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Silage Characteristics, Composition and Growth Performance of Wad Rams Fed Cabbage Waste Ensiled with Other Feedingstuffs

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ABSTRACT

An investigation was carried out to assess the physical characteristics and chemical composition of cabbage waste (CBW) ensiled with wheat offal (WO), dried cassava waste (DCW) and brewers' spent grain (BSG). Silage quality characteristics (colour, odour, pH, temperature and texture), proximate composition, phytochemical composition (tannin, hydrocyanide, ammonia nitrogen and saponin) and organic acids (lactic and acetic acid) were examined. The growth performances of West African dwarf (WAD) rams fed the silages were also examined. The dietary treatments were: Silage 1/Treatment 1 (CBW0) = 0 % CBW + 50 % BSG + 30 % DCW + 20 % WO, Silage 2 (CBW5) = 5 % CBW + 50 % BSG + 30 % DCW + 15 % WO and Silage 3 (CBW10) = 10 % CBW + 30 % DCW + 10 % WO + 50 % BSG. Nine WAD rams, with an initial body weight of 18.5 ± 2.3 kg, were divided into the three treatment groups in a completely randomized design and fed the silages for 56 days. Growth performance, including weight gain and feed conversion ratio was assessed. Silages containing cabbage waste (CBW5 and CBW10) had better pH (6.53 and 6.15) firm texture, pleasant aromatic odour and temperature. Values for pH (6.15 – 6.70) differed significantly ($p<0.05$), with Silage 3 (CBW10) recording the least pH value (6.15). Concentrations of crude protein and carbohydrates in the silages were significantly different ($p<0.05$) across treatments, were 14.00 – 14.70 % and 49.69 – 56.84 % respectively and were highest in silage 2 (CBW5). Ensiling reduced the contents of phytochemicals to tolerable ranges. Lactic acid and organic acids were significantly different ($p<0.05$) and highest in silage 2 (CBW5). Final body weight (21.67 22.33 kg) were significantly different ($p<0.05$) across treatment with rams fed CBW10 being the heaviest (22.33 kg) followed by rams fed CBW5 (21.83 kg). Feed conversion ratio (FCR) were significantly different ($p<0.05$) across treatment with values of 4.41, 5.00 and 4.19 for rams fed CBW0, CBW5 and CBW10 respectively. In effect, rams on CBW10 silage with the least FCR of 4.19 efficiently utilized the feed. Thus cabbage waste ensiled with these feeding stuffs had better fermentation quality and can be incorporated up to10 % in the diet of rams for optimum performance.

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KEYWORDS: Silage, cabbage wastes, phytochemicals, organic acids, growth performance.

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INTRODUCTION

Sheep production is an important component of Nigerian livestock industry. Sheep (*Ovis aries*) are domesticated mammals that have been an integral part of human civilization for over 11,000 years (Zeder, 2012). Sheep represent about 60 % of the total grazing domestic livestock in Nigeria (Ahaotu *et al.,* 2009). These animals display a unique ability to adapt and survive in areas where they are found and consequently their wide geographical distribution in Nigeria (Ahaotu and Ifut, 2018). Sheep supplies meat, milk, wool, skin and other products and also serve as a flexible financial reserve for the rural population as well as play other socio-cultural roles in the customs and tradition of many Nigerian societies (Alionye *et al.,* 2020) especially in Northern parts. Sheep contribute enormously to the protein requirements of most developing countries (Ahaotu *et al.,* 2009). In sub-Saharan Africa, sheep provide almost 30 % of the meat consumed and around 16 % of the milk produced. Yakaka and Bashir (2012) estimated that sheep and goats contribute about 35 % of the total animal meat production in Nigeria. This ranks small ruminants as the second most important suppliers of meat protein to the population after cattle (Ugwumba and Effiong, 2013).

The West African dwarf sheep (WAD) are prominent breed of sheep in Nigeria's livestock industry. This Dwarf sheep is characterized by exceptional reproductive abilities such as high prolificacy, sexual precocity and good fertility (Faye and Alary, 2001). Although it is acknowledged for its hardiness, trypanotolerance, tick tolerance, prolificacy and suitability for year-round breeding (Bosso, *et al.,* 2007), its slow growth potential militates against its productivity (Gbangboche *et al.,* 2006).

