EVALUATING THE PERFORMANCE AND NUTRIENT DIGESTIBILITY OF WEST AFRICAN DWARF GOATS FED DIETARY LEVELS OF RICE MILLING WASTES

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Abstract

This study evaluated the performance and nutrient digestibility of West African dwarf goats (WADG) fed dietary levels of rice milling waste (RMW). Twenty-four West African dwarf bucks (average weight 5.49 kg and aged 6–8 months) were used for the study. Four experimental diets were formulated and designated as T1, T2, T3 and T4. T1 was the control and contained 0% of RMW while T2 contained 10%, T3 20% and T4 30% of RMW. The experimental goats were randomly assigned to four the dietary treatments: T1, T2, T3 and T4 in a completely randomized design. The trial lasted 90 days. Nutrient intake, body weight changes, haematology, serum biochemistry and nutrient digestibility were studied. Supplement dry matter intake (DMI) was significantly higher ($p<0.05$) in T3, while DMI as a percentage of body weight was higher in T1 and T4. Crude protein intake was lower ($p<0.05$) in T4. Neutral detergent fibre intake was higher ($p<0.05$) in T4. Acid detergent fibre and acid detergent lignin intakes were high ($p<0.05$) in T3 and T4. Daily weight gain was highest ($p<0.05$) in T2. The feed conversion ratio were better ($p<0.05$) in T1, T2 and T3. Packed cell volume and mean cell haemoglobin concentration were improved ($p<0.05$) in T1 and T2, while haemoglobin, red blood cell count, and mean cell volume were lower ($p<0.05$) in T4. Crude protein, neutral detergent fibre and acid detergent lignin digestibility were high ($p<0.05$) in T1. The study concludes that rice milling waste can be incorporated into the diets of WAD goats at levels up to 30% without adverse effects on performance, or digestibility. Better results in weight gain, feed conversion, haematology and nutrient utilization were observed at 10% inclusion and hence recommended for enhanced goat production.
Keywords: goats, agro-byproducts, nutrient intake, blood profile, growth performance, rice milling waste.

Introduction

Goats are among the relatively few ruminant species in the animal kingdom. Goats have a very high potential for productivity, which, with better management, can greatly contribute to economic improvement of the farmer substantially. The subsistence farmer's thinking has not

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yet changed from employing goats as a savings asset to managing them as a productive asset, which is regrettably why the goat business has not been as developed and intensified as most other livestock. Goat production in Nigeria is largely extensive, with minimal housing and health management, and animals depend mainly on natural grazing, crop residues, and household wastes with little or no supplementation, in contrast to the USA and Australia where goats are managed under semi-intensive to intensive systems with controlled housing, strategic health programs, and scientifically formulated rations including improved pastures, hay, silage, and concentrate feeds (Tella A, Chineke, 2022; Silva et al., 2022). According to Adekanbi *et al.* (2020) feed is the most crucial element in managing goats as productive assets, providing high-quality, fresh, and nutritive feed is essential to profit maximization in goat production. Increasing the productivity of small stock seems to depend more on improved goat nutrition. The least expensive source of nutrients for goats is native rangelands, and for most of the year, the grasslands are unable to offer enough nutrients to goats for increased productivity. High-quality dry season supplements are necessary to boost production because most tropical forage species have low dry matter digestibility (Aregheore, 2001), especially when the natural forages are scarce in both quantity and quality during the dry season.
In the tropics, the main constraint to goat production is the supply of affordable, high-quality feedstuffs. Feed accounts for 70–80% of the cost of raising livestock. Due to seasonality, scarcity, and competition between humans and animals for traditional feedstuffs, the ready availability of these feeds is limited. However, non-conventional feed resources (NCFRs), or alternative low-cost feed ingredients, can be used as substitutes to reduce feeding costs (Jiwuba, 2020). The wastes from milling rice (rice bran, husk, broken rice), cassava peel, and bambara nut wastes are a few examples of NCFRs. The byproduct known as rice milling waste (RMW) is derived from rice milling industries that process parboiled rice using a mechanism that combines the removal of husk and polishing into a single operation to produce clean grain and rice offal, which contains husk, bran, polishing, and small amounts of broken grains (Dafwang and Shwaremen, 1996). Developed nations split this waste into several components and turn them into goods with added value. In Nigeria, however, it is typically used for livestock feeding, improperly discarded in waste heaps causing pollution, or utilized as firewood. Due to its high fibre, and low protein, it has not been well utilized as animal feed despite being readily available (Oyawoye and Nelson, 1999). In most parts of Nigeria where rice is produced, one of the most prominent agro-industrial wastes produced in significant quantities is rice milling waste. Nigeria's rice-producing regions are rich in rice milling enterprises, which provide by-products for rice processing (Omotola and Ikechukwu, 2006). According to NAERLS and PCU (2004), Nigeria produces an estimated 1,032,993.6 metric tonnes of rice milling by-products annually. The rice industry will in nearest feature experience significant decrease in disposal issues and value addition if rice milling wastes are efficiently used as animal feed. However, there is a dearth of information on the utilization of rice milling wastes by goats. The objectives of the study therefore are to evaluate the nutrient intake, body weight changes, haematology, serum biochemistry and apparent nutrient digestibility of goats fed diets containing rice milling wastes. We assume that the inclusion of 0–30% of rice milling waste will have a beneficial effect on nutrient intake, body weight change, haematology, serum biochemistry and apparent nutrient digestibility in West African dwarf goats.

