# Growth, physiology and rumen ecology of West African dwarf goats in response to dietary soyabean haulms with or without garlic supplementation

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**Abstract**

*There are continuous efforts to identify alternative feed resources which have less competition with monogastric and humans. The objective of this research was to assess the response of West African dwarf (WAD) goats to dietary soyabean haulms with or without garlic powder supplementation. Fifteen WAD bucks aged between 9-10 months with mean weight of 7.94±0.6 were used in this experiment. The bucks were randomly assigned to three treatment diets, making five bucks per treatment. The experimental design was a completely randomized design (CRD) with three treatment diets designated as T1 (Control: no inclusion of soyabean haulms), T2 (30% inclusion of soyabean haulms in the diet), and T3 (30% inclusion of soyabean haulms + 0.5% inclusion of garlic powder). Every animal served as a replicate and the feeding trial lasted for 77 days. Data was collected on growth indices, blood profile, rumen pH, volatile fatty acids and their proportions and microbial count, subjected to one-way analysis of variance using SPSS (version 23). Findings from the study indicate that average daily weight gain, feed intake and feed conversion ratio were not affected ($p>0.05$) by the inclusion of soyabean haulms with or without garlic powder in the diets of the goats. Except for a reduction ($p<0.05$) in chloride concentration in the blood of goats fed 30% soyabean haulms with or without garlic powder, all other haematological, serum indices, oxidative biomarkers and metabolite measured in this study were not affected ($p>0.05$) by feeding soyabean haulms to the goats with or without garlic powder. Also, apart from increased numbers of Isotricha fungi species in treatment with soyabean haulms with garlic, compared to soyabean haulms alone, rumen pH, total volatile fatty acids and various proportions, total microbial counts were not influenced ($p>0.05$) by the various treatments. In conclusion, 30% inclusion of soyabean haulms in diets of WAD goats without supplementation of garlic powder is recommended to maintain the performance, physiology and gut health of the animals.*

**Keywords:** WAD goats, soyabean haulms, garlic Powder, Physiology and rumen microbial profile

Running title: Response of WAD goats to dietary soybean haulms and/or garlic powder

# Croissance, physiologie et écologie du rumen des chèvres West African dwarf en réponse aux tiges de soja dans l'alimentation avec ou sans supplémentation en ail

**Résumé**

*Il y a des efforts continus pour identifier des ressources alimentaires alternatives qui ont moins de concurrence avec les monogastriques et les humains. L'objectif de cette recherche était d'évaluer la réponse des chèvres West African dwarf (WAD) aux tiges de soja dans l'alimentation avec ou sans supplémentation en poudre d'ail. Quinze boucs WAD âgés de 9 à 10 mois avec un poids moyen de 7,94 ± 0,6 ont été utilisés dans cette expérience. Les boucs ont été assignés aléatoirement à trois régimes alimentaires, cinq boucs par traitement. Le plan expérimental était un plan complètement randomisé (PCR) avec trois régimes alimentaires désignés comme T1 (Témoin : sans inclusion de tiges de soja), T2 (inclusion de 30 % de tiges de soja dans le régime) et T3 (inclusion de 30 % de tiges de soja + 0,5 % d'inclusion de poudre d'ail). Chaque animal a servi de répétition et l'essai d'alimentation a duré 77 jours. Les données ont été collectées sur les indices de croissance, le profil sanguin, le pH du rumen,*

*les acides gras volatils et leurs proportions, ainsi que le comptage microbien, soumis à une analyse de variance à un facteur utilisant SPSS (version 23). Les résultats de l'étude indiquent que le gain de poids quotidien moyen, la consommation alimentaire et le rapport de conversion alimentaire n'ont pas été affectés (p>0,05) par l'inclusion de tiges de soja avec ou sans poudre d'ail dans les régimes des chèvres. Sauf pour une réduction (p<0,05) de la concentration en chlorure dans le sang des chèvres alimentées avec 30 % de tiges de soja avec ou sans poudre d'ail, tous les autres indices hématologiques, sériques, biomarqueurs oxydatifs et métabolites mesurés dans cette étude n'ont pas été affectés (p>0,05) par l'alimentation avec des tiges de soja. De plus, à l'exception d'une augmentation du nombre d'espèces de champignons Isotricha dans le traitement avec des tiges de soja et de l'ail, par rapport aux tiges de soja seules, le pH du rumen, les acides gras volatils totaux et diverses proportions, ainsi que le total des comptages microbien n'ont pas été influencés (p>0,05) par les différents traitements. En conclusion, l'inclusion de 30 % de tiges de soja dans les régimes des chèvres WAD sans supplémentation en poudre d'ail est recommandée pour maintenir la performance, la physiologie et la santé intestinale des animaux.*

