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Rumen fermentation and nutrient utilization of growing Yankasa rams fed a mixed ration containing tiger nut (*Cyperus esculentus*) residue and cowpea husk (*Vigna unguiculata* L. Walp)

Hosea Yakubu[1], Ahmed Amin Njidda[2], Isaac Sammani Butswat[2], Olurotimi Ayobami Olafadehan[1] & Abayomi Samuel Bankole[2]

[1] Department of Animal Science, University of Abuja, P. M. B. 117, FCT, Abuja, Nigeria

[2] Department of Animal Science and Fisheries, National Open University of Nigeria, Km 4, Kaduna-Zaria road, Riga-chukun, Kaduna State, Nigeria

Correspondence: Yakubu Hosea, Department of Animal Science, University of Abuja, Nigeria. Email: hosea.larai@gmail.com

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Abstract

Thirty (30) Yankasa growing rams were used to investigate the effect of feeding cowpea husk and tiger nut residue in a mixed ration on the rumen ecology, nutrient intake, nutrient digestibility, and nitrogen balance of Yankasa rams. Significant differences ($p < 0.05$) were observed in the rumen ecology, nutrient intake, nutrient digestibility, and nitrogen balance between the treatments. Rumen ecology was influenced by the diet, with variations in rumen pH, temperature, and volatile fatty acid production. The results indicated that the highest rumen pH and temperature were observed in Treatment 2, while acetate, butyrate, and propionate levels varied among treatments. Nutrient intake and digestibility were significantly affected by the diet. Dry matter intake, crude protein intake, nitrogen detergent fiber (NDF), and acid detergent fiber (ADF) intake varied among treatments. Treatment 3 showed the highest dry matter intake, while Treatment 5 had the highest NDF intake. Crude protein intake was highest in Treatment 3, and the highest values for most nutrients were observed from the same treatment. The results for nitrogen balance in Yankasa rams indicate a positive nitrogen balance, suggesting that the rams received adequate amounts of nitrogen from the diets fed. Feeding 20% cowpea husk and 20% tiger nut residue provides optimum performance for rams in terms of rumen fermentation, and nutrient utilisation.

Keywords: Yankasa, rams, rumen fermentation, nutrient utilization.

Fermentação ruminal e utilização de nutrientes de carneiros Yankasa em crescimento alimentados com ração mista contendo resíduo de chufa (*Cyperus esculentus*) e casca de feijão-caupi (*Vigna unguiculata* L. Walp)

Resumo

Trinta (30) carneiros Yankasa em crescimento foram utilizados para investigar o efeito da alimentação com casca de feijão-caupi e resíduo de castanha de tigre em uma ração mista sobre a ecologia ruminal, ingestão de nutrientes, digestibilidade de nutrientes e balanço de nitrogênio de carneiros Yankasa. Diferenças significativas ($p < 0,05$) foram observadas na ecologia ruminal, consumo de nutrientes, digestibilidade dos nutrientes e balanço de nitrogênio entre os tratamentos. A ecologia ruminal foi influenciada pela dieta, com variações no pH ruminal, temperatura e produção de ácidos graxos voláteis. Os resultados indicaram que os maiores pH e temperatura ruminal foram observados no Tratamento 2, enquanto os níveis de acetato, butirato e propionato variaram entre os tratamentos. A ingestão e a digestibilidade dos nutrientes foram significativamente afetadas pela dieta. O consumo de matéria seca, proteína bruta, fibra em detergente nitrogenado (FDN) e fibra em detergente ácido (FDA) variaram entre os tratamentos. O tratamento 3 apresentou maior consumo de matéria seca, enquanto o tratamento 5 apresentou maior consumo de FDN. O consumo de proteína bruta foi maior no Tratamento 3, e os maiores valores para a maioria dos nutrientes foram observados no mesmo tratamento. Os resultados do balanço de nitrogênio em carneiros Yankasa indicam um balanço de nitrogênio positivo, sugerindo que os carneiros receberam quantidades adequadas de nitrogênio das dietas fornecidas. A alimentação com 20% de casca de feijão-caupi e 20% de resíduo de castanha de tigre proporciona ótimo desempenho para carneiros em termos de fermentação ruminal e utilização de nutrientes.

Palavras-chave: Yankasa, carneiros, fermentação ruminal, aproveitamento de nutrientes.

1. Introduction

The efficient utilization of feed resources is a paramount concern in ruminant nutrition, especially in regions where access to high-quality forage is limited (Osinowo et al., 1992; Wanapat et al., 2015). Yankasa rams, a breed indigenous to West Africa, are valued for their adaptability to challenging environments and their potential for meat production (Adegun et al., 2018). In such regions, alternative, and cost-effective feed sources play a crucial role in sustaining livestock production (Amole et al., 2022). Cowpea husk and tiger nut residue are among the readily available byproducts with potential as ruminant feed ingredients.

Rumen fermentation is a symbiotic process between ruminant animals and their rumen microbes. The microbes break down complex carbohydrates, such as cellulose and hemicellulose, into simpler molecules such as simple sugars like glucose that the animal can absorb and use for energy and growth (Matthews et al., 2019). Rumen fermentation is a complex process that is influenced by several factors, including the composition of the diet, the pH of the rumen, and the activity of the rumen microbes. The main products of rumen fermentation are volatile fatty acids. Other products are methane, carbon dioxide, and heat (Cammack et al., 2018).