Materials and methods

Location of the study

The study was carried out at Federal College of Agriculture's sheep and goat unit, Ishiagu, Ivo L.G.A., Ebonyi State, Nigeria. The college is about 3 kilometres from the major town of Ishiagu. The College is located at latitude 5.56^0 N and longitude 7.31^0E, with an average annual rainfall of 1653 mm, a prevailing temperature of 28.500°C, and a relative humidity of approximately 80%.

Sourcing of the rice milling wastes and formulation of the experimental diets

The rice milling wastes were obtained from a rice processing mill in Eke market Ishiagu, Ivo L. G. A., Ebonyi State, Nigeria. They were further sun-dried in batches and stored for future use. Four experimental diets T1, T2, T3, and T4 were formulated from rice milling waste, brewers dried grain, palm kernel cake, soybean, cassava peels, bone meal, and salt. The rice milling wastes (RMW) were included at the levels of 0%, 10%, 20% and 30% for T1, T2, T3, and T4 respectively as presented in Table 1.

Table 1: Composition of the experimental diets

Ingredient	T1 (0.00%)	T2 (10.00%)	T3 (20.00%)	T4 (30.00%)
Rice milling wastes	0.00	10.00	20.00	30.00
Palm Kernel Cake	40.00	30.00	20.00	10.00
Soya Bean Cake	7.00	7.00	7.00	7.00
Brewer Dried Grain	20.00	20.00	20.00	20.00
Cassava Peel	30.00	30.00	30.00	30.00
Bone meal	2.50	2.50	2.50	2.50
Salt	0.50	0.50	0.50	0.50
Total	**100.00**	**100.00**	**100.00**	**100.00**

Animal management

Twenty-four West African dwarf bucks weighing about 5.49kg and aged 6 to 8 months were selected from the College herd. For a preliminary period of 14 days, each animal was fed the control diet on 3% of their body weight in the morning (7:00 hour) and 2 kg of wilted *Panicum maximum* that was cut in the morning as basal in the evening (15:00 hour). This was done to increase the appetite of the goats for concentrate feeding. The experimental goats were acclimatized for 14 days before the start of the study, as per the approval and rules of the Animal Ethics Committee of the Federal College of Agriculture, Ishiagu, Ebonyi State, Nigeria.

Nutrient intake and body weight gain

Four groups of six goats each were randomly selected, with each goat serving as a replicate. Using a completely randomised design (CRD), the groups were assigned to the four experimental diets (T1, T2, T3, and T4) at random. Each animal was kept in a separate pen with a concrete floor, adequate air circulation, and drinking and feeding facilities. For 90 days, each animal was fed respective treatment diet on 3% of their body weight in the morning (7:00 hour) and 2 kg of wilted *Panicum maximum* that was cut in the morning as basal in the evening (15:00 hour). Fresh drinkable water was made available regularly. Each animal's voluntary feed intake was calculated daily by subtracting the previous day's feed refusals from the current day's feed supply. The goats' initial live weights were taken using spring balance at the start of the feeding trial and weekly afterwards in the morning before feeding. After the trial, the goats were weighed to determine their final live weight. Other growth performance indexes were computed accordingly.

