

Effects of dietary protein supplementation on the performance of West African dwarf (WAD) goats infected with *Haemonchus contortus* and *Trichostrongylus colubriformis*

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Abstract: Twenty worm-free male West African dwarf (WAD) goats, 7–8 months of age, were used to study the effect of dietary protein on their response to mixed infections of trychostrongyles. The goats were divided into 4 groups (A–D), each containing 5 animals. Groups A and B were fed forages with concentrate feed containing 17.06% crude protein, whereas Groups C and D were fed forages alone. An escalating infection of 500 infective larvae (L3), 1000 L3, 2000 L3, and 4000 L3 was given consecutively at weeks 0, 1, 2, and 3, respectively, for 4 weeks to groups A and D. Patency and level of infection were monitored by carrying out fecal egg counts (FECs) twice weekly. All of the animals were humanely sacrificed 42 days after infection, and the abomasum and intestines were recovered and processed for worm recovery. The results showed that there was a positive correlation between the dietary protein and body weight gain and body condition score. However, the dietary protein had no significant ($P > 0.05$) effect on the packed cell volume (PCV), total serum protein, and serum albumin levels. The supplemented goats shed significantly fewer helminth eggs in the feces and harbored lighter burdens of the 2 worm species compared to unsupplemented goats. There was a negative significant correlation between the worm burden and the body weight and body condition scores. The correlation between the worm burden and PCV was also negative but not significant, while that between the worm burden and FEC was positive and significant. Infection significantly affected the feed intake but did not affect water intake. These results therefore demonstrate that nutritional supplementation enhances the resistance of WAD goats to mixed infections of *H. contortus* and *T. colubriformis* and results in their improved performance.

Key words: Goats, performance, mixed infection, supplement feeding, *Haemonchus contortus*, *Trichostrongylus colubriformis*

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Introduction

Nematode parasitism has been reported as a major limiting factor to ruminant production worldwide (1). In Nigeria, one of the most prevalent consequences of nematode infections and a major cause of poor productivity in small ruminants, including West African dwarf (WAD) goats, is parasitic gastroenteritis. This syndrome is caused by several species of gastrointestinal (GI) nematodes, the most important of which are *Haemonchus contortus*, *Trichostrongylus colubriformis*, and *Oesophagostomum* spp. (2). In the past, helminth control was based on chemotherapy and pasture rotation to minimize the effect of the parasite. Currently, resistance and consumer concern for drug residues are influencing alternative strategies to control these parasites (3). Earlier studies in sheep (4,5) and in goats (6) indicate that nutritional manipulation improves resistance to nematode infections.

Recent studies on the Nigerian WAD goat have shown that this breed expresses an unusually strong resistance and resilience to its native species of GI nematodes in general and *H. contortus* in particular (7,8). This innate resistance and resilience to *H. contortus*, known as haemonchotolerance, is strongly believed to be genetically controlled. It is not clear to what extent other factors such as host nutrition and acquired immunity influence this attribute, especially under field conditions, where seasonal malnutrition is common. This study was therefore designed to investigate the effect of protein supplementation on the productivity, resilience, and resistance of the Nigerian WAD goat to mixed infections with *H. contortus* and *T. colubriformis*.

Materials and methods

Animals and their management

Twenty healthy male WAD goats, aged between 7–8 months, were purchased from the Opi, Orba, and Ibagwa markets located in the Nsukka, Udenu, and Igbo-Eze South local government areas, respectively, in Enugu State, Nigeria. After procurement, each animal was identified using a neck tag, weighed to determine its live weight, and assessed for body condition score (BCS). Subsequently, all of the animals were drenched with anthelmintic fenbendazole (Panacur^R) at 7.5 mg/kg body weight and coccidiostat diclazuril (Vecoxan^R) at 1 mg/kg body weight. In addition, they were vaccinated against peste des petits ruminants and the whole body was liberally dusted with insecticide/acaricide powder (6% permethrin) to rid them of ectoparasites. The animals were also treated prophylactically with oxytetracycline (Tridox^R) at a dose rate of 20 mg/kg body weight. The animals were fed twice daily (0930 and 1530 hours) with cut-and-carry forages that were harvested from experimental plots inaccessible to other livestock. Groups A and B were supplemented daily with 300 g of concentrate mix containing 17.06% crude protein in addition to the forages. The feed was analyzed using AOAC procedures (9), while neutral-detergent fiber and ash were determined according to the method of Goering and Van Soest (10). Water was provided ad libitum.

