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Nutritional impact of hydroponic fodder supplementation on hematological and serum biochemical parameters in West African Dwarf rams

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Abstract

Background and Objective: Livestock production in the tropics is constrained by the limited availability and low nutritive value of forage, particularly during the dry season, compounded by insufficient land for cultivation. Hydroponic fodder production, a method of growing plants using water-based nutrient solutions in minimal land space, has the potential to address these challenges. This study evaluated the effects of hydroponic fodders irrigated with poultry manure nutrient solution on the hematological and serum biochemical parameters of West African Dwarf (WAD) rams, with implications for their nutritional and physiological health.

Methodology: Twenty-five WAD rams (average weight: 9.55 ± 0.25 kg) were randomly allocated into five treatment groups (n = 5 per group) in a completely randomized design. All groups were fed a basal diet of *Megathyrsus maximus* hay, supplemented with hydroponic fodders (maize, millet, sorghum, or wheat) as treatments, while a control group received a concentrate supplement. Key parameters measured included dry matter intake, crude protein content, and hematological and serum biochemical indices after an 84-day feeding trial.

Main Results: Hydroponic maize fodder exhibited the highest ($P < 0.05$) crude protein content (17.54%) among treatments, and rams fed this fodder achieved the highest dry matter intake (831.18 g/day). Hematological indices such as mean corpuscular volume, white blood cell count, and lymphocytes fell within normal ranges across treatments. However, rams-fed millet and sorghum fodders exhibited suboptimal hemoglobin and packed cell volume levels. Serum protein and urea nitrogen levels in all treatment groups remained within the normal range, indicating no adverse effects on physiological health.

Conclusions: This study demonstrates that hydroponic fodders, particularly maize, can be a sustainable and nutritionally adequate supplement for WAD rams during feed-scarce periods, supporting optimal health and performance without detrimental effects on hematological or biochemical parameters. The findings underscore the potential of hydroponics as a practical solution for enhancing livestock productivity in resource-constrained settings.

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INTRODUCTION

The unavailability of feed throughout the year, especially in the dry season, has been a great constraint in livestock development, especially in the tropics. This has negatively affected the growth, production and reproduction of animals (Baris, 2023). Aside from this, the profit margin and protein intake of the populace have been impaired as a result of the lack of quality feed for animals. The concentrate farmers use to augment the feed available to livestock is expensive and does not easily come from poor resource farmers (Ajakemo, 2021).

Green fodders have been reported to be of vital importance for efficient production and reproductive performances of ruminants (Dadhich and Dhuria, 2024). Sheep, one of the ruminants, are extremely important economically in Nigeria since rearing them has no cultural or religious barriers (Adelusi *et al*., 2019). They are sources of meat supply, provide food and nutritional security, and are a source of income to smallholder farmers, especially in rural areas (Wodajo *et al*., 2020). However, constraints such as the availability of land to grow forages for animals, climate changes, equipment, labor required, pests, and diseases are major challenges in providing high quality and quantity to livestock throughout the year. Naik *et al*. (2014) have reported using hydroponic fodder, which is the method of growing plants without soil using a minimal amount of water. It also uses a limited area of land for its growth, it uses little water, it requires less labor, and the technical know-how is quite easy to undertake. Potential cereals used as hydroponic fodder, such as millet, sorghum, and maize, are readily available and can produce a good quality yield within a short period (Garba *et al*., 2023). They are low in fiber and easily digestible by the animals, and this helps to improve the growth performance and productivity of the animals (Hassen and Dawid, 2022; Arif *et al*., 2023). Research has shown that the addition of maize and barley hydroponics fodder, which are more palatable, increased the dry matter intake and weight gain of Konkan Kanyal goats compared to those fed sole millet straw (Gebremedhin, 2015), according to Dadhich *et al*. (2019) who reported an improved growth performance and nutrient digestibility for calves fed maize hydroponics fodder.

Feed intake and nutrient digestibility, hematological parameters, and serum biochemicals in animals are very germane in understanding the physiological changes that occur in an animal based on its nutritional status (Ajagbe *et al*., 2019). Alalade *et al*. (2021) reported that so many factors influence the hematological values of animals, and nutritional status is essential among them. Blood is a useful tool for tracking an organism's health (Joshi *et al*., 2002), and ingestion of various feed components has been reported to have quantifiable effects on the blood components of various animals (Arowora and Tewe, 2003). Feeding hydroponics fodder to animals has no negative influence on the blood profile of the animals (Adebiyi *et al*., 2018; Jatutu *et al*., 2024), and this indicates hydroponics fodder cannot have a detrimental effect on the health status of the animals. The study was therefore carried out to determine the effects of supplementing hydroponic fodders on serum biochemical and hematological parameters of WAD rams.