Digestibility study

Twenty-four, six- to eight-month-old WAD bucks were used in this investigation. Under zero grazing conditions, the goats received supplemental feed at a daily rate of 3% body weight per head on a DM basis. Following their first disinfection, the goats were put in separate metabolism cages equipped with faeces collection equipment. The goats were randomly assigned to the four test diets (T1, T2, T3, and T4) following the adjustment phase in a CRD design. Twice daily, at a rate of 3% of body weight, the goats were fed the diets at 7:00 hour and 15:00. hour. There was provision of clean wholesome water as free choice. The goats were given experimental diets for 28 days. Data were collected from days 21 to 28. For each buck, the amount of faeces excreted was measured every day for seven days. Over the course of a week, faeces were collected and bulked for each buck. For each animal, 20% of the faecal samples were bulked. After that, the faecal samples were freeze-dried, powdered, and stored for further evaluation.

Proximate analyses

AOAC (2005) procedures were used to analyze all the faecal samples for proximate components. Following AOAC (2005) guidelines, three separate samples of the dietary levels of rice milling were examined for dry matter (DM), crude protein (CP), crude fibre (CF), ash, ether extract (EE), and nitrogen-free extract (NFE). The neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) fractions were determined using Van Soest *et al.* (1991) methods.

Gross Energy Determination: The formula was used to determine the gross energy.

$T = 5.72Z1 + 9.50Z2 + 4.79Z3 + 4.03Z4 \pm 0.9\%$; according to Nehring and Haelein (1973).

Where;

T = Gross energy;

ZI = Crude protein;

Z2 = Crude fat;

Z3 = Crude fibre;

Z4 = Nitrogen free extract.

Experimental design and statistical analyses

The experimental design used was a completely randomized design (CRD). Data obtained were analysed using analysis of variance (ANOVA) as described by SAS (2008). Significant means were separated using the Duncan Multiple New Range Test at $p<0.05$.