**Mots-clés :** Chèvres WAD, tiges de soja, poudre d'ail, physiologie et profil microbien du rumen

**Introduction**

Ruminants perform better when feed stuffs are strategically combined to supplement their feeding on grasses, which are the most abundant basal feed for ruminants (Ikyume *et al*., 2018). However strategic feeding combinations have become increasingly difficult due to the high cost of feed ingredients such as maize, soyabean, groundnut cake, wheat, cowpea etc (Shi *et al*., 2014; Hao *et al*., 2021). The high cost is largely due to increased competition for these feed stuffs between animals and humans, arising from an increase in the population of human beings. The sustained production of ruminants, therefore, will depend on the use of local and cheaper alternatives or unconventional feedstuff with little or no completion from human beings (Singh, 2018). One such alternative is the use of crop residues that are in abundance including soyabean haulms.

Soyabean haulms are the portion of the soyabean plant, which remains after harvesting and threshing the mature pods and this constitutes the stalks, stems and empty pods. In localities where these crops are dominant, the residues can be well used as alternative basal roughage for animals, especially during the dry season (Alebel *et al*., 2019), as well as incorporated in rations of animals (Arigbede *et al*., 2008; Ikyume *et al*., 2023). Soyabean is among the major industrial and food crop grown on every continent including Africa (Omoigui *et al*., 2020). The crop can be successfully grown in the many states of Nigeria using low agricultural inputs, and its cultivation has expanded as a result of its nutritive and economic importance as well as diverse domestic use (Omoigui *et al*., 2020), including raw materials for oil production, cash income, animal feed, soil fertility, and also serve as a good intercrop (Geleta *et al*;., 2007; Wijnands *et al.*, 2009; Hailegirgis, 2010; Jagwe and Owuor, 2014). Soyabean meal production in Nigeria has continued to rise over the years with a projected production of 2.4 mt/ha (Ogbanje, 2023). The vast area of land in Nigeria and the progressive increase in the production of soyabean in Nigeria supports the availability of the haulms for alternative uses including incorporating them in livestock feeds. It has been reported that soyabean haulms could replace corn offal at a 30% level in low-cost concentrate rations for goats (Arigbede *et al.*, 2008). However, the structural fibre concentrations and morphological characteristics of the legume hay generally may limit their utilization in feed. It is possible that manipulating the rumen environment using feed additives with antibacterial effects especially those that will improve the digestibility of fibre may well improve the utilization of soyabean haulms in the diet of ruminants. One feed additive that has been

reported to manipulate the rumen environment to increase the populations of bacteria, especially fibre-digesting bacteria is garlic powder at a 0.5% inclusion level (Ikyume *et al.*, 2017; Ikyume *et al.,* 2020). Its inclusion in the diet therefore is predicted to further improve the efficient utilization of soyabean haulms. The report of Ikyume *et al.* (2023) indicates that the addition of garlic to soyabean haulms-based diets did not further improve the performance response of sheep. Because different species of ruminants may respond differently to dietary planes, it is important to validate the results obtained for sheep in different species of ruminants to develop a sustainable feeding regime using soyabean haulms and garlic powder as feed additives for improved nutrient utilisation. This research was therefore designed to assess the growth performance, haematological parameters, serum indices, oxidative biomarkers and rumen ecology of West African dwarf goats to dietary soyabean haulms with or without garlic powder.

## Materials and Methods

### *Study environment*

The research was carried out at the Animal Science Livestock Teaching and Research Farm, Joseph Sarwuan Tarka University Makurdi. Makurdi is located in the Guinea savannah zone of Nigeria with coordinates as reported by Ikyume *et al.* (2020). Other weather parameters were as reported in Ikyume *et al.* (2023).