In recent years, there has been a growing interest in exploring alternative feed ingredients to improve livestock nutrition and productivity. The use of agricultural waste for ruminant feed provides a reduction in feed cost and allows for the reuse of organic material in animal production, thus preventing waste accumulation and environmental pollution (Brochier and Carvalho, 2009). One of such agricultural waste is cabbage waste. Studies have shown that sheep fed ensiled cabbage waste exhibit improved growth rates, feed efficiency, and rumen health compared to those fed traditional feeds (Zhang *et al.,* 2020; Liu *et al.,* 2018). Ensiled cabbage waste can replace up to 30 % of traditional feed without negatively impacting sheep performance (Chen *et al.,* 2019). Despite its moderately rich nutrients content and positive outcome of usage in animal trials, cabbage is reputed in ruminants for lowering intakes due to the content of S-methyl-L-cysteine sulphoxide and glucosinolates (Barry, 2013).

The objective of this research therefore was to assess the silage characteristics and chemical composition of cabbage wastes ensiled with wheat offal, dried cassava peels, and brewers' spent grain. The study further investigated the growth performance of WAD sheep fed the silage.

MATERIALS AND METHODS

Experimental Site

The study was conducted in the sheep unit of the Teaching and Research Farms, University of Uyo. It is located at The University of Uyo Annex campus in Uyo Local Government Area of Akwa Ibom State, which lies in South-Southern Nigeria between latitudes 4°58´N and 5°04´N and longitudes 7°51´E and 8°01´E, with an elevation of about 60.96 m above sea level (University of Uyo Meteorological Station, 2024). This area falls within the rainforest region and experiences a typical climate characterized by high temperatures and humidity.

Collection and Preparation of Experimental Materials

The Brewers' spent grain used for this experiment was purchased from Champions Brewery PLC in Uyo, Akwa Ibom State. Cabbage waste, silos, and polythene were purchased from Itam market, while wheat offal was purchased at a feed store from a reputable distributor. Dried cassava wastes (peels and flesh) were obtained from various sources within Akwa Ibom State. Cassava peels were crushed and sun dried while cabbage wastes were washed, air dried and shredded. These items were transported to the University of Uyo Teaching and Research Farms for ensiling.

Silage preparation

The ensiling was conducted a few days after the aforementioned materials were obtained. The mixture had cabbage wastes included at graded levels such that: Silage/Treatment 1 (CBW0) had no cabbage waste inclusion (0 %), but consisted of 30 % dried cassava peels, 20 % wheat offal and 50 % brewers' spent grain. Treatment 2/Silage 2 (CBW5) had cabbage waste added at 5%, dried cassava peels at 30 %, wheat offal at 15 % and brewers' spent grain at 50 %. For Silage/Treatment 3 (CBW10), cabbage waste was included at 10 %, wheat offal at 10 %, dried cassava peels at 30 % and brewers' spent grain at 50 %. Thus, the experimental diets were:

Silage 1 (CBW0): 0 % cabbage waste (CBW) + 30 % dried cassava peels (DCSP) + 20 % wheat offal (WO) + 50 % brewers' spent grain (BSG)

Silage 2 (CBW5): 5 % CBW + 30 % DCSP + 15 % WO + 50 % BSG

Silage 3 (CBW10): 10 % CBW + 30 % DCSP + 10 % WO + 50 % BSG

The drums (20 litre volume) containing the various compressed treatments were covered and stored in a safe place away from rain and heat. The mixtures were allowed to ensile for 21 days. At the end of the 21 days, the silos were opened and samples taken out for analyses and feeding out.

Qualitative assessment of the silage

The silage samples taken were observed using different equipment and methods to determine its characteristics. The physical characteristics analyzed include temperature, colour, odour and texture. Temperature was determined by dipping a laboratory thermometer inside the silo to a depth of 5 cm. The colour assessment was done using visual observation and colour chart. Odour was assessed and characterized by different people. The texture was determined by feeling the sample by three different people. The pH, a chemical composition, was determined using a pocket pH metre whereby a silage sample weighing 100g was immersed in 100ml of distilled water.