VFAs are the main source of energy for ruminant animals. They are absorbed from the rumen and used by the animal for energy, growth, and milk production. Methane and carbon dioxide are gases that are released into the atmosphere. Heat is also produced during rumen fermentation, which can help to keep the animal warm (Króliczewska et al., 2023). Moreover, nutrient utilization is the ability of the animal to absorb and use the nutrients from its diet. The digestibility of a feed ingredient is a measure of how much of the nutrients in the feed ingredient the animal can absorb (Azizi et al., 2021).

Cowpea husk, a byproduct of cowpea processing, is rich in fiber and protein but is often underutilized or discarded. Tiger nut residue, a byproduct of tiger nut processing, similarly contains valuable nutrients and it is a functional food (Dhakal et al., 2023). When combined, these feed ingredients have the potential to provide a balanced diet for Yankasa rams during the critical growth phase. Cowpea husk and tiger nut residue are two agro-industrial by-products that can be used as feed for ruminant animals. In recent years, there has been a growing interest in using cowpea husk (Oluokun, 2005) and tiger nut residue as feed for ruminant animals, as they are a cheap and abundant source of nutrients. However, further research is needed to understand the effects of feeding these by-products on rumen fermentation (such as the microbial population, and composition of volatile fatty acids), and nutrient utilization.

The digestibility of cowpea husk and tiger nut residue is relatively low for monogastric animals, however, studies have shown that the digestibility of these by-products can be improved by processing them, such as soaking, grinding, or fermenting them (Nkhata et al., 2018). There is a paucity of information regarding the utilization of a mixed ration of cowpea husk and tiger nut residue on the rumen ecology and nutrient utilization in rams which necessitated this study.

Understanding the rumen fermentation processes and nutrient utilization in Yankasa rams when fed such unconventional diets can contribute to the development of sustainable and cost-effective feeding strategies. This, in turn, can enhance the productivity and livelihoods of small-scale livestock producers in West Africa, which necessitated this study.

2. Materials and Methods

2.1 Experimental site

The study was conducted at the small ruminant experimental unit of the National Open University of Nigeria (NOUN), Kaduna farm located at Latitude N10.61362 Longitude E7.46852 at an altitude of 612.65 m. The climate is tropical wet and dry, classified as Köppen Aw. The wet season lasts from April through to mid-October with a peak in August; while the dry season extends from mid-October of one calendar year to April the next year (Abaje *et al.,* 2018). The spatial and temporal distribution varies, decreasing from an average of about 1,203 mm. The highest average air temperature occurs in April (28.9 ℃) and the lowest temperature range of 22.9 ℃ in December to 23.1 ℃ in January (Abaje et al., 2016). The mean atmospheric relative humidity ranges between 70-90% and 25-30% for the rainy and dry seasons respectively (Abaje et al., 2018).

2.2 Experimental Animals and Diet

Thirty (30) growing Yankasa rams aged six to eight months with an initial weight of 15.50 ± 0.67 kg were used for this study. The animals were purchased from an open livestock market in Makarfi LGA of Kaduna State. The pens and the surroundings were cleaned and disinfected with a strong antiseptic (Morigad) two weeks before the arrival of the animals. Upon arrival, the animals were administered a prophylactic treatment consisting of a long-acting antibiotic (Oxytetracycline 20% LA at 1.0 $mL/10kg^{-1}$ body weight) intramuscularly, and Ivomec injection at 200 $\mu g/kg^{-1}$ (0.3 $mL/10kg^{-1}$) to control endo and ectoparasites (subcutaneous). The animals were housed in their cages and allowed to adapt to the environment for 14 days before the commencement of the experiment. The cowpea husks used for the study were from the previous harvest from nearby farms that have been allowed to dry in the sun while the tiger nut residue used was obtained from a local processor who produces local drink, and the residue was dried under shade.

2.3 Experimental Design and Treatment

The experimental animals (Yankasa rams) were allocated to five dietary treatments with six animals per treatment in a complete randomized design as presented below:

T1 = Cowpea husk 40% + Tiger nut residue 0%

T2 = Cowpea husk 30% + Tiger nut residue 10%

T3 = Cowpea husk 20% + Tiger nut residue 20%

T4 = Cowpea husk 10% + Tiger nut residue 30%

T5 = Cowpea husk 0% + Tiger nut residue 40%

2.4 Feeding and Management

The study comprised 14 days of the feed adaptation period and 13 weeks (91 days) of the measurement period. Feed was weighed and fed twice daily at 8 a.m. and 2 p.m. Water was provided *ad libitum*. The quantity of feed provided, and the residue of the previous day were weighed to determine the feed intake of each animal. The rams were weighed at the beginning of the experiment at weekly intervals in the morning before feeding.

2.5 Chemical analysis

The feed samples of experimental diets were collected and dried in an air-draft oven at 600 ºC for 96 h, ground separately to pass through a 1 mm sieve in a Wiley mill and sampled for chemical analysis using the standard methods of the Association of Official Analytical Chemists (AOAC, 2005). Dry matter was determined by drying at 100 ℃ for 24 h (AOAC 2005.03), ash concentration was determined after ignition at 550 ℃ for 4 h in a muffle furnace and used to calculate organic matter (OM). Fiber fraction analysis was done by the methods of Van Soest et al. (1991). Hemicellulose and cellulose were estimated as differences between neutral detergent fiber (NDF) and acid detergent fiber (ADF) and ADF and lignin, respectively.

2.6 Collection of rumen liquor

Rumen liquor (100 mL) was collected from rams across the 5 treatments at the end of the experiment using a suction tube. Temperature and pH were determined immediately using a thermometer and glass electron pH meter respectively. Following that, rumen fluid samples were filtered through four levels of cheesecloth. The rumen liquor was separated into two parts for rumen fermentation and rumen microbial population determination.