MATERIALS AND METHODS

Experimental Site

This study was carried out at the Screen House of the Department of Pasture and Range Management. In contrast, the animal experiment was carried out at the Small Ruminant Unit, Directorate of University Farms (DUFARMS), Federal University of Agriculture Abeokuta, Ogun State, Nigeria (FUNAAB), located at latitude 7°13'28" N and longitude 3°25'2" E.

Sourcing and Preparation of Nutrient Solution and Planting

Poultry fecal samples (manure) were collected from the Poultry Unit in DUFARMS, FUNAAB. The samples were air-dried for 14 days after collection. The dried samples were suspended in water at a ratio of 1 (kg) manure:10 L water and mixed at intervals of 3 hours. The mixture was now used as the organic nutrient solution. Premier Oba Super 2 maize cultivar (hybrid maize), millet, sorghum (white), and wheat seeds were purchased from a respectable market store selling agricultural products in the city of Abeokuta. The seeds were soaked in distilled water for 8 hours and sown at 450 g/tray, or roughly 4.0 kg/m^2, based on the recommendations of Al-Karaki and Al-Momani (2011). Previously cleaned and disinfected trays were properly labelled, and the seeds were spread in individual trays according to treatment in the screen house. The seeds were irrigated with a total of 100 mL of the nutrient solution (morning and evening) twice a day.

Experimental Diet

The sprouted seeds were grown in the screen house for 10 days, and the hydroponics fodder was harvested. *Megathyrsus maximus* was harvested from an already established pasture cut back to 15 cm above ground level before the commencement of the experiment. The grass was harvested at 8 weeks of re-growth and conserved as hay.

The experimental diets were:

Treatment 1: *M. maximus* hay + Concentrate

Treatment 2: *M. maximus* hay + Maize hybrid fodder

Treatment 3: *M. maximus* hay + Millet fodder

Treatment 4: *M. maximus* hay + Sorghum white fodder

Treatment 5: *M. maximus* hay + Wheat fodder

The concentrate ingredients consisted of 30% palm kernel cake, 10% groundnut cake, 2% limestone, 20% wheat offal, 18% rice bran, 17% corn bran, 1% salt, and 2% sulphur.

The chemical composition of *M. maximus* hay used as the basal feed in this study was: dry matter (DM) 81.00%, crude protein (CP) 8.15%, ether extract (EE) 5.20%, ash 9.50%, non-fiber carbohydrates (NFC) 20.15%, neutral detergent fiber (NDF) 57.00%, acid detergent fiber (ADF) 36.00%, acid detergent lignin (ADL) 11.50%, hemicellulose 21.00%, and cellulose 24.50%.

Experimental Animals and Management

Twenty-five (25) West African Dwarf (WAD) rams aged 10 months with an average weight of 9.55 ± 0.25 kg were used for this experiment. During the month-long acclimatization period, the animals received preventive care to guarantee their well-being. By intramuscular injection, ivermectin, oxytetracycline, and vitamins were administered at 1 mL/10 kg of body weight. The pens (2 m^2 floor spaces) and environment were cleaned and disinfected before the arrival of the rams. A basal diet of *M. maximus* was fed to the animals, and the hydroponics fodder was fed as a supplement.

The animals were randomly divided into five groups, each housed intensively in clean, well-ventilated pens with wooden slated floors and corrugated aluminium roofing sheets. The experiment commenced in August and was terminated in late November 2023. The Ethics Committee of the Federal University of Agriculture, Abeokuta, Nigeria, College of Animal Science and Livestock Production approved all experimental and animal management practices (ethical permission number: FUNAAB/COLANIM/DRIP/40).

Experimental Design

The study was designed with five treatments, which were laid out as a completely randomized design with five treatments (Premier Oba Super 2 maize cultivar (hybrid maize), millet, sorghum (white), and wheat) and the control was replicated five times.

Feeding Trial

Feed intake

Individual animals in each treatment were offered known quantities of the experimental diets daily for 84 days. During the feeding trial, the rams were first offered *M. maximus* hay *ad libitum* at 08:00 a.m. An hour later, 400 g of concentrate/hydroponic fodders were offered based on the treatment in separate feeding troughs. The concentrate diet was used as the control for the animals (treatment 1), while hydroponic fodders (maize, millet, sorghum, and wheat fodders) were offered to other animals (treatments 2, 3, 4, and 5). Clean water was adequately provided throughout the experimental period.

