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Silage Characteristics and Nutritive Value of Differently Ensiled Napier Grass (*Pennisetum Purpureum*)

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ABSTRACT

The study was conducted to evaluate the silage characteristics and nutritive value (chemical and mineral compositions) of differently ensiled Napier grass. Napier grass harvested at 16 weeks after planting was wilted for a day and ensiled in black polythene sheets for two months. Four treatments were investigated thus; T_1=untreated/plain, T_2=treated with 4% urea, T_3=treated with 4% molasses and T_4=treated with 2% molasses and 2% urea. All the treatments produced well-fermented silage with pH values ranging from 4.03 to 4.31. The most favorable qualities were observed in T_3, which had a drier texture, light brown colour and plesantly ethanolic smell. Crude protein content was highest in T_2 (10.35%), followed by T_4 (10.24%), indicating improved nitrogen retention from urea addition. T_3 exibited the highest dry matter (48.11%), ether extract (3.32%) and ash (10.24%) contents. Mineral analysis revealed that the contents varied marginally across the treatments but the concenrations were all within acceptable ranges. Sodium and calcium were highest in T_2 (0.71 g/kg) and T_4 (2.25 g/kg) respectively, while phosphorus was slightly elevated in T_3 (1.93 g/kg). In conclusion, the inclusion of additives (molasses and/or urea) enhanced the silage quality and nutritional quality better than ensiling without additives. Ensiling Napier grass with 4% molasses is highly recommended as it has shown to have a superior fermentation quality and nutrient availability.

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INTRODUCTION

Livestock production plays a vital role in the Nigerian agricultural economy, contributing significantly to household income, national food security, and employment. Ruminant animals such as cattle, sheep, and goats are predominantly raised under traditional systems, often relying on natural pastures during the rainy season and crop residues during the dry season. Livestock production is an important sector in the economy of developing countries (Hyelda, 2017). The development of the Nigerian animal production industry is of serious importance from the socioeconomic and public health point of view (Bamaiyi, 2013). Despite the sector's potential, productivity remains low due to several constraints, the most critical being inadequate availability of quality feed throughout the year. Feed cost constitutes the single largest expenditure of livestock enterprise and accounts for approximately 60 % of total cost of production (Jagadeesh et al., 2017). The majority of ruminant animals in tropical Africa are raised on natural pastures which drop rapidly in quality (Amole et al., 2021). To mitigate these seasonal variations and ensure feed availability and security, effective forage preservation techniques are indispensable.

Napier grass (Pennisetum purpureum) is a native grass grown and commonly used as a silage crop in tropical climates due to its high quality and yield (Bureenok et al., 2012). Napier grass is native to Sub-Saharan Africa from where it is believed to have been distributed to other tropical and subtropical regions around the world (Negawo et al., 2017). It is considered one of the most important tropical forages because of its high potential for biomass production, easy adaptation to diverse ecosystems and good acceptance by the animals (Ferreira et al., 2014). It has grown in almost all tropical and subtropical regions of the globe due to its high potential for forage accumulation, nutritive value, acceptability by different animal species, vigor and persistence (Pereira et al., 2021). It is widely used to feed herds in the forms of pasture and especially as silage, because of its high soluble carbohydrate content that favors good fermentation (Patrizi et al., 2004). It is highly valued for its exceptional biomass yield, rapid regrowth rate, and adaptability to diverse agro-ecological zones, making it a major component of ruminant diets for smallholder farmers across the tropics and subtropics. Despite its high productivity, the nutritive value of Napier grass rapidly declines with increasing maturity, primarily due to lignification and a reduction in crude protein content, which can compromise animal performance if fed alone.