Following the separation, the first sample (45 mL) from 100 mL of ruminal fluid was kept in 9 mL of 1M H_2SO_4 (to disrupt further microbial activity fermentation process) centrifuged at 3000x g for 15 min at 10 ºC, and used to analyse ammonia nitrogen (NH_3N) concentration using an analyzer according to Bremner and Keeney (1965), and volatile fatty acid (VFA) such as acetic acid (C_2), propionic acid (C_3), butyric acid (C_4) using a high-performance liquid chromatography according to Samuel et al. (1997). Another sample (20 mL) from 100 mL of ruminal fluid was collected with a large-bore pipette and kept in 9 mL of 10% formalin solution. After dilution, samples were used to enumerate the bacteria, protozoa, and fungi populations using a 400-chamber hemocytometer according to Galyean (1989) using a microscope.

2.7 Metabolism trial

To investigate nutritional digestibility, feed, and faecal samples were collected from rams using the total collection method during the last 7 days of the experiment. The samples were dried at 72 ºC, milled (1mm screen using a Cyclotech Mill, Tecator, Sweden), and measured for dry matter (DM), ash, ether extract (EE), and crude protein (CP) by the protocols of the Association of Official Analytical Chemists (AOAC, 2005). Analyses of NDF and ADF were performed with α-amylase but without sodium sulphite according to Van Soest et al. (1991).

Digestibility be determined using the formula below:

$$D\% = \frac{\text{Nutrient consumed} - \text{nutrient in feaces}}{\text{Nutrient consumed}} * 100$$

2.8 Urine sampling method

Whole urine was collected on the same number of days as faeces in a plastic container treated with ten percent H_2SO_4, to keep the final pH below three and prevent urinary nitrogen (N) extinction. Urine samples were taken at approximately 100 mL of the total volume, frozen, and pooled at the end of the experiment using the AOAC total N measurement method.

2.9 Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) in a completely randomized design using the SAS software (SAS, 2005) where significant differences were observed, and means were separated using the *Duncan* Multiple Range Test (DMRT). Polynomial (linear, quadratic, and cubic) contrasts were used to determine responses to varying levels of the mixed ration of cowpea husk and tiger nut residue.

3. Results and Discussion

3.1 Chemical composition of experimental diets

The chemical composition of the experimental diets is shown in (Table 1). The dry matter content of the experimental diets ranged from 895.7 g kg^{-1} DM in T4 (10% Cowpea husk and 30% Tiger nut residue ration mix) to 920.1 g kg-1 DM in T3 (20% Cowpea husk and 20% Tiger nut residue ration mix). T1 was observed to have the lowest ash content compared to other treatments. The pattern of significant differences ($p < 0.05$) for Lignin and NDF were similar with the highest values (122 g kg^{-1} DM and 453.7 g kg^{-1} DM respectively) recorded in T1 and lowest values (113 g kg^{-1} DM and 420.6 g kg^{-1} DM respectively) in T5. ADF was significantly different with T1 recording the highest value of 265.1 g kg^{-1} DM and the lowest in T5 232.0 g kg^{-1} DM. Crude protein values for dietary treatments were significant ($p < 0.05$) with T1 higher (155.1 g kg^{-1} DM), lowest in T5 (145.1 g kg^{-1} DM), and 150.3 g kg^{-1} DM, 149.2 g kg^{-1} DM, 148.0 g kg^{-1} DM respectively compared to other treatments. A similar trend was observed with the energy content of feeds with T1 having the highest energy of 10.68 MJ and the lowest for T5 (10.13 MJ).

The crude protein content decreased as the level of cowpea husks decreased with increasing levels of Tiger nut residue. The crude protein level in this study is within the range of 139 g kg^{-1} DM to 220 g kg^{-1} DM reported by Olafadehan et al. (2022) who used cowpea husks to feed goats but lower than the range of 162.1 – 203.3 g kg-1 DM and 354 g kg^{-1} DM to 383 g kg^{-1} DM reported by Njidda et al. (2018) and Nasir et al. (2014) respectively. Abdu et al. (2012) and Okafor et al. (2012) reported 102.5 and 137.3 g kg^{-1} DM which is lower than the results from this study. The variation observed between previous reports and results from this study could be attributed to the difference in the composition of diets offered to the experimental animals.

The crude protein content in this study is above 7% CP recommended for rumen microbes of tropical livestock by Minson (1990) below which performance will be deficient. The NDF and ADF were highest at T1 (453.7 g kg^{-1} and 265.1 g kg^{-1} DM respectively) and lowest at T5 (420.6 g kg^{-1} and 232.0 g kg^{-1} DM) which implies that increasing the inclusion of Tiger nut residue decreases and the values reported from this experiment is lower than the range of 527 g kg^{-1} DM – 540.31 g kg^{-1} DM for NDF and 321.31 g kg^{-1} DM – 325 g kg^{-1} DM for ADF as reported by Njidda et al. (2018). Meissner et al. (1991) posited that NDF level of forages beyond 65% can limit feed intake. The EE obtained from this study fell within the range of 22.10 g kg^{-1} DM – 42.21g kg^{-1} DM reported by Njidda et al. (2018). The Lignin content reported from this study is higher than that reported by Nasir et al. (2014) and Njidda et al. (2016). Differences observed in the composition of the feed are attributed to the ration used as Njidda et al. (2018) used a mix of soybean meal and Gmelina arborea leaves, Nasir et al. (2014) used cotton seed cake while a mixed ration of cowpea husk and tiger nut residue was used for this study.