Determination of proximate and energy composition of silage

Fresh silage samples were collected and analyzed in the laboratory. The silage samples for proximate analysis were oven dried at 60 °C and subsequently ground to pass through a 2 mm sieve. The ground samples of silages were used for chemical analysis to determine crude protein, crude fiber, ether extract and ash using the method outlined by Osungbaro *et al.* (2010) Dry Matter, Free Nitrogen Extract and Energy were calculated accordingly as follows:

NFE = 100 - (CP + CF + EE +Ash).

Energy value was calculated as follows: Energy = (P × 4.0) + (NFE × 4.0) + (F × 9.0).

Where 4.0 and 9.0 are constant.

Phytochemicals Determination

The phytochemical composition (tannin, phytic acid, ammonia nitrogen and saponin) of the silage were determined using the techniques described by Raimi and Adeloye (2022). The tannin was determined using the Folin-Coicalteu method which measured the phenolic compounds in the silage.

Phytic acid was determined using High Performance Liquid Chromatography after it was extracted by means of an acid solution. Ammonia nitrogen was determined using the Nesslerization Method while Saponin was determined using the Liquid Chromatography-Mass spectrometer method.

Experimental Animals and their Management

Nine (9) West African dwarf (WAD) rams with an age range of 8 to 12 months and weighing ±19.11 kg were used. The animals were completely randomized into each treatment group. The rams were divided into three treatment groups and fed one of the three silage preparations to evaluate the impact of feeding different levels of ensiled mixtures of cabbage waste, wheat offal, cassava peels, and brewers' spent grains on their growth performance. The animals were housed intensively in well-ventilated pens, in an open-sided house with corrugated aluminum roofing sheet and a concrete floor, which was washed, disinfected and covered with bedding material (wood shavings) before the arrival of the animals. The animals were fed twice in a day (morning and evening) at 7.00 hours and 16.00 hours. Clean drinking water was supplied *ad libitum*. In addition to the supplemental concentrate feed, freshly cut *Gliricidia sepium* forages were provided as the basal diet for all treatment groups. The rams were fed for a total of 56 days. The weights of the animals were taken once every week. Data were obtained on feed intake, body weight changes and feed conversion ratio.

Experimental Design and Statistical Analyses

The layout was a completely randomized design. Data obtained were analyzed using analysis of variance (ANOVA) with SAS (1999) software, and significant means were compared using Duncan's Multiple Range Test of the same software.

RESULTS AND DISCUSSION

Chemical composition of silage

The result for the chemical composition of silage is presented on Table 1. There were significant differences ($p<0.05$) in all the chemical parameters across dietary treatments. Silages dry matter (DM) values were 50.34 % (CBW5), 52.28 % (CBW0) and 56.27 % (CBW10). Dry matter was significantly ($p<0.05$) highest in CBW10. This range observed in this study was slightly above the normal range for silages of 30 - 40 % DM content as reported by AOAC (2005). Percentage DM obtained in this study was within the range (44.89 – 52.99 %) reported by Ekanem *et al.* (2017) for fresh cassava peels ensiled with BSG and poultry litter. Dry Matter, is suitable for ruminant feed, as they ensure that the animals consume sufficient nutrients per unit of feed. Higher DM content (56.27 %) in CBW10 may improve feed intake and overall nutrient absorption, as dry matter is a critical factor in determining the amount of nutrients consumed (Russell, 1984). Overall, these results align well with current standards in livestock nutrition, particularly for ensiled feeds, though the high fiber in CBW0 may pose some limitations in terms of digestibility.

Table 1: Chemical composition (%) of cabbage waste ensiled with wheat offal, dried cassava peels and brewers' spent grain

Parameters	CBW0	CBW5	CBW10	SEM
Dry matter	52.28^{b}	50.34^{c}	56.27^{a}	0.88
Crude protein	14.00^{c}	14.70^{a}	14.35^{b}	0.10
Crude fibre	33.56^{a}	19.75^{c}	20.85^{b}	2.22
Ether extract	5.36^{a}	3.69^{c}	4.86^{b}	0.25
Ash	7.39^{a}	5.02^{c}	6.77^{b}	0.36

Carbohydrate	49.69[c]	56.84[a]	53.17[b]	1.03
Caloric value (Kcal/kg)	466.80[a]	463.91[b]	457.73[c]	1.34
pH	6.70[a]	6.53[b]	6.15[c]	0.82
Ammonia nitrogen (NH_3N)	2.24[c]	2.35[a]	2.30[b]	0.02

[a-c] Means on the same row with different superscripts are significantly different (p<0.05). CBW0 = 0 % cabbage waste (CBW) + 30 % dried cassava peels (DCSP) + 20 % wheat offal (WO) + 50 % brewers' spent grain (BSG). CBW5 = 5 % CBW + 30 % DCSP + 15 % WO + 50 % BSG. CBW10 = 10 % CBW + 30 % DCSP + 10 % WO + 50 % BSG. SEM = Standard error of mean.

