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Nutrient Digestibility and Haematological Indices of Wad Rams Fed Ensiled Mixture of Cabbage Waste, Wheat Offal, Dried Cassava Waste and Brewers' Spent Grain

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ABSTRACT

This experiment sought to assess the digestibility of various nutrients and the haematological responses of West African dwarf (WAD) rams fed silages containing varying levels of cabbage waste (CBW), wheat offal (WO), dried cassava waste (DCSW) and brewers' spent grain (BSG). Silage 1 (CBW0) = 0 % CBW + 20 % WO + 30 % DCSW + 50 % BSG; Silage 2 (CBW5) = 5 % CBW + 15 % WO + 30 % DCSW + 50 % BSG and Silage 3 (CBW10) = 10 % CBW + 10 % WO + 30 % DCSW + 50 % BSG. Nine WAD rams averaging 18.5±2.3 kg, were divided into three treatment groups in a completely randomized design and fed the silages for 56 days. At the 9th week, the rams were placed on metabolic cages for digestibility studies. Blood samples were also obtained for haematological studies. Results revealed significant differences ($p<0.05$) in the digestibility (%) of nutrients, with dry matter (45.85 – 51.38), crude fiber (61.74 – 77.63) and ether extract (24.82 – 34.67) digestibility being highest by WAD rams fed CBW0 silage. Among the cabbage wastes treated groups (CBW5 and CBW10), rams fed Treatment 2 (CBW5) recorded higher crude protein (58.29 %), ether extract (27.85 %) and nitrogen free extract (52.78 %) digestibilities. There were also significant differences ($p<0.05$) in the nitrogen intake, absorbed and retained by the rams, with rams on diet 1 without cabbage waste (CBW0) recording highest values in nitrogen balance (2,66 g/d) and retention (42.04 %). Among the cabbage waste treated groups, rams on CBW5 had higher values for nitrogen intake (6.33 g/d), absorbed nitrogen (4.05 g/d), nitrogen balance (2.58 g/d) and percentage nitrogen retention (40.74 %) indicating better protein utilization. Haematological parameters (packed cell volume, haemoglobin, red blod cell, white blood cell, lymphocytes, neutrophils, monocytes, eosinophil, basophils, mean corpuscular volume, mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration) differed significantly ($p<0.05$) across treatments, but were all within range that did not affect the normal physiological functions of the rams. Thus, rams can be fed other agro-industrial by-products without cabbage waste for maximal dry matter, crude fiber and ether extract digestibility. Additionally rams can be fed up to 5 % cabbage waste with no deleterious effect on digestibility, nitrogen retention and haematological indices.

KEYWORDS: Agricultural waste, cabbage waste, silage, nutrients digestibility, nitrogen retention, haematology.

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INTRODUCTION

Alternative feed ingredients have the potential to be used in sheep diets as a cost-effective and sustainable option. Furthermore, there is need to rid our environments of agricultural wastes that constitute a nuisance to the society health wise. Some of these agricultural waste and agro-industrial by-products incorporated in ruminant feed include cassava waste (including the peels), cabbage waste, wheat offal and brewers' spent grain (Ekanem *et al.*, 2017). Among the various industrial wastes, brewers' grains utilization has increased due to the excessive supply used for increased beer production (Albuquerque *et al.,* 2011; Ekanem *et al.*, 2017). Brewers' dried grain is a good protein and energy source and a lot of work has been reported on its incorporation in the diet of animals (Mervat *et al.,* 2019; Andressa *et al.,* 2017; Ekanem *et al.*, 2023). The utilization of brewers' dried grain (BDG), presents an opportunity to improve the nutritional value of sheep diets and enhance milk production. Its availability, low cost, and potential nutritional benefits make it an attractive option for livestock feed formulations. Wheat offal, a by-product of wheat processing, can be a valuable feed resource for sheep, providing a nutritious and cost-effective alternative to traditional feeds (Singh *et al.,* 2018). Wheat offal is high in fiber, energy, and nutrients, making it an ideal feed supplement for sheep (AOAC, 2019). Cassava wastes (peels and flesh), a by-product of cassava processing, can be a valuable feed resource for sheep, providing a nutritious and cost-effective alternative to traditional feeds (Okeke *et al.,* 2018). Cassava peels are high in fiber, energy, and other nutrients, making them an ideal feed supplement for sheep (AOAC, 2019).