Experimental design

The goats were divided into 4 groups, labeled A, B, C, and D. Groups A and B were supplemented, while Groups C and D were fed only the forage (Table). The experimental animals were acclimatized for 4 weeks to adapt to their respective diets. Groups A and D

Table. Proximate analysis of the experimental feed.

Nutrient	Dry matter	Ash	Ether extract	Crude fiber	Nitrogen	Crude protein	ADF	Lignin	Cellulose
Forage (<i>Bracharia</i> spp. & <i>Panicum maximum</i>) (%)	88.85	8.0	0.22	34.2	1.4	8.5	48.8	43.3	9.08
Concentrate ration (growers mash & palm kernel cake) (%)	95.3	5.4	0.18	12.19	2.73	17.06	34	24.8	5.47

were selected and infected with *H. contortus* and *T. colubriformis* at the end of the adaptation period, while Groups B and C were not infected. On the first day (D0) of the infection, a single dose of 500 infective larvae (L3) was administered to the infected groups. Doses of 1000 L3, 2000 L3, and 4000 L3 were administered in weeks 2, 3, and 4, respectively. Body weight, packed cell volume (PCV), and BCS were determined on D0 and then subsequently on a weekly basis until the end of the experiment. At the end of the 42-day period, the animals were humanely sacrificed and both the abomasal and intestinal worms were recovered for worm counts. The carcass was then weighed to calculate the dressing percentage.

Blood collection hematology and serum protein analysis

Blood collection for PCV and serum protein analysis was carried out on D0 and thereafter weekly until the end of the study. From each animal, 3 mL of blood was collected by jugular venipuncture, of which 2 mL was dispensed into clean sample bottles with no anticoagulant and allowed to stand for 6 h to clot. The remaining 1 mL was dispensed into bijou bottles, each containing 4 μ L of heparin, for the determination of PCV using the method of Dacie and Lewis (11). The serum from the clotted blood was harvested for the determination of serum protein concentrations. Total serum protein was determined using the biuret method as described by Weichselbaum (12), while the albumin level was determined using the bromocresol method (13).

Fecal worm egg count and worm burden

Fresh fecal samples were collected from all of animals once a week between D0 and D14, and subsequently daily from D15, until patency was established in all of the infected animals. After patency was established (D23), fecal egg counts (FECs) were carried out twice weekly using a combination of salt flotation and a modified McMaster technique (14,15). The 2 weekly FECs were summed up and the mean was expressed as the weekly FEC for each goat. At the end of the study, all of the infected animals were humanely sacrificed and the total and differential worm counts were carried out according to the method of Fakae et al. (8).

Statistical analysis

All of the data collected were analyzed using SPSS 15.0 for Windows. Data on the FECs were normalized using $\log_{10}(\text{FEC} + 1)$. Data on the other parameters (body weight, BCS, PCV, feed intake, total serum protein, serum albumin, and FEC) were analyzed by repeated measures analysis of variance using a general linear model (16) with time as the within-subject factor and treatments as the between-subject factor. Correlations between the variables were analyzed by Pearson's test. $P \leq 0.05$ was considered significant.

Results

Body weight

The body weights of the goats in the supplemented groups (A and B) increased throughout the period of the experiment. However, those of the goats in the unsupplemented groups (C and D) remained static during the first 14 days of the study, followed by a period of loss in body weight. Comparison between the mean increases in Groups A and B showed that these were comparable (Figure 1). However, at the end of the study, Groups A and B gained 14.4% and 18.7% of their initial (D0) body weight, respectively. In contrast, Groups C and D lost 9% and 22% of their D0 weight, respectively, over the same period. The effect of diet on body weight gain was significant ($F_{3,16} = 5.21, P < 0.011$). There was a significant effect of time on body weight changes. Groups C