The leftover feeds from *M. maximus* hay and hydroponic fodders were measured every morning to calculate the feed intake of the animals by subtracting feed leftover from feed offered.

Feed intake (g) = Quantity of feed offered (g) – Quantity of feed refused (g)

Weight gain

The weight of the animals was recorded weekly using spring balance to determine the weight gain. Weight gain was determined by subtracting the weight of the animals in the previous week (initial weight) from the weight of the animals (final weight).

Weight gain (kg) = Final weight – Initial weight

Feed conversion ratio

The feed conversion ratio was determined by calculating the ratio of daily feed intake to total weight gain per treatment.

Blood Sampling and Analyses

Blood samples (about 15 mL) were drawn from each animal at the end of the 84-day feeding trial. The blood sampling was done before feeding via the jugular vein using hypodermic syringes. About 5 mL of the blood samples were dispensed into tubes containing ethylene diamine tetra acetate (EDTA) for hematological analysis, while the remaining portions were collected into plain tubes. The plain tubes were left at room temperature for 30 minutes to allow the blood to clot. Tubes were centrifuged for 15 minutes at 2,500 rpm to harvest serum for biochemical analysis. According to Benjamin (1978), the acid hematin method was used to determine hemoglobin concentration and the capillary microhematocrit method was used to determine packed cell volume (PCV) for hematological indices. The hemocytometer method, as reported by Chirkena *et al*. (2016), was used to measure the red blood cell (RBC) and white blood cell (WBC). Packed cell volume, red blood cell, and hemoglobin values were used to estimate mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) values, following Jain (1986). Serum glucose was determined according to the method of Bauer *et al*. (1974), which reported using the glucose oxidase procedure, total serum protein, albumin, and globulin were analyzed using the biuret method (Reinhold, 1953), while Marsh *et al*. (1965) method was used to measure serum urea.

Chemical Composition

The proximate composition of *M. maximus* hay and hydroponic fodders (dry matter, crude protein, ether extract, and ash) were determined according to AOAC (2005), non-fiber carbohydrate (NFC) was calculated as NFC (%) = 100 – NDF – CP – EE – Ash. Fiber fractions (NDF, ADF, and ADL) were determined according to the procedure of van Soest *et al*. (1991). Hemicellulose was calculated as the difference between NDF and ADF, while cellulose was calculated as the difference between ADF and ADL.

Statistical Analysis

All the data generated were subjected to a one-way analysis of variance in a completely randomized design using version 9.1 of the SAS software package (SAS, 2003). Significant differences between means were compared at a 5% probability level using the Duncan's multiple range test (SAS, 2003). The statistical model used was: $y_{ij} = \mu + T_i + \varepsilon_{ij}$; where y_{ij} is the observed value of the dependent variable, μ is the population mean, T_i is the effect of the experimental diets, and ε_{ij} is the random residual error.

RESULTS AND DISCUSSION

Table 1 shows the chemical composition of concentrate and different hydroponic fodders. There is a significant ($P < 0.05$) difference in the chemical composition except NFC. Among the hydroponics fodders, the highest value of DM content was observed in maize fodder, and the lowest value was recorded for sorghum fodder. Hydroponic fodder typically has a DM content of around 12–15%. Lower DM in hydroponic fodder is attributable to the sprouting process in which starch is converted to soluble sugars to support the metabolism of energy requirements of the growing plant for respiration and cell wall synthesis (Harerimana *et al*., 2023). However, the values obtained from this current study were higher, which implied that animals would be able to receive more nutrients for various productive purposes. The CP content was significantly higher in maize fodder and concentrate, followed by wheat fodder, with the lowest value recorded for millet and sorghum fodder. This might be due to sprouting conditions that could have altered the amino acid of the seeds (El-Morsy *et al*., 2013) and the nutrient uptake efficiency of each grain during its growth. Research has shown that the ability of seed used for hydroponic fodders to absorb high

Table 1 Chemical composition (%DM basis) of concentrate and different hydroponic fodders

