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Nutritive value and forage quality indices of *Calopogonium mucunoides- Zea mays* stover mixtures for ruminant production

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***Target Audience**: Forage scientists; Animal nutritionists; Livestock farmers; Researchers; Students*

Abstract

Forages, either as natural or sown pastures are a major feed source for ruminants but are limited in terms of quality. The nutritive value of Calopogonium - maize stover mixtures was assessed for proximate, fibre fraction, protein fractions, forage quality indices and in vitro gas characteristics. Two maize stover (Oba super 2 and Suwan 1) and an herbaceous forage legume (Calopogonium mucunoides) were arranged into six different proportions (75:25, 50:50 and 25:75 % DM basis) making up to nine treatments in a completely randomized design (CRD) with five replicates. The result revealed that Calopogonium had highest significant (p<0.05) CP (194.70 g/kg DM), followed by similar (p>0.05) values (162.70 and 158.80 g/kg DM) for C75:O25 and C75:S25, respectively while the least (p<0.05) was recorded for Suwan 1 (51.01g/kg). Sole Suwan 1 maize stover had the highest (P<0.05) NDF (615.43 g/kg DM) while the least values (453.34, 467.26 and 468.18 g/kg DM) were recorded similar for Calopogonium, C75:O25 and C75:S25, respectively. Highest (p<0.05) DMI was similar for Calopogonium, C75:O25 and C75:S25 with least value recorded for Suwan 1. Highest (p<0.05) CP fraction B1, B2, B3 and in vitro dry matter digestibility (IVDMD) as well as Utilizable crude protein (uCP) were observed for Calopogonium while Suwan 1 recorded their least contents. Therefore, either mixture of Calopogonium and Oba super 2 or Suwan 1 at 75:25 will improve the intake and digestibility of forage legume and maize stover. Hence, legumes can improve the digestibility of maize stover and might improve the performance of ruminant animals.

***Keywords**: digestibility, forage, fibre, nutritive quality, palatability*

Description of Problem

The population of Nigeria has been projected to hit 440 million by the year 2050 and this might make her the fourth most populous country in the world (1). This increase in population is considered a threat to food security resulting in Nigeria been tagged a food insecure country (2). Food Agriculture Organization recommendation of daily protein consumption is 60g per person in the developing countries and 50% is also expected to be of animal protein source but the average animal protein source for Nigeria is 10g as against 55g animal protein intake in developed countries (3, 4). Going by the above, for Nigerians to meet up with the 30 g per person daily animal protein intake, the major source of animal protein which are the ruminants must be given attention especially their nutrient requirements.

Forages have been known to be the major source of feed for this class of livestock (ruminant) either natural or sown pastures but are also limited by the effect of season both in quantity and quality especially during the dry season. To combat the low productivity of this class of livestock during the dry season, farmers result into the use of agricultural waste such as maize stover which also has their limitations as well because of their low in protein and fibrous nature. The supplementation of these agricultural by-products with forage legumes either in their fresh forms or conserved have gained attention over some decades (5, 6 and 7) and have been encouraged. Calopogonium is vigorous, hairy annual or short-lived perennial trailing leguminous forage with massive foliage (8) and mostly found in uncultivated and abandoned lands (9) and which are barely grazed by ruminants during the wet/rainy season because of its hairy nature (10) but it is high in protein (8). The glabrous nature of the leaves and stems of Calopogonium has been noted for its low or lack of palatability (11) especially the fresh herbage but is well acceptable by animals when wilted (12). Calopogonium palatability improves with maturity (11). The aggressive nature of Calopogonium development and allelopathy towards the seeds of other species made it become a localized in humid-tropical environments which made it common in southwest Nigeria. The aim of this study was to investigate the inclusion of Calopogonium at different proportions with maize stover as a quality feed resource for ruminants.

Materials and Methods

Experiment site

The study was investigated at the Department of Pasture and Range Management, Federal University of Agriculture, Abeokuta, (FUNAAB), this area lies at 7◦13'55◦ North and 3◦26'11◦ east, at an elevation of 146 m above sea level. The rainfall pattern of Abeokuta is bimodal with its peaks in July and September and associated two to three weeks break in August. In the rainy season (April – September), the temperatures with daytime values of 28 to 30 °C and 30–34 °C during the dry season (October – March) with the lowest night temperature of around 24 °C during the harmattan period between December and February. The Relative humidity is ranged between 63 and 96 % and 55–84 % during the rainy and dry seasons, respectively. (Source: Agromet Dept., FUNAAB).