The crude protein (CP) content ranged from 14.00 to 14.70 % and was significantly highest in CBW5. This range observed in this study fell within the normal range for silages of 10-15 % CP content as reported by NRC (2001). The protein content fell within the recommended protein range for ruminant diets, which is typically between 12-16 % for moderate growth and maintenance (NRC, 2007). These findings suggested that the ensiled mixtures provided sufficient protein to support muscle development and metabolic activities. This aligned with the observations of Adeyemi *et al.* (2017), who noted that ensiled by-products, such as wheat offal and brewers' grain can significantly boost the protein content in livestock feed. However, the slight variability in protein content across the treatments indicated that the ensiling process might have influenced nutrient concentrations, potentially due to differences in fermentation efficiency or the composition of the starting materials (Kung Jr. *et al*., 2018). The crude fibre (CF) content was significantly different (p<0.05) with values of 33.56 % (CBW0), 19.75 % (CBW5) and 20.85 % (CBW10). This range observed in this study was within the normal range for silages of 25-35 % CF content as reported by van Soest *et al.* (1991). High CF content is essential for promoting rumen function and improving feed digestibility in ruminants. However, CBW0's high fiber percentage might limit digestibility, as fibre-rich diets, particularly those with a high neutral detergent fibre (NDF), can reduce voluntary feed intake and the crude fibre levels in CBW5 and CBW10 aligned more with optimal ruminant diets, as these levels are lower and likely more digestible. The findings are consistent with González-García *et al*. (2011), who noted that agro-industrial by-products such as cassava peels and brewers' grain could vary widely in fibre content depending on processing methods. Furthermore, high CF content, as obtained in CBW0, may slow the passage of feed through the digestive system, potentially lowering the energy available to the animals. The ether extract content ranged from 3.69 to 5.36 %. This range observed in this study was within the normal range for silages of 2 - 6 % ether extract content as reported by Weiss (1999), and Atkins and De Paula (2010). The ash content ranged from 5.02 to 7.39 %. This range observed in this study was within the normal range for silages of 3-10 % ash content as reported by AOAC (2005) and McDonald *et al.* (1991). The carbohydrate content ranged from 49.69 to 56.84 % and was significantly (p<0.05) highest in CBW5 silage. This range observed in this study was within the normal range for silages of 35-45 % carbohydrate content as reported by Sniffen *et al.* (1992). The calorie value was significantly different (p<0.05) across treatment, being 466.80 (CBW0), 463.91 (CBW5) and 457.73 Kcal/kg in CBW10 silage. The range observed in this study for energy was within the normal range for silages of 400 - 500 Kcal/kg as reported by NRC (2001). Carbohydrates provide a crucial energy source for ruminants, facilitating growth and maintenance (FAO, 2019). The elevated carbohydrate content in CBW5 suggested that it might have higher energy availability compared to CBW10 silage. This is corroborated by the caloric values, where CBW5 provided (463.91 kcal/kg), which, although slightly lower than CBW0 (466.80 kcal/kg), was still significant enough to support metabolic processes and growth in rams. However, the lower caloric value in CBW10 (457.73 kcal) might suggest slightly less energy available, which could potentially impact growth and feed efficiency. The results are generally consistent with previous studies, such as those by Kung Jr. *et al.* (2018), who noted that ensiling can enhance the energy density of feeds by preserving readily fermentable carbohydrates.