Parameters	Concentrate	Hydroponic fodders				SEM	P-value
		Maize	Millet	Sorghum	Wheat		
DM (%)	93.00[a]	30.38[b]	23.19[d]	17.65[e]	28.65[c]	0.22	<0.001
Crude protein	17.40[a]	17.54[a]	13.04[c]	14.00[c]	15.56[b]	0.51	<0.001
Ether extract	6.07[a]	6.93[a]	4.00[b]	6.31[a]	6.09[a]	0.29	<0.001
Ash	6.00[a]	6.15[a]	3.25[b]	7.50[a]	7.50[a]	0.46	0.001
NFC	33.03	31.88	33.54	32.19	32.01	0.53	0.875
NDF	37.50[b]	37.50[b]	46.17[a]	40.00[b]	38.33[b]	0.95	0.001
ADF	19.00[bc]	18.01[c]	21.80[a]	20.05[b]	18.50[c]	0.40	0.001
ADL	5.72[c]	4.70[e]	6.60[a]	5.90[b]	5.20[d]	0.17	<0.001
Hemicellulose	18.50[b]	19.49[b]	24.37[a]	19.95[b]	20.33[b]	0.67	0.025
Cellulose	13.28[b]	13.31[b]	15.20[a]	14.15[ab]	13.30[b]	0.25	0.026

Note: Means within the same row followed by different superscript letters (a, b, c, d, e) are significantly different ($P < 0.05$). DM = dry matter, NFC = non-fiber carbohydrate, NDF = neutral detergent fiber, ADF = acid detergent fiber, ADL = acid detergent lignin, SEM = standard error of the mean.

quantities and nutrient solution during growth increases the protein content (Dung *et al*., 2010). However, poultry feces soaked in water were used as nutrient solution in this study.

The CP contents of the hydroponic fodders in this study are higher than the range of 10–12% CP reported as a moderate level required for better production of ruminant animals (Gatenby, 2002). The CP content of maize fodder, whose values varied from 9.96–12.48%, as reported by Gunasekaran *et al*. (2018), is lower than the CP content of maize fodder obtained in this study. Chrisdiana (2018) reported 13.94% CP content in sorghum KD4, which is similar to the 14.00% recorded for sorghum in this study but lower than the 17.24% for sorghum Super-1 reported by the same authors. The CP content of millet in this study was slightly lower than 14.84% for millet fodder harvested at 7 days after planting (DAP), as reported by Akinmutimi *et al*. (2023). The differences in the values might be due to the varieties of seeds used and nutrient solutions used to irrigate in this study. In the previous study, the authors used water to irrigate hydroponic fodders compared to the poultry feces solution used in this study. Dung *et al*. (2010) reported that using a nutrient solution instead of tap water raises the CP content of hydroponic fodder because nitrogenous compounds are absorbed.

The ash and EE contents represent the level of minerals and fat in the feed of the animals. Ash and EE were significantly lower in millet fodder than others. The ash content of maize fodder observed fell within the range of 6.56–7.13% reported for maize OBA 98 and locally harvested at 6, 8, and 10 DAP (Lamidi *et al*., 2022). Ali *et al*. (2019) reported values of 4.09% (ash) and 3.29% (EE) for wheat, which were lower than the values obtained in this study. The EE content of maize fodder is higher than the range of 4.02–4.48% for different varieties of maize, as reported by Lamidi *et al*. (2022). This might result from the growth of plants producing more chlorophyll and structural lipids (Naik *et al*., 2015). Non-fiber carbohydrates, though not significantly different across treatments, it indicates that the diets can serve as calorific substitutes, ensuring that the animals receive similar rate soluble carbohydrates that readily supply energy that supports rumen microbes for their growth and protein synthesis (Wei *et al*., 2021).

Millet fodder has the highest value of NDF content. The ADF and ADL ranged from 18.01–21.80% and 4.70–6.60%, respectively, with the highest value recorded in millet fodder and the least observed in maize fodder. The highest value of hemicellulose content was obtained for millet fodder. The cellulose content in millet fodder was similar to that of sorghum and significantly higher than others. The value of NDF content (37.50%) of maize fodder in this study was lower than 44.49% for the Swan-1 maize cultivar reported by Adeyemi *et al*. (2021), and this might be due to differences in the ages of the harvest of maize from the different studies. However, the ADF content (18.01%) is similar to the 18.57% reported by the same authors. Garuma and Gurmessa (2021) evaluated the NDF content of sorghum var. chemeda and reported 40.34%, similar to the value (40.00%) obtained in this study.