Sources of Forage materials

The maize (Oba super 2 and Suwan 1) stovers were sourced from a portion of an experiment that was planted late April and harvested in July 2017 with fertilizer application rate of 120 kg N/ha (NPK 15:15:15). Two seeds of each maize variety were planted per hole at a spacing of 75cm by 25cm. The Calopogonium was sourced from the wild within six hours after harvesting of the maize stovers.

Experimental design

The experiment was arranged in a completely randomized design with five replications. Two maize stover (Oba super 2 and Suwan 1) and an herbaceous forage legume (*Calopogonium mucunoides*) were arranged into six different proportions (75:25, 50:50 and 25:75 % DM basis) of legume with the two maize stover making nine (9) treatments. The nine treatment combinations are given as: *C. mucunoides* (100%) = [C100] ; *Z. mays* (Oba super 2) (100%) = [O100]; *Z. mays* (Suwan 1) (100%) = [S100]; *C. mucunoides* (75%) + *Z. mays* (Oba super 2) (25%) = [C75:O25]; *C. mucunoides* (50%) + *Z. mays* (Oba super 2)

(50%) = [C50:O50; *C. mucunoides* (25%) + *Z. mays* (Oba super 2) (75%) = [C25:O75]; *C. mucunoides* (75%) + *Z. mays* (Suwan 1) (25%) = [C75:S25]; *C. mucunoides* (50%) + *Z. mays* (Suwan 1) (50%) = [C50:S50] and *C. mucunoides* (25%) + *Z. mays* (Suwan 1) (75%) = [C25:S75].

Chemical Analysis

Proximate and fibre analysis

The samples were analyzed for dry matter (DM), crude protein (CP) (N x 6.25), ash and ether extract (EE) according to AOAC (13). Total carbohydrate (TC) = DM-CP-EE-Ash (g/kg DM). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) and acid detergent lignin were determined (14), cellulose was taken as the difference between ADF and ADL while hemicellulose was calculated as the difference between NDF and ADF.

Protein fractions

Fractionation of CP in forage mixtures was conducted according to the CNCPS (15). The CP is partitioned into three fractions: fraction A is nonprotein nitrogen (NPN × 6.25); fraction B is true protein, and fraction C is unavailable protein. Fraction B is further devided into three subfractions (B_1, B_2 and B_3) that are believed to have different rates of ruminal degradation. Fraction C is the protein that is insoluble in acid detergent (acid detergent-insoluble protein, ADICP).

Utilizable crude protein (uCP) estimation

The uCP was estimated according to (16)

$$uCP = (9.95 \pm 2.73)A + (2.92 \pm 1.36)B1 + (7.24 \pm 0.86)B2 + (8.20 \pm 3.33)B3 + (17.67 \pm 3.79)C + (63.26 \pm 18.02)$$

Forage quality indices (FQI)

The FQI were estimated according to (17)

Total digestible nutrient, TDN = 87.84 – (ADF% × 0.7)

Dry matter digestibility, DDM (% DM) = 88.9 – 0.779 × ADF (% DM)

Dry matter intake, DMI (% Body weight) = 120/NDF (% DM)

Relative feed value, RFV = (DDM × DMI)/1.29

Relative forage quality, RFQ = (DMI x TDN)/1.23

In vitro gas production, methane and dry matter digestibility

The *in vitro* gas production of the samples was determined using the procedure of (18). At 72 h, the IVDMD was determined according to the report of (19). Determination of methane production was done by introducing 4 ml of sodium hydroxide (NaOH, 10M) was introduced to estimate the methane production at post incubation (20).

Statistical analysis

The data generated were subjected to general linear model using (21) statistical software and differences in means separated using turkey HSD Test at (P<0.05) level of probability.