Table 1. Chemical composition of experimental diets on dry matter (DM) (g kg^{-1} DM).

Parameter	T_1	T_2	T_3	T_4	T_5	SEM
DM	904.70^{ab}	908.00^{a}	920.10^{a}	895.70^{b}	910.10^{a}	1.80
CP	155.10^{a}	150.30^{ab}	149.20^{ab}	148.00^{ab}	145.10^{b}	0.70
EE	41.00^{a}	39.40^{a}	36.70^{ab}	35.40^{ab}	34.00^{b}	0.60
Ash	68.50^{b}	71.10^{a}	71.80^{a}	72.60^{a}	73.30^{a}	0.40
ADF	265.10^{a}	244.70^{b}	240.60^{bc}	235.90^{bc}	232.00^{c}	2.60
NDF	453.70^{a}	433.60^{b}	429.00^{b}	422.00^{b}	420.60^{b}	2.70
Lignin	122.00^{a}	117.70^{b}	115.00^{b}	114.20^{b}	113.30^{b}	0.70
NFE	470.30^{c}	494.50^{b}	501.70^{b}	508.10^{ab}	515.60^{a}	3.50
Cellulose	143.10^{a}	127.00^{b}	125.60^{bc}	121.70^{c}	118.70^{c}	1.90
Hemicellulose	188.60^{a}	188.90^{a}	188.40^{a}	186.10^{b}	188.60^{a}	0.20
Energy (MJ)	10.68^{a}	10.44^{ab}	10.26^{b}	10.14^{c}	10.13^{c}	0.05

Note: ^{a,b,c} means in the same row with different superscripts are significantly ($p < 0.05$) different, DM = Dry matter, CP = Crude protein; EE = Ether extract; ADF = Acid detergent fibre; NDF = Neutral detergent fibre; NFE = Nitrogen free extract; MJ = Mega Joule SEM = Standard error of mean. Source: Authors, 2024.

3.2. Effect of cowpea husk and tiger nut residue in a mixed ration on rumen ecology of Yankasa rams

There were significant differences ($p < 0.05$) observed in the effect of cowpea husk and tiger nut residue on the rumen ecology of Yankasa rams as presented in (Table 2). The highest rumen pH was observed in T2 (6.11) and the lowest in T3 (5.92). The highest temperature of the ruminal fluid was observed from Treatment 2 (39.40 ºC) and the lowest from T1 (38.10 ºC). Acetate was higher in Treatment 2 (51.80 mol/100 mL) and lowest in Treatment 5 (33.50 mol/100mL). Butyrate was highest in Treatment 2 (16.62 mol/100 mL) and least in Treatment 5 (9.12 mol/100 mL). The highest propionate content of 46.92 mol/mL was observed in Treatment 5, while Treatment 1 had the least propionate content (27.31 mol/mL).

Methane was highest in T1 (22.11 nm/L) and lowest in T5 (10.14 nm/L). The highest acetate-to-propionate acid ratio was recorded in Treatment 1 (2.75) and the lowest in Treatment 5 (0.72). The total volatile fatty acids were highest in Treatment 5 (166.30) and lowest in Treatment 1 (116.50). Bacteria content obtained from this study was higher in treatment 5 (7.02 x 10^{-8} CFU/mL^{-1}) and lowest in treatment 1 (4.02 x 10^{-8} CFU/mL). Fungi was observed to be highest in Treatment 5 (4.22 x 10^{-4} CFU/mL) and least in Treatment 1 (2.55 x 10^{-4} CFU/mL). Protozoa content was higher in Treatment 5 (7.38 x 10^{-8} CFU/mL) and lowest in Treatment 1 (3.03 x 10^{-8} CFU/mL). the highest rumen ammonia was observed in Treatment 5 (20.93 mg/dL) and the least in Treatment 1 (10.08 mg/dL).

The pH and temperature of the ruminal fluid obtained from this study were consistent with the findings of Maxiselly et al. (2022), and Sani et al. (2023). The pH of the ruminal fluid is within the normal pH range of 5.5 to 7.0 reported to be optimal for microbial digestion of fibre and proteins in ruminants (Krause; Oetzel, 2006). The acetate to propionic acid ratio was lower than the range of 2.09 to 2.79 reported by Maxiselly et al. (2022). The quantity of methane from this study was lower than the quantity (22.83-26.92 nm/L^{-1}) reported by Maxiselly et al. (2022).

Total volatile fatty acids from this study fell within the range of 31 to 196 mml/L documented by Woyengo et al. (2004), and the normal range of 70 to 150 mmol/L^{-1} by McDonald et al. (1995), but higher than the range of 69.4 – 78.5 mmol/L^{-1} reported by Olafadehan et al. (2016). Rumen ammonia obtained from this study was lower than the findings from Bello (2017) who documented 30.1 mg/L^{-1} to 31.6 mg/L^{-1}. The rumen ammonia from this study fell within the range of 9 mg/L^{-1} to 234 mg/L^{-1} reported by Woyengo et al. (2004) thus adequate for ruminal fermentation activities for digestion.

Rumen microbial load counts from this study compared with other reports as follows; Bacteria count fell within the range of 4.0 to 5.9 reported by Bello (2017), fungal count from this study was lower than the range of 2.87 to 6.32 reported by Bello (2017). The protozoa count from this study was lower than the results from Bello (2017) but within the normal value of 3.95 to 5.34 x 10^{-6} (Omotoso et al., 2021). The differences observed between this study and the report by Bello (2017) are attributable to the diets utilized in both studies. The increase of microbes in the rumen for rapid degradation of roughages or fibrous feed is a function of ruminal fermentable dietary nutrients in the ecosystem of the rumen (Newbold; Ramos-Morales, 2020). There is limited literature on the use of a mixed ration of cowpea husk and tiger nut residue as feed for ruminant animals.

