ESTIMATION OF THE NUTRITIVE VALUE OF PLANTAIN LEAVES ENSILED WITH DIFFERENT ADDITIVES USING IN VITRO GAS FERMENTATION METHOD

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ABSTRACT

This study compared the quality characteristics and nutritive potential of plantain leaf ensiled with different additives as dry season feed for ruminants using in vitro gas fermentation procedure. Plantain leaf was ensiled with groundnut cake (PLGNC), cassava peel (PLCAP), and without additive (PLNAD) and their chemical composition and anti-nutritional factors were determined. The nutritive value of all ensiled plantain leaves using in vitro gas production technique was assessed every 3 hours for 24 hours to predict the in vitro gas production parameters such as Metabolizable Energy (ME), Organic Matter Digestibility (OMD), Short Chain Fatty Acids (SCFA), methane (CH_4); and characteristics like soluble degradable fraction(a), insoluble degradable fraction (b), potential degradability (a+b) and rate of degradation (c). Results revealed that the pH and temperature of all silages ranged from 3.10 to 5.30 and 25.50 to 31.30 ^0C in PLGNC and PLNAD respectively. All silages fermented with additives had a firm texture, pleasant aroma, and adequate colour. Significant ($p<0.05$) differences were observed for chemical composition. Dry matter and NDF ranged from 96.01 to 96.72% and 65.13 to 63.10% in PLGNC and PLNAD respectively, while the highest (18.64%) crude protein was obtained for PLGNC, and the least value (18.21%) was obtained for PLNAD. It was observed that the values recorded for anti-nutritional factors for all silages were similar. Same significant variations were also observed for the values of a, b, a+b, c, ME, OMD, SCFA ranging from 2.67-4.01ml, 4.51-6.31ml, 7.81-10.33ml 0.12-0.22ml/hr and 2.24-3.55 MJ/Kg DM, 33.02 – 40.05%, 0.10 – 0.18mmol, in PLNAD and PLGNC respectively. The total gas produced and methane were highest (14.43 and 3.33ml/200mg DM) in PLGNC and lowest (9.33 and 2.03ml/200mg DM) in PLNAD. Conclusively, plantain leaf ensiled with additives has potential as feed for livestock during the dry season in the tropics.

Keywords: *In vitro* gas fermentation, Additives, Nutritive value, Plantain leaves, Silage
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INTRODUCTION

The uncontrollable high cost of conventional feedstuff has compelled researchers in both tropical and temperate regions to investigate alternative feed ingredients continually, particularly browse plants that are not utilized as human foods but an easy means of feeding animals (Mako *et al.,* 2018). It is a fact that the pattern of rainfall in Nigeria affects the quality and quantity of grasses and browses available to ruminants negatively during the dry season (Mako *et al*., 2018). Yet another major culpable condition that has persistently negated the high yield of these alternative feed resources is climate change and global warming, which are of serious world concern today. Both issues have been researched to cause devastating disruption in the regular rainfall patterns, high crop pest and disease susceptibility, and a decrease in soil fertility, photosynthesis, and crop yield, among other complicated issues (Yuan *et al.,* 2024).

Plantain (*Musa paradisiaca*) is a perennial crop widely cultivated in most regions of Africa. Nigeria occupies a strategic position for rapid production, notably in the South-Western part of the country (Akinyemi *et al.,* 2010). Research indicates that Nigeria remains one of the largest plantain-producing countries in the world, due to its ingenious integration into various cropping systems by smallholder farmers who largely cultivate it in Nigeria (Akinyemi *et al.,* 2010). Despite the preponderances in crop farming today, plantain crop is typically endowed with the ability to form green long feathery leaves all year round, thereby positioning its leaves as a very vital cheap source of non-human edible agricultural waste that can be fed to animals, especially in the dry season, when green grasses and other alternate sources of cheap feed are a mirage for ruminant feeding. Adepoju (2012) opined that plantain leaves are essential feed resource, containing 7.7 g of crude protein and 24.4 g of carbohydrate, with the capacity to provide high nutrients to livestock, thereby contributing towards addressing nutritional deficiencies experienced by livestock farmers in many developing countries, especially in Nigeria. This research is therefore geared towards the determination of quality characteristics, nutrient and anti-nutrient composition of ensiled plantain leaves ensiled with different additives as a feed resource for ruminants.