Haematology is a vital tool for assessing the health and nutritional status of animals. In Rams, haematological parameters can provide valuable insights into their overall well-being and response to different feed sources. (Tahir *et al.,* 2017). Rams are known to have a unique haematological profile compared to other livestock species. Normal haematological values for rams include: Red blood cell count (RBC): 9.5-15.5 x10^12/L (Radostits *et al.,* 2007), Haemoglobin (Hb): 100-150 g/L (Smith *et al.,* 2015), Haematocrit (Hct): 30-45 % (Kaneko *et al.,* 2008), White blood cell count (WBC): 4-12 x10^9/L (Thrall *et al.,* 2012). Platelet count: 100-500 x 10^9/L (Bohn *et al.,* 2020). These values can be influenced by various factors such as nutrition, age, and health status. Studies have shown that feeding rams with alternative feed sources can affect their haematological parameters. For example, a study by Okeke (2018) found that feeding rams with cassava peels-based diets increased their RBC and Hb values. Another study by Lee *et al.* (2000) reported that brewers' spent grains-based diets improved the WBC count in rams.

However, there is a lack of research on the specific effects of feeding ensiled brewers' spent grain, cabbage wastes, wheat offal and cassava wastes in the hematological indices of WAD rams in Nigeria. This knowledge gap limits the ability of sheep farmers to optimize their feeding strategies and make informed decisions regarding the incorporation of cabbage wastes in the sheep (rams) diet. Therefore, there is a need to investigate the impact of ensiled mixture of brewers' spent grain, wheat offal, cabbage wastes and cassava wastes (peels and flesh) in blood of WAD rams, in order to provide evidence-based recommendations for improved sheep nutrition and productivity. The objective of this study therefore was to evaluate the feeding value in terms of nutrient digestibility and haematological indices of by WAD rams fed silages containing cabbage waste, dried cassava waste, wheat offal and brewers' spent grain.

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 1 (CBW0) silage had no cabbage waste inclusion (0 %), but consisted of dried cassava peels (30 %), wheat offal (20 %) and brewers' spent grain (50 %). 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 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: 0 % cabbage waste (CBW) + 20 % wheat offal (WO) + 30 % dried cassava waste (DCSW) + 50 % brewers' spent grain (BSG)
Silage 2: 5 % CBW + 15 % WO + 30 % DCSW + 50 % BSG
Silage 3: 10 % CBW + 10 % WO + 30 % DCSW + 50 % BSG
The drums (20 litre volume) containing the various compressed silage mass 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.

Experimental animals and their management
Nine (9) West African dwarf (WAD) rams aged 8 to 12 months with an average weight of ±19.11 kg were used. The animals were completely randomized into three treatment groups with three animals per replicate. 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 materials (wood shavings). Prior to this study, the rams were fed *Gliricidia sepium* forages and the silages for a total of 56 days to determine their growth performance. In this study, the digestibilities of the nutrients in the different silages containing varying mixtures of cabbage waste, wheat offal, cassava peels, and brewers' spent grain by the rams were evaluated. Additionally, the influences of these diets on the rams' haematological parameters were also assessed.

Digestibility Procedures
To assess the digestibility of the experimental diets, the rams were housed in individual metabolic cages designed to facilitate the separate collection of feces and urine after the 56-day feeding period. The cages allowed for accurate measurements of feed intake, fecal output, and urine excretion, ensuring precise data collection for digestibility calculations. Known quantities of the silages were offered in feeders. Clean drinking water was also offered in separate bowls.
The animals were acclimatized to the cages and feed for 4 days. Thereafter, fecal output from each ram was collected daily during the following 7-day digestibility trial. Faeces were weighed immediately after collection, and a 10 % representative sample was taken. The fecal samples were preserved by sun drying them for 48 hours in order to reduce the moisture contents. Sun dried fecal samples were ground and stored in airtight containers for subsequent chemical analysis. Urine from each ram was collected in containers placed beneath the metabolic cages. To prevent nitrogen losses due to volatilization, 10 ml of 10 % sulfuric acid was added to the urine collection containers. Urine volume was measured daily, and a 10 % aliquot was stored at -10°C for nitrogen analyses. Samples were bulked for each treatment and 10 % subsamples obtained for analyses.