Table 2. Effect of cowpea husk and tiger nut residue in a mix ration on rumen fermentation parameters of Yankasa rams.

	Treatment						p-value		
Parameter	T_1	T_2	T_3	T_4	T_5	SEM	Linear	Quadratic	Cubic
pH	6.02^{ns}	6.11^{ns}	5.92^{ns}	6.06^{ns}	5.91^{ns}	0.04	0.138	0.549	0.082
Temperature (°C)	38.10^{ns}	39.40^{ns}	38.60^{ns}	38.80^{ns}	39.40^{ns}	0.25	0.223	0.399	0.914
Acetate (mol/100 mL)	75.30^{a}	51.80^{ab}	40.85^{b}	36.60^{b}	33.50^{b}	7.58	0.770	0.002	0.137
Butyrate (mol/100 mL)	14.49^{ab}	16.62^{a}	12.03^{ab}	9.60^{b}	9.12^{b}	1.43	0.071	0.554	0.004
Propionate (mol/mL)	27.31^{c}	30.60^{c}	38.02^{b}	40.17^{b}	46.92^{a}	3.49	0.240	0.006	0.122
CH_4 (nm/L)	22.11^{a}	17.60^{b}	16.02^{b}	13.50^{c}	10.14^{c}	2.01	0.375	0.002	0.398
Acetate to propionate acid ratio	2.75^{a}	1.69^{b}	1.07^{b}	0.91^{c}	0.72^{c}	0.03	0.375	0.002	0.398
Total Volatile Fatty Acids	116.50^{c}	123.60^{c}	135.40^{bc}	141.70^{b}	166.30^{a}	8.61	0.102	0.018	0.042
Bacteria (10^{-8} CFU/mL)	4.02^{b}	5.44^{b}	5.87^{b}	6.28^{a}	7.02^{a}	0.50	0.695	0.002	0.650
Fungi (10^{-4} CFU/mL)	2.55^{b}	3.60^{ab}	3.76^{ab}	4.04^{a}	4.22^{a}	0.29	0.834	0.001	0.596
Protozoa (10^{-6} CFU/mL)	3.03^{c}	4.26^{b}	5.70^{ab}	7.02^{a}	7.38^{a}	0.82	0.434	0.003	0.856
Rumen NH_3 (mg/dL)	10.08^{c}	15.83^{bc}	17.10^{b}	18.94^{ab}	20.93^{a}	1.84	0.845	0.001	0.930

Note: ^{a,b,c} Means within the same rows with different superscripts differed significantly ($p < 0.05$); ns = not significant ($p > 0.05$); SEM = Standard error of mean. Source: Authors, 2024.

3.3. Effect of Cowpea husk and tiger nut residue on nutrient intake for Yankasa rams

Significant differences ($p < 0.05$) were observed in nutrient intake for Yankasa rams (Table 3). The highest dry matter intake was recorded in T3 (91.57 g Kg^{-1}) while the least was from treatment 5 (88.58 g Kg^{-1}). A similar trend was observed in the metabolic body weight dry matter intake with T3 (29.60 g Kg^{-1}) and T5 (28.87 g Kg^{-1}). The crude protein intake was highest in T3 (11.30 g Kg^{-1}) and lowest in T4 (9.40 g Kg^{-1}) likewise the metabolic body weight crude protein intake, T3 (6.16 g Kg^{-1}) and T4 (5.37 g Kg^{-1}) were highest and lowest respectively. The Nitrogen Detergent Fibre (NDF) was higher in T2 (9.49 g Kg^{-1}) and lowest in T5 (8.99 g Kg^{-1}), also the metabolic NDF was higher in T2 (5.41 g Kg^{-1}) and least in T5 (5.19 g Kg^{-1}).

Treatment 4 had the highest Acid Detergent Fibre (ADF) of 40.71 g Kg^{-1} while Treatment 2 had the lowest (33.63 g Kg^{-1}). The metabolic body weight ADF followed a similar trend with T4 being the highest with 16.12 g Kg-1 and T2 (13.97 g Kg^{-1}). The highest Ether Extract (EE) content was observed in T5 (9.62 g Kg^{-1}) and the lowest in T1 (7.25 g Kg^{-1}). The highest metabolic body weight value of EE was observed in T5 (5.46 g Kg^{-1}) and the lowest in T1 (4.42 g Kg^{-1}). Treatment 5 had the highest crude fibre intake (CFI) of 28.66 g/kg^{-1} while treatment 3 recorded the lowest CFI (23.90 g Kg^{-1}). The metabolic body weight CFI of 12.39 g Kg^{-1} (highest) and 10.81 g Kg^{-1} (lowest) was observed for Treatment 5 and 3 respectively.

The results for dry matter intake from this study are higher than the findings of Maxiselly et al. (2022) who reported a range between 77.84 g Kg^{-1} to 84.90 g Kg^{-1} for goats. The dry matter intake (metabolic body weight) obtained from this study was lower than the range of 99.65 to 108.45 g Kg^{-1} reported by Lakpini et al. (2015). The Crude Protein (CP) intake (metabolic body weight) from this study fell within the range of 10.77 g Kg^{-1} to 11.19 g Kg^{-1} for concentrate feed reported by Lakpini et al. (2015), and Olafadehan et al. (2016). Crude fibre (CF) intake from this study fell below the result reported by Lakpini et al. (2015) who had a range of 27.01 g Kg^{-1} to 41.46 g Kg^{-1}. Ether extract (EE) intake from this study is higher than the range of 2.35 g Kg^{-1} to 3.22 g Kg^{-1} reported by Lakpini et al. (2015).