MATERIALS AND METHODS

Sample collection

Several Plantain (*Musa paradisiaca*) stands at Agriwas farm plantain plantation at Aboke village, Lagelu Local Government Area, Oyo State, Nigeria, were marked randomly for sample collection. Consequently, after the plantain bunches had been harvested from the marked plantain stands, 3-5kg of plantain leaves were then harvested from each marked plantain plant in the environment.

Silage making

These leaves were chopped and ensiled with different additives, as the experimental treatments, namely:

PLNAD =plantain leaf ensiled with no additive.

PLCAP = plantain leaf ensiled with cassava peel.

PLGNC = plantain leaf ensiled with groundnut cake.

The plantain leaves and additives were mixed at a ratio of 4:1 (4 parts of leaves and 1 part of additives) separately. Each separate mixture was placed in a bucket that contain a cellophane bag as a silo, compaction of materials was thorough to eliminate any air pockets to ensure an anaerobic environment, after which, a large weight was placed on the content to ensure proper fermentation activity and prevention of rodent attack. The silage was left to ferment for forty-two (42) days (calculating day 1 as the day the silage was prepared), after which the silage was opened to determine the following parameters:

1. The silage quality characteristics such as its pH, temperature, aroma, texture, and colour.
2. Proximate and fibre composition: Dry Matter (DM), Crude Protein (CP), Crude Fibre (CF), Ether Extract (EE), Ash, Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), and Acid Detergent Lignin (ADL)
3. Anti-nutritional factors: Tannin, saponin, oxalate, and phytate
4. The in *vitro gas* production parameters to predict Metabolizable Energy (ME), Organic Matter Digestibility (OMD), Short Chain Fatty Acids (SCFA) of ensiled plant-

tain leaves (*Musa paradisiaca*).

The in *vitro gas* production parameters to predict soluble degradable fraction 'a', insoluble degradable fraction 'b', potential degradability 'a+b', and rate of degradation 'c' of ensiled plantain leaves (*Musa paradisiaca*).

Determination of Silage characteristics

pH: 2gms of sample was measured into a beaker of 15ml and 20 ml of distilled water was added, then it was placed on a bunsen burner and allowed to boil at 100 °C for 5 minutes. The liquid content was then decanted and allowed to cool. The pH meter was standardized using a buffer solution, after which it was dipped into the decanted liquid to determine the pH.

Temperature: Immediately after the silage was opened, a thermometer was dipped into the silage to measure the temperature of the ensiled plantain leaves.

Aroma: The smell of the silage was perceived as either pleasant or unpleasant.

Texture: Some samples were taken by hand to feel the texture, either as firm, wet, or watery.

Chemical analysis

Crude protein, crude fibre, ether extract, and total ash of samples were analyzed in triplicate using the standard procedure of AOAC (2023). The crude protein was determined with the micro kjeldahl distillation apparatus, while the NDF, ADF, and ADL were determined by Van Soest method (1995).

Quantitative determination of phytochemicals

Tannin, saponin, and oxalate contents were determined as described by Ejikeme *et al.* (2014). Phytate contents were determined as described by Maga (1983).

In vitro gas production procedure

The different silages were left to ferment for 42 days, after which they were opened and taken to the laboratory for *in vitro* gas production analysis. Rumen fluid was obtained from three West African female dwarf Goats through the suction tubes before the morning feed. The animals were fed concentrate consisting of 40 % corn bran, 35% wheat offal, 20% palm kernel cake, 4% oyster shell, 0.5% salt, and 0.5% grower premix for three (3) days before the collection of rumen liquor. Incubation was as reported by (Menke and Steingass, 1988) using 120ml calibrated syringes in three batches incubation at 39^0C while 30ml inoculums were introduced into 200mg samples in the syringes containing cheese cloth strained rumen liquor and buffer ($NaHCO_3$+ Na_2HPO_4 + KCL + NaCl + $MgSO_4$ $7H_20$ + $CaCL_2$ $2H_2O$) (1:2, v/v), under continuous flushing with CO_2. The gas production was measured at 3,6,9,12,15,18,21 and 24hours of incubation. About 4ml of NaOH (10M) was introduced to estimate the amount of methane produced. The average volume of gas produced from the blanks was deduced from the volume of gas produced per sample.

The volume of gas produced at intervals was plotted against the incubation time, and from the graph, the gas production characteristics were estimated using the equation.

