e-h</sup>	39.42 <sup>fgh</sup>	0.35 <sup>cd</sup>	4.60 <sup>cd</sup>	41.78 <sup>def</sup>	7.00 <sup>ef</sup>
	0M:100D	16.00 <sup>def</sup>	23.00 <sup>e-h</sup>	33.95 <sup>h</sup>	0.32 <sup>cde</sup>	4.50 <sup>cde</sup>	41.55 <sup>def</sup>	17.33 <sup>a</sup>
SEM		0.81	1.26	1.13	0.02	0.11	0.68	0.56

abcdefgh means on the same column with different super scripts are significantly ( $p < 0.05$ ) different

M- Maize, D- Daniella, SEM- Standard Error of Mean, DMD- Dry matter digestibility, SCFA- Short Chain Fatty Acid, ME- Metabolizable Energy, OMD- Organic Matter Digestibility, CH<sub>4</sub> – Methane gas

isms.

Silage that has been properly fermented (particularly greater production of lactic acid) exhibits low aerobic stability after silo opening (Filyal, 2003) because the lactic *per se* has no antifungal properties (Moon, 1983). The lactic acid content of silage recorded decreased with increase in the inclusion level of Daniella and is in contrast with the report of Azim *et al.* (2000) that reported increase in the lactic acid of silage with increase in the inclusion level of cowpea.

Presence of lactic acid in silage shows that the silage is of good quality and thus usually responsible for most of the drop in silage pH (McDonald *et al.*, 1991). The low pH in this study together with elevated levels of lactic acid showed that the herbage contained sufficient amounts of soluble carbohydrate to effectively preserve the silage, which is in line with the report of Kato *et al.* (2004) when maize was ensiled with browse plants. An increase in silage pH following mixing maize with browse legumes observed in this study was in agreement with that reported by Titterton and Maasdorp (1997). The pH values of the silages with Daniella with 50 - 75 % inclusion reported in this study falls within the range 4.50 – 5.50 reported and classified as good silage by Meneses *et al.* (2007) whereas the 100% Daniella silage throughout the whole ensiling duration had pH > 5.5 are classified as poor silages which is considered clostridial loaded leading to high values of butyric acid content as observed in the result. This may also be due to the level of dry matter, according to Kung, (2010) who stated that the common reasons for legume silages having a higher pH include ensiling at 30 % dry matter (DM) which causes a clostridia fermentation, and ensiling at > 45- 50 % DM,

which restricts fermentation.

The higher lactic acid content in this study with lesser inclusion of Daniella showed that maize is richer in sugar content that is easily converted and this also reflected in the decline in the pH values and as the ensiling duration advanced the acetic acid increased and the lactic acid decline according to the reports of Oude Elferink *et al.* (2001) and Muck *et al.* (2018). Majority of the silage with 75% inclusion of Daniella had butyric acid < 5.5 g/kg DM and are referred to as silage well preserved. The acetic acid concentration of most silage, especially those with < 75% inclusion of Daniella in this study are within the range classified as normal for grass silage (Kung Jr *et al.*, 2018). Kung and Shaver (2002) reported that high acetic acid concentration could suppress dry matter intake when fed to ruminants especially for silage with inclusion level of  $\geq 75\%$  Daniella.

The crude protein content of feed has been given special attention in feed evaluation. The crude protein contents of *Z. mays* and *D. oliveri* mixtures in different proportions showed substantial variations. In this study, the crude protein content of pure ensiled *D. oliveri* increased as the length of ensiling increased which is in agreement with the report of Keady and Murphy (1998). It was also observed in this study that, where *D. oliveri* was mixed with *Z. mays*, crude protein content increased compared to pure ensiled maize. There was an increase in the crude protein content of the silage with increase in the Daniella inclusion, justifying inclusion of browse plants in ruminant feed to help supplement protein requirement. This is in line with the report of Kato *et al.* (2004) when maize was ensiled with Leuceana, Gliricidia and Calliandra at different levels. This also corroborates the report of Simons and Stew-

art (1994) that inclusion of legume in silage will linearly increase the crude protein content of tropical grass silage. This shows that low quality grasses can be significantly improved when mixed with browse plants. The CP content of pure ensiled maize recorded in this study that was similar to the CP value reported by Massafera *et al.*(2015) of 100 % Aruana grass but higher than the CP value reported by Phiri *et al.*(2007) for Maize silage. 75 % maize silage had the highest CP content at eight weeks of ensiling in this study in which the value is similar to the report of Massafera *et al.* (2015) for 75 % Aruana grass replaced by *Gliricidia* which also had the highest crude protein content. Variations in CP values have been ascribed to soil type, age of the plant, season and geographical location (Norton, 1994; Nworgu and Ajayi, 2005). The increased crude protein content of the silage in this study with increasing ensiling period is in line with the report of Man and Wiktorsson (2003). The CP of the silages in this study was higher than the critical value of 70 g/kg recommended for small ruminants (NRC, 1981).

The ash contents of un-ensiled and ensiled maize- *Daniella* mixtures recorded in this study were higher than the value between 57 g/kg DM and 62 g/ kg DM, reported for pure ensiled maize and maize+ browse plants reported by Phiri *et al.* (2007). The value obtained from the interaction of plant proportion and ensiling duration for the ash contents of pure ensiled maize at twelve weeks of storage agreed with the value reported by Ukanwoko and Igwe (2012) for *Panicum maximum*. The ash content values recorded in this study were within the range reported by Topps and Oliver (1993) for maize mixed with browse plants.