Results

The proximate composition of the maize stovers, Calopogonium and their different mixtures were significantly (P<0.05) different except for the dry matter content. The CP ranged between 51.00 to 194.70 g/kg DM as the Suwan 1 maze stover and Calopogonium recorded the lowest and highest (p<0.05) CP content, respectively. The mixtures irrespective of their different proportions had higher CP than the sole Oba super 2 and Suwan 1 maize stovers. Calopogonium recorded the highest significant (p<0.05) total ash content (91.90

g/kg DM) whereas the least significant (P<0.05) content of ash was recorded for sole Oba super 2 maize stover. The ether extract content was observed to follow similar pattern with that of the ash. The total carbohydrate favoured the sole maize stovers with Oba super 2 maize stover observed to have the highest significant (p<0.05) value and Calopogonium having the least (p<0.05) value (Table 1).

Table 1: **Effect of forage proportions on the proximate composition (g/kg DM) of Calopogonium - maize stover mixtures**

Forage Mixtures	DM	CP	Ash	EE	TC
C100	928.10	194.70^{a}	91.90^{a}	55.70^{a}	657.71^{g}
O100	957.00	66.60^{f}	32.09^{g}	21.24^{g}	880.22^{a}
S100	946.94	51.01^{g}	43.50^{f}	41.33^{e}	864.21^{b}
C75:O25	935.10	162.70^{b}	84.91^{b}	47.11^{cd}	705.30^{f}
C50:O50	946.00	130.70^{c}	62.03^{d}	38.53^{e}	768.83^{e}
C25:O75	937.47	98.60^{d}	44.91^{f}	29.82^{f}	826.74^{c}
C75:S25	948.10	158.80^{b}	79.82^{b}	52.09^{b}	709.31^{f}
C50:S50	955.10	122.91^{c}	67.70^{c}	48.53^{c}	760.90^{e}
C25:S75	944.40	86.90^{e}	55.62^{e}	44.90^{d}	812.60^{d}
SEM	5.02	6.80	2.92	1.57	10.84

$^{a,b\ c..g}$: Means in each column with different superscripts are significant (p<0.05)

C: Calopogonium; O: Oba super 2; S: Suwan 1; DM: Dry matter content; CP: Crude protein; EE: Ether extract; TC: Total carbohydrate and SEM: Standard error of means

The fibre fractions (g/kg DM) of Calopogonium - maize stover mixtures are as presented in Table 2. The sole Suwan 1 maize stover had the highest (p<0.05) NDF fraction and the least (p<0.05) value was recorded for sole Calopogonium. The ADF ranged from 281.27 to 371.97 g/kg DM with sole Calopogonium and sole Suwan 1 stover had the least (p<0.05) and highest (p<0.05) ADF values, respectively.

Table 2: **Effect of forage proportions on the fibre fractions (g/kg DM) of Calopogonium - maize stover mixtures**

Forage Mixtures	NDF	ADF	ADL	Hemicellulose	Cellulose
C100	453.34^{d}	281.27^{d}	41.08^{ef}	172.07^{c}	240.19^{e}
O100	604.78^{a}	337.44^{b}	53.63^{c}	267.34^{a}	283.80^{b}
S100	615.43^{a}	371.97^{a}	62.25^{b}	243.46^{ab}	309.72^{a}
C75:O25	467.26^{cd}	295.28^{cd}	38.37^{f}	171.98^{c}	256.91^{c}
C50:O50	522.64^{b}	300.91^{cd}	44.74^{de}	221.73^{b}	256.17^{c}
C25:O75	591.63^{a}	316.35^{bc}	61.15^{b}	275.27^{a}	255.20^{c}
C75:S25	468.18^{cd}	296.21^{cd}	40.36^{f}	219.91^{b}	255.85^{c}
C50:S50	505.83^{bc}	285.93^{d}	48.73^{d}	171.96^{c}	237.20^{e}
C25:S75	592.08^{a}	316.74^{bc}	67.14^{a}	275.35^{a}	249.60^{d}
SEM	9.74	4.34	1.54	6.63	3.53

$^{a,b,c..f}$: Means in each column with different superscripts are significant (p<0.05)

C: Calopogonium; O: Oba super 2; S: Suwan 1; NDF: Neutral detergent fibre; ADF: Acid detergent fibre; ADL: Acid detergent lignin and SEM: Standard error of means

Table 3 shows the effect of forage proportions on the protein fractions (g/kg DM) of Calopogonium - maize stover mixtures. There was a significant difference in the protein fractions across the experimental treatments. The CP fraction A ranged from 5.48 to 66.88 g/kg DM as the sole Suwan 1 maize stover was observed to have recorded the least significant ($p<0.05$) value and sole Calopogonium the highest significant ($p<0.05$) value. The CP fraction B1, B2 and B3 followed similar pattern for the CP fraction A. For CP fraction C, the mixtures with 75% maize stovers recorded the highest significant ($p<0.05$) values.