Results

The proximate composition of the experimental diets is presented in Table 2. There are significant ($p<0.05$) differences for CP, NDF and ADF, while every other parameter measured were not affected ($p>0.05$). crude protein contents were significantly ($p<0.05$) high in T1, and T2 in comparison to T4. On the other hand, NDF and ADF followed a similar pattern with T3 and T4 having significantly ($p<0.05$) higher values than T1. The nutrient intake of West African dwarf goats fed dietary levels of rice milling waste is presented in Table 3. The supplement dry matter intake (SDMI), supplement dry matter intake as percentage of body weight (SDMI % body weight), crude protein intake, neutral detergent fibre intake, acid detergent fibre intake and acid detergent lignin intake showed significant ($p<0.05$) differences, while forage dry matter intake, total dry matter intake, forage dry matter intake as percentage of body weight, total dry matter intake as percentage of body weight and ash intake remained statistically similar ($p>0.05$). The dry matter as a percentage of body weight for supplements were significantly ($p<0.05$) higher in T1 and T4 than for T2 and T3. The CP intake (g/d and g/kg $W^{0.75}$) of the goats fed the T1 and T2 diets had the highest ($p<0.05$) values (47.19 and 48.12 g/d and 18.00 and 18.27 g/kg $W^{0.75}$ respectively) while T4 had the least ($p>0.05$) value (36.56 g/d and 14.87 g/kg W0.75). The neutral detergent fibre, (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) intakes were significantly ($p<0.05$) high in T4 in comparison to the other groups. The body weight changes of West African dwarf goats fed dietary levels of rice milling waste is presented in Table 4. The final body weight was significantly ($p<0.05$) affected with goats in T4 (9.95kg) having the lowest ($p<0.05$) value in comparison to T1, T2 and T3. Body weight gain/goat was also lower ($p<0.05$) for animals on diets T4 (2.80 kg) than those obtained in T1 (6.34 kg) T2 (7.33 kg) and T3 (6.12 kg). T4 showed significantly ($p<0.05$) lower daily weight gain in comparison with T1, T2 and T3. Daily weight gain was highest for T2 goats (81.44 g/d) and least (P<0.05) for T4 goats 31.11 g/d). The feed conversion ratio (FCR) ranged from 3.60 to 9.57 and was significantly (p<0.05) high in T4. The haematology of West African dwarf goats fed dietary levels of rice milling waste is presented in Table 5. The packed cell volume (PCV) for T1 and T2 differed (p<0.05) significantly from the value of T3 and T4. The haemoglobin (Hb) (g/dl) values obtained in this study showed significant (p<0.05) differences among dietary groups, with goats on T4 having significantly (p<0.05) lower values than the goats on the other dietary treatments. The red blood cells (RBC) were significantly affected (p<0.05) by treatment diets in the present study. The RBC and mean cell volume followed a similar trend as the PCV and Hb. T4 differed (p<0.05) significantly with T1, T2 and T3. T4 showed a significantly lower value when compared to the other treatments. Mean cell haemoglobin concentration was significantly (p<0.05) high in T1 and T2 when compared to T3 and T4. The serum biochemical indices of West African dwarf goats fed milling waste are presented in Table 6. All the serum biochemical indices examined in this study showed no significant difference (p>0.05) across the groups. The apparent nutrient digestibility of West African dwarf goats fed dietary levels of rice milling waste is presented in Table 7. Dry matter digestibility showed a significant (p<0.05) difference with T1 and T2 having high (p<0.05) DM digestibility in comparison with T3 and T4. CP digestibility was least digested in T4 (47.69%) and better digested in T1 (58.32%), T2 (55.52%) and T3 (56.36%). Crude protein and neutral detergent digestibilities were significantly (p<0.05) high in T1 in comparison with T3 and T4, but similar to T2. Acid detergent lignin digestibility showed significantly (p<0.05) lower digestibility for T3 and T4 when compared with T1, which was also higher (p<0.05) than T2.

Table 2: Chemical composition of the experimental diets

PARAMETERS (%)	T1 (0%)	T2 (10%)	T3 (20%)	T4 (30%)	SEM
Dry Matter	90.51	89.53	91.87	92.05	6.38
Crude protein	16.42^{a}	16.19^{a}	14.97^{ab}	12.63^{b}	1.73
Crude fibre	14.56^{d}	16.62^{c}	19.28^{b}	23.76^{a}	1.56
Ether extract	3.87	3.86	4.02	3.73	0.11
Ash	9.76	8.53	9.68	9.05	0.17
Nitrogen free extract	45.90	44.33	43.92	42.88	1.56
Gross energy (Kcal/g)	382.98	387.54	393.18	394.24	12.87
Neutral detergent fibre	36.97^{b}	45.65^{ab}	48.35^{a}	51.87a	3.16
Acid detergent fibre	20.78^{b}	23.19^{ab}	26.73^{a}	30.09^{a}	2.68
Acid detergent lignin	10.80	13.62	14.70	15.18	1.43

$^{a-b}$ means within the same row with different superscripts are significantly different (P<0.05)

Table 3: Nutrient intake of West African dwarf goats fed dietary levels of rice milling waste

Parameters	T1 (0%)	T2 (10%)	T3 (20%)	T4 (30%)	SEM
Dry matter intake (DMI) (g/d)					
Supplement	260.13^{b}	262.41^{b}	278.45^{a}	266.48^{ab}	17.23
Forage	30.78	30.44	31.24	31.30	3.15
Total DMI	290.91	292.85	309.69	297.78	13.18
Total DMI (g/kgW$^{0.75}$)	70.44	70.79	73.82	71.68	3.25
Total DMI % body weight (BW) (%)					
Supplement	3.01^{a}	2.69^{b}	2.61^{b}	2.98^{a}	0.11
Forage	0.36	0.31	0.29	0.35	0.06
Total DMI % BW	3.37	3.00	2.90	3.33	0.12
Total DMI % BW (g/kgW$^{0.75}$)	2.49	2.28	2.22	2.47	0.08
Crude protein intake (g/d)	47.19^{a}	48.12^{a}	45.52^{ab}	36.56^{b}	11.32
Crude protein intake (g/kgW$^{0.75}$)	18.00^{a}	18.27^{a}	17.52^{a}	14.87^{b}	1.92