Y= a+b (1-e-ct) described by Orskov and McDonald (1979). Where

- Y = volume of gas produced at time 't'
- a = intercept (gas produced from insoluble fraction)
- c = gas production rate constant for the insoluble fraction (b)
- t = incubation time
- Metabolizable energy and (ME, MJ/Kg DM) and organic matter digestibility (OMD%) were estimated as established by (Menke and Steingass, 1988), and short-chain

fatty acids (SCFA, umol) were calculated as reported by (Getachew *et al.*, 1999).

- ME = 2.20 + 0.136*GV + 0.057*CP + 0.0029*CF
- OMD = 14.88 + 0.889GV + 0.45CP + 0.651XA
- SCFA = 0.0239*GV – 0.0601

Where GV, CP, CF, and XA are net gas productions (ml/200mg DM), crude protein, crude fibre, and ash of the incubated samples, respectively.

Statistical analysis and design

Data obtained were analyzed and subjected to analysis of variance procedure (ANOVA) of SAS (2021). Significant treatment means were separated by Duncan's multiple range test of the same package. Completely Randomized Design was used.

RESULTS AND DISCUSSION

Physical characteristics of plantain (Musa paradisiaca) leaves ensiled with different additives

The physical characteristic profile of ensiled plantain leaves is as presented in Table 1 below. Here, the dark green colour, slightly moist texture, and unpleasant aroma, obtained for PLNAD (i.e. silage without additive) shows the characteristics of poorly fermented silage, this agrees with the report of Babayemi, (2009) in silage quality of Guinea grass (*Panicum maximum*) harvested at 4 and 12-weekof growth. PLCAP and PLGNC silages presented a pleasant aroma, very firm texture, and greenish-yellow colour. Visual appearance and texture feeling are good methods of determining silage quality (Akinwande, 2011). Good physical characteristics observed in silages with additives might be attributed to proper fermentation, hence the keeping quality. Also, the additives must have absorbed the moisture from the plantain leaves, and this might have resulted in the low moisture content of PLCAP and PLGNC ensiled mixtures Observation made here suggests that to make good silage from plantain (*Musa paradiasca*) leaves, the addition of additives is essential. In most cases, silage additives improve the nutrient content. Fermentation in the silages inhibits bacteria and mold growth and cultures the silage to stimulate acid production and increase nutrient content of the silage (Akinwande, 2011).

Table 1: Physical characteristics of plantain leaves ensiled with different additive

	Quality		Indicator
Silage	**Colour**	**Texture**	**Odour/Smell**
PLNAD	Dark Green	Wet and Slimy	Unpleasant
PLCAP	Greenish yellow	Firm	Pleasant Alcohol
PLGNC	Greenish yellow	Firm	Pleasant Alcohol

PLNAD = plantain leaf *silage* (no additive). **PLCAP =** plantain leaf cassava peel silage;
PLGNC = plantain leaf groundnut cake silage.

The temperature (^{0}C) of Plantain leaves ensiled with different additives is shown in **F**igure1. The temperature ranged from 25.50 to 31.30^{0}C in PLGNC and PLNAD, respectively. These values compared well with the values reported by Akinwande (2011) for water hyacinth ensiled with different additives, however, the range of values is higher than 25-27.5^{0}C reported by Babayemi (2009) for ensiled Guinea grass (*Panicum maximum*) harvested at 4 and 12-week re-growth. Akinwande *et al.* (2011) reported that silage temperatures above 30^{0}C result in very dark coloured silage (caramelization of sugar in the forage), indicating poor fermentation. The temperature obtained for silages fermented with additives in this study is below 30^{0}C indicating that they were properly fermented.