Haematological Procedure
At the end of the feeding trial which lasted for 56 days, 5mls of blood samples were collected from each of the animals via jugular vein puncture using syringes. The blood in the syringe was gently transferred into a plane sample bottles placed in a slanted position and ready for the determination of haematological parameters i.e., the analysis of packed cell volume (PCV) (Merck, 2018), hemoglobin (Hb) (Jain, 2015), white blood cells (WBC), red blood cells (RBC), lymphocytes (LYM), neutrophils (NEUT), monocytes (M), (Feldman *et al.*, 2015), Mean Corpuscular Haemoglobin Concentration (MCHC), Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH), (Jain, 2015), platelet count (PLT) (Merck, 2018), eosinophils (E) and basophils (B) (Feldman *et al.,* 2015).

Chemical Analysis
Both the feed and faecal samples were subjected to proximate analysis to determine the concentrations of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and ash (AOAC, 1990). The digestibility of the nutrients was calculated using the following formula:

$$\text{Digestibility (\%)} = \left(\frac{\text{Nutrient Intake} - \text{Nutrient in Feces}}{\text{Nutrient Intake}}\right) \times 100$$

Urine samples were analyzed for nitrogen content using the Kjeldahl method to determine nitrogen balance. This allowed for the assessment of protein utilization efficiency and nitrogen retention.

Experimental design and analyses
A completely randomized design (CRD) was employed to evaluate the effects of varying levels of the ensiled mixture on the growth performance of rams. The statistical model used was:

$$Y_{ij} = \mu + \tau_i + \epsilon_{ij}$$

where:

- Y_{ij} = single observation
- τ_i = treatment effect
- μ = overall mean
- ϵ_{ij} = random error

Data 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 the silages is presented on Table 1. There were significant differences ($p<0.05$) in all the chemical parameters across dietary treatments. Dry matter was significantly ($p<0.05$) highest in CBW10, while crude protein (CP) content (14.00 - 14.70 %) and ammonia nitrogen (NH_3N) was significantly highest in CBW5. Unah *et al.* (2025) discussed the implications of these parameters on the growth performance of rams fed these silages.

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 (DCSW) + 20 % wheat offal (WO) + 50 % brewers' spent grain (BSG). CBW5 = 5 % CBW + 30 % DCSW + 15 % WO + 50 % BSG. CBW10 = 10 % CBW + 30 % DCSW + 10 % WO + 50 % BSG. SEM = Standard error of mean.

Apparent nutrient digestibility of West African dwarf rams fed cabbage waste ensiled with dried cassava peels, wheat offal and brewers' spent grain

Table 2 shows the apparent nutrient digestibility data for rams fed ensiled mixtures across three treatment groups (CBW0, CBW5 and CBW10). There were significant differences ($p<0.05$) in all parameters tested across dietary treatment. The silage intake was highest in rams fed CBW0 (1533.33 g), followed by rams fed CBW10 (1451.67 g) and then by rams fed CBW5 (1383.33 g). Digestibility plays a vital role in the effective utilization of feed, and higher intake often correlates with higher digestibility due to enhanced microbial fermentation in the rumen. In this study, the higher intake in rams fed CBW0 aligned with increased digestibility, which is supported by (González-García *et al*. 2017), who noted that higher intake generally leads to better fermentation, resulting in higher digestibility. This showed that animals on CBW0, which had the highest silage intake, were more efficient at converting the consumed feed into energy for growth. Rams fed CBW5, with the lowest intake, may have experienced slower digestion due to the higher fiber content, which could impede nutrient absorption.