### *Processing of soyabean haulms and garlic powder*

Soyabean haulms used in the experiment were collected from crop fields within Joseph Sarwuan Tarka University, Makurdi. The soyabean haulms were sorted to remove the prominent fibrous stalks, thereafter the haulms were milled into the finely coarse form using a hammer mill from the feed mill at the Animal Science Teaching and Research Farm. The finely coarse soyabean haulms were used to formulate concentrate diets. Garlic powder was obtained from the open market in Makurdi.

### *Experimental animals and management*

Fifteen (15) West African dwarf bucks were purchased from the market around Makurdi and its environs. The animals on arrival were administered prophylaxis treatment against a possible bacteria infection, endo and ecto parasites, using Penstrep® (Intramuscular: 1 mL/10 kg body weight) and Ivermectin® (subcutaneously: 0.3 mL/10 kg body weight), respectively. The animals were also administered oxytetracycline LA to provide prophylaxis treatment for the period of the experiment. The animals were housed in separate pens measuring 1.0 x 1.5 m each. The house was constructed using wooden materials for the fence and metallic zinc as the roof. The floor was slated and made of wooden material. The experimental animals were fed concentrate diets (experimental diets) at 7.00 am and forage (*Panicum maximum*) as basal diets at 1.00 pm. Fresh water was provided to the animals daily *ad libitum*. The animals were maintained under hygienic conditions and were confined throughout the experimental period. The research was conducted with the approval of the ethical committee of the College of Animal Science, Joseph Sarwuan Tarka University, Makurdi (JOSTUM/ANS/ANP/2020/2021).

### *Experimental design and diets*

The experimental design was a completely randomised design (CRD). Five animals each were assigned to three experimental diets (Table 1) designated as T1 (control: no inclusion of soyabean haulms) T2 (30% inclusion of soyabean haulms) T3 (30% inclusion of soyabean haulms+ 0.5% inclusion of garlic powder). The levels of inclusion of soyabean haulms and garlic powder were adopted from recommendations of Arigbede *et al*. (2008) and Ikyume *et a*l. (2017), respectively. Each animal served as a replicate (n=5)

## Data collection

### *Growth performance*

The initial body weights of the WAD bucks were determined at the commencement of the experiment with the aid of a digital scale (Model: SCS-AS14, Manufacturers: Changzhou Asia Weighing system solution).

Weight changes in the animals were subsequently determined weekly to observe the trend in growth. Feed intakes for forage and experimental diets were determined daily throughout the experiment. The feed conversion ratio was estimated as the ratio of feed intake to weight gain.

***Blood sample collection and analysis***

Approximately, 2 mL of blood was collected from all the experimental animals in sample bottles with EDTA for haematological studies, while another 3 mL was collected in plain sample bottles to harvest serum. Samples in plain bottles were allowed to clot at room temperature for 3 hours of collection. Serum samples were separated following the centrifugation at 3000 g for 5 min and used for the determination of serum indices and oxidative biomarkers. All laboratory procedures for the determination of haematological, serum indices, and oxidative biomarkers are similar to those described in Ikyume *et al*. (2023).

***Rumen sample collection and analysis***

The procedure of Babayemi and Bankole (2006) was used for the collection of rumen samples from all the bucks used in the study. Rumen samples were collected 6 hours post-feeding of experimental diets to analyse for pH, volatile fatty acids, microbial counts and diversity. At collection, the samples were immediately assessed for rumen pH using a pH meter (Universal pH Test kit-Digital pH Meter®). The rumen samples were subsequently filtered using a four-layer cheesecloth and divided into three portions for determination of ammonia nitrogen, volatile fatty acids and rumen microbial count and diversity, respectively.