Table 3: Effect of forage proportions on the protein fractions (g/kg DM) of Calopogonium - maize stover mixtures

Forage Mixtures	A	B1	B2	B3	C	uCP
C100	66.88^{a}	6.98^{a}	63.72^{a}	68.21^{a}	15.50^{b}	260.14^{a}
O100	10.93^{g}	4.42^{f}	28.01^{e}	30.14^{f}	12.60^{d}	141.55^{f}
S100	5.48^{h}	4.09^{g}	22.10^{f}	23.71^{g}	10.59^{e}	123.15^{g}
C75:O25	56.11^{b}	6.43^{b}	56.40^{b}	56.55^{b}	14.40^{c}	233.01^{b}
C50:O50	39.13^{c}	5.94^{c}	46.61^{c}	48.69^{c}	15.14^{bc}	203.39^{c}
C25:O75	20.22^{e}	5.06^{d}	34.89^{d}	41.40^{d}	16.93^{a}	172.61^{d}
C75:S25	53.92^{b}	6.26^{b}	56.21^{b}	56.13^{b}	14.81^{bc}	229.97^{b}
C50:S50	34.75^{d}	5.58^{c}	46.07^{c}	45.51^{c}	15.74^{b}	197.04^{c}
C25:S75	14.95^{f}	4.82^{e}	30.92^{de}	36.41^{e}	16.99^{a}	160.66^{e}
SEM	3.14	0.14	2.09	2.01	0.30	6.49

$^{a,b,c…h}$: Means in each column with different superscripts are significant ($p<0.05$)

C: Calopogonium; O: Oba super 2; S: Suwan 1; A: crude protein soluble in the borate-phosphate buffer and tungstic acid solution; B1: true protein soluble in buffer solution and precipitated by the tungstic solution; B2: true protein insoluble in buffer solution but soluble in the neutral-detergent solution; B3: true protein soluble in acid-detergent solution but insoluble in neutral-detergent solution; and C: true protein insoluble in the acid-detergent solution and SEM: Standard error of means.

The effect of forage proportions on the forage quality indices of Calopogonium - maize stover mixtures shows in Table 4. The total digestible nutrient (TDN) of sole Calopogonium was the highest though not significantly ($p>0.05$) different when in mixture with Suwan 1 maize stover at 50% (C50:S50) but the two maize stovers had lesser values when compared with Calopogonium and its mixtures. Digestible dry matter (DDM) varied significantly ($p<0.05$) with the Calopogonium having the highest value and sole Suwan 1 maize stover with the least value. Calopogonium and its mixtures at 75% with both stovers recorded significantly ($P<0.05$) higher dry matter intake (DMI) when compared to other mixtures and sole stovers (Table 4). There were observed significant ($P<0.05$) variation in the relative feed value (RFV) and relative feed quality (RFQ). The highest values for RFV and RFQ were recorded for sole Calopogonium.

Table 4: **Effect of forage proportions on the forage quality indices of Calopogonium - maize stover mixtures**

Forage Mixtures	TDN % DM	DDM % DM	DMI % BW	RFV	RFQ
C100	63.76[a]	66.89[a]	2.65[a]	137.46[a]	137.42[a]
O100	59.09[c]	62.51[c]	1.99[c]	96.31[d]	95.48[d]
S100	56.23[d]	59.82[d]	1.95[c]	90.60[d]	89.31[d]
C75:O25	62.59[ab]	65.80[ab]	2.57[a]	131.19[ab]	130.89[ab]
C50:O50	62.12[ab]	65.36[b]	2.30[b]	116.50[c]	116.13[c]
C25:O75	60.84[bc]	64.16[bc]	2.03[c]	101.02[d]	100.47[d]
C75:S25	62.51[ab]	65.72[ab]	2.57[a]	130.81[ab]	130.49[ab]
C50:S50	63.37[a]	66.53[a]	2.37[b]	122.49[bc]	122.36[bc]
C25:S75	60.81[bc]	64.13[bc]	2.03[c]	100.86[d]	100.31[d]
SEM	0.36	0.34	0.04	2.58	2.63