Table 2: Apparent digestibility (%) of West African dwarf rams fed cabbage waste ensiled with dried cassava peels, wheat offal and brewers' spent grain

Parameters	CBW0	CBW5	CBW10	SEM
Silage intake (g)	1533.33[a]	1383.3[c]	1451.67[b]	21.68
Gliciridia spp. intake (g)	1770.00[b]	1773.33[a]	1756.67[c]	2.55
Silage dry matter intake (g)	266.95[a]	240.84[c]	252.74[b]	3.77
Gliciridia spp. dry matter intake (g)	112.28[b]	112.49[a]	111.43[c]	0.16
Total dry matter Intake (g)	379.23[a]	353.33[c]	364.17[b]	3.76
Dry matter digestibility	51.38[a]	45.85[c]	48.05[b]	0.80
Crude protein digestibility	56.09[b]	58.29[a]	52.00[c]	0.92
Crude fibre digestibility	77.63[a]	61.74[c]	67.15[b]	2.33
Ether extract digestibility	34.67[a]	27.85[b]	24.82[c]	1.46
Nitrogen free extract digestibility	50.90[b]	52.78[a]	50.61[c]	0.34

[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 (DCSW) + 20 % wheat offal (WO) + 50 % brewers' spent grain (BSG). CBW5 = 5 % CBW + 30 % DCSW + 15 % WO + 50 % BSG. CBW10 = 10 % CBW + 30 % DCSW + 10 % WO + 50 % BSG. SEM = Standard error of mean.

In terms of dry matter (DM) intake, rams on CBW0 showed the highest silage DM intake (266.95 g/day), followed by those on CBW10 (252.74 g/day), and rams on CBW5 had the lowest intake (240.84 g/day). Total DM intake followed a similar pattern, with animals fed CBW0 having the highest value (379.23 g/day), CBW10 slightly lower (364.17 g/day), and CBW5 the lowest (353.33 g/day). The higher DM digestibility performance of rams on CBW0 can be linked to its highest dry matter intake (51.38 %), followed by CBW10 (48.05 %) and CBW5 (45.85%). This supported the idea that the rams fed silage CBW0 were able to extract more nutrients from the feed, contributing to their superior growth performance. This observation aligned with McDonald *et al.* (1991), who found that higher DM digestibility improves the availability of energy and nutrients, which directly impacts growth. Animals fed CBW5 lowered digestibility could be attributed to the low total dry matter intake (Ndlovu *et al.,* 2020).

The crude protein (CP) digestibility was highest in rams fed CBW5 (58.29%), followed by those on CBW0 (56.09 %) and CBW10 (52.00%). Although rams on CBW5 had lower DM and fiber digestibility, it had the highest CP digestibility, suggesting that the rams on CBW5 were able to better utilize the protein content of the feed despite its lower overall digestibility. This could be due to the high crude protein of that silage and the presence of specific microbial populations that aid in protein fermentation, as suggested by (Nurfeta and Abebe 2018), who observed variations in CP digestibility based on ruminal microbial adaptation. High CP digestibility of CBW5 silage by rams might be due to the high contents of saponin in that diets that made it possible for protein binding and escape of rumen fermentation which was degraded in the abomasum (Ekanem *et al.*, 2020). However, rams on CBW0's relatively high CP digestibility is still in line with the overall better performance of this group, as higher DM intake typically supports improved protein utilization (Kung Jr. *et al.,* 2018). Animals on CBW10, with the lowest CP digestibility, may have had less efficient microbial protein fermentation, which could be linked to the slightly lower silage intake and overall digestibility.