The first portion was transferred into a plastic bottle to which 5 mL of 1M $H_2SO_4$ had been added to stop microbial fermentation and then centrifuged at 3,000 xg for 10 min. About 25 ml of the supernatant was then collected and analysed for NH3-N according to the AOAC (2000) method. The second portion of the filtered rumen sample was used to analyse for total volatile fatty acid (VFA) and the proportions of acetate, propionate, and butyrate as illustrated by Samuel *et al*. (1997). The samples were centrifuged at 3,000 xg for 10 min; then allowed to settle and subsequently decanted. The decanted sample was titrated with 0.1 M of sodium hydroxide (4/1000 $gmL^{-1}H_2O$) solution each with 2 – 3 drops of phenophtaline (1/100 $gmL^{-1}$ethanol) as the indicator. The third portion of the rumen filtrate was used for microbial count and identification. For protozoa count, the procedure of Dehorty (1984) was adopted by direct observation using a microscope at 10× magnification. In the case of bacteria and fungi, colony-forming units/mL (CFU/mL) methodology was adopted with the pour plate technique using nutrient algae (NA) and potato dextrose agar (PDA), respectively. The plates were incubated for 24 hours at 37°C. All colonies appearing at the end of the incubation period were counted using a digitally illuminated colony counter. Bacteria isolates were suspected based on their morphology and were sub-cultured for pure culture. The pure cultures were gram-stained and examined microscopically under the oil immersion (X 100 objective) of the light microscope and identified using a biochemical test as described by Chessbrough (2005). All greenish metallic colonies were suspected to be *E. coli* on eosin methylene blue agar plates, all yellow colonies were suspected to be *Staphylococcus aureus* on mannitol salt agar plates and all smooth, moist and medium-sized colonies were suspected to be Bacillus spp. on tryptone soya agar. Methane output from the rumen was calculated according to the formula by Moss (2000).

***Chemical analysis***

The proximate compositions of the experimental diets were determined following the methodology outlined in AOAC (2005). While fibre fractions of the feeds were obtained using the methodology of Van Soest *et al.* (1991).

***Statistical analysis***

All data generated from the experiment were subjected to a one-way analysis of variance with the aid of SPSS statistical software. Where

mean differences exist, they were separated using the Duncan Multiple Range Test as is contained in the statistical software at a 5% level of probability ($p<0.05$).

**Results**

***Growth response of goats to dietary soyabean haulms with or without garlic***

Table 2 represents the growth response of West African dwarf goats to dietary soyabean haulms with or without garlic powder. All growth parameters measured were not influenced ($p>0.05$) by the inclusion of soyabean haulms with or without garlic powder in the diets of West African dwarf goats. However, marginal improvements ($p>0.05$) were observed in daily weight gain and feed conversion rate in goats on soyabean haulms-based diets. Daily weight gain ranged from 66.19 g in T1 to 73.03 g in T2, while daily weight gain was 70.30 g in T3. Total daily feed intake was 616.04 g, 650.13 g and 673.43 g in T1, T2 and T3, respectively. The feed conversion ratio was 10.19 in T1, 9.72 in T3 and 8.97 in T2.

***Haematological indices of goats as affected by feeding soyabean haulms with or without garlic powder supplementation***

The haematological parameters obtained from West African dwarf goats fed concentrate diets containing soyabean haulms with or without garlic powder are presented in Table 3. The feeding of soyabean haulms with or without garlic powder did not influence ($p>0.05$) any of the haematological parameters measured in this experiment. Marginal increases ($p>0.05$) were observed for packed cell volume, red blood cells, white blood cells, and hand haemoglobin. Packed cell volume ranged between 32.75 to 35.00% in the experimental animals, red. Red blood cells were 14.70 $x10^{12}$/dL in T1, 15.23 $x10^{12}$/dL in T3 and 15.83 $x10^{12}$/dL in T2, while white blood cells were 5.50 $x10^{6}$/dL in T1, 5.55 $x10^{6}$/dL in T3 and 8.00 $x10^{6}$/dL in T2. Haemoglobin was 10.93 g/dL in T1 with a marginal increase in T2 and T3 compared to control (11.65 and 11.15 g/dL, respectively). The means of the different differential counts observed in the experiment were also not affected ($p>0.05$) by the inclusion of soyabean haulms with or without garlic powder in the diets of the goats.