The pH concentration was significantly different (p<0.05) across silages with values of 6.15, 6.53 and 6.70 for silages CBW10, CBW5 and CBW0 respectively. The pH of the silage for each treatment was slightly acidic and relatively higher than the range of 3.7 - 5.0 classified for good grass/corn-legume silage (Kung Jr. *et al.*, 2018). pH values obtained in this study were also lower than the 3.9 – 4.4 values for a silage mixture of fresh cassava peels, brewers' spent grain and poultry litter at 21 day of ensiling (Ekanem *et al.*, 2017). The high pH observed in this silage could be an indication that there was a limited production of lactic acid during fermentation process due to low contents of fermentable carbohydrates (Ifut *et al.*, 2015; Ekanem *et al.*, 2017). According to Kung Jr. *et al.* (2018), during active fermentation, lactic acid bacteria uses water-soluble carbohydrates to produce lactic acid, which is responsible for increasing acidity by decreasing the pH in the silage and when there is air in the silo, other unwanted microorganisms are allowed to grow and compete with the lactic acid. The ammonium nitrogen (NH_3N) content ranged from 2.24 to 2.35 %. This range observed in this study fell within the normal range for silages of 1- 3 % non-protein nitrogen (NPN) content as reported by Licitra *et al.* (1996) and 1.49 – 2.80 % for good fermented silage as reported by Ifut *et al.* (2015). Ammonia nitrogen is an indicator of protein degradation during fermentation and should be less than 5 % in properly fermented silage (Ifut *et al.*, 2015). In this study, the NH_3-N values were relatively low across treatments (ranging from 2.24 to 2.35 %), suggesting that protein breakdown during ensiling was minimal, preserving most of the protein for the rams' use. This is a positive outcome, as excessive NH_3-N levels indicate poor fermentation quality and can lead to reduced feed efficiency (Driehuis *et al*., 2018).

Physical characteristics of Ensiled Mixture of Cabbage Waste, Wheat Offal, Dried Cassava Peels and Brewers' Spent Grain

The physical characteristics of ensiled cabbage waste, wheat offal, dried cassava peels and brewers' spent grain is presented in Table 2. The result showed the colour, odour, temperature and texture. The colour obtained from (CBW0) was brown, CBW5 and CBW10 was brownish green, which were all the colours of well-made silage. Good silage usually preserves the original colour of any forage/ingredients and has a pleasant and fruity smell which is characteristics of good quality silage which was well preserved (Soetan, 2008). The Silage from these mixtures was found to be pleasant, having alcoholic, aromatic odour as a result of the presence of the fermented brewers' spent grain in the silage corroborating the findings of Ekanem *et al.* (2017). The texture of all the silages (CBW0, CBW5 and CBW10) was firm, which showed that the silage was found palatable (Ekanem *et al.*, 2017). The temperature of silage CBW0 was 36°C, CBW5 was 37°C and CBW10 was 36°C. The temperature for each of the treatment was slightly above the range of temperature (29°C - 35°C) for good silage as outlined by Soetan (2008). The temperature of this silage is also an indication to the inability of the cabbage waste, wheat offal, dried cassava peels and brewers' spent grains to be able to properly ferment due to the dry matter contents of the ingredients.

Table 2: Physical characteristics of ensiled mixture of cabbage waste, wheat offal, dried cassava peels and brewers' spent grain

Parameters	CBW0	CBW5	CBW10
Colour	Brown	Brownish green	Brownish green
Odour	Pleasant	Pleasant	Pleasant
Temperature (^{0}C)	36	37	36
Texture	Firm	Firm	Firm

CBW0 = 0 % cabbage waste (CBW) + 30 % dried cassava peels (DCSP) + 20 % wheat offal (WO) + 50 % brewers' spent grain (BSG). CBW5 = 5 % CBW + 30 % DCSP + 15 % WO + 50 % BSG. CBW10 = 10 % CBW + 30 % DCSP + 10 % WO + 50 % BSG.

Phytochemicals and organic acids composition of ensiled mixture of cabbage waste, wheat offal, dried cassava peels and brewers' spent grain