For fiber digestibility, rams on CBW0 (77.63 %) significantly ($p<0.05$) outperformed those on CBW5 (61.74 %) and CBW10 (67.15 %), reflecting the ability of the rams in CBW0 to break down and utilize the fiber in their diet more effectively. This is an important observation because fiber digestibility is often the limiting factor in ruminant nutrition, as it directly affects the availability of energy from fibrous feeds. The higher fiber digestibility in rams on CBW0 could be attributed to the optimal fermentation of the silage in this group, which may have reduced the lignin content and improved the availability of digestible fiber (Muck, 2010). Studies by Kung Jr. *et al.* (2018) and Dewhurst *et al*. (2019) have similarly reported that well-fermented silage enhances fiber digestibility by breaking down complex carbohydrates, making them more accessible to rumen microbes. The lower fiber digestibility in rams on CBW5 could be linked to the silage low fiber content.

Energy efficiency, as indicated by the ether extract (EE) digestibility, was lowest in rams on CBW10 (24.82%), higher by those on CBW5 (27.85%) and highest by rams fed CBW0 (34.67%). This suggested that CBW0 provided the most efficient fat metabolism, likely due to better microbial fermentation of lipids in the rumen. Lipid digestibility in ruminants is crucial as it affects the energy density of the diet. The lower EE digestibility in animals fed CBW5 and CBW10 may have contributed to their lower overall energy availability, explaining the slightly reduced growth performance compared to CBW0. According to González-García *et al.* (2017), diets with higher EE digestibility typically result in better energy utilization, leading to enhanced growth and metabolic efficiency. In contrast, diets with lower fat digestibility, like those in CBW5 and CBW10, may reduce the energy available for growth, which could partly explain their lower weight gains.

Nitrogen-free extract (NFE) digestibility was highest in rams fed CBW5 (52.78 %), followed by those on CBW0 (50.90 %) and CBW10 (50.61 %). NFE digestibility indicated how well the rams could utilize carbohydrates in their diet, particularly non-fibrous

carbohydrates like sugars and starches. The high NFE digestibility in rams on CBW5 may have compensated for its lower fiber digestibility, allowing the rams to still derive sufficient energy from non-fiber carbohydrates. This could explain why rams on CBW5, despite having the lowest silage intake and fiber digestibility, were still able to maintain acceptable levels of growth. These findings were in line with research by Adeyemi *et al.* (2017), who reported that high carbohydrate digestibility could offset lower fiber digestibility, supporting overall energy balance in ruminants.

Nitrogen Balance of West African dwarf rams fed cabbage waste ensiled with dried cassava peels, wheat offal and brewers' spent grain

Table 3 presents the nitrogen balance data for rams fed ensiled mixtures in the three treatment groups (CBW0, CBW5, and CBW10). Nitrogen balance is a crucial indicator of the protein utilization efficiency in ruminants, reflecting the difference between nitrogen intake and nitrogen excretion. There were significant differences ($p<0.05$) across dietary treatment. The total nitrogen intake was consistent for rams fed treatments 1 and 2 (CBW0: 6.33 g, CBW5: 6.33 g), but significantly lowest for rams fed silage 3 (CBW10: 6.21 g). However, nitrogen output (via feces and urine) varied slightly, affecting nitrogen retention and overall balance. These results aligned with previous findings that nitrogen intake depends primarily on protein availability in the feed (Nurfeta and Abebe, 2018). According to Kung Jr. *et al.* (2018), maintaining a similar protein intake across treatments is critical to assess how different treatments impact nitrogen metabolism and retention.

Table 3: Nitrogen balance of West African dwarf rams fed cabbage waste ensiled with dried cassava peels, wheat offal and brewers' spent grain

Parameters	CBW0	CBW5	CBW10	SEM
Silage nitrogen (g/d)	2.24^{c}	2.35^{a}	2.28^{b}	0.02
Gliricidia spp. nitrogen (g/d)	4.09^{a}	3.98^{b}	3.93^{c}	0.07
Total nitrogen intake (g/d)	6.33^{a}	6.33^{a}	6.21^{b}	0.02
Faecal nitrogen (g/d)	2.37^{b}	2.28^{c}	2.43^{a}	0.02
Urine nitrogen (g/d)	1.30^{c}	1.47^{a}	1.37^{b}	0.03
Total nitrogen output (g/d)	3.67^{c}	3.75^{b}	3.80^{a}	0.02
Nitrogen balance (g/d)	2.66^{a}	2.58^{b}	2.41^{c}	0.04
Nitrogen retention (%)	42.04^{a}	40.74^{b}	38.89^{c}	0.46
Nitrogen absorbed (g/d)	3.96^{b}	4.05^{a}	3.78^{c}	0.04