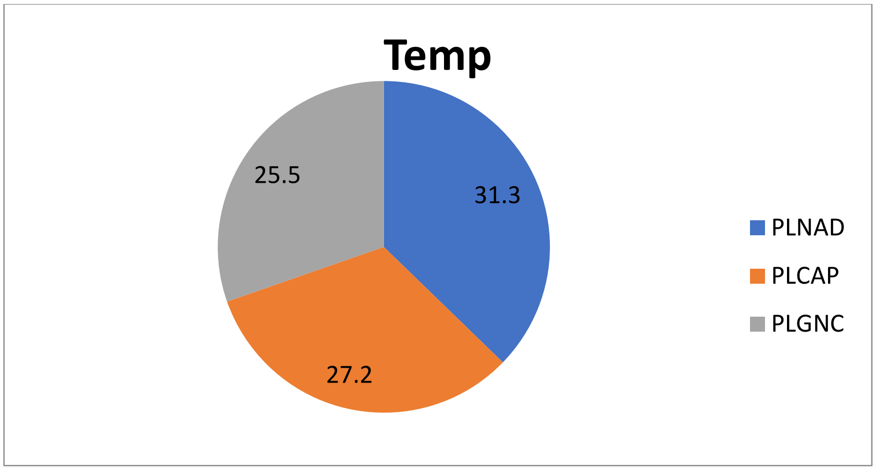

Fig 1: Temperature (^{0}C) of plantain leaves ensiled with different additives

The pH of ensiled plantain leaves is as shown in Fig. 2. It was observed that pH decreased with the addition of additives. Plantain leaves ensiled with GNC recorded the lowest (3.10) pH, while the plantain leaf ensiled without an additive recorded the highest (5.30) pH. This result agrees with the findings of Olorunnisomo (2011), who ensiled Moringa leaf with different levels of cassava peel. The pH values in this study are also compared well with the value range of 3.17 and 4.29 reported by Oni *et al.* (2014) for cassava leaf ensiled with molasses and cage layer waste, respectively. Petterson (1998) reported that pH values of silages below 4.50 are considered good silages. The pH values of all plantain leaves ensiled with additives were below 4.0, suggesting that they are good silages. Though plantain leaves ensiled with GNC will be more stable and better for animal consumption. The lower the acidity of a silage, the lower the growth ability of unwanted anaerobic bacteria.

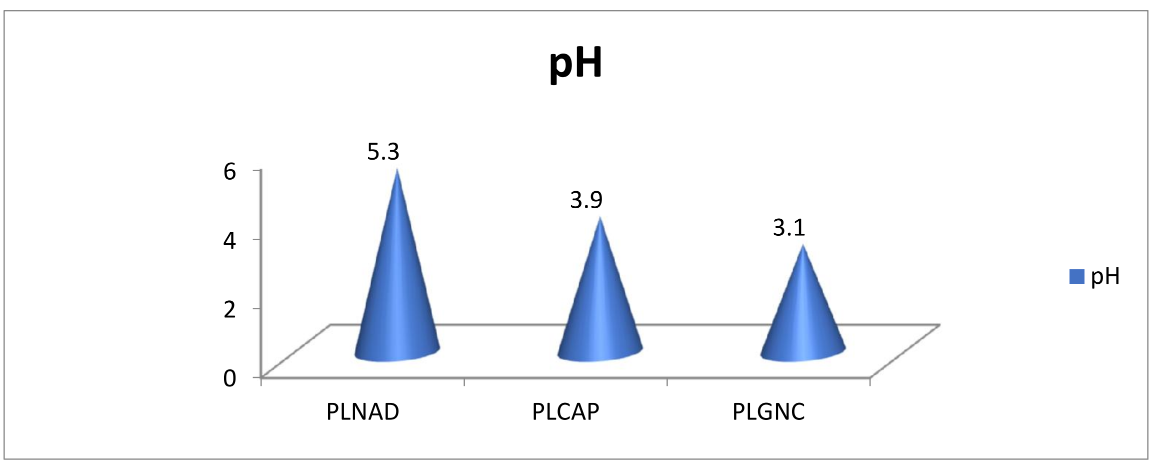

Fig 2: pH of plantain leaf ensiled with different additives

The proximate composition of ensiled plantain leaves and ensiled plantain leaves without additives is as shown in Table 2. The highest dry matter (96.72 %) was obtained for PLNAD, and the lowest value (96.01 %) for PLGNC. The crude protein values ranged from 18.21 to 18.23 and 18.64 in PLNAD, PLCAP, and PLGNC, respectively. PLNAD recorded the highest crude fibre (40.39%) while the least value (37.62%) was recorded for PLGNC. Ash content varied from 21.33

to 21.66 % in PLGNC and PLNAD, respectively.