***Serum and oxidative biomarkers of West African dwarf goats as influenced by feeding soyabean haulms with or without garlic supplementation***

The results of serum biochemical indices and oxidative biomarkers of goats as affected by feeding soyabean haulms with or without garlic powder is presented in Table 4. All serum indices measured were not significantly ($p<0.05$) influenced by feeding the goats with soyabean haulms with or without garlic powder in the diets. Total protein ranged between 6.18 and 6.35 mg/dL across the treatments, albumin was 2.68 mg/dL in T3, 3.05 mg/dL in T2 and 3.93 mg/dL in T1. Glucose ranged from 82.78 mg/dL in T2 and 90.73 mg/dL in T3, while 85.53 mg/dL was found in T1. Total cholesterol ranged from 120.00 to 149.20 mg/dL across the treatment groups, triglyceride was 174.85 mg/dL in T2, 177.33 and 177.83 mg/dL in T3 and T1. Low-density lipoprotein ranged from 63.80 to 95.00 mg/dL across the various treatment groups, while high-density lipoprotein was from 18.75 to 24.25 mg/dL. Uric acid was 6.40 mg/ml in T3, 6.85 mg/dL in T2 and 7.30 mg/dL in T1, and malondehyde ranged between 0.20 to 0.23 unit/mg protein across the treatment groups. Superoxide dismutase was 101.98 U/L in T2, 105.05 and 105.98 U/L in T3 and T1. Glutathione peroxidase was from 65.95 to 77.48 µ/mg protein across the treatment groups.

***Serum metabolites of goats fed concentrate diets containing soyabean haulms with or without garlic powder supplementation***

Table 5 represents the result of blood metabolites of West African dwarf goats fed concentrate diets containing soyabean haulms with or without garlic powder. Potassium concentration reduced ($p<0.05$) in diets with soyabean haulms (4.53 mmol/L) compared to control (6.13 mmol/L). However, similar ($p>0.05$) results of potassium concentration were obtained in control (6.13 mmol/L) and those on soyabean haulms and garlic powder (5.30 mmol/L). Chloride concentration was

reduced ($p<0.05$) in all diets with soyabean haulms with or without garlic powder, compared to control. Chloride concentrations were 112.18, 114.78 and 161.65 mmol/L in treatments T3, T2 and T1, respectively. Sodium and calcium concentration in the blood was not affected ($p>0.05$) by feeding soyabean haulms with or without garlic powder in the diets of the goats. Sodium was 107.03, 11.90 and 115.43 mmol/L in T1, T3 and T2, respectively. Calcium ranged from 8.73 to 9.88 mmol/L in treatments T3 and T2, respectively.

***Rumen pH, methane and metabolites from West African dwarf goats on concentrate diets containing soyabean haulms with or without garlic powder***

The result of rumen pH and metabolites of goats as affected by feeding soyabean haulms with or without garlic powder is presented in Table 6. The rumen pH and metabolites measured were not affected ($p>0.05$) by feeding soyabean haulms with or without garlic powder in the diets of the goats. The pH was in the range between 5.46 and 5/70 across the treatment groups. Total volatile acids were 4.78, 4.714.36 mol/100 mol/100 mol in T1, T2 and T3, respectively. The proportion of acetic was 2.05, 2.02 and 1.87 mol/100 mol in T1, T2, and T3, while propionic acid was 1.36, 1.34 and 1.24 mol/100 mol in T1, T2, and T3. Butyric acid was 0.20, 0.20 and 1.87 mol/100 mol, in T1, T2 and T3. Methane production was 0.46, 0.46 and 0.42 mol/100 mol in T1, T2 and T3.

***Rumen microbial counts and fungi isolated from the rumen of West African dwarf goats fed diets containing soyabean haulms with or without garlic powder***