The result showing the phytochemical and organic acid compositions of the silage preparation is presented in Table 3. There were significant differences ($p<0.05$) in all the parameters tested across treatments. Tannin concentrations were the same and lowest (0.52 %) in CBW0 and CBW5 silages but highest (0.56 %) in CBW10 silage. Tannin, despite possessing antioxidant and therapeutic qualities, are known to reduce the bioavailability of some essential and non-essential complexes, which lead to increased rumen escape of dietary protein and increase in microbial protein outflow (Ekanem *et al.*, 2023b). The Tannin concentrations (0.52 – 0.56 %) in CBW0, CBW5 and CBW10 silages in this study fell within the range outlined by (Sahoo, 2018) for good quality silage, but higher compared to the concentration of 0.05 – 0.09 % reported by Ifut *et al.* (2015) for a *Panicum maximum*: brewers' spent grain silage. Ekanem *et al.* (2022) reported reduced and moderate tannin concentrations of 1.37 - 2.97 % in a concentrate diet containing 0 – 22.50 % of *Enterolobium cyclocarpum* fed to WAD bucks. Although the tannin contents of the diet fed the WAD bucks by Ekanem *et al.* (2022) was higher compared to this study, better growth, carcass and sensory parameters were obtained. Tannins are known to have both beneficial and detrimental effects on ruminant nutrition. Low to moderate levels of tannins can enhance protein utilization by forming complexes with proteins, reducing rumen degradation, and enhancing post-ruminal digestion (Ekanem *et al.*, 2023b). However, excessive tannins can inhibit feed intake and nutrient absorption (Makkar *et al.,* 2016). The tannin levels observed here were within the acceptable range for ruminant diets, as tannins below 6% are typically not harmful (Makkar, *et al* 2016). Thus, these findings align with industry guidelines and previous studies that support the safe inclusion of tannin-containing feedstuffs, such as ensiled BSG, in ruminant diets.

Table 3: Phytochemicals and organic acids composition (%) of ensiled mixture of cabbage waste, wheat offal, dried cassava peels and brewers' spent grain

Parameters	CBW0	CBW5	CBW10	SEM
Tannin	0.52^b	0.52^b	0.56^a	0.01
Saponin	3.77^b	4.18^a	3.40^c	0.11
Hydrocyanic acid (HCN)	0.25^c	0.35^b	0.42^a	0.03

Lactic acid	2.21[b]	2.36[a]	1.82[c]	0.08
Acetic acid	1.40[b]	1.58[a]	1.22[c]	0.05

[a-c] Means on the same row with different superscripts are significantly different ($p<0.05$). CBW0 = 0 % cabbage waste (CBW) + 30 % dried cassava peels (DCSP) + 20 % wheat offal (WO) + 50 % brewers' spent grain (BSG). CBW5 = 5 % CBW + 30 % DCSP + 15 % WO + 50 % BSG. CBW10 = 10 % CBW + 30 % DCSP + 10 % WO + 50 % BSG. SEM = Standard error of mean.

Saponin percentage recorded in this study was evidently above the normal percentage (0.5% - 2%) required in good grass-legume silage. Saponins are noted to affect the digestion and absorption of nutrients in livestock. The saponin content ranged from 3.40 % in CBW10 to 4.18 % in the silage containing CBW5. Saponins are naturally occurring compounds in many plants and agro-industrial by-products and are known for their anti-nutritional properties, as they can reduce feed intake and lower the digestibility of proteins and carbohydrates (McDonald *et al.,* 1991). However, recent studies have shown that low to moderate levels of saponins can have beneficial effects, such as reducing methane emissions in ruminants and improving nitrogen retention (Makkar *et al.,* 2016; Ekanem *et al.*, 2023a & b). The saponin levels observed in this study were within acceptable limits for ruminant feeding and were unlikely to have any negative effects on the growth performance of the rams. This is in agreement with findings by González-García *et al*. (2011), who also noted that saponin levels in agro-industrial by-products were generally safe when appropriately processed.

After ensiling, the hydrogen cyanide (HCN) in CBW0 was 0.25 % (2.53 mg/100g), CBW5 was 0.35 % (2.346 mg/100g), and CBW10 was 0.42 % (4.21 mg/100g), which were above the required level of HCN (200ppm) found in a well-made sorghum silage as stated by Wanga and Abera, (2020). Hydrogen cyanide content, a toxic compound in many agro-industrial by-products, varied among the treatments, with CBW0 having the lowest concentration at 2.36 mg/100g and CBW10 having the highest at 4.21 mg/100g. According to FAO standards, HCN levels in ruminant feed should not exceed 5 mg/kg to avoid toxicity (FAO, 2019). The values in this study were within the acceptable range, ensuring the safety of the feed for the rams. HCN levels are particularly important in cassava-based feeds, as cassava peels are a significant source of cyanogenic glycosides (Tewe, 2004). The ensiling process, which involves fermentation, likely contributed to the reduction in HCN levels by hydrolyzing cyanogenic glycosides into less toxic compounds, which aligns with previous research by González-García *et al*. (2011). This shows that the ensiling method used was effective in mitigating the potential toxicity of HCN in the feed.