[a,b,c,d]: Means in each column with different superscripts are significant ($p<0.05$)

C: Calopogonium; O: Oba super 2; S: Suwan 1; DDM: Digestible dry matter; DMI: Dry matter intake; RFV: Relative feed value; RFQ: Relative forage quality and SEM: Standard error of means

Figure 1 shows the effect of forage proportions on the methane production (mL/200mg DM) of Calopogonium - maize stover mixtures. The total gas production was significantly ($p<0.05$) affected by the forage proportion. The sole Calopogonium producing the highest significant ($p<0.05$) gas volume and sole Suwan 1 maize stover had the least ($p<0.05$) gas volume. Methane production was suppressed by the inclusion of Calopogonium in increasing order. The IVDMD followed similar pattern with trend of the gas production.

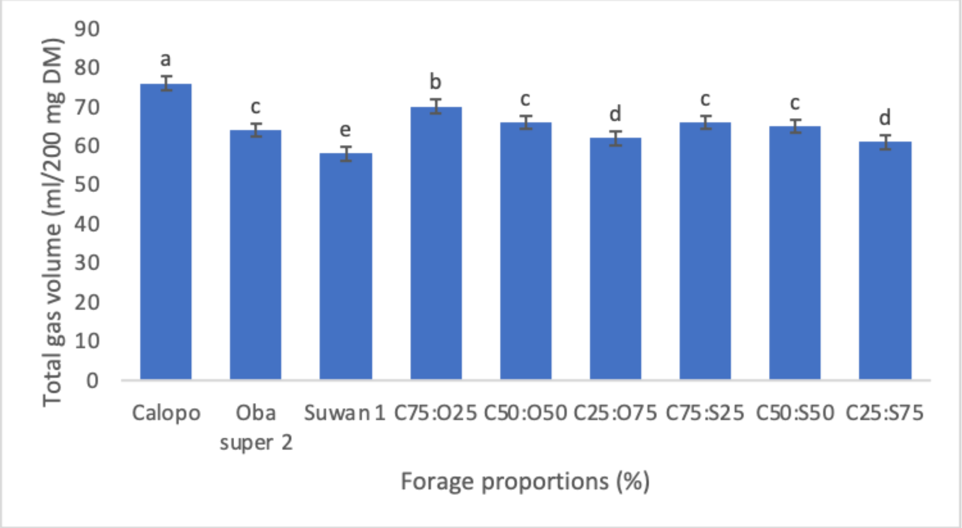

Figure 1: Effect of forage proportions on the total gas production (mL/200mg DM) of Calopogonium - maize stover mixtures

[a,b,c,d]: Means with different superscripts are significant ($p<0.05$)