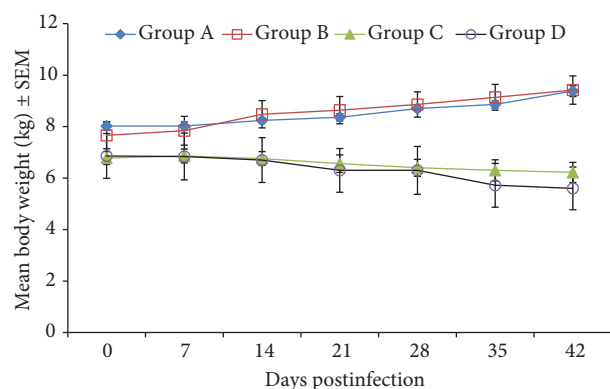


Figure 1. Effect of protein supplementation on the body weight of WAD goats. Group A: infected, supplemented; Group B: uninfected, supplemented; Group C: uninfected, unsupplemented; Group D: infected, unsupplemented.

and D experienced weight loss, while Groups A and B experienced weight gain over the same period of time ($F_{6,96} = 6.29$, $P < 0.001$). The mean body weights of Groups A and B were comparable throughout the period of study ($F_{1,8} = 1012.6$, $P > 0.05$), as well as those between Groups C and D ($F_{1,8} = 193.8$, $P > 0.05$). However, there was a significant difference between Groups A and D ($P = 0.01$) and between Groups B and C ($P = 0.01$).

Body condition score

There was a strong correlation between diet and BCS, as shown in Figure 2. There was a significant effect of diet on the BCSs ($F_{3,16} = 1.46$, $P < 0.001$). Groups A and B had comparable BCSs, but Group A was significantly higher than Group D ($P < 0.05$). Similarly, the BCS of Group B was significantly higher than that of Group C ($P < 0.05$). However, the BCSs of Groups C and D were comparable ($P > 0.05$).

Packed cell volume

Figure 3 shows the changes in the PCV in the various dietary and infection groups. Generally, there was no significant difference in the mean PCV values among the various groups, although the PCV values of Group B were generally higher than those of the other groups. However, from postinfection D28, the mean PCV values for Group D dropped from 22.3% to 20.4%.

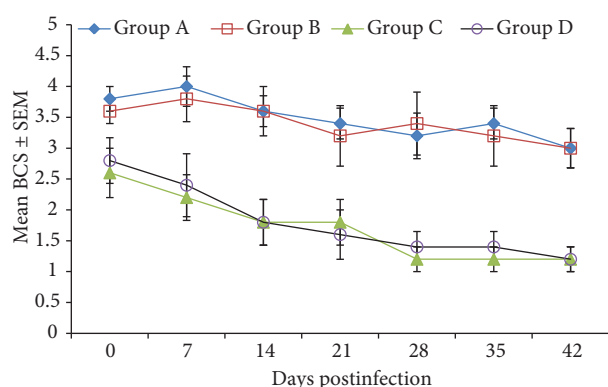


Figure 2. Effect of protein supplementation on the body condition score of WAD goats. Group A: infected, supplemented; Group B: uninfected, supplemented; Group C: uninfected, unsupplemented; Group D: infected, unsupplemented.

Feed intake

The patterns of feed consumption in Groups A and B were similar, while those of Groups C and D were also similar (Figure 4). Generally, diet had a significant effect on feed intake among the various groups ($F_{3,16} = 6.63$, $P = 0.004$). Group A consumed a significantly lower amount of feed than Group B ($F_{1,8} = 4.9$, $P = 0.04$), while the amount of feed consumed by Group C was significantly higher than that of Group D ($F_{1,8} = 1.01$, $P = 0.043$). Group B was significantly higher than Group D ($F_{1,8} = 9.56$, $P = 0.011$), but was not significantly different from Group C. Group A also consumed a significantly higher amount of feed than Group D ($F_{1,8} = 5.46$, $P = 0.012$), but no difference was observed between Groups A and C.

Fecal egg counts

Figure 5 shows the FEC profile of the infected groups. Patency was established in both groups on D23, and on D29 all of the animals became patent. The peak mean FECs in Groups A and D occurred on D40 and D38, respectively. The mean FEC for Group D was significantly higher than that of Group A ($F_{1,8} = 13.59$, $P < 0.001$).