The Neutral Detergent Fibre (NDF) intake obtained from this study is lower than the range of 15.14 to 15.76 g Kg^{-1} reported by Lakpini et al. (2015). The acid detergent fibre (ADF) intake from this study did not agree with the results reported by Lakpini et al. (2015) who obtained a range between 12.03-12.53 g Kg^{-1} for concentrate and 17.95-22.42 g Kg^{-1} for forage. ADF intake from this study was lower than the findings of Njidda et al. (2018) who reported a range between 156-273.05 g Kg^{-1}. Variations observed in nutrient intake of growing Yankasa rams fed a mixed ration of cowpea husk and tiger nut residue are attributed to the differences in feed used for this study and other studies. Lakpini et al. (2015) used to concentrate and ensiled eggplant forage, Olafadehan et al. (2016) used *Ficus polita* foliage-based rations, while Njidda et al. (2018) used *Gmelina arborea* leaf substituting soybean meal.

Table 3. Effect of tiger nut residue and cowpea husk on nutrient intake for Yankasa rams (g Kg^{-1} DM).

	Treatment						P-value		
Parameter	T_1	T_2	T_3	T_4	T_5	SEM	Linear	Quadratic	Cubic
DM Intake	90.98^a	89.61^b	91.57^a	90.78^a	88.58^b	0.54	0.164	0.218	0.751
DM Intake ($BW^{0.75}$)	29.46^a	29.13^a	29.60^a	29.41^a	28.87^b	0.13	0.093	0.297	0.356
CP Intake	11.10^a	10.50^{ab}	11.30^a	9.40^b	10.70^{ab}	0.33	0.241	0.093	0.015
CP Intake ($BW^{0.75}$)	6.08^a	5.83^{ab}	6.16^a	5.37^b	5.92^{ab}	0.14	0.319	0.114	0.302
NDF Intake	9.18^{ab}	9.49^a	9.14^{ab}	9.15^{ab}	8.99^b	0.08	0.082	0.105	0.091
NDF Intake ($BW^{0.75}$)	5.27^{ab}	5.41^a	5.26^{ab}	5.26^{ab}	5.19^b	0.04	0.043	0.295	0.117
ADF Intake	35.82^b	33.63^b	35.46^b	40.71^a	39.72^a	1.47	0.072	0.153	0.524
ADF Intake ($BW^{0.75}$)	14.64^{ab}	13.97^b	14.53^{ab}	13.05^b	15.83^a	0.45	0.137	0.252	0.108
EE Intake	7.25^b	9.38^a	7.72^b	8.79^{ab}	9.62^a	0.46	0.281	0.195	0.617
EE Intake ($BW^{0.75}$)	4.42^b	5.36^a	4.63^b	5.10^a	5.46^a	0.20	0.558	0.242	0.146
CF Intake	27.36^a	27.37^a	23.90^b	28.55^a	28.66^a	0.86	0.225	0.202	0.102
CF Intake ($BW^{0.75}$)	11.96^a	11.97^a	10.81^b	12.35^b	12.39^a	0.29	0.101	0.216	0.171

Note: ^{a,b} Means within the same rows with different superscripts differed significantly ($p < 0.05$); DM = Dry matter; CP = Crude protein; NDF = Neutral detergent fibre; ADF = Acid detergent fibre; EE = Ether extract; CF = Crude fibre; $BW^{0.75}$ = Metabolic body weight; SEM = Standard error of mean. Source: Authors, 2024.

3.4. Effect of cowpea husk and tiger nut residue in a mix ration on nutrient digestibility of Yankasa rams

Cowpea Husk and Tiger nut residue in a mixed ration had a significant effect ($p < 0.05$) on the nutrient digestibility of Yankasa rams (Table 4). Dry matter digestibility was highest in T3 (915.70 g Kg^{-1}) and lowest in T5 (858.80 g Kg^{-1}). The digestibility of organic matter was higher in T1 (796.40 g Kg^{-1}) and lowest in T5 (763.70 g Kg^{-1}). The highest crude protein digestibility of 116.30 g Kg^{-1} was observed in T5 and the least in Treatment 2 (101.20 g Kg^{-1}). Treatment 5 showed a high digestibility (286.40 g Kg^{-1}) of crude fibre and the lowest recorded in T2 (239.10 g Kg^{-1}).

The digestibility of NDF was highest in T2 (433.10 g Kg^{-1}) and lowest in Treatment 5 (402.90 g Kg^{-1}). Acid detergent fibre was highly digestible in Treatment 5 (397.20 g Kg^{-1}) and the least in Treatment 4 (307.10 g Kg^{-1}). A high digestibility was observed for cellulose in Treatment 3 (115.60 g Kg^{-1}) and low in Treatment 2 (62.60 g Kg^{-1}). Hemicellulose had the highest digestibility in Treatment 4 (105.30 g Kg-1) and the lowest digestibility in

Treatment 5 (50.90 g Kg^{-1}). Lignin indicated a high digestibility in Treatment 1 (133.30 g Kg^{-1}) and low digestibility in Treatment 5 (42.90 g Kg^{-1}). Ether extract (EE) was highly digestible in Treatment 5 (96.20 g Kg^{-1}) and least in Treatment 1 (72.50 g Kg^{-1}). A high digestibility of 132.40 was observed in Treatment 4 while the lowest was in Treatment 2 (111.40 g Kg^{-1}).