C: Calopogonium; O: Oba super 2; S: Suwan 1

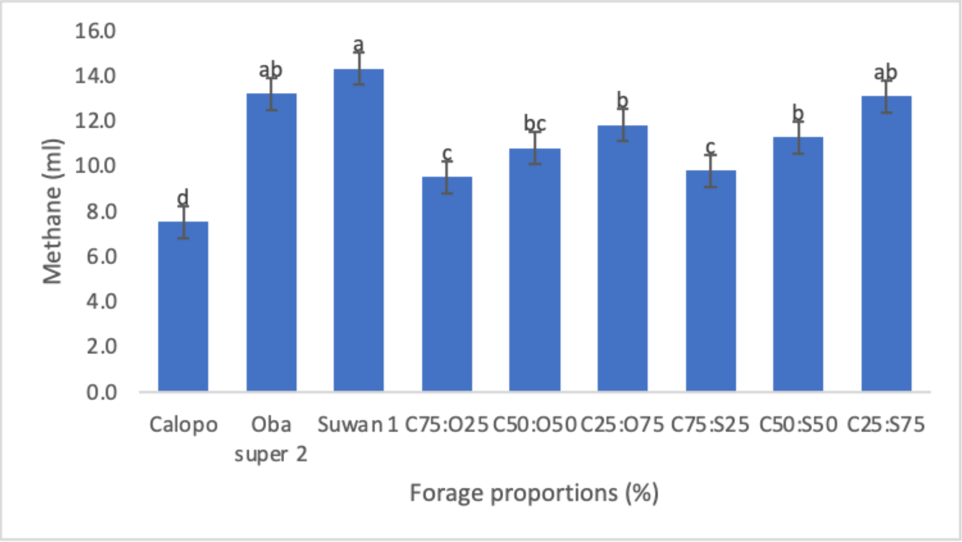

Figure 2: Effect of forage proportions on the methane production (mL/200mg DM) of Calopogonium - maize stover mixtures

[a,b,c,d]: Means with different superscripts are significant ($p<0.05$)

C: Calopogonium; O: Oba super 2; S: Suwan 1

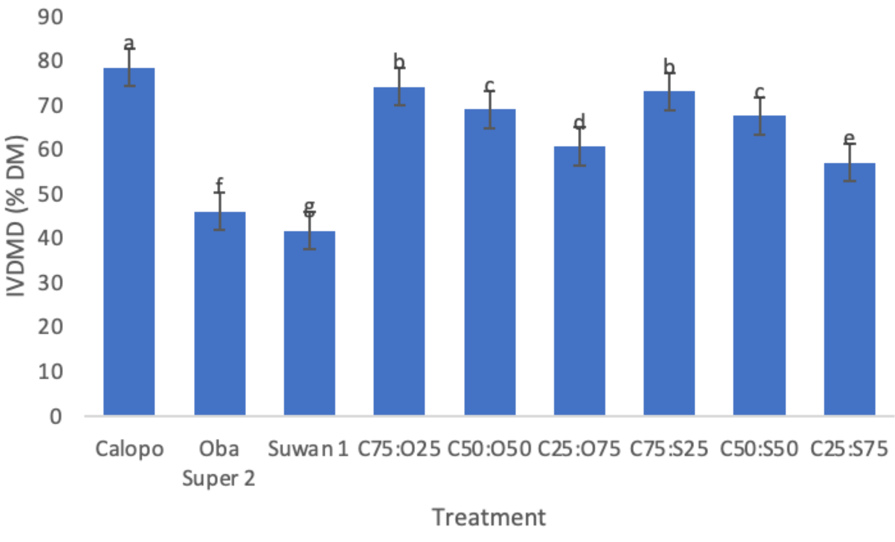

Figure 3: Effect of forage proportions on the *in vitro* dry matter digestibility (% DM) of Calopogonium - maize stover mixtures

[a,b,c..g]: Means with different superscripts are significant ($p<0.05$)

C: Calopogonium; O: Oba super 2; S: Suwan 1

Discussion

The CP content of the stovers was higher than those reported by (22,23 and 24) but the CP of Suwan 1 maize stover was lower than that reported by (25). The higher CP of the two stovers understudy might be as a result of the time of sourcing the stovers. The stovers were sourced immediately after the cobs were harvested at the dough stage because the cobs were harvested for consumption (26). The CP of the two maize stovers is within the range (40 – 90 g/kg DM) reported by (27) as common CP for maize stovers. The CP of the Calopogonium and its mixtures as well as the sole Oba Super 2 stover were higher than 65 g/kg DM which was considered the critical limit below which intake and rumen microbial activities will be adversely affected (28). The CP of Oba Super 2 maize stover fell within the range (65-80 g/kg DM) prescribed by (29) as minimum for optimum performance for tropical ruminants

The range values of the NDF (453.34 – 592.08 g/kg DM) of the legume and its mixtures with the two maize stovers as observed in this study are below the range of 600-650 g/kg suggested as the critical limit above which efficiency of utilization of tropical forages by ruminants would be impaired (30, 31) whereas the two maize stover fell within the critical limit above which utilization will be impaired. The moderate fibre level of the two maize stovers as well as the legume and its mixtures is a evidence that stovers can be a good feed resource if not allowed to lignify (32). The moderate fibre levels in this study will be of help in facilitating the colonization of ingesta by rumen microorganism which in turn might induce higher fermentation rates, hence improving digestibility, intake and animal performance. The lower NDF and ADF contents of Calopogonium when compared with the stovers in this study confirmed the report of (33) that herbaceous legumes are generally lower in fibre composition than members of the grass family. The mixtures in this study reduced the fibre content of the stovers which if fed will favour intake and digestibility than when it is sole stover. From this study, with the value of ADF (453.34 g/kg DM) for Calopogonium, it shows that it will be more digestible than others and that the mixtures will be more digestible than the sole stovers, because ADF is inversely related to digestibility (34).