The NDF, ADF, and ADL values were all highest in PLNAD, while the lowest values were recorded in PLGNC. The variations in dry matter reported here could be a result of the different types of additives used, since the buffering capacity of the original materials is essential in the eventual dry matter outcomes of silages (Falola *et al.,* 2013). Additionally, the dry matter of a silage has a direct influence on the pH of an ensiled product. Moore *et al.* (2020) opined that high moisture in silages and feeds is detrimental as it encourages high nutrient loss through fermentation and also the production of effluent. A well-fermented forage presents a low pH (acidity). This can be noticed in the lowest pH and dry matter values obtained in PLGNC. The trend of crude protein content recorded here agrees with that of Dairu*et* al (2022), where *Moringa oleifera* leaves were used in enhancing the ensiling quality of *Triticuma estivum*at graded levels. Legume inclusion in forage silages assists in boosting the protein level while solving the low carbohydrate level in legume (Abdurrahaman *et al.,*2018).

Therefore, the mixture of legumes with forage or grasses remains one of the best methods used to improve their nutritive value through ensiling. (Abdurrahaman *et al.* 2018). This illustrates why PLGNC will be more suitable as feed for ruminants than PLNAD and PLCAP. The ash content is a measure of the total amount of minerals present within a feed (NewsDesk, 2016). Though the ash content reported for PLNAD (21.66) was higher than those of PLGNC (21.33) and PLCAP (21.50), yet it might not serve as the best silage because of its high fibre fraction content than those of the other two treatments, PLGNC and PLCAP. Although a high content of ADF and NDF is essential in ruminant feed, excessively high ADF content negatively relates to digestibility (Ismartoyo *et al,* 2022). This implies that the nutrients in PLNAD may not be easily found within the useful reach of animals. Interestingly, ensiling is a potent general method of forage preservation and also a form of treatment to occasionally salvage the under-utilized pasture or forage for better acceptability and degradability, and a way of resolving the seasonal shortage of feed for ruminants (Falola *et al.,*2013; Olorunnisomo *et al.,* 2014). Therefore, the main focus of silage making is not to disregard any ensiled feed, but to make feed available for animal use, especially in the hopeless situation of the dry season, to maintain the body conformation of ruminant animal.

Table 2: Proximate composition (%) of ensiled plantain leaves with or without additives

Parameters	PLGNC	PLCAP	PLNAD	SEM
Dry matter	96.01^{c}	96.63^{b}	96.72^{a}	0.04
Crude protein	18.64^{a}	18.23^{b}.	18.21^{b}	0.02
Crude fibre	37.62^{c}	38.73^{b}	40.39^{a}	0.03
Ether extract	7.36^{c}	8.40^{b}	8.43^{a}	0.01
Ash	21.33^{a}	21.50^{b}	21.66^{c}	0.02
Neutral detergent fibre	63.10^{c}	64.11^{b}	65.13^{a}	0.03
Acid detergent fibre	40.05^{c}	42.00^{b}	43.37^{a}	0.25
Acid detergent lignin	11.81^{c}	12.33^{b}	12.62^{a}	0.15

$^{a-c}$Means on the same column with different superscript differed significantly (p<0.05).
PLGNC = Plantain leaf ensiled with groundnut cake; PLCAP =Plantain leaf ensiled with cassava peel; PLNAD= plantain leaf ensiled without additives

The anti-nutrient composition of ensiled plantain leaves with additives and without additives reveals that PLGNC presented the lowest values for tannin, saponin, oxalate, and phytate (0.51, 2.58, 0.06, and 0.60mg/100g respectively), followed by PLCAP; and the highest numerical values were observed in PLNAD. In this study, the type of additives used in ensiling had varied effects on the anti-nutritional factors, showing that PLGNC had the lowest values in tannin production. This can be explained by the tannin-protein complex formed during the ensiling process. (Mako, 2018). Capacious results from various authors have shown legumes to improve the ensiling quality of grasses in several grass-legume mixtures (Ahmad *et al.,* 2012; Abdurrahaman *et al.,* 2018; Muhammad *et al.*, 2009). Oliver *et al* (2017) opined that the content and fermentability of silage fiber, starch, and protein, together with fermentation end products, influence ruminant animal feeding behavior and dry matter intake. Equally, indigenous natural fermentation has been reported to involve a mixed colony of microorganisms (Kobawila *et al.,*2005). All these reports may imply that adding additives to plantain leaves, that is, groundnut cake and cassava peel in this study, had influenced a lower outcome of the anti-nutrients observed in both treatments. The value of tannin for PLCAP in this study is lower than that reported by Amos *et al.* (2019). It is a fact that cassava contains anti-nutritive compounds like tannins, which hinder the absorption and digestion of valuable nutrients, but they are usually lost during processing (Amos *et al, 2*019). Anti-nutritional characteristics of tannin includes its antioxidant property, inhibition of starch and protein digestibility, and hindering of iron and thiamin absorption (Bravo, 1998; Silva and Silva, 1999). Rodriguez *et al*. (1998) reported that the concentration of tannin decreased as the duration of fermentation increased. In this work, the type of additives assisted in the reduction of tannin content found in plantain leaves. Though more reduction was observed in PLGNC.