Digestibility of nutrients from this study for dry matter, organic matter, crude protein, crude fibre, and EE, is higher than the result obtained by Lakpini et al. (2015) who reported a range between 603.4 g Kg-1 – 681.7 g Kg-1, 684.8 to 721.2 g Kg^{-1}, 645.5 g Kg^{-1} to 810.1 g Kg^{-1}, 620.9 to 806.4 g Kg^{-1}, 23.86 g Kg^{-1} to 56.25 g Kg^{-1} respectively. NDF fell within the range of 346.2 to 508.4 g Kg^{-1}. Similarly, ADF fell within the range of 335.2 to 455.9 g Kg^{-1} reported by Lakpini et al. (2015). The results from this study are higher than the report from Mekuriaw & Asmare (2018) for dry matter digestibility (69-77%), organic matter (71-79%), and crude protein (60-79%). The results for NDF and ADF from this study were lower than the report from Mekuriaw & Asmare (2018), who obtained NDF (44-66%), and ADF (42%-63%). The digestibility of ash from this study was higher than the range of 78.80-79.82%) reported by Millam et al. (2021). Observed differences in the digestibility of feed are attributed to the type of diets offered to the animals in the various studies. Higher digestibility values obtained from this study could be attributed to the crude protein content of the diet which in turn improved the digestibility of the diet (Abdu et al., 2015; Hassan et al., 2016).

Table 4. Effect of cowpea husk and tiger nut residue in a mix ration on nutrient digestibility (g Kg^{-1} DM) of Yankasa rams.

	Treatment					
Parameter	T_1	T_2	T_3	T_4	T_5	SEM
Dry matter	909.80^a	896.10^b	915.70^a	907.80^a	885.80^b	5.35
Organic matter	796.40^a	784.70^b	788.10^a	775.40^c	763.70^c	3.14
Crude Protein	111.30^a	101.20^b	111.90^a	103.10^b	116.30^a	2.84
Crude fibre	273.60^b	273.70^b	239.10^c	285.50^a	286.40^a	8.63
NDF	413.90^b	433.10^a	411.50^b	412.40^b	402.90^c	4.97
ADF	358.20^b	336.30^c	354.60^b	307.10^c	397.20^a	14.73
Cellulose	84.60^b	62.60^c	115.60^a	112.60^a	110.60^a	17.22
Hemicellulose	55.70^b	96.80^a	56.90^b	105.30^a	50.70^c	17.75
Lignin	133.30^a	114.30^a	66.50^b	54.30^b	42.90^b	17.62
EE	72.50^c	93.80^a	77.20^c	87.90^b	96.20^a	4.62
Ash	113.40^c	111.40^c	127.60^c	132.40^a	122.10^b	3.98

Note: ^{a,b,c,d} Means within the same rows with different superscripts differed significantly ($p < 0.05$); NDF = Neutral Detergent Fibre; ADF = Acid Detergent Fibre, EE = Ether Extract; SEM = Standard error of mean. Source: Authors, 2024.

3.5. Effect of cowpea husk and tiger nut residue in a mix ration on nitrogen balance of Yankasa rams

Table 5 presents the significant effect ($p < 0.05$) of cowpea husk and tiger nut residue on the nitrogen balance in Yankasa rams. The Nitrogen intake was observed to be highest in Treatment 1 (19.72 g day^{-1}) and least in Treatment 5 (17.89 g day^{-1}). Faecal nitrogen was highest in Treatment 5 (5.81 g day^{-1}) and least in Treatment 2 (5.07 g day^{-1}). Similarly, urine nitrogen was higher in Treatment 5 (2.91 g day^{-1}) and lowest in Treatment 2 (2.53 g day-1). The highest total nitrogen loss was observed in Treatment 5 (8.72 g day^{-1}) and the lowest in Treatment 2 (7.60 g day^{-1}). Nitrogen balance was highest in Treatment 1 (11.38 g/day^{-1}) and least in Treatment 5 (9.18 g day^{-1}).

Nitrogen absorption was highest in Treatment 1 (14.16 g day^{-1}) and lowest in Treatment 5 (12.08 g day^{-1}). Nitrogen retention as a percentage (%) of intake was highest in Treatment 2 (59.60 g day^{-1}) and lowest in Treatment 5 (51.30 g day^{-1}). The nitrogen balance on metabolic body weight basis was higher in Treatment 1 (6.19 g day-1) and lowest in Treatment 5 (5.27 g day^{-1}). Parameters expressed in percent as nitrogen intake indicated that faecal nitrogen was highest in treatment 3 (3.54 g day^{-1}) and lowest in Treatment 2 (2.71 g day^{-1}). Urine nitrogen was highest in treatment 5 (1.65 g day^{-1}) and lowest in treatment 2 (1.33 g day^{-1}). Absorbed nitrogen was highest in

Treatment 2 (73.04 g day^{-1}) and least in Treatment 5 (68.01 g day^{-1}, the retained nitrogen was observed to be higher in Treatment 2 (60.32 g day^{-1}) and lowest in Treatment 5 (51.63 g day^{-1}).