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

In terms of fecal nitrogen, the differences between treatments were minimal but significantly different, with rams on CBW0 excreting 2.37 g, CBW5 2.28 g, and CBW10 2.43 g. The slightly higher fecal nitrogen output in rams on CBW10 suggests that protein digestion may not have been as efficient as in the other groups. When comparing these findings to that of Dewhurst *et al.* (2019), higher fecal nitrogen output can indicate reduced protein digestibility or increased passage rates, limiting microbial protein synthesis in the rumen. Alternatively, the rams might have partitioned more nitrogen to feaces, corroborating the fact that ruminant animals fed forages containing phytochemicals/plant secondary metabolites such as tannin and saponin favours faecal nitrogen output. (Ekanem *et al.*, 2020; 2023). The lower faecal nitrogen in rams fed CBW5, despite its lower dry matter and fiber digestibility (as seen in Table 2), might indicate that the rams in CBW5 had better access to soluble proteins, leading to more efficient nitrogen absorption in the intestines. This could be linked to the higher CP digestibility in rams on CBW5, which may have allowed for greater protein utilization.

Urine nitrogen excretion was highest in rams fed CBW5 (1.47 g), followed by those on CBW10 (1.37 g) and CBW0 (1.30 g), showing significant differences between the treatments. The higher urinary nitrogen output in rams on CBW5 suggests that more nitrogen was lost through urine, likely due to the excessive breakdown of dietary protein that exceeded the rams' metabolic needs. According to Adeyemi *et al*. (2017), higher urinary nitrogen excretion is a sign of poor protein utilization, where excess nitrogen is converted into urea and excreted. This finding is consistent with the overall nitrogen retention data, where rams on CBW5 had lower nitrogen retention (40.74%) compared to CBW0 (42.04%). The lowest nitrogen output in animals on CBW0 further confirmed that the protein in this treatment was better utilized, reducing nitrogen loss and improving nitrogen retention efficiency. González-García *et al.* (2017) had emphasized that lowering urinary nitrogen excretion is crucial for enhancing the nitrogen-use efficiency in ruminants, reducing nitrogen waste and improving overall protein utilization.

Nitrogen retention, a critical measure of protein metabolism, was highest in rams fed CBW0 (2.66 g), followed by those on CBW5 (2.58 g) and CBW10 (2.41 g), indicating that the rams in CBW0 were able to retain more nitrogen for growth and maintenance.

Nitrogen retention percentage was similarly highest in animals fed CBW0 (42.04%), slightly lower in those on CBW5 (40.74%), and lowest in those of CBW10 (38.89%). These results aligned with the superior digestibility observed in CBW0 in earlier Tables, where the better digestibility of dry matter, protein, and fiber in CBW0 allowed for improved nitrogen retention. This finding is consistent with research by Nurfeta and Abebe (2018), which noted that higher nitrogen retention is positively correlated with enhanced protein digestibility and overall feed efficiency. In contrast, the lower nitrogen retention in rams fed CBW10 could be attributed to its lower CP digestibility (52.00%), as seen in Table 5, which likely reduced the availability of amino acids for absorption and retention.

The nitrogen absorption values also highlight the differences in nitrogen metabolism between the treatments, with rams on CBW5 showing the highest value (4.05 g), followed by those on CBW0 (3.96 g) and CBW10 (3.78 g). The higher nitrogen absorption in rams on CBW5 may reflect better protein solubility and absorption in the intestines, despite its lower nitrogen retention. This pattern of high nitrogen absorption but lower nitrogen retention in rams fed CBW5 suggested that much of the absorbed nitrogen was lost through urine, indicating inefficient nitrogen utilization. This aligned with Kung Jr. *et al*. (2018), who noted that when nitrogen absorption exceeds the animal's needs, the excess is converted into urea and excreted through urine. On the other hand, rams fed CBW0 recorded slightly lowered nitrogen absorption but higher retention indicating a more efficient utilization of absorbed nitrogen, as more of it was retained for growth and metabolic functions.