While phytates had been found culpable in reducing the absorption of metal ions in the body, by forming insoluble salts with metals (Igbabu *et al.,* 2014), oxalates, on the other hand, have been implicated in forming complexes with protein and inhibiting peptic digestion (Massey, 2007; Oboh, 1986). A reduction in both anti-nutrients has been observed more in this study in PLGNC than in the other 2 treatments (PLCAP and PLNAD). This illustrates that PLGNC has more potential to release enough nutrients required to meet the needs of animals in the dry season.

Though the results of 0.06mg/100g are higher than the recommended safe level of (<0.05%) of soluble oxalate to be found in foods as reported by Abdullah *et al. (*2013), the relief is that this was reported only at the preliminary level. The rumen bacteria had been found to have high accommodating capacity for degrading oxalate in feeds when the levels are contained, to avoid oxalate poisoning, as further opined by Abdullah *et al.* (2013).

Though the conditions of fermentation and the materials ensiled were different, yet the results in ensiled PLGNC and PLCAP showed lower anti-nutrients compared to the high results obtained in PLNAD, compared with those obtained in the works of Amos *et al.,* (2019), they also reported a reduction in anti-nutrients across all ensiled cassava roots compared to the un-ensiled roots. In all of the anti-nutritional factors reported, PLGNC still presented the lowest percentages, making it more nutrient-rich, based on all the illustrations by other researchers reported in this work.

In vitro gas fermentation parameters of Musa paradiasca plant leaves ensiled with different additives

The *in vitro* gas fermentation parameters of (*Musa paradiasca*) plantain leaves ensiled with different additives is shown in Table 4. Significant variations (p<0.05) were observed for all parameters measured. It was observed that plantain leaves ensiled with groundnut cake

(PLGNC) recorded the highest ME value (3.55 MJ/Kg) while those ensiled without an additive recorded the least value (2.24 MJ/Kg DM) for ME. This shows that the PLGNC contains more ME than plantain leaves ensiled with cassava peels and those with no additives. The value is lower than the Aregheore value range (5.31 to 6.31 MJ/Kg DM) obtained for ensiled *Alternanthera brasiliana* leaves (Mako *et al*., 2021), but lower than the range of values (5.92 to 11.58 MJ/Kg DM) reported for some tropical browse plants (Adebayo *et al.,* 2019).

The same trend was observed for organic matter digestibility, PLGNC contained the highest value of 40.05%, while PLNAD recorded the lowest (33.02%) value. These values were also lower than the range of values (38.46 to 43.94%) reported by Mako *et al.* (2021) for *Alternanthera brasiliana* leaf ensiled with different additives. ME is a source of energy for animals consuming the feed samples. Feedstuff inherent with certain anti-nutritive factors has been reported to be low in ME and organic matter digestibility (Aregheore and Abdulrazak, 2005). The low ME and OMD obtained in this study might be an indication of the high anti-nutritional factor present in the plantain leaves. The ME, OMD, and SCFA are energy sources for animals. Feedstuffs that are inherent with certain anti-nutritive factors have been reported to be low in ME and organic matter digestibility (Aregheore and Abdulrazak 2005). This might be the reason for the low ME and OMD obtained in this study. The SCFA ranged from 0.10 to 0.18mmol in PLNAD and PLGNC, respectively. However, these values were lower than the values (0.334 - 0.454 mmol) reported for ensiled *Alternanthera brasiliana* (Mako *et al.,* 2021).

The SCFA values obtained in this study compared well with range of values (0.12 – 0.21 mmol) reported for some dry season forages (Mako *et al.*,2015). Short-chain fatty acid content is an indication that the silage contains energy. This result agrees with the findings of Gatechew *et al.,* (1999) on the stoichiometric relationship between SCFA and *in vitro* gas production, presence and absence of polyethylene glycol for tannin-containing browses.