The CP Fraction A of Calopogonium (66.88 g/kg DM) as observed in this study fell within the range (24 – 75 g/kg DM) reported for tropical forage legumes (35) and higher than that reported (57.4 g/kg DM) for same legume in the dry season. The difference might be because of the season in which the studies were carried out. The CP Fraction A of sole Oba super 2 was doubled that of sole Suwan 1 as this could be as a result of the quality of true protein. There was a significant decrease in the CP Fraction A of the mixtures with increase in the proportion of the maize stovers. The CP Fraction B1 of the sole Calopogonium (6.98 g/kg DM) was within the range reported (0.2 – 17.2 g/kg DM) for tropical forage legumes (35) and the CP Fraction B1 of the sole maize fell within the range (0.3 – 9.2 g/kg DM) reported by (36) for tropical grasses. The undegraded forage protein and microbial protein synthesis are a determinant of the value of uCP (37). Sole Calopogonium had higher uCP than the sole maize stovers and the different mixtures which is a reflection of the CP and as well as the soluble portion of the protein fraction and non-protein nitrogen.

The total digestible nutrients (TDN) of sole Oba super 2 maize stover (59.09 % DM) was slightly higher than that reported (57.9

% DM) by (38) whereas that of sole Suwan 1 was slightly lower than that reported by the authors above. The variation of the TDN of sole Oba super 2 and Suwan 1 could be attributed to the fibre composition of the two stovers. The TDN of the maize stovers (56.23 – 59.09 % DM) and legume (63.76 % DM) as well as their mixtures (60.81 – 63.37 % DM) are within the range of 55 - 65 % reported by (39) as high-quality forage.

The digestible dry matter (DDM) values also grouped the sole Calopogonium and mixtures at Calopogonium: maize stover (75:25) in the prime dairy class, whereas sole Suwan and Oba super 2 stovers were grouped into “good beef” and “good dairy” class, respectively as (40) reported a forage to be ranked as in the class of “prime dairy” if the DDM is greater than 65 %DM and for the DMI, only the sole Calopogonium fell in the good dairy (2.6 – 3.0 % BW) class and the sole maize stovers were classified as “poor quality” if the DMI is less than 2.0 % BW (40), this implied that the sole maize stovers will not be appropriate as sole feedstuff for ruminants and therefore, whenever maize stovers are fed to ruminants, supplementation should be encouraged.

The relative feed value (RFV) of the sole Calopogonium and mixtures at Calopogonium: maize stover (75:25) were the highest, which fell within the range (125 – 151 % BW) of the class of good dairy and the sole maize stovers were found to be in the class of maintenance (87-102 % BW) as reported by (40). The relative feed quality (RFQ) values of sole Calopogonium and mixtures at Calopogonium: maize stover (75:25) suggested that these forages will meet the nutrient requirement of different classes of cattle (41).

Maize stover is well known to be a fibrous feedstuff with a low digestibility as observed in this study, the *in vitro* dry matter digestibility (IVDMD) of the two maize stover investigated were lower than IVDMD (52%) reported by (42) for maize stovers in their study and the difference might be as a result of varietal or cultivar differences. The IVDMD reported in this study is higher than that reported by (12) as ranging between 58 to 66%. The IVDMD of the mixtures as reported in this study showed that addition of legumes can improve the digestibility of maize stover and hence the performance of animals if fed.

Conclusion and Applications

1. Based on the result of this study, it was therefore notable that, either mixture of Calopogonium and Oba super 2 or Suwan 1 at 75:25 will improve intake and digestibility as the CP were better.
2. Legumes can improve the digestibility of maize stover and might improve the performance of ruminant animals.

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