Overall, the findings in Table 3 highlighted the superior nitrogen utilization in rams fed CBW0, where better nitrogen retention and lower urinary nitrogen excretion reflect more efficient protein metabolism. This suggested that silage CBW0 was better balanced in terms of protein digestibility and energy availability, supporting enhanced nitrogen retention. In contrast, the higher urinary nitrogen excretion in rams on CBW5 and lower nitrogen retention in those on CBW10 indicated less efficient nitrogen utilization, which could have limited growth performance. These results aligned with the broader literature, where studies by Dewhurst *et al.* (2019) and Adeyemi *et al.* (2017) emphasized the importance of balancing protein intake and digestibility to optimize nitrogen retention and minimize nitrogen waste.

Haematological profile of West African dwarf rams fed cabbage waste ensiled with dried cassava peels, wheat offal and brewers' spent grain

Table 4 shows the haematological indices of rams fed the silages for 56 days. The result indicated that there were significant differences ($p<0.05$) in all the parameters observed except for basophils. Ramprabhu *et al.* (2010) had noted that blood is an important and reliable medium for assessing the health status of animals.

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

Parameters	CBW0	CBW5	CBW10	SEM
Packed cell volume (%)	27.50^{c}	28.00^{b}	31.00^{a}	0.55
Haemoglobin (g/dL)	9.63^{b}	9.80^{a}	9.50^{c}	0.04
Red blood cell ($x10^{6}$/µl)	1.00^{c}	1.10^{b}	1.13^{a}	0.02
White blood cell ($x10^{3}$/µl)	17.40^{a}	11.30^{b}	11.10^{c}	1.03
Lymphocyte (%)	63.67^{a}	56.00^{c}	60.00^{b}	1.11
Neutrophil (%)	32.00^{c}	38.67^{a}	35.00^{b}	0.96
Monocyte (%)	1.00^{b}	1.67^{a}	1.00^{b}	0.11
Eosinophil (%)	2.33^{c}	3.00^{a}	2.67^{b}	0.10
Basophil (%)	0.67	0.67	0.67	0.00
Mean Corpuscular volume (fL)	26.67^{c}	28.67^{a}	27.67^{b}	0.29
Mean Corpuscular Haemoglobin (pg)	9.30^{b}	9.47^{a}	8.67^{c}	0.12
Mean Corpuscular Haemoglobin Concentration (MCHC) (g/dL)	35.00^{a}	33.67^{b}	31.33^{c}	0.54

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

The packed cell volume (PCV) values for animals on all treatments recorded a lower count than the normal range of 36-46 %, (Radostits *et al.,* 2007). Specifically, rams on CBW0 had a PCV of (27.50%), and those on CBW5 had (28.00%), and CBW10 had (31.00%) and may indicate anemia, blood loss, or dehydration. These values were comparable to 29.90% - 33.60% reported by Mitruka and Rawnsley (1977) for clinically healthy sheep. Banerjee (2007) had reported a PCV range of 28.47% - 30.25% for sheep and is similar to that obtained here. Daramola *et al*. (2005) had opined that PCV below the normal range is an indication that the