Results for nitrogen intake, fecal nitrogen, urine nitrogen, nitrogen loss, nitrogen absorbed, and nitrogen retained as % intake from this study were higher than the reports from Millam et al. (2021), who obtained 2.97 g day-1 for nitrogen intake, 0.21-0.31 g day^{-1} for faecal nitrogen, 0.29-0.30 g day^{-1} (urine nitrogen), 0.50-0.60 g day^{-1} (nitrogen losses), 2.66-2.76 g day^{-1} (nitrogen absorbed). Faecal nitrogen from this study was lower than the range of 3.48 g day^{-1} to 4.81 g day^{-1} reported by Njidda et al. (2018). Nitrogen balance as (%) of intake from this study was lower than the report of Millam et al. (2021) who had a range between 79.66% to 83.27%. The results for Nitrogen retained as intake is within the range of 52.81% to 61.18% reported by Bello (2017) and Njidda et al. (2018) who fed growing Yankasa lambs groundnut haulms and Red Sokoto goats, *Daniella oliveri* forage and cowpea husk respectively.

The nitrogen absorbed and retained nitrogen from this study are higher than the result from Njidda et al. (2018) of 47.10-71.84 g day^{-1} and 23.12% to 35.77% respectively. Bello (2017) reported a range of 7.60-8.71 g day^{-1} for faecal nitrogen, 0.86-1.09 g day^{-1} (urine nitrogen), (8.50-9.57 g day^{-1}) total nitrogen losses, nitrogen balance which is higher than the results from this study. The nitrogen balance from this study was lower than the range of 10.76-13.92 g day^{-1} reported by Bello (2017). Nitrogen retention is the key indicator used to assess the protein nutritional status of ruminant livestock (Abdu et al., 2012; Hassan et al., 2016).

All animals were in positive nitrogen balance which indicates that growing Yankasa rams received adequate amounts of nitrogen from the diets fed. Higher nitrogen absorbed and retained a percentage of intake in rams fed 30% cowpea husk and 10% tiger nut residue agrees with the report of Sarwar et al. (2003) and Bello (2017) which suggested that nitrogen retention depends on good digestibility of nutrients and/or utilization. Additionally, nitrogen excreted in the faces and urine is related to the digestion and absorption of nitrogen. High urinary nitrogen excreted is associated with highly degradable rumen nitrogen (McDonald et al., 2002).

Table 5. Effect of cowpea husk and Tiger nut residue in a mix ration on nitrogen balance in g day^{-1} of Yankasa rams.

	Treatment						P-value		
Parameters	T_1	T_2	T_3	T_4	T_5	SEM	Linear	Quadratic	Cubic
Nitrogen Intake	19.72^a	18.80^b	18.66^b	18.29^b	17.89^c	0.14	0.002	0.536	0.794
Faecal nitrogen	5.57^a	5.07^b	5.60^a	5.16^b	5.81^a	0.06	0.521	0.002	0.021
Urine nitrogen	2.78^a	2.53^b	2.80^a	2.58^b	2.91^a	0.03	0.520	0.001	0.026
Total Nitrogen lost	8.35^a	7.60^b	8.39^a	7.73^b	8.72^a	0.09	0.436	0.075	0.034
Nitrogen balance	11.38^a	11.20^a	10.27^b	10.55^b	9.18^c	0.18	0.002	0.002	0.003
Nitrogen absorbed	14.16^a	13.73^a	13.06^b	13.13^b	12.08^b	0.16	0.006	0.008	0.002
Nitrogen retained as % intake	57.7^b	59.60^a	55.00^c	57.70^b	51.30^d	0.90	0.022	0.216	0.653
Nitrogen balance ($BW^{0.75}$)	6.19^a	6.12^a	5.73^b	5.86^b	5.27^b	0.07	0.016	0.003	0.006
Percent as N intake									
Faecal N	2.83^b	2.71^b	3.54^a	2.83^b	3.24^a	0.04	0.023	0.215	0.635
Urine N	1.40^{bc}	1.33^c	1.52^a	1.48^b	1.65^a	0.02	0.031	0.227	0.569
Absorbed N	72.51^a	73.04^a	70.81^b	72.30^a	68.01^c	0.04	0.043	0.168	0.351
Retained N	58.13^b	60.32^a	55.41^b	58.50^b	51.63^c	0.06	0.072	0.139	0.115

Note: ^{a,b,c} Means within the same rows with different superscripts differed significantly ($p < 0.05$); N = Nitrogen; $BW^{0.75}$ = Metabolic Body weight; SEM = Standard error of mean. Source: Authors, 2024.

4. Conclusions

Results obtained indicate that rams fed 10% cowpea husk and 30% tiger nut residue have the highest daily dry matter intake of 751.90 g day^{-1}. However, the highest daily weight gain of 117.22 g was observed from rams fed a diet mix of 20% cowpea husk and 20% tiger nut residue. Based on the findings, it is concluded that there is no negative impact of the varying levels of tiger nut residue and cowpea husk on the rumen fermentation of Yankasa rams as the parameters were within the optimum range. However, the nutrient utilization and digestibility in growing Yankasa rams were optimum at 20% tiger nut residue and 20% cowpea husk mixed rations.

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6. Authors' Contributions

Yakubu Hosea: study design, collection and processing of cowpea husk and tiger nut residue, sample preparation, laboratory analysis, animal testing, data analysis, study writing, corrections, submission, and publication. *Ahmed Amin Njidda*: study design, study animals, research farm, writing, corrections, and publication. *Isaac Sammani Butswat*: research farm, corrections, and publication. *Olurotimi Ayobami Olafadehan*: writing, corrections, and publication. *Abayomi Samuel Bankole*: corrections and publication.

7. Conflicts of Interest

No conflicts of interest.

8. Ethics Approval

Not applicable.

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