Ensilage is the method of forage conservation based on conversion of water-soluble carbohydrates in organic acids by the activity of lactic acid bacteria, which reduces the pH and preserve the fresh forage. The ensiling process shows advantages such as conservation of large quantities of forage in short time and forage conservation is less weather dependent (de Oliveira et al., 2016). Ensiling tropical grasses has gained importance due to the high productivity of these forages, which favors the reduction of the cost of feeding ruminants compared to traditional crops like corn and sorghum (Ribeiro-Junior et al., 2014). Generally, ensiling is considered as an efficient process of preserving forage with high moisture content in sufficiently good quantity (Rambau et al., 2022). Effective ensilage can reduce the cost of feeding ruminants and ensure a steady supply of quality feed (Pirmohammadi et al., 2006). Molasses, rich in readily fermentable sugars, enhance lactic acid production, reduce pH, and improve the palatability and energy content of silage. On the other hand, urea serves as a non-protein nitrogen source that can improve crude protein content and microbial activity during fermentation. This study was therefore conducted to assess the silage quality, chemical composition, and mineral profile of Napier grass ensiled with, no additives, 4% molasses, 4% urea, and a combination of both, with the aim of identifying the most effective treatment for improving forage quality and conservation efficiency.

MATERIALS and METHODS

Experimental Site

The study was carried out at Duware, 2 km away from Yola South Metropolis of Adamawa state, Nigeria (where the Napier grass pasture was established). Yola South Local Government was created in 1996 and has an area of 719km^2. It is located on latitude 9^0 12′ 10″ N and longitude 12^0 28′ 48″ E, with an altitude of 198.9m above sea level. The area falls within the Northern Guinea Savannah Zone and has a tropical wet and dry climate. Average annual rainfall is about 945 mm and average annual temperature is 34.5^{o}C (maximum) and 21.6^{o}C (minimum). Dry season lasts for a minimum of five months (November – March) while the wet season spans April to October (Adebayo *et al*., 2020).

Experimental Material

The forage used for this study was harvested at 16 weeks after planting (WAP) from the Napier grass pasture established in the location as described above. This was the first harvest after the establishment of the pasture. At this harvesting stage, the stems and roots of the Napier grass were well established for regrowth and the dry matter content was above 24%.

Ensiling Procedure

The grass was then chopped mechanically using a chopping machine to a size of 0.5cm to 1cm. The ensiled Napier grass was preserved in black, air-tight polythene sheets, covered with sacks for two months. A total of 100kg grass was ensiled per treatment and each treatment was preserved in five polythene sheets, making 20kg per replicate.

T_1 = Untreated/plain wilted Napier grass

T_2 = 4kg of urea fertilizer dissolved in 8 litres of water and sprinkled on 100kg of the wilted Napier grass;

T_3 = 4kg of molasses mixed in 8 litres of water and sprinkled on 100kg of the wilted Napier grass;

T_4 = 2kg of molasses and 2kg of urea fertilizer mixed/dissolved in 8 litres of water and sprinkled on 100kg of the wilted Napier grass.

Chemical Analysis

The chemical composition of the ensiled Napier grass was determined following standard methods of the Association of Official Analytical Chemists (AOAC, 2019). Neutral detergent fibre, acid detergent fibre and acid detergent lignin were determined according to Van Soest *et al*. (1991) procedure. Cellulose, hemicellulose and non-fibre carbohydrates were determined by calculation.

Cellulose = ADF – Lignin

Hemicellulose = NDF – ADF

Non-fibre carbohydrates = 100 – (CP + NDF + Ash + EE)

Mineral Analysis

Dry ashing technique as described by AOAC (2019) was used for the mineral analysis. After ashing, 2 ml of concentrated nitric acid (HNO_3) was used to dissolve each sample. Buck Model 210 VGP Atomic Absorption Spectrophotometer was used to measure calcium, potassium, zinc, copper, manganese and iron. JENWAY PFP7 Flame Photometer was used to measure sodium and phosphorus.

RESULTS and DISCUSSION

Silage Characteristics of Ensiled Napier Grass

The silage characteristics of the ensiled Napier grass is presented in Table 1. The pH values for T_1 to T_4 were 4.31, 4.25, 4.03 and 4.17 respectively. The colours observed were light green for T_1, pale green to pale brown for T_2, light brown for T_3 and pale brown to pale green for T_4. The four treatments had a firm texture with T_3 looking drier than the other treatments. For the smell, T_1 was pleasant (normal), T_2 was moderately ethanolic, T_3 was plesantly ethanolic and T_4 was slightly ethanolic.