Nutrient intake and growth performance of WAD rams fed *M. maximus* hay supplemented with concentrate and hydroponic fodders are presented in Table 2. Significant differences ($P < 0.05$) were observed in all the parameters considered. Among the hydroponics fodders, the highest DM hydroponics intake was recorded for rams-fed maize fodder. This might be attributed to high DM and low NDF contents in maize fodder. Lower DM hydroponics intake for rams supplemented with sorghum and millet fodders could be due to their high moisture content, which makes them bulky (Fazaeli *et al*., 2011). Rams supplemented with maize fodder had the highest ($P < 0.05$) total dry matter intake (831.18 g/day), while the ones supplemented with concentrate and millet fodder had the lowest intake (653.41 and 660.01 g/day, respectively). Lower total dry matter intake in rams-fed millet fodder could be due to higher hemicellulose content. Ajayi and Joseph (2019) stated that intake of dry matter is one of the factors that determines how well ruminants utilize their feed, consume energy, and function overall. The highest total dry matter intake in rams on maize fodder could be that the animals found the ration more palatable (Ahamefule and Elendu, 2010). Also, Bunyeth and Preston (2006) reported that the desire for moist feed could enhance the highest dry matter intake recorded for animals supplemented with maize fodder above dry hay in this study.

The highest CP intake recorded for rams-fed maize fodder might be due to the high CP content in the feed, and this is in line with the findings of Chana *et al*. (2021). A feeding trial was carried out on Balami rams fed different varieties of sorghum hydroponics fodder by the authors. The result shows that rams-fed sorghum fodder var. Jigari had the highest dry matter intake (145.41 g/day) with the highest CP content (14.05%). Rams fed sorghum var. red, white Chakalari and Kaura had a lower intake with values of 136.36, 135.44, and 137.97 g/day, respectively, due to their lower CP content. Ojo *et al*. (2023) related increased feed intake in an animal to the resultant dietary CP level in a feed. The high value (17.51%) recorded for maize fodder in this study could have increased the total intake of the feed offered to the animal above others. Increased intake of protein by ruminants has a lot to contribute to their overall performance. This is because bacteria in the rumen of the ruminants require both nutrients and fermentable nitrogen for their activity, and it makes room for opportunities to escape the rumen fermentation of some protein (Oni *et al*., 2010).

Rams supplemented with maize and wheat fodders had higher NDF intake, which shows that the diets are good sources of carbohydrates for ruminant animals (Oba and Kammes-Main, 2023). Higher NDF intake in rams supplemented with maize and wheat fodders could be due to lower ADF contents in their feeds. The ADF content indicates the level of digestibility and is negatively correlated to the rate of feed digested by the animals. Hence, the higher the rate of digestibility, the higher the intake of the animals. The higher fiber intake of hay by animals supplemented with hydroponic fodders in this study was a result of the hay that

Table 2 Nutrient intake (g/day) and growth performance of West African Dwarf rams fed *Megathyrsus maximus* hay supplemented with concentrate and hydroponic fodders

Parameters	**Dietary treatments**					**P-value**
	***M. maximus* hay + Concentrate**	***M. maximus* hay + Maize fodder**	***M. maximus* hay + Millet fodder**	***M. maximus* hay + Sorghum fodder**	***M. maximus* hay + Wheat fodder**	
Dry matter hay	399.48 ± 3.93^{d}	604.66 ± 17.50^{b}	556.10 ± 3.20^{c}	643.48 ± 2.39^{a}	628.32 ± 3.25^{a}	<0.001
Dry matter concentrate/ hydroponics	253.94 ± 2.90^{a}	226.52 ± 3.57^{b}	103.91 ± 3.29^{d}	106.96 ± 0.66^{d}	175.42 ± 1.94^{c}	<0.001
Total dry matter	653.41 ± 2.15^{d}	831.18 ± 19.42^{a}	660.01 ± 6.34^{d}	750.45 ± 1.94^{c}	830.74 ± 1.65^{b}	<0.001
Crude protein	76.74 ± 0.35^{b}	89.00 ± 2.49^{a}	58.87 ± 0.78^{d}	67.43 ± 1.86^{c}	78.50 ± 0.31^{b}	<0.001
Ether extract	36.19 ± 0.35^{d}	47.15 ± 1.05^{a}	33.06 ± 0.20^{e}	40.21 ± 0.96^{c}	43.36 ± 0.42^{b}	<0.001
Ash	53.19 ± 0.24^{d}	71.36 ± 2.63^{ab}	56.18 ± 1.61^{c}	69.15 ± 0.73^{b}	72.85 ± 0.98^{a}	<0.001
Neutral detergent fiber	322.93 ± 1.44^{d}	429.64 ± 13.59^{a}	364.94 ± 2.83^{c}	409.56 ± 4.91^{b}	426.29 ± 1.18^{a}	<0.001
Acid detergent fiber	192.06 ± 1.00^{c}	258.47 ± 6.65^{a}	222.86 ± 2.60^{b}	258.64 ± 0.82^{a}	253.10 ± 2.41^{a}	<0.001
Initial weight (kg)	9.57 ± 0.60	9.35 ± 1.43	10.12 ± 0.47	9.62 ± 0.47	9.76 ± 0.51	0.809
Final weight (kg)	14.60 ± 1.56^{ab}	15.83 ± 1.33^{a}	12.40 ± 0.55^{c}	12.77 ± 0.56^{bc}	13.71 ± 0.29^{bc}	0.010
Weight gain (kg)	5.04 ± 1.15^{b}	6.48 ± 0.55^{a}	2.28 ± 0.08^{d}	3.15 ± 0.92^{cd}	3.96 ± 0.24^{bc}	<0.001
ADWG (g/day)	59.95 ± 13.63^{b}	77.16 ± 6.55^{a}	27.11 ± 0.99^{d}	37.49 ± 11.01^{cd}	47.11 ± 2.88^{bc}	<0.001
FCR	11.32 ± 2.80^{c}	10.84 ± 1.13^{c}	24.36 ± 0.66^{a}	21.44 ± 7.32^{ab}	17.10 ± 1.05^{bc}	0.003