The methane production indicates that plantain leaves ensiled with groundnut cake yielded more methane gas (3.33 ml) than the samples ensiled with cassava peel (2.87 ml) and those with no additive (2.03 ml). This is expected because it is a fact that feedstuff with high gas production also has high methane (CH_4) production (Mako, 2009). Methane production indicates an energy loss to the ruminant in the process of methanogenesis (Babayemi and Bamikole, 2006).

Table 3: Anti-nutrient composition (mg/100g) of ensiled plantain leaves

Parameters	Tannin	Saponin	Oxalate	Phytate
PLGNC	0.51	2.58	0.06	0.60
PLCAP	0.62	3.00	0.08	0.75
PLNAD	0.74	3.65	0.13	0.94
SEM	1.0	1.25	1.13	0.50

Means on the same column with same superscript are not significantly (p>0.05) different.
PLGNC = Plantain leaf ensiled with Groundnut cake; PLCAP = plantain leaf ensiled with cassava peel; PLNAD= plantain leaf ensiled without additives

Table 4: *In vitro* gas production parameters of ensiled plantain leaves

Parameters	ME (MJ/KgDM)	OMD (%)	SCFA Mmol	CH_4 ml/200mg DM
PLGNC	3.55[a]	40.05[a]	0.18 [a]	3.33[a]
PLCAP	3.00[b]	36.35[b]	0.15 [b]	2.87[b]
PLNAD	2.24[c]	33.02[c]	0.10 [c]	2.03[c]
SEM	0.50	1.50	0.01	0.10

[a-c]Means on the same column with different superscripts differ significantly (p<0.05).
ME= Metabolisable Energy; OMD= Organic Matter Digestibility (%); SCFA= Short Chain Fatty Acid (mmol); CH_4; = Methane; PLGNC = Plantain leaf ensiled with groundnut cake; PLCAP = Plantain leaf ensiled with cassava peel; PLNAD =Plantain leaf ensiled without additives. SEM = Standard error of means

In vitro gas fermentation characteristics of plantain (Musa paradiasca) leaves ensiled with different additives

The *in vitro* gas fermentation characteristics of plantain (*Musa paradiasca*) leaves ensiled with different additives are as shown in Table 5. The result showed that the value of the soluble degradable fraction (a) of plantain leaves ensiled with different additives was significant (p< 0.05). The PL ensiled with groundnut cake recorded the highest value of "a" (4.02ml/200mg DM), while PL ensiled with no additives recorded the least value of 2.67 ml/200mg DM. This result is similar to the range of values (2.5 - 4.0ml) obtained by Mako *et al*. (2018) for *Persea americana* leaves. The soluble degradable fraction (a) indicates the amount of gas produced from soluble degradable fraction of the samples. This is the fraction of rumen microbes that ferment first to obtain energy for body metabolism.

The same trend was observed for the insoluble degradable fraction (b) where the results showed that the PL ensiled with GNC had the highest value (6.31ml), while 5.63ml and 4.5ml were obtained from PL ensiled with cassava peels and those with no additive, respectively. These values were lower than the values (9.48 - 11.78ml) obtained for *Persea americana* leaves (Mako*et al.*, 2018). Babayemi *et al.,* (2009) in the study of *in vitro* fermentation of tropical browse leaves concerning the content of secondary metabolites, also supported the findings of this research. This is the fraction that is fermentable at lower rate compared to the soluble fraction. It is the fraction that rumen microbe ferments after the rapidly fermented fractions have been depleted. The lower the values obtained for insoluble degradable fraction (b), the higher the fibrous nature of the incubated samples (Mako 2009).

The a+b fractions indicate the potential degradability, while c is the rate of degradation of the ensiled PL with different additives. The same trend was observed for these two parameters as obtained for soluble and insoluble fractions, with PL ensiled with GNC recording the highest value (10.33ml), while PL ensiled with cassava peels and those with no additives had 8.63ml and 7.18ml, respectively for a+b fraction. These values were lower than the value (98.1ml) reported for *Leucaena leucocephala* (Babayemi, 2007), while PLGNC recorded the highest value (0.22ml/h) for the rate of degradation, and the least value (0.12ml/h) was obtained for PLNAD. These values were higher than 0.0007ml/h recorded for *Leucaena leucocephala* by Babayemi (2007).