Table 1. Silage characteristics of ensiled Napier grass

Parameters	Treatments			
	T_1	**T_2**	**T_3**	**T_4**
pH	4.31	4.25	4.03	4.17
Colour	Light green	Pale green to pale brown	Light brown	Pale brown to pale green
Texture	Firm (wet)	Firm (wet)	Firm (drier)	Firm (a bit dry)
Smell	Pleasant (normal)	Moderately ethanolic	Pleasantly ethanolic	Slightly ethanolic

T_1 = Ensiled Napier grass (untreated), T_2 = Ensiled Napier grass (treated with 4% urea), T_3 = Ensiled Napier grass (treated with 4% molasses), T_4 = Ensiled Napier grass (treated with 2% molasses and 2% urea)

Chemical Composition (%DM) of Ensiled Napier Grass

The chemical composition (%DM) of ensiled Napier grass is presented in Table 2. Dry matter content for T_1 to T_4 were 48.02%, 46.59%, 48.11% and 46.82% respectively. Crude protein content obtained were 9.18%, 10.35%, 9.98% and 10.25% for T_1 to T_4 respectively. Crude fibre, ether extract, ash and nitrogen free extract contents ranged from 34.52% (T_2) to 37.44% (T_1), 1.91% (T_4) to 3.32% (T_3), 9.71% (T_2) to 10.24% (T_3) and 40.28% (T_3) to 43.36% (T_2) respectively. Organic matter content was highest in T_2 (90.29%) and lowest T_3 (89.76%). Neutral detergent fibre content for T_1 to T_4 were 76.07%, 75.99%, 74.87% and 74.54% respectively. Acid detergent fibre ranged from 39.64% (T_2) to 41.27 (T_4). Highest cellulose, hemicellulose and acid detergent lignin contents were obtained in T_4 (35.03%), T_2 (36.35%) and T_1 (6.68%) respectively, while lowest contents were obtained in T_3 (33.54%), T_4 (33.27%) and T_2 (5.97%) respectively. Non-fibre carbohydrates content was highest in T_4 (3.13%) and lowest in T_3 (1.59%).

Table 2. Chemical composition (%DM) of ensiled Napier grass

Trts	DM	CP	CF	EE	Ash	NFE	OM	NDF	ADF	CEL	HEM	ADL	NFC
T_1	48.02	9.18	37.44	2.57	9.98	40.83	90.02	76.07	40.87	34.19	35.20	6.68	2.20
T_2	46.59	10.35	34.52	2.06	9.71	43.36	90.29	75.99	39.64	33.67	36.35	5.97	1.89
T_3	48.11	9.98	36.18	3.32	10.24	40.28	89.76	74.87	40.12	33.54	34.75	6.53	1.59
T_4	46.82	10.24	36.91	1.91	10.18	40.76	89.82	74.54	41.27	35.03	33.27	6.24	3.13

Trts=Treatments, DM=Dry matter, CP=Crude protein, CF=Crude fibre, EE=Ether extract, NFE=Nitrogen free extract, OM=Organic matter, NDF=Neutral detergent fibre, ADF=Acid detergent fibre, CEL=Cellulose, HEM=Hemicellulose, ADL=Acid detergent lignin, NFC=Non-fibre carbohydrates
T_1 = Ensiled Napier grass (untreated), T_2 = Ensiled Napier grass (treated with 4% urea), T_3 = Ensiled Napier grass (treated with 4% molasses), T_4 = Ensiled Napier grass (treated with 2% molasses and 2% urea)

Mineral Composition (%DM) of Ensiled Napier Grass

The mineral composition (%DM) of ensiled Napier grass is presented in Table 3. Sodium content (g/kg) for T_1 to T_4 were 0.68, 0.71, 0.62 and 0.59 respectively. Phosphorus (g/kg) content for T_1 to T_4 were 1.87, 1.89, 1.93 and 1.77 respectively. Calcium and potassium contents (g/kg) were highest in T_4 (2.25) and T_2 (16.12) respectively. Lowest contents of the macro-nutrients (sodium, phosphorus, calcium and potassium) analysed were obtained in T_4 (0.59 g/kg), T_4 (1.77 g/kg), T_1 (2.02 g/kg) and T_1 (13.41 g/kg) respectively.