Note: Means within the same row followed by different superscript letters (a, b, c, d) are significantly different ($P < 0.05$). ADWG = average daily weight gain, FCR = feed conversion ratio.

constituted the diets; this gave the rumen enough coarse insoluble fiber for normal function, which is linked to enough rumination and the breakdown of cellulose.

The final weight was significantly higher for rams-fed maize fodder (15.83 kg) and concentrate supplement (14.60 kg). The highest weight gain (6.48 kg) and average daily weight gain (77.6 g/day) were recorded for rams-fed maize fodder, possibly due to high total dry matter and crude protein intake. Recent research also shows that calves fed hydroponic maize fodder gained more weight (Rajkumar *et al*., 2018). Rams-fed millet (24.36) and sorghum (21.44) fodder had higher FCR, which indicates lower feed efficiency and subsequent lower weight gain.

Table 3 shows the hematology parameters of WAD rams supplemented with different hydroponics fodders. There were significant ($P < 0.05$) differences in all the parameters considered except in MCH, MCHC, neutrophils, and lymphocytes that were not significantly ($P > 0.05$) different. Rams supplemented with hydroponic maize fodder had the highest PCV and hemoglobin compared to other supplements, and this could be due to their higher CP intake. Hemoglobin and PCV values are generally lower when protein intake is low, but they tend to improve when protein intake is high (Ogbuewu *et al*., 2015). The values recorded for PCV were within the ranges of 24–45% for growing sheep by Pampori (2003). According to Daramola *et al*. (2005), PCV lower than the required range for goats in healthy conditions is a sign of anemia and is caused by diets low in high-quality protein. The hemoglobin range for animals supplemented with concentrate, maize, and wheat fodders in this study fell within the normal range of 80–160 g/L as normal for sheep (Research Animal Resources, 2016). Hemoglobin serves as a transporter of protein in the red blood cells due to its iron-containing oxygen constitution. Animals with hemoglobin values within the normal range indicate that the animals fed experimental diets had matching blood pigment for appropriate oxygen transport, preventing iron deficiency-related microcytic hypochromic anemia (Daramola *et al*., 2005). Evaluating the hemoglobin content is a means of determining the oxygen-carrying capacity of the ram circulatory system. The hemoglobin readings demonstrated that the supplemental feed that falls within the normal range for healthy animals met the nutritional needs and did not provide any risk to the animals. Animals with low oxygen-carrying capacities are more susceptible to stressors that can cause respiratory issues (Daramola *et al*., 2005).

The RBC counts reported in this study for the animals supplemented with hydroponic fodders fall within the range normal range of 5–10 × 10^6/µL reported by Blood *et al*. (2007) and 5–11 × 10^6/mL for sheep (Pampori, 2003). Also, animals supplemented with maize fodders fall with 6.51–7.06 × 10^6/µL reported by Ogunbosoye *et al*. (2018) as the normal range for goats as well as within the reported range of 7.38–13.62 × 10^{12}/L for WAD goats by Aina and Akinsoyinu (1996).

Oxygen is carried from the lungs to the body's cells by red blood cells (Ibhaze and Fajemisin, 2015). The respiratory pigments (hemoglobin) are carried by RBCs, so a drop in the number of circulating RBCs indicates a drop in hemoglobin levels and, consequently, a drop in the animal's ability to carry oxygen. The higher RBC value in rams supplemented with maize fodder suggests its superiority in maintaining the blood's high oxygen-carrying capacity and the absence of disorders connected to anemia that an iron shortage may cause.