The ether extract (EE) values obtained in

this study for pure un-ensiled *D. oliveri* compares favorably with the value reported by Obua *et al.* (2012) for *L. leucocephala*. The value reported by Obua *et al.* (2012) is higher than the value of fresh un-ensiled pure maize in this present study. Crude fibre content value obtained in this study for fresh un-ensiled maize was similar to the value reported by Obua *et al.* (2012) and within the range for wheat reported by Xie *et al.* (2012). The nitrogen free extract (NFE) content of fresh 100 % *D. oliveri* was similar to the value reported by Obua *et al.* (2012). The nitrogen free extract obtained in this study was within the range reported by Xie *et al.* (2012).

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 in the silages irrespective of the factor under consideration in the present study was below suggested maximum limit above which intake of tropical feeds by ruminants would be limited (Van Soest *et al.*, 1991). Inclusion level of *Daniella* in the silage also reduced the NDF content of the silages which was in agreement with the report of Kato *et al.* (2004) when maize was ensiled with *Leuceana* at different inclusion levels. The ensiled forage also had a lower NDF content than the un-ensiled material. The ADF content of pure ensiled maize under this study was within the range and lower than the value obtained by Ukanwoko and Igwe (2012) for ensiled *P. purpureum*. The ADF content of 75 % maize silage in this study was similar to the report of Ukanwoko and Igwe (2012) for *P. maximum* and *P. purpureum* mixed with *C. pubescens*, respectively. Also, Kato *et al.* (2004) reported 41.41 % ADF content for pure ensiled *Z. mays* which was higher than the value of pure ensiled maize obtained in this present study. At four weeks of ensiling, equal proportions of

maize- Daniella silage in this study had a value similar to the value of 40 % level of *G. sepium* mixed with maize reported by Kato *et al.* (2004). The ADF content value of silage stored for different duration in this study is within the maximum acceptable and desirable levels of 350 g/kg DM and 380 g/kg DM (Mahanna, 1994). The value of pure ensiled maize ADF content obtained in this study was similar to the value reported by Ozturk *et al.* (2006). The ADL content obtained in this study was higher than the ADL content at different level of browse inclusion with maize reported by Kato *et al.* (2004) but similar to the value of Calliandra mixed with maize (Kato *et al.*, 2013). Also, fresh un-ensiled *D. oliveri* ADL content under this study was higher than the ADL content reported by Ogunbosoye *et al.* (2015). Cellulose is a principal constituent of the cell wall of plants. It is most abundant in the more fibrous feeds. It is generally low in digestibility and may reduce the digestibility of other nutrients. The cellulose and hemi-cellulose content of un-ensiled Daniella obtained in this study was similar to the values reported by Njidda and Ikhima (2010) for *Ficus thonningii*. The hemi-cellulose content of fresh un-ensiled maize and Daniella was higher than the value reported by Ridwan *et al.* (2015). 75 % of maize silage had a cellulose content which is in agreement with the report of Ridwan *et al.* (2015).

The fleigh point of silage in this present study was within the range of score as described by Kilic (1986). The fleigh score reported for the silage at different proportion as influenced by ensiling duration was within the range of score regarded as very good quality silage and as good quality silage (Kilic, 1986). The fleigh score of maize silage stored for four weeks is in agreement

with the report of Ozturk *et al.* (2006) when maize was ensiled with Alfalfa.

The *in vitro* gas production technique has the potential to reflect the *in vivo* digestibility of feeds to ruminant animals. Although, gas production is regarded as nutritionally wasteful (Mauricio *et al.*, 1999) especially the methane portion, it however provides a useful basis from which metabolizable energy; organic matter digestibility and short chain fatty acid can be predicted (Babayemi *et al.*, 2006). Results obtained in this present study for the gas production of fresh un-ensiled Maize - Daniella mixture stored at different duration had the highest gas volume although at the 48 hour of incubation. This might be because of fermentation of protein as it causes the production of ammonia which inhibits the CO<sub>2</sub> release from the carbonate buffer (Cone and Valk, 1997).

Digestibility has been reported to be synonymous to *in vitro* gas production (Fievez *et al.*, 2005) so that the higher the gas production, the higher the digestibility. The DMD value of corn silage reported by Jalc *et al.* (2009) was above the value reported in this study. SCFA is one of the end products of rumen fermentation, and is a reflection of energy availability in a feed stuff (Ajayi and Babayemi, 2008). The metabolizable energy (ME) and organic matter digestibility (OMD) values obtained in this study were below the value reported by De Boever *et al.* (1997) and Ozturk *et al.* (2006). The value of ME under this study of fresh un-ensiled maize-Daniella mixtures fell within the range reported by Tona *et al.* (2014). Methane production is energy loss to ruminants and also contributes to global warming (Babayemi and Bamikole, 2006). Fresh un-ensiled maize had low volume of methane gas in this study which was above the value reported by Ajayi *et al.* (2013). Pure ensiled *D. oliveri* had the highest

volume of methane gas production as observed in this study which agrees with the statement of Yusuf *et al.* (2013) who reported that high methane production has a negative effect on ruminants as it implies an energy loss and when it accumulates in the rumen, this could result in bloat.

## CONCLUSION

Ensiling maize with *Daniella oliveri* significantly influenced fermentation characteristics, nutrient composition, and fibre fractions. Pure maize silage exhibited superior fermentation quality, higher digestibility, and lower butyric acid content, making it the most stable option. Inclusion of *D. oliveri* improved crude protein and ether extract levels; however, higher proportions of *D. oliveri* more than 50% elevated pH and compromised fermentation quality. Moderate inclusion level of 25% *D. oliveri* maintained good silage quality while providing balanced nutritional benefits. Maize-dominated silages supported greater energy efficiency, whereas sole *D. oliveri* silage resulted in higher methane emissions. Overall, maize–*Daniella* mixtures represent a sustainable strategy to address dry-season feed shortages in tropical livestock production systems.

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