Total serum protein

Changes in the total serum protein concentrations of the 4 groups of goats are shown in Figure 6. Total serum protein values were fairly stable across the groups during the first 14 days after infection. The

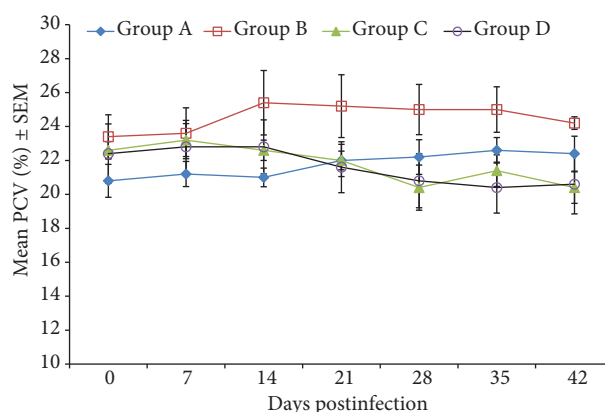


Figure 3. Effect of protein supplementation on the packed cell volume of WAD goats. Group A: infected, supplemented; Group B: uninfected, supplemented; Group C: uninfected, unsupplemented; Group D: infected, unsupplemented.

Effects of dietary protein supplementation on the performance of West African dwarf (WAD) goats infected with *Haemonchus contortus* and *Trichostrongylus colubriformis*

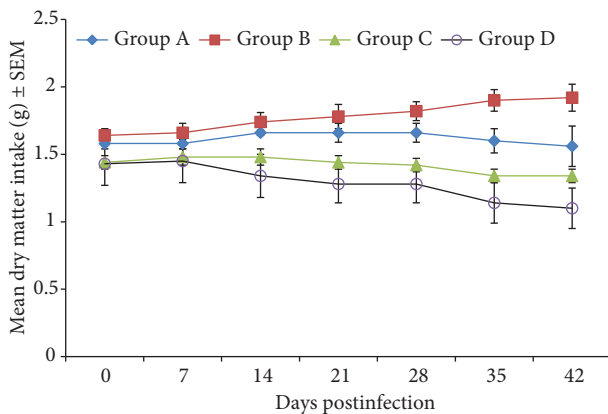


Figure 4. Effect of protein supplementation on the feed intake of WAD goats. Group A: infected, supplemented; Group B: uninfected, supplemented; Group C: uninfected, unsupplemented; Group D: infected, unsupplemented.

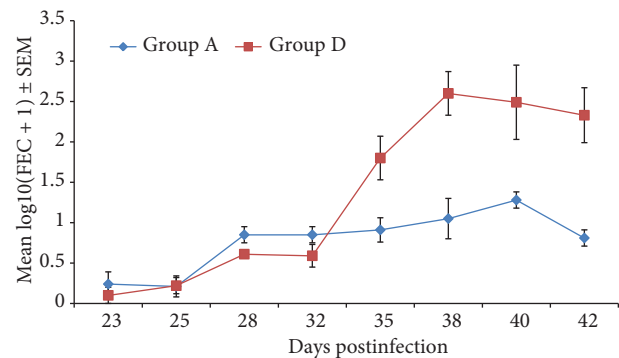


Figure 5. Effect of protein supplementation on the fecal egg counts due to *H. contortus* and *T. colubriformis*. Group A: infected, supplemented; Group D: infected, unsupplemented.

results show that time had a significant effect on the total serum protein ($F_{6,96} = 2.62$, $P = 0.021$). The interaction between time and treatment was also highly significantly different ($F_{18,96} = 3.11$, $P < 0.001$). There was a decline in the total serum protein of Groups C and D. The decline was more pronounced in the animals in Group D than those in Group C, but not significantly ($P > 0.05$).

Serum albumin

The variation in serum albumin is shown in Figure 7. The main effect of treatment was not significant, but

time had a significant effect on the serum albumin ($F_{6,96} = 6.66$, $P < 0.001$). The interaction between time and treatment was not significant ($P > 0.05$).

Worm burden

The combined *H. contortus* and *T. colubriformis* worm counts are illustrated in Figure 8. Group A had a worm burden of 102 ± 22.4 (mean \pm standard error of the mean [SEM]) due to *H. contortus*, while Group D had 326 ± 51.34 due to the same species, which was significantly different ($P < 0.05$). Similarly, Group A's mean \pm SEM for *T. colubriformis* burden was 712