Ash intake (g/d)	28.05	25.00	29.43	26.14	2.17
Ash intake (g/kgW$^{0.75}$)	12.19	11.18	12.64	11.56	1.02
Neutral detergent fibre intake (g/d)	106.25^{d}	133.80^{c}	147.24^{b}	150.16^{a}	9.41
Neutral detergent fibre intake (g/kgW$^{0.75}$)	33.09^{d}	39.34^{c}	42.27^{b}	42.90^{a}	2.87
Acid detergent fibre intake (g/d)	59.72^{c}	67.97^{b}	81.29^{a}	87.11^{a}	10.74
Acid detergent fibre intake (g/Wkg$^{0.75}$)	21.48^{c}	23.67^{b}	27.07^{a}	28.51^{a}	3.68
Acid detergent lignin intake (g/d)	31.04^{c}	39.92^{b}	44.70^{a}	43.95^{a}	3.54
Acid detergent lignin intake (g/kgW$^{0.75}$)	13.15^{c}	15.88^{b}	17.29^{a}	17.07^{a}	0.84

$^{a-d}$ means within the same row with different superscripts are significantly different (P<0.05)

Table 4: Body weight changes of West African dwarf goats fed dietary levels of rice milling waste

Parameters	T1 (0%)	T2 (10%)	T3 (20%)	T4 (30%)	SEM
Initial body eight (kg)	6.31	6.43	7.54	7.15	0.42
Final body weight (kg)	12.65^{a}	13.76^{a}	13.66^{a}	9.95^{b}	0.81
Body weight gain (kg)	6.34^{a}	7.33^{a}	6.12^{a}	2.80^{b}	0.11
Daily weight gain (g/d)	70.44^{b}	81.44^{a}	68.00^{b}	31.11^{c}	3.32
FCR	4.13^{b}	3.60^{b}	4.55^{b}	9.57^{a}	0.85

$^{a-c}$ means within the same row with different superscripts are significantly different (P<0.05)
FCR = Feed conversion ratio.

Table 5: Haematology of West African dwarf goats fed dietary levels of rice milling waste

	Diets				
Parameters	T1 (0%)	T2 (10%)	T3 (20%)	T4 (30%)	SEM
Packed Cell Volume (%)	29.87^{a}	31.76^{a}	27.65^{b}	26.97^{b}	1.76
Haemoglobin (g/dl)	11.48^{a}	11.41^{a}	10.65^{a}	9.08^{b}	0.26
Red blood cell (x10^{12}/L)	16.72^{a}	15.87^{a}	16.12^{a}	11.74^{b}	0.35
Mean cell volume (fL)	23.17^{a}	19.65^{a}	21.54^{a}	17.04^{b}	0.93
Mean cell haemoglobin conc. (%)	35.22^{a}	35.79^{a}	33.78^{b}	30.37^{b}	0.71
Mean cell haemoglobin (pg)	6.75	5.81	7.99	7.15	1.01
White blood cell counts (x10^{9}/L)	8.19	9.05	7.43	8.69	0.54
Lymphocyte (%)	58.90	61.62	57.76	59.24	0.49
Neutrophil (%)	25.84	28.41	28.92	27.32	0.75

$^{a-b}$ means within the same row with different superscripts are significantly different (P<0.05)

Table 6: Serum biochemistry of West African dwarf goats fed dietary levels of rice milling waste

	Diets				
Parameters	T1 (0%)	T2 (10%)	T3 (20%)	T4 (30%)	SEM
Cholesterol (mmol/l)	3.01	2.96	2.83	3.11	0.22
Creatinine (µmol/ l)	70.65	73.87	71.32	72.62	1.64
Urea (mg/dl)	15.56	15.61	14.79	14.33	0.58
Total protein (g/I)	65.87	67.19	66.01	67.35	0.76
Globulin (g/I)	30.86	31.12	30.93	30.63	1.10
Albumin (g/I)	35.01	36.07	35.08	36.72	1.57
Total bilirubin (µmol/l)	0.76	0.43	0.46	0.21	0.11
AST (U/L)	54.86	55.78	53.65	51.98	1.61
ALT (U/L)	19.35	17.82	18.69	21.94	0.11