Table 3. Mineral composition (%DM) of ensiled Napier grass

Trts	Macro-nutrients (g/kg)				Micro-nutrients (mg/kg)			
	Na	P	Ca	K	Zn	Cu	Mn	Fe
T_1	0.68	1.87	2.02	13.41	14.56	11.65	41.43	480.27
T_2	0.71	1.89	2.13	16.12	14.44	10.85	40.11	482.53
T_3	0.62	1.93	2.17	14.75	15.12	11.01	43.18	475.96
T_4	0.59	1.77	2.25	15.83	14.76	10.52	41.69	477.14

Trts=Treatments, Na=Sodium, P=Phosphorus, Ca=Calcium, Zn=Zinc, Cu=Copper, Mn=Manganese, Fe=Iron. T_1 = Ensiled Napier grass (untreated), T_2 = Ensiled Napier grass (treated with 4% urea), T_3 = Ensiled Napier grass (treated with 4% molasses), T_4 = Ensiled Napier grass (treated with 2% molasses and 2% urea)

The values for zinc content (mg/kg) were 14.56, 14.44, 15.12 and 14.76 for T_1 to T_4 respectively. Treatment one (T_1) had the highest copper content (11.65 mg/kg) and the lowest copper content was obtained in T_4 (10.52 mg/kg). Manganese content (mg/kg) for T_1 to T_4 were 41.43, 40.11, 43.18 and 41.69 respectively. Iron content (mg/kg) ranged from 475.96 (T_3) to 482.27 (T_2).

DISCUSSION

Silage Characteristics of the Ensiled Napier Grass

The pH values of the silages in this study (4.03 to 4.23) are comparable to 4.2 and 4.4 for molasses treated and untreated Napier grass silages reported by Rambau et al. (2022). The pH values in this study are within 3.68 to 4.96 for untreated and molasses treated Napier grass silages reported by Ofori and Nartey (2018). Hapsari et al. (2016) reported lower pH range (3.02 to 4.00) and Rong et al. (2013) reported higher pH range (4.1 to 4.7) for Napier grass silages when compared to the pH range (4.03 to 4.23) in this study. The variations in pH may be due to differences in grass maturity at harvest, moisture content at the point of ensiling, ensiling duration or variations in environmental temperature during ensiling. It was observed in this study that molasses produced silages with the lowest pH and Sebolai et al., (2011) also reported the same outcome when they studied the effects of different silage preservatives on silage quality of Napier grass. Yunus et al. (2000) reported that urea treated silage had higher pH than molasses treated and urea + molasses treated silages and this agrees with the findings in this study. The results of this study also agree with the findings of Olorunnisomo and Ibhaze (2013) that used cassava peels to ensile Napier grass and Ofori and Nartey (2018) who used molasses to ensile Napier grass. The pH for the silages in this study (4.03 to 4.23) are higher than 3.76 to 4.02 for Gamba grass silages (Amuda et al., 2020) but lower than 4.30 to 4.44 for Bracharia grass silages (Costa et al., 2011). These differences could be due to variation in buffering capacity and initial carbohydrate concentration, which affect the rate and extend of acidification.

The light green colour for the untreated silage in this study tallies with light green to brown, greenish and pale green colour observed by Delena and Fulpagare (2015), Ofori and Nartey (2018) and Olorunnisomo and Ibhaze (2013) respectively for untreated Napier grass silages. Similarly, the light green colour for the untreated silage in this study tallies with greenish colour reported by Lamidi and Akhigbe (2018) for ensiled Guinea grass but differs with brownish to green colour of untreated Napier grass silage (Nurhayu et al., 2021) and brown colour of untreated Gamba grass silage (Yerima et al., 2022). This may be as a result of different storage durations, extend of compaction, temperature conditions or oxidation levels during fermentation. The light brown colour observed for molasses treated silage in this study corresponds with the same colour (light brown) reported by Ofori and Nartey (2018) for molasses treated Napier grass silage.

For the silage texture, both Nurhayu et al. (2021) and Ofori and Nartey (2018) reported a compact (firm) texture for untreated and treated Napier grass silages and this collaborates with the observation in this study. Amuda et al. (2020) reported firm texture for Gamba grass silages and this also collaborates with the findings in this study. The pleasant (normal) smell for the untreated silage in this study varies from the slightly acidic and pleasant alcoholic smell reported by Randa et al. (2017) and Nurhayu et al. (2021) respectively for Napier grass silages but agrees with the pleasant smell reported by Olorunnisomo and Ibhaze (2013) for untreated Napier grass silage. Differences in texture among studies can be attributed to variations in silage compaction, dry matter content, and fermentation rate.

The slightly ethanolic smell for the molasses treated silage is the same with the ethanolic smell reported by Ofori and Nartey (2018). Abdurrahaman et al. (2018) reported pleasant to very sweet smell for ensiled Gamba grass, and this collaborates with the pleasant to pleasantly ethanolic smell of the silages in this study.

Chemical Composition (%DM) of Ensiled Napier Grass

The results of the chemical composition of ensiled Napier grass indicated that the dry matter contents of the silages in this study (46.59 to 48.11%) are higher than 21.20 to 26.05%, 21.11 to 24.71% and 20.2 to 22.8% reported by Yunus et al. (2000), Sarker et al. (2019) and Rahman et al. (2021) respectively but lower than 68.03 to 73.51% and 97.68% reported by Sebolai et al. (2011) and Randa et al. (2017) respectively for Napier grass silages. These differences may be attributed to variation in wilting duration, dry matter content of the grass at ensiling, and temperature during fermentation. The dry matter values of 39.65 to 42.24% reported by Ofori and Nartey (2018) for differently ensiled Napier grass fall within 46.59 to 48.11% recorded in this study. The dry matter contents of the silages in this study (46.59 to 48.11%) are higher than 25.25 to 26.55 % for Bracharia grass silages (Costa et al., 2011) and 20.14 to 25.66% for Guinea grass silages

(Zanine et al., 2018). These differences could be due to species variation, and the nature and duration of wilting before ensiling.

Ensiling Napier grass with additives resulted in higher crude protein when compared to ensiling with no additive and this was also reported by Manyawu et al. (2003a), Nurjana et al. (2016), Zailan et al. (2018) and Rahman et al. (2021) when the authors ensiled Napier grass. Ofori and Nartey (2018) reported lower crude protein content (5.70 to 7.61%), Rahman et al. (2021) reported higher crude protein content (10.4 to 12.4%) and Sarker et al. (2019) reported similar crude protein content (9.14 to 9.86%) for differently ensiled Napier when compared to the crude protein contents of the silages in this study (9.18 to 10.35%). The differences in crude protein content among studies can be linked to variation in fertilizer type and application rate during forage cultivation, stage of maturity at harvest, and additive type. Amuda et al. (2020) reported higher crude protein contents (9.44 to 14.88%) when Gamba grass was ensiled but Costa et al. (2012) reported lower crude protein contents (4.85 to 5.37%) when Bracharia grass was ensiled. Such species variation arises from different inherent nitrogen metabolism and leaf-to-stem ratio among grass species.

The crude fibre contents of the silages in this study (34.52 to 37.44%) are within 29.7 to 42.7% compiled by Heuze et al. (2020) but slightly lower than 38.43% reported by Widiyastuti et al. (2014) and higher than 30.80 to 36.00% reported by Hapsari et al. (2016) for Napier grass silages. Lamidi and Akhigbe (2018) reported 28.65 to 31.68% as crude fibre contents of Guinea grass silages and Yerima et al. (2022) reported 15.19 to 16.87% as crude fibre contents of Gamba grass silages, and these figures are lower than 34.52 to 37.44% recorded in this study. Ether extract contents in this study (1.91 to 3.32%) are comparable to 1.30 to 3.18% reported by Ridwan et al. (2015) but lower than 2.31 to 4.40% reported by Hapsari et al. (2016) and higher than 1.15 to 1.61% reported by Kaewpila et al. (2020) for Napier grass silages. Ether extract contents of the silages in this study (1.91 to 3.32%) collaborate with 1.56 to 3.34% reported by Abdurrahaman et al. (2018) for Gamba grass silages, but are lower than 4.30 to 4.79% for Bracharia grass silages (Costa et al., 2011) and higher than 1.76 to 2.27% for Gamba grass silages (Amuda et al. 2020). Variations in values among different studies on Napier grass may be due to differences in maturity stage, leaf-stem proportion, and extend of fermentation. The species-related differences may be due to genetic variation, and other factors like the coarseness o the stem structue and cell wall content.

The ash contents in this study (9.71 to 10.24%) are within 9.0 to 15.7% compiled by Heuze et al. (2020) but lower than 10.71 to 12.08% reported by Hapsari et al. (2016) and higher than 8.80% reported by Mapato and Wanapat (2018) for Napier grass silages. The variation in ash content could arise from soil mineral compostion, fertilization type and regime, and contamination with soil during harvesting. The ash contents of the silages in this study (9.71 to 10.24%) are also comparable to 10.69 to 10.95% for Guinea grass silages (Lamidi and Akhigbe, 2018). However, the values in this study

(9.71 to 10.24%) are lower than 9.80 to 11.60% for Gamba grass silages (Yerima et al., 2022) but within 5.50 to 12.30% for Gamba grass silages (Abdurrahaman et al., 2018). The organic matter contents in this study (89.76 to 90.29%) are within 87.57 to 92.38% and 88.60 to 92.70% reported by Ridwan et al. (2015) and Kaewpila et al. (2020) respectively, but lower than 91.2% reported by Mapato and Wanapat (2018) and higher than 88.8% reported by Ribeiro et al. (2015) for various Napier grass silages. Such variations reflect differences in the proportion of structural carbohydrates and minerals, since higher ash content reduces organic matter percentage. The organic matter contents of the silages in this study (89.76 to 90.29%) are similar to 88.4 to 90.2% for Gamba grass silages (Yerima et al., 2022) and 89.05 to 89.31% for Guinea grass silages (Lamidi and Akhigbe, 2018).

The neutral detergent fibre contents of the silages in this study (74.54 to 76.07%) collaborates with 73.60 to 77.40% reported by Kaewpila et al. (2020) but lower than 86.45 to 88.06% reported by Sarker et al. (2019) and higher than 73.13% and 65.32 to 72.74% reported by Ferreira et al. (2015) and Sebolai et al. (2011) respectively for various Napier grass silages. Acid detergent fibre contents of the silages in this study (39.62 to 41.27%) are comparable to 33.28 to 41.63% reported by Rong et al. (2013) but lower than 45.35% and 50.80 to 62.19% reported by Hapsari et al. (2016) and Ferreira et al. (2015) respectively for Napier grass silages. However, the values in this study are higher than 34.34 to 38.22% and 11.5% reported by Sebolai et al. (2011) and Mapato and Wanapat (2018) respectively for Napier grass silages. Zanine et al. (2018) reported 62.89 to 74.33% and 33.04 to 37.98% as neutral detergent fibre and acid detergent fibre contents respectively for Guinea grass silages, and these figures are lower than 74.54 to 76.07% (neutral detergent fibre contents) and 39.62 to 41.27% (acid detergent fibre contents) recorded in this study. Acid detergent lignin contents in this study (5.97 to 6.68%) are lower than 7.90 to 12.86% reported by Hapsari et al. (2016) but higher than 3.27 to 4.49% reported by Sebolai et al. (2011) for Napier grass silages. Differences in neutral detergent fibre, acid detergent fibre and acid detergent lignin content can result from grass maturity, leaf-stem proportion, and degree of fermentation, as lignin and cellulose fractions are less degradable.

The cellulose contents (33.54 to 35.03%) are within 28.63 to 35.29% reported by Rong et al. (2013) but lower than 45.37 to 56.81% reported by Hapsari et al. (2016) and higher than 31.43% reported by Ferreira et al. (2015) for Napier grass silages. The hemicellulose contents of the silages in this study (33.27 to 36.35%) are much higher than 10.22 to 19.26% reported by Hapsari et al. (2016) but comparably to 31.43% reported by Ferreira et al. (2015) for differently ensiled Napier grass.

The ensiled Napier grass in this study recorded a considerable increase in dry matter, crude protein, ether extract and ash contents, but a decrease in crude fibre when compared to the fresh Napier grass. This tallies with the findings of Manyawu et al. (2003b) who reported that wilting fresh grass before ensiling increased the dry matter content significantly. The findings in this study also collaborate with Pereira et al. (2021), who opined that wilting silage forage is an option in reducing the limitations caused by high moisture content of the fresh forage, thereby increasing the dry matter content and carbohydrates concentrations.

Mineral Composition (%DM) of Ensiled Napier Grass

The sodium contents of the Napier grass silages in this study (0.59 to 0.71 g/kg) are comparable to 0.51 to 0.55 g/kg (Cunha et al., 2022) but higher than 0.02 to 0.04 g/kg (Rahman et al., 2021) for ensiled Napier grass. Abdurrahaman et al. (2018) reported 0.23 to 0.34 g/kg as the sodium contents of Gamba grass silages and these figures are lower than 0.59 to 0.71 g/kg recorded in this study. Phosphorus contents (1.77 to 1.93 g/kg) are within the range of 0.5 to 2.2 g/kg (Cunha et al., 2022) but lower than the average of 3.6 g/kg compiled by Heuze et al. (2020) and higher than 0.04 to 0.065 g/kg (Aganga et al., 2005) for ensiled Napier grass. Lamidi and Akhigbe (2018) reported 0.42 to 0.45 g/kg as the phosphorus contents of Guinea grass silages and these figures are lower than 1.77 to 1.93 g/kg recorded in this study. Calcium contents (2.02 to 2.25 g/kg) are similar to the average of 2.5 g/kg compiled by Heuze et al. (2020) but lower than 4.6 to 13.2 g/kg (Cunha et al., 2022) and higher than 0.14 to 0.18 g/kg (Aganga et al., 2005) for Napier grass silages. Potassium contents (13.41 to 16.12 g/kg) are lower than 32.6 to 41.0 g/kg (Cunha et al., 2022) but higher than 1.99 to 2.84 g/kg (Rahman et al., 2021) and much lower than the minimum value of 29.5 g/kg compiled by Heuze et al. (2020) for ensiled Napier grass.

Zinc contents and copper contents of the silages in this study (14.44 to 15.12 mg/kg and 10.52 to 11.65 mg/kg respectively) are lower than 26.1 to 35.6 mg/kg and 11.4 to 15.6 mg/kg respectively (Cunha et al., 2022) for various Napier grass silages. Aganga et al. (2005) reported higher Napier grass silage zinc content (48.40 to 62.50 mg/kg) and similar copper content (10.20 to 11.40 mg/kg) when compared to 14.44 to 15.12 mg/kg and 10.52 to 11.65 mg/kg (zinc and copper contents respectively) in this study. Manganese contents for the silages in this study (40.11 to 43.18 mg/kg) are lower than 63.70 to 70.08 mg/kg (Aganga et al., 2005) but higher than 32.9 to 37.1 mg/kg (Cunha *et* al., 2022) for ensiled Napier grass. Iron contents recorded in this study (475.96 to 482.53 mg/kg) are comparable to 280.9 to 421.7 mg/kg (Cunha et al., 2022) but higher than 218.50 to 253.70 mg/kg (Aganga et al., 2005) for ensiled Napier grass. Lamidi and Akhigbe (2018) reported 165.7 to 169.2 mg/kg as the iron contents of Guinea grass silages and these figures are lower than 475.96 to 482.53 mg/kg recorded in this study. Generally, these mineral variations can be linked to mineral status of the soil, fertilization history, plant absorption efficiency, geographical location, and plant maturity.

It was observed in this study that the ensiled Napier grass had better mineral composition when compared to the mineral composition of the fresh Napier grass and this is supported by the findings of Aganga et al. (2005) who reported an increase in the mineral composition of Napier grass silages when compared to the fresh Napier grass.

CONCLUSION AND RECOMMENDATION

The study demonstrates that treating Napier grass with molasses and/or urea significantly impacts the silage characteristics, chemical composition and mineral profile. The 4% molasses treated silage had a lower pH (an indication of good fermentation), pleasant ethanolic smell and desirable light brown colour. Additionally, ensiling with the additives resulted in silage with less fibre components and more mineral contents. Based on the findings of this study, the inclusion of molasses, or a combination of molasses and urea when ensiling Napier grass is recommended in order to improve the general quality of the silage.

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Conflict of Interest

The authors have declared that there is no conflicting interest.

Authors Contribution

All the authors contributed equally.

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