Table 7 represents the rumen microbial population and diversity of fungi isolates as influenced by feeding soyabean haulms with or without garlic powder in the diets of West African dwarf goats. Bacteria, fungi and protozoa counts were not influenced ($p<0.05$) by feeding soyabean haulms with or without garlic powder in the diets of the goats. Bacteria counts were 2.60 cfu/mL $x10^5$ in T1, 2.68 cfu/mL $x10^5$ in T2 and 2.62 cfu/mL $x10^5$ in T3. Total fungi counts ranged between 0.91 cfu/mL $x10^5$ and 1.02 cfu/mL $x10^5$ across the treatment groups. A marginal decrease ($p>0.05$) was observed in protozoa counts and ranged from 10.80 to 13.20 ml/100 ml across the treatment groups. For fungi isolates, it was observed that *isotricha spp*. decreased ($p<0.05$) in T2 (2.40 cfu/mL $x10^{5)}$ and T3 (2.40 cfu/mL $x10^{5)}$ compared to T1 (4.60 cfu/mL $x10^{5)}$. Other fungi isolates were not affected ($p>0.05$) by feeding soyabean haulms with or without garlic powder in the concentrate diets of goats. *Endodinium spp*. ranged from 6.40 to 7.40 2.40 cfu/mL $x10^5$ across the treatments, Ostracodinum *spp*. ranged from 0.40 to 0.60 2.40 cfu/mL $x10^5$ across treatment groups. The amount of *Diplodinium spp*. ranged from 1.40 and 1.60 2.40 cfu/mL $x10^5$ across the treatments.

**Discussion**

Growth indices have remained a veritable tool in measuring diet appreciation in livestock. Non-significant differences in growth indices observed in the goats on soyabean haulms with or without garlic powder compared to control is an indication that the goats efficiently utilized soyabean haulms up to 30% in their diet. Similar to these findings, there is a report that sheep fed up to 30% soyabean haulms in their diets also gave similar growth responses with control (Ikyume *et al.*, 2023). The similar results observed for both goats and sheep when 30% soyabean haulms were included in their diets under similar environmental conditions validates the fact that soyabean haulms can be a viable feed resource for ruminant production, and further research is advocated to ascertain if levels of inclusion can be increased without detrimental effect to their growth. In other research on yearling red Sokoto goats, a better, performance was achieved when soyabean haulms were included in complete diets at 40 and 50% compared to feeding solely (Adu and Osuhor, 1993). The form in which soyabean haulms can be utilized in ruminant diets is therefore important and may have been the differences between the two researches that gave different growth responses in goats. Contrary to non-significant feed intake in this present study, dry matter intake improved in

goat fed diets with 20% soyabean hay compared to the control (Adamu *et al*., 2016). While the intake in this experiment was expressed on a dry matter basis, the current report represented intake as fed. Aside from this reason, the form (straw and hay) and level of inclusion may have accounted for the differences in dry matter intake in the two reports.

Apart from maintaining growth performance when adopting feeding regimes, it is important to ensure that the welfare and health of the animals are ensured. Feeding soyabean haulms with or without garlic powder in this current study gave similar responses in the haematological and serum indices of the goats when compared to the control. Contrary to findings in this study, sheep that were fed complete diets with soyabean haulms at 30% experienced a reduction in packed cell volume, haemoglobin and total protein (Ikyume *et al*., 2023), while sheep fed mixed rations of different types of crop residues gave higher packed cell volume and haemoglobin (Omotosho *et al*., 2021). Goats have higher digestive efficiency of coarse roughages than sheep (Yami and Merkel, 2008), and this difference in the two species of animals may be responsible for the observed differences in some of the haematological and serum indices. As observed in the result of oxidative biomarkers in this current study, feeding soyabean haulms to sheep that were raised in a similar environment as the goats in this study did not distort the oxidative balance of the animals (Ikyume *et al*., 2023). This means feeding soyabean haulms to both sheep and goats is not likely to cause oxidative stress and health problems in the animals. The observed reduction in chloride concentration in goats on soyabean haulms with or without garlic powder may be because the consumption of roughages is likely to increase water consumption in the animals which can dilute the concentration of chloride in the blood. In this current study, data was not collected on water intake to confirm this dilution claim resulting in lower chloride concentration. Also, some components in the roughage are likely to interfere with the absorption of chloride or other electrolytes in the digestive tract, leading to reduced uptake into the bloodstream. Contrary to the observation in chloride concentration in the goats, that of sheep remained unchanged when soyabean haulms were included in the diets at 30% (Ikyume *et al*., 2023). Diets are capable of altering pH and metabolites in the rumen of animals. This alteration determines the status of gut health and energy levels in the rumen (Wang *et al.*, 2020). The non-significant difference in pH and rumen total volatile fatty acids and the various proportions in all treatments in this current study explains that soyabean haulms in the diets did not distort the fermentation pattern in the animals when compared to the control. These findings validate the claim by the report of Afele *et al*. (2024), that rumen pH and metabolites of sheep were not affected by the inclusion of soyabean haulms with or without garlic in the diets of sheep. The non-significance of ruminal VFAs concentrations across the treatments explains a possible similar proportion of dietary fibre components (e.g. Neutral detergent fibre), substrate composition, and specific types of rumen microbes to degrade the diets as explained by Haddad and Grant, (2000) across all the treatments including those on soyabean haulms with or without garlic powder. In this report, it was observed that total counts of bacteria, protozoa and fungi were similar across the treatment groups.