The values for MCHC across treatment groups fell between 30.0 and 34.5 g/L, as reported by Mitruka and Rawnsley (1981) and within the normal range reported by Research Animal Resources (2009) for clinically healthy animals. The values of MCV are within the normal range reported by Research Animal Resources (2009) but higher than 25 and 31 fL reported for WAD rams under an extensive and intensive management system (Olayemi *et al*., 2000).

According to Daramola *et al*. (2005), WBC values found in this study were typical for clinically healthy sheep. Animal WBCs have phagocytic ability. The WBCs are responsible for developing antibodies that circulate in the bloodstream in response to antigens or foreign substances, or they aid in developing cellular immunity (Glenn and Armstrong, 2019). Neutrophils are a type of white blood cell, and their value in this study revealed that the WAD rams had a strong immune system and were, therefore, well-defended against infection. Lymphocytes aid the body's defense against viral infections. Plumb (2005) reported that lower and higher levels of lymphocytes in animals are signs of active and exhausted immune systems, respectively.

Serum biochemical parameters of WAD rams fed *M. maximus* hay and supplemented with different hydroponics fodders are shown in Table 4. There was no significant ($P > 0.05$) difference in the total protein of rams fed supplemented with hydroponics fodders. There was a significantly ($P < 0.05$) higher value of the total protein in the rams supplemented with maize and wheat fodders above the rams supplemented with concentrate. No difference ($P > 0.05$) was observed in the glucose parameter of all the rams supplemented.

Analysis of the hematology parameters of animals is a good indicator of the physiological changes in animals (Adenkola and Durotoye, 2004). An analysis of the hematology parameters of the animals fed them is required to evaluate the innovative non-conventional feed ingredient's suitability and quality as animal diets (Attia *et al*., 2018). Harper (1971) reported that serum biochemical analysis is used to assess the degree of liver damage and heart attack and to estimate the quality of proteins and requirements of amino acids in animals. The serum protein content of the animals in this study was within 5.9–7.8 g/dL, which was reported as the standard range (Plumb, 2005). This demonstrated that the animal's protein metabolism has not changed because the amount of protein synthesized depends on its availability in the diet (Coelho-Junior *et al*., 2020).

One of the metabolites used to gauge an animal's energy level is glucose. Propionate, a key glucose precursor, is sufficiently synthesized in the liver to produce normal glucose levels (van Houtert, 1993). There was no significant difference in blood glucose between rams-fed hydroponics fodders and those supplemented with concentrate. This indicates that hydroponics fodders did not have any negative effect on the blood glucose of the animals. This agrees with the findings of Sharma *et al*. (2021) and Micera *et al*. (2009) on the feeding of calves and sheep with hydroponics maize fodders, and the authors observed that the blood glucose of the animals was not affected. Chattopadhyay (1996) and Bopanna *et al*. (1997) reported that plant constituents containing phenolic properties can completely block the peripheral utilization of glucose and glycogenolysis effect due to epinephrine action.

The higher blood globulin values of rams supplemented with maize and wheat fodders could most probably be a result of the higher CP they both contained. The globulin contents in animals' blood help the immune system fight disease as the result of improvement in the animals' system (Iheukwumere *et al*., 2005).

Rams supplemented with maize fodder had the highest blood urea nitrogen, which might be attributed to the higher CP intake of the animals. Research has shown that an increase in dietary protein levels increases the blood urea nitrogen of animals (Norrapoke *et al*., 2012), which indicates enhanced protein digestion but inefficient clearance of the urea waste from the blood by the kidney. Nonetheless, the results of every diet fall within the recommended normal range of values (Daramola *et al*., 2005) for blood urea nitrogen of goats reflecting good immunity.

Table 3 Hematology parameters of West African Dwarf rams fed *Megathyrsus maximus* hay and supplemented with different hydroponics fodders