[a-b] means within the same row with different superscripts are significantly different (P<0.05)

Table 7: Apparent nutrient digestibility of West African dwarf goats fed dietary levels of rice milling waste

	Diets				
Parameters (%)	**T1 (0%)**	**T2 (10%)**	**T3 (20%)**	**T4 (30%)**	**SEM**
Dry matter	78.66^{a}	74.54^{a}	67.56^{b}	68.19^{b}	2.62
Crude protein	64.54^{a}	60.76^{ab}	56.76^{b}	57.54^{b}	3.09
Ash	56.73	56.82	58.17	53.49	2.51
Neutral detergent fibre	68.11^{a}	63.67^{ab}	58.65^{b}	60.55^{b}	7.71
Acid detergent fibre	43.44	41.07	39.65	38.26	1.87
Acid detergent lignin	47.11^{a}	37.34^{b}	22.71^{c}	22.43^{c}	2.21

[a-c] means within the same row with different superscripts are significantly different (P<0.05)

Discussion

The CP value of 12.63-16.42% obtained in this study is higher than the 10 to 12% minimum protein requirements for goats as recommended by ARC (1985) and well above the 7.0–8.0 g/100g DM recommended as grave limit, below which intake by ruminants and rumen microbial activities may be negatively affected (Van Soest, 1994). It is important to highlight that the experimental diets' crude protein and energy needs fall within the ranges reported for goats by ARC (1980), NRC (1981), and Norton (1994). The increased supplement DM intake for 20% RMW may be attributed to the greater palatability of the diets. The improved intake obtained in this study can be described by the better supply of both nitrogen and readily available carbohydrates to the rumen microbes which possibly enhanced the microbial growth, the fractional outflow of liquid materials from the rumen, and the rate at which the diets degrade. In an earlier study, Mpairwe *et al.* (2003) observed that providing supplements with adequate CP to ruminants could enhance DMI, rumen degradation and nutrient flow to the small intestine and culminated in higher animal performance. Across all groups, the dry matter percentages (2.90–3.37%) compared favourably to the 3%, 2.8%, and 2.8%–4.0% percentages recommended daily DM intake (as % BW) requirements for meat type goats in the tropics by Devendra and MCleroy (1982), Akinsoyinu (1985) and Nuru (1985) respectively. The results generally indicated that the animals on the various diets showed positive DM status as evidenced by a generally positive performance of the goats. Protein intake is one of the major determinants of goat performance due to the increased availability of fermentable nitrogen and other nutrients required by rumen microbes as well as the increased chances of some protein escaping the rumen fermentation. The high CP intake of goats fed T1 andT2 could be attributed to the higher CP content of the diets because of the higher protein content of the diet. This is consistent with previous findings by Jiwuba et al. (2023) that a diet high in protein content increases intake. High dietary fibre content may be the cause of the high fibre fraction intake. ADF and ADL-rich diets are predicted to improve resistance to rumen fullness and physical breakdown, which will reduce voluntary intake. Thus, the lower ADF and ADL intake recorded for T1 might be attributed to the high levels of ADF and ADL in the diets which corroborate the view of Van Soest *et al.* (1991) who claimed that quantity of fibre fractions might be used to forecast intake. The fact that every goat in the groups gained weight supports Devendra and Mcleroy's (1982) findings that a CP of 11% is sufficient for goats to gain weight normally. The highest live weight gain obtained by goats on T1 T2, and T3 may be attributed to the significant CP intake of the goats. The variation observed in the body weight changes of the goats could also be attributed to the variation in the nutrient utilization by each animal from the diets. The goats fed T4 had the highest feed conversion ratio, which is calculated by dividing feed intake by the gain in weight. The lower feed conversion ratio obtained for goats fed T1, T2 and T3 could be attributed to the diet that boosted the multiplication of rumen microbes which must have enhanced the degradability of the nutrients. The composition of packed cell volume, which is employed as a feed toxicity measure, differs among goat breeds (Ahamefule et al., 2005). In the present study, the PCV values ranged between 26.97 – 31.76% and nevertheless fell within the normal physiological range of 22-38% for clinically healthy goats by Radostits *et al*. (2006), and 21-35% by Daramola *et al*. (2005) for clinically healthy WAD goats. Aikhuomobhogbe and Orheruata (2006) observed that low PCV results in anaemia which causes a reduced oxygen-carrying capacity of the blood, increased pulse rate and consequently heart failure. Nonetheless, the values found here were within the typical physiological range for clinically healthy goats (8–12 g/dl) (Radostits *et al*., 2006). Also, the Hb range of 9.08 – 11.48 g/dl obtained in this current study fell within the reference range of 7 – 15g/dl reported by Daramola *et al*. (2005) for clinically healthy WAD goats. It is possible that the fact that the experimental goats' blood oxygen-carrying capacity was within the reference range for WAD goats suggests that all of the diets provided excellent blood oxygen-carrying capacity. Jiwuba and Kadurumba (2019) support the idea that the high quality of the dietary proteins may be indicated by the Hb concentration of WAD goats on the diets. The RBC values (11.74 -16.72 x 106/µl) recorded for the WAD bucks herein fell within the normal physiological range of 8 - 18 x 106/µl) reported by Radostits *et al*. ('2006) for clinically healthy goats. Red blood cell characterizes anaemia and other conditions affecting red blood cells (Etim *et al*., 2013). This result thus shows that the diets supported the good health status of the goats, and hence the animals were not anaemic. The significant and within normal physiological range observed in this study for MCV is an indication that the nutritional quality of the diets were not compromised. The MCV values (17.04 - 23.17 fl) in this study fell within the reference ranges of 16-25 fl by Radostits *et al*. (2006) respectively for apparently healthy goats, confirmed that the goats were not anaemic. The non-significant effect reported for the serum biochemical parameters may indicate that the diets were not toxic but nourishing since all the parameters were within the normal physiological range for apparently healthy goats reported by Kaneko *et al.,* (1997). Generally, the DM digestibility values were high and ranged between 68.19 and 78.66%. This compared well to goats fed oil palm fronds treated with *Lentinus sajor-caju*, the coefficient of DM digestibility ranged from 68.65 to 78.66% (Hamchara *et al*., 2018). However, it was lower than the 82.20 to 88.70% found for WAD goats fed fungal-treated rice straw-based diets (Wuanor and Carew 2018) and higher than 54.43 to 62.98% found by Udo *et al.* (2021) for WAD goats fed varying levels of boiled rubber seed meal-based diets. Differences in the diets fed may account for the differences in the observed results. The higher CP digestibility coefficients reported in T1 and T2 may indicate that dietary proteins were better utilized by the goats fed the respective diets. The crude protein contents of the T1 and T2 diets were positively correlated with fibre fraction digestibilities. This lends credence to the claim made by Fasae et al. (2005) that CF digestibility declines with dietary CP levels. The harmonizing of nutrients, especially protein and energy, should be a key factor in farm animal management in order to maximise nutritional utilisation. Improved digestibility at higher nitrogen levels had previously been linked to low fibre levels (Kayouli *et al*. 1993). The lignin content of the feed mixtures could be responsible for the discrepancies in digestibility values of fibre fractions reported for the treatment groups. According to Mertens (1977), changes in cell wall composition including lignin and possibly silica, reduce the possible extent of digestion. Fibre fraction contents in the diets containing rice milling waste were higher and this may have impacted negatively on digestion due to its low microbial colonisation rate in the rumen. It is remarkable to note that the rate of digestion is controlled by chemical entities other than the crystalline or physical nature of the fibre.

Conclusion

It could be concluded that T1, T2 and T3 showed significant improvement in crude protein intake, daily weight gain, feed conversion ratio, packed cell volume, haemoglobin, red blood cells, mean cell volume, mean cell haemoglobin concentration, dry matter digestibility, crude protein and neutral detergent fibre and hence recommended for enhanced WAD goat production. Lastly, higher inclusion levels of rice milling waste above 10% should be discouraged.

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