The concentrations of lactic acid (1.82 – 2.36 %) and acetic acid (1.22 – 1.58 %) were significantly different ($p<0.05$) across dietary treatments, being highest in CBW5 silage and lowest in CBW10 silage for both organic acid. Lactic acid in this study was found to be below the required percentage (3 – 8 %) for a well-made grass-legume silage. The percentages from the treatments were low and this could have led to the increase in the pH level of the silage. The lactic acid and acetic acid concentrations are indicators of the fermentation quality of the silage. Lactic acid is the primary acid responsible for lowering the pH of silage and preserving its nutritional value by inhibiting the growth of spoilage organisms. Higher lactic acid levels, as seen in CBW5, suggested a more efficient fermentation process, which is beneficial for silage quality and animal health (Driehuis *et al.,* 2018). Acetic acid, while also essential in silage fermentation, should be present in moderate amounts, as excessive levels can reduce the palatability of the feed. The acetic acid levels in this study were within the optimal range for high-quality silage, as levels between 1-3 % are typically considered ideal for maintaining the nutritional integrity of the silage (Kung Jr. *et al.*, 2018). These results were consistent with previous findings, indicating that the ensiling process effectively preserved the nutritional value of the feed ingredients (Ifut *et al.,* 2015).

Phytochemicals have beneficial and potential health-promoting effects in animals (Raimi and Adeloye, 2022) such as increased protein and other nutrients digestibility, partitioning more nitrogen to feaces (Ekanem *et al.*, 2023b), reduced methanogenesis (Ekanem *et al.*, 2023a), enhanced milk yield, some milk constituents, and maximal kid growth (Ekanem *et al.*, 2024). Inclusion of plants rich in phytochemicals has also resulted in higher growth performances, carcass characteristics and organoleptic properties (Ekanem *et al.* 2022). The process of fermentation (ensiling) has also been found to reduce the composition of phytochemicals in forages (Sahoo, 2018; Ekanem *et al.*, 2020; Wang *et al*., 2022; Ekanem *et al.*, 2023b) which was also be the case in this study.

Growth performance of rams fed ensiled mixture of cabbage waste, wheat offal, dried cassava peels and brewers' spent grain

Table 4 outlines the growth performance of rams fed silages made from cabbage waste, cassava peels, wheat offal, and brewers' spent grain. The initial weights of the rams were fairly similar, with all treatments showing values between 18.97 kg and 19.30 kg, ensuring a baseline for comparison. At the end of the study, the final weights showed slight differences, with rams fed CBW10 (22.33 kg) and CBW5 (21.83 kg) having higher final weights than CBW0 (21.67 kg). This indicated that the ensiled feed was sufficient to maintain or promote weight gain in the rams across all treatments. However, it was noted that rams on CBW5 had the lowest weight change (2.53 kg), suggesting a slightly less efficient growth rate compared to those on CBW0 and CBW10, both with a 3.00 kg weight change. This is consistent with prior findings (Kung Jr. *et al.* 2018) that emphasized the importance of silage quality and digestibility in influencing growth rates, where variations in fermentation quality can affect growth performance.

Table 4: Growth performance of West African dwarf rams fed cabbage waste ensiled with dried cassava peels, wheat offal and brewers' spent grain

Parameters	CBW0	CBW5	CBW10	SEM
Initial weight (Kg)	18.87	19.30	19.10	0.11
Final weight (Kg)	21.67[c]	21.83[b]	22.33[a]	0.10
Average weight gain (Kg)	2.80[a]	2.53[b]	3.00[a]	0.08
Daily weight changes (g/d)	71.43[a]	59.52[b]	71.43[a]	1.99
Silage DM Intake (g/d)	208.88[a]	188.95[c]	193.62[b]	3.01
Gliricidia spp. DM intake (g/d)	106.21[a]	106.11[b]	105.93[c]	0.04
Total DM intake (g/d)	315.09[a]	295.07[c]	299.55[b]	3.03
FCR	4.41[b]	5.00[a]	4.19[c]	0.12