Total gas produced from ensiled plantain leaves is shown in Figure 3. The rate and extent of gas production provide data on the digestibility and fermentation of feeds and microbial protein synthesis (Pashaei *et al.,* 2010). The result showed that the net volume of gas produced increased progressively with incubation time. Total gas produced ranged from 1.17 – 3.67ml within the first 3hrs, and after 24hrs, the total gas produced increased to 9.33ml in plantain leaves ensiled without any additive and 14.33ml in plantain leaves ensiled with groundnut cake. This result is lower than the range of values (17 to 28 ml) reported by Mako *et al.*, (2021) for the ensiled *Alternanthera brasiliana* plant. Gas production indicates the degradability of samples (Pashaei *et al.,* 2010). The degradation observed in the samples implies that ensiled plantain leaves can serve as a good feed supplement for ruminants.

Table 5: *In vitro* gas production characteristics of ensiled plantain leaves

Parameters	a(ml)	b(ml)	a+b (ml)	c(ml/h)
PLGNC	4.01[a]	6.31[a]	10.33[a]	0.22[a]
PLCAP	3.00[b]	5.63[b]	8.63[b]	0.18[b]
PLNAD	2.67[c]	4.51[c]	7.18[c]	0.12[c]
SEM	0.20	0.51	1.00	0.01

[a-s]*Means on the same column with different superscripts differ significantly ($p<0.05$).).
'a'=soluble degradable fractions (ml/200mgDm),'b'= insoluble but degradable (ml/200mgDm), a+b= potentials degradability (ml/200mgDm), c=rate of degradation ml/hr; PLGNC = Plantain leaf ensiled with Groundnut Cake; PLCAP = Plantain leaf ensiled with cassava peel; PLNAD=Plantain leaf ensiled without additives. SEM = Standard error of mean

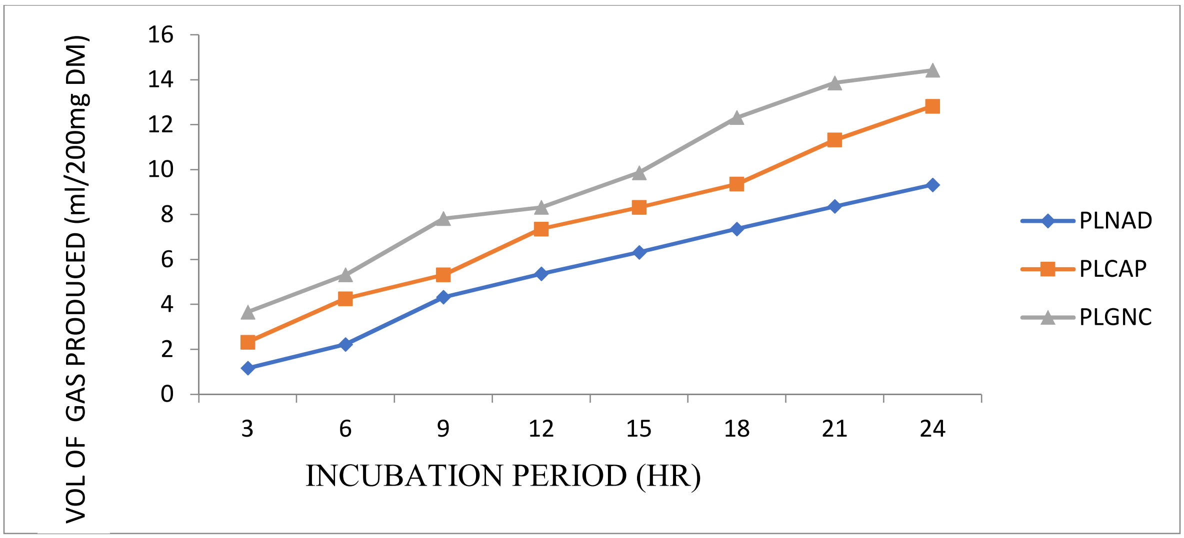

Fig 3: *In vitro* gas production of ensiled plantain leaves

CONCLUSION AND RECOMMENDATION

- Ensiling plantain leaves, with additives such as groundnut cake and cassava peel stabilized and improved its nutritional quality for ruminants. This can be of great respite during the dry season when the ruminant animal farmers have fewer alternative feeds for their animals.

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