Isotricha fungi are components of the microbial community that are found in the digestive tract of ruminant animals. The observed reduction in isotricha numbers in diets with soyabean haulms may be because soyabean haulms may have exhibited antifungal properties that inhibit the growth and proliferation of isotricha fungi. Certain secondary metabolites in plants such as phytochemicals which may be present in soyabean haulms can inhibit the proliferation of isotricha fungi. However, other fungi species were not affected by the presence of soyabean haulms in the diet of the goats. Contrary to findings on isotricha numbers in this report,

there was an increase in isotricha numbers when garlic powder was added to diets with soyabean haulms (Afele *et al*., 2024). The differences in species of ruminants may have been responsible for the different reports on soyabean haulms in diets with garlic powder. Non-significant differences in the bacteria, protozoa and total fungi count are consistent with findings in the report of Afele *et al*. (2024).

**Conclusion**

From the findings of this research, it can be concluded that soyabean haulms inclusion in the diets of WAD goats at 30% did not affect the growth and physiology of the animals. Also, use of the soybean haulms did not alter the fermentation pattern in the rumen of the animals. However, inclusion of soybean haulms in the diets of Wad buck reduced the chloride concentration in the blood and also the *isotricha spp.* fungi in the rumen. The supplementation of garlic powder in soybean haulms based diets did not also influences the responses of the animals to dietary soybean haulms based diets. The study recommended dietary 30% inclusion levels of soyabean haulms in diets of WAD goats without necessary supplementing with garlic powder.

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***Conflict of Interest***

The authors declare that there is no conflict of interest in the design, implementation, and drafting of this manuscript.

**Table 2 Effect of dietary soyabean haulms with or without garlic powder on growth performance of West African dwarf goats.**

| Parameters | T1 | T2 | T3 | SEM |
|---|---|---|---|---|
| Initial body weight (kg) | 7.98 | 7.86 | 7.98 | 0.14 |
| Final body weight (kg) | 12.88 | 13.26 | 13.18 | 0.28 |
| Daily body weight gain (g) | 66.19 | 73.03 | 70.30 | 3.53 |
| Daily concentrate intake (g) | 162.59 | 205.93 | 175.36 | 10.93 |
| Daily forage intake (g) | 453.45 | 444.20 | 498.07 | 13.14 |
| Total daily feed intake (g) | 616.04 | 650.13 | 673.43 | 14.14 |
| Feed conversion ratio | 10.19 | 8.97 | 9.72 | 0.58 |

**Table 3. Haematological parameters of West African dwarf goat bucks fed diets containing soyabean haulms with or without garlic powder**

| Parameters | T1 | T2 | T3 | SEM |
|---|---|---|---|---|
| Packed cell volume (%) | 32.75 | 35.00 | 33.50 | 0.63 |
| Red blood cells ($10^{12}$/dL) | 14.70 | 15.83 | 15.23 | 0.24 |
| White blood cells ($10^{6}$ /dL) | 5.50 | 8.00 | 5.55 | 0.65 |
| Haemoglobin (g/dL) | 10.93 | 11.68 | 11.15 | 0.21 |
| Mean corpuscular volume (*fl*) | 22.28 | 22.08 | 22.10 | 0.11 |
| Mean corpuscular haemoglobin (*pg*) | 74.33 | 73.75 | 73.18 | 0.43 |
| MCHC (g/dL) | 33.33 | 33.33 | 33.25 | 0.02 |
| Lymphocyte counts (%) | 67.75 | 68.25 | 67.00 | 1.14 |
| Neutrophil counts (%) | 25.50 | 26.00 | 26.50 | 0.69 |
| Eosinophil count (%) | 2.25 | 1.75 | 2.25 | 0.38 |
| Basophil count (%) | 0.25 | 0.25 | 0.00 | 0.11 |
| Monocyte counts (%) | 5.00 | 4.25 | 4.25 | 0.31 |