animal is anemic and is due to poor quality of protein of the diet. This was not observed in this study, inferring that the diet had no negative effect and was adequate in terms of animal health. The hemoglobin (Hb) levels for all the animals were below the normal range of 13.5-17.5 g/dL as reported by Kaneko *et al.* (2008). Rams on CBW0 had (9.63 g/dL), while those of CBW5 had (9.80g/dL) and CBW10 had (9.50g/dL). Haemoglobin when lower than normal indicates severe anemia, iron deficiency, or chronic disease. The Hb values obtained in this study fell within the normal values (8.47g/dl - 9.7g/dl) recorded for healthy sheep as reported by Amuda and Okunlola (2018). The concentration of Hb in the cytoplasm of the red blood cells has been reported to give an indication of oxygen carrying capacity of the blood. The Hb value obtained also compared favorably with the Hb of 8.00 g/dl - 14.00g/dl (Mitruka and Rawsnley, 1977). The values indicated that the rams had sufficient blood pigment for proper transportation of oxygen, thus they were healthy (Binuomote and Babayemi, 2017). The red blood cell (RBC) counts for all the animals were below the normal range of 4.3-5.7 million cells/µL (Weiss and Wardrop, 2010). Rams on CBW0 had (1.00), and those of CBW5 had (1.10), and CBW10 had (1.13) and may indicate severe anemia, blood loss, or bone marrow dysfunction. Animals on CBW0 recorded a slightly higher white blood cell (WBC) count (17.40) than those on CBW5 (11.30) and CBW10 (11.10), which may indicate a mild inflammatory response or infection. However, all values were within the normal range of 4,000-11,000 cells/µL as reported by Radostits *et al.* (2007).

The lymphocyte and neutrophil counts were all within normal ranges (LYM% 40-60%, NEUT% 30-50%) (Kaneko *et al.,* 2008), for all rams, suggesting a balanced immune system. Monocyte counts are within normal ranges for all treatment groups (Weiss and Wardrop, 2010). Rams fed CBW0 had 1.00 %, while others on CBW5 had 1.67 %, and CBW10 had 1.00%. This may indicate decreased monocyte production. Eosinophil (EOS) and basophil (BAS) counts were within normal ranges (0-5%, 0-1%) (Weiss and Wardrop, 2010) indicating no significant allergic or parasitic infections. Rams fed CBW0 had (2.33) EOS and (0.67) BAS, silage CBW5 fed lambs had (3.00) EOS and (0.67) BAS, and CBW10 had (2.67) EOS and (0.67) BAS. All three treatment groups had Mean Corpuscular volume (MCV) values lower than the normal range of 80-100 fL (Kaneko *et al.,* 2008). Rams on CBW0 had 26.67fL, while those on CBW5 had 28.67fL, and CBW10 had 27.67fL, and this may indicate microcytic anemia. Except for rams on CBW5, others fell below the range reported by Merck Manual (2018) of 28 – 40 fl. The Mean Corpuscular Haemoglobin (MCH) values were lower than normal range while the Mean Corpuscular Haemoglobin Concentration (MCHC) values were within normal ranges (27-31pg and 31-35g/dL) as reported by Radostits *et al.* (2007) suggesting normal red blood cell size and hemoglobin content. Merck manual (2018) has reported a range value for MCH for normal WAD sheep to be 8 – 12 pg and the values obtained in this study fell within it.

CONCLUSION

The study demonstrated that the inclusion of ensiled cabbage wastes (CBW), dried cassava peels (DCSW), wheat offal (WO), and brewers' spent grains (BSG) as a feed component in rams' diets can effectively support growth performance, nitrogen retention, and nutrient digestibility. Rams fed silage without cabbage waste (CBW0) showed superior dry matter digestibility, protein digestibility, and nitrogen retention, proved to be the most efficient, indicating better utilization of nutrients and reduced nitrogen losses. Rams fed CBW5 had higher nitrogen absorption; its increased urinary nitrogen excretion highlighted inefficiencies in nitrogen utilization compared to that of CBW0. Rams on CBW10 partitioned more nitrogen to feces, recorded the lowest nitrogen retention, had relatively lower crude protein digestibility, which could limit its effectiveness as a dietary option for optimal growth. These findings suggest that the ensiling mixtures with optimal nutrient balancing offers a promising approach for enhancing ruminant feed efficiency, aligning with industry goals of sustainable livestock production through the effective use of agro-industrial by-products. The haematological profile of the rams fed the silage showed that most of the parameters were within the range for normal physiological functions, indicating a healthy red blood cell production and function, balanced immune system, and normal blood clotting function. However, rams fed CBW0 had a slightly higher WBC count, suggesting a mild inflammatory response or infection.

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