Parameters	Normal range	Dietary treatments					P-value
		M. maximus **hay + Concentrate**	***M. maximus*** **hay + Maize fodder**	***M. maximus*** **hay + Millet fodder**	***M. maximus*** **hay + Sorghum fodder**	***M. maximus*** **hay + Wheat fodder**	
PCV (%)	27–45	24.00 ± 2.00^{b}	30.50 ± 2.50^{a}	20.00 ± 1.73^{b}	20.00 ± 2.65^{b}	24.00 ± 3.00^{b}	0.002
Hemoglobin (g/L)	80–160	83.00 ± 2.00^{b}	99.50 ± 8.50^{a}	65.00 ± 10.54^{c}	67.00 ± 2.65^{c}	82.00 ± 5.29^{b}	0.001
RBC ($\times 10^{12}$/L)	9–15	6.30 ± 0.20^{ab}	7.60 ± 0.60^{a}	5.00 ± 2.65^{b}	5.30 ± 0.53^{ab}	5.90 ± 0.61^{ab}	0.043
MCV (fL)	23–48	37.23 ± 0.87^{b}	40.12 ± 0.12^{ab}	40.00 ± 3.61^{ab}	37.74 ± 0.13^{ab}	40.68 ± 0.39^{a}	0.010
MCH (pg)	8–12	12.86 ± 0.31	13.09 ± 0.09	13.00 ± 2.65	12.64 ± 0.09	13.90 ± 0.61	0.763
MCHC (g/L)	30.0–34.5	34.54 ± 0.04	32.62 ± 0.12	32.50 ± 2.29	33.50 ± 0.82	34.17 ± 0.21	0.159
WBC ($\times 10^{9}$/L)	4–12	8.00 ± 1.00^{b}	7.95 ± 0.25^{b}	4.40 ± 0.36^{c}	9.20 ± 0.36^{a}	7.90 ± 0.56^{b}	<0.001
Neutrophils (%)	10–50	40.00 ± 12.00	31.50 ± 0.50	33.00 ± 2.65	33.00 ± 2.00	38.00 ± 2.65	0.350
Lymphocytes (%)	40–70	51.50 ± 16.50	66.00 ± 1.00	67.00 ± 3.61	64.00 ± 4.36	60.00 ± 5.29	0.208
Eosinophils (%)	0–10	1.50 ± 0.50^{a}	0.50 ± 0.50^{bc}	0.00 ± 0.00^{c}	1.00 ± 0.26^{ab}	0.00 ± 0.00^{c}	0.001
Basophils (%)	0–1.5	0.50 ± 0.50^{ab}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	1.00 ± 0.44^{a}	0.006
Monocytes (%)	0–6	1.50 ± 0.50^{a}	2.00 ± 1.00^{a}	0.00 ± 0.00^{b}	2.00 ± 0.78^{a}	1.00 ± 0.36^{ab}	0.015

Note: Means within the same row followed by different superscript letters (a, b, c, d) are significantly different ($P < 0.05$). ADWG = average daily weight gain, FCR = feed conversion ratio.

Table 4 Serum biochemical parameters of West African Dwarf rams fed *Megathyrsus maximus* hay and supplemented with different hydroponics fodders

Parameters	Normal range	Dietary treatments					P-value
		M. maximus **hay + Concentrate**	***M. maximus*** **hay + Maize fodder**	***M. maximus*** **hay + Millet fodder**	***M. maximus*** **hay + Sorghum fodder**	***M. maximus*** **hay + Wheat fodder**	
Total protein (g/dL)	5.9–7.8	6.00 ± 0.20^{b}	6.85 ± 0.05^{a}	6.40 ± 0.44^{ab}	6.20 ± 0.56^{ab}	6.90 ± 0.61^{a}	0.020
Albumin (g/dL)	2.7–3.7	3.40 ± 0.20^{b}	3.30 ± 0.01^{b}	4.10 ± 0.52^{a}	3.70 ± 0.44^{ab}	3.10 ± 0.26^{b}	0.034
Globulin (g/dL)	3.2–5.0	3.00 ± 0.40^{ab}	3.55 ± 0.05^{a}	2.30 ± 0.44^{b}	2.50 ± 0.30^{b}	3.80 ± 0.26^{a}	0.001
Glucose (mg/dL)	50–100	56.70 ± 2.20	48.00 ± 2.00	51.20 ± 3.92	44.50 ± 1.73	41.00 ± 2.00	0.272
Urea nitrogen (mmol/L)	0.8–9.7	8.29 ± 0.18^{c}	9.23 ± 0.12^{a}	8.72 ± 0.08^{b}	7.87 ± 0.05^{d}	7.57 ± 0.04^{e}	<0.001

Note: Means within the same row followed by different superscript letters (a, b, c, d, e) are significantly different ($P < 0.05$).

CONCLUSIONS

The findings from this study indicated that maize fodder had the highest crude protein content among the hydroponics, and rams-fed maize hydroponics fodder supplement had the highest dry matter intake and weight gain. Feeding of hydroponic fodders, especially maize fodder in WAD rams, has no adverse effect on haemato-biochemical parameters. As such, it can be fed as supplements, especially during the dry season when feeds are scarce.

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