MCHC-Mean corpuscular haemoglobin concentration

**Table 4 Serum and oxidative biomarkers of West African dwarf goats as influenced by feeding soyabean haulms with or without garlic powder in diets**

| Parameter | T1 | T2 | T3 | SEM |
|---|---|---|---|---|
| Total proteins (mg/dL) | 6.30 | 6.35 | 6.18 | 0.19 |
| Albumin (mg/dL) | 3.93 | 3.05 | 2.68 | 0.26 |
| Glucose (mg/dL) | 85.53 | 82.78 | 90.73 | 3.79 |
| Total cholesterol (mg/dL) | 123.60 | 120.00 | 149.20 | 8.06 |
| Triglyceride (mg/dL) | 177.83 | 174.85 | 177.33 | 3.43 |
| Low-density lipoprotein (mg/dL) | 63.80 | 60.88 | 95.00 | 9.50 |
| High-density lipoprotein (mg/dL) | 24.25 | 24.20 | 18.75 | 1.58 |
| Uric acid (mg/mL) | 7.30 | 6.85 | 6.40 | 0.26 |
| Malondehyde (unit/mg protein) | 0.22 | 0.20 | 0.23 | 0.01 |
| Superoxdide dismutase (U/L) | 105.98 | 101.98 | 105.05 | 3.70 |
| Glutathione peroxidase (µ/mg protein) | 75.55 | 65.95 | 77.48 | 4.95 |

**Table 5. Blood minerals of goats fed experimental diets containing soyabean haulms with or without garlic powder**

| Parameters | T1 | T2 | T3 | SEM |
|---|---|---|---|---|
| Sodium (mmol/L) | 107.03 | 115.43 | 111.90 | 1.76 |
| Potassium (mmol/L) | 6.13[a] | 4.53[b] | 5.30[ab] | 0.31 |
| Chloride (mmol/L) | 161.65[a] | 114.78[b] | 112.18[b] | 7.31 |
| Calcium (mmol/L) | 8.85 | 9.88 | 8.73 | 0.29 |

**Table 6. Rumen pH, methane and metabolites from West African dwarf goats on concentrate diets containing soyabean haulms with or without garlic powder**

| Parameters | T1 | T2 | T3 | SEM |
|---|---|---|---|---|
| pH | 5.50 | 5.70 | 5.46 | 0.11 |
| Total volatile fatty acids (mol/100mol) | 4.78 | 4.71 | 4.36 | 0.12 |
| Acetic acid acids (mol/100mol) | 2.05 | 2.02 | 1.87 | 0.05 |
| Propionic acid acids (mol/100mol) | 1.36 | 1.34 | 1.24 | 0.04 |
| Butyric acid acids (mol/100mol) | 0.20 | 0.20 | 1.87 | 0.01 |
| Methane acids (mol/100mol) | 0.46 | 0.46 | 0.42 | 0.01 |

**Table 7. Rumen microbial counts and fungi isolated from the rumen of West African dwarf goats fed diets containing soyabean haulms with or without garlic powder**

| Parameters | T1 | T2 | T3 | SEM |
|---|---|---|---|---|
| Bacteria (cfu/mL x$10^5$) | 2.60 | 2.68 | 2.62 | 0.13 |
| Fungi (cfu/mL x$10^5$) | 0.91 | 0.94 | 1.02 | 0.07 |
| Protozoa (ml/100 mL | 13.20 | 10.80 | 12.00 | 1.15 |
| Isotricha (cfu/mL x$10^5$) | 4.60[a] | 2.40[b] | 2.40[b] | 0.46 |
| Endodinium (cfu/mL x$10^5$) | 6.40 | 6.60 | 7.40 | 0.77 |
| Ostracodinum (cfu/mL x$10^5$) | 0.60 | 0.40 | 0.60 | 0.22 |
| Diplodinium (cfu/mL x$10^5$) | 1.60 | 1.40 | 1.60 | 0.39 |

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