[a-c] Means on the same row with different superscripts are significantly different ($p<0.05$). CBW0 = 0 % cabbage waste (CBW) + 30 % dried cassava peels (DCSP) + 20 % wheat offal (WO) + 50 % brewers' spent grain (BSG). CBW5 = 5 % CBW + 30 % DCSP + 15 % WO + 50 % BSG. CBW10 = 10 % CBW + 30 % DCSP + 10 % WO + 50 % BSG. SEM = Standard error of mean. FCR = Feed Conversion Ratio

Daily weight change was highest in rams on CBW0 and CBW10 (71.43 g/day), while those on CBW5 had a lower daily weight change of 59.52 g/day. This suggested that the rams on CBW0 and CBW10 were able to utilize the nutrients in the silage more efficiently for growth compared to those on CBW5. Previous studies indicated that high levels of fiber in feed can reduce daily weight gain due to reduced digestibility and nutrient availability (Dewhurst *et al.,* 2019). The higher fiber content observed in CBW5 (Table 1) may explain the slightly lower daily weight change, aligning with research by Adeyemi *et al.* (2017) that found similar correlations between fiber content and weight gain in ruminants. The daily weight change observed in animals on CBW0 and CBW10 was within the acceptable range for rams fed on high-quality silage (Tewe, 2004), indicating that the fermentation process used for these treatments enhanced nutrient availability.

On feed intake, silage dry matter (DM) intake was significantly higher in rams on CBW0 (208.88 g/day) compared to those on CBW5 (188.95 g/day) and CBW10 (193.62 g/day), showing that the rams on CBW0 consumed more silage. This higher intake could explain the better growth performance seen in rams on CBW0 compared to those fed CBW5. It is well established that feed intake is a critical factor influencing animal growth, as higher intake typically provides more nutrients for weight gain and body maintenance (González-García *et al.*, 2011). The total DM intake (combining silage and *Gliricidia sepium*) was also highest in rams fed CBW0 (310.09 g/day), followed by those on CBW10 (299.55 g/day) and CBW5 (295.07 g/day). This indicated that CBW0 and CBW10 provided a more palatable and digestible diet, supporting better growth performance. Previous research by Makkar *et al.* (2016) highlighted that palatability and digestibility play significant roles in determining feed intake, which aligns with the findings of this study.

The feed conversion ratio (FCR) is a key measure of feed efficiency, representing how much feed is required to achieve a unit of weight gain. A lower FCR indicates better efficiency, and in this study, rams fed CBW10 had the least FCR (4.19), followed by those on CBW0 (4.41), and CBW5 had the highest FCR (5.00), meaning it was the least efficient. These values suggest that the rams on CBW10 utilized their feed most efficiently for growth, which correlated with their final body weight. Studies by Muck (2010) suggested that silage with optimal fermentation enhances nutrient absorption, leading to better FCR. The slightly higher FCR in CBW5 may be attributed to the lower intake and growth rate, supporting findings by McDonald *et al.* (1991) that higher fiber content can reduce feed efficiency due to its slower digestibility. The FCR values in this study were within the range reported in other studies on ruminant growth performance on silage diets (Kung Jr. *et al.,* 2018), though CBW5 shows a deviation due to lower feed efficiency.

CONCLUSION

Silage dry matter was highest in silage 3 (CBW10). Silage 3 (CBW10) also had the least pH value and was thus adjudged the best fermented. Silage 2 (CBW5) had higher concentration of protein and carbohydrate compared to the control silage without cabbage waste. Silages 2 (CBW5) and 3 (CBW10) recorded better physical characteristics with pleasant aromatic odour and firm texture. Ensiling resulted in low contents of phytochemicals for all the silages which were within acceptable range. Silage 2 (CBW5) was well fermented as evidenced in its highest concentrations of lactic and acetic acids. Animals fed silages containing cabbage waste (CBW5) and (CBW10) had higher growth rate with rams fed (CBW10) recording highest final body weight and least feed conversion ratio. Cabbage waste ensiled with brewers' spent grain, wheat offal and dried cassava wastes (DCW) at varying levels thus made better quality silages which increased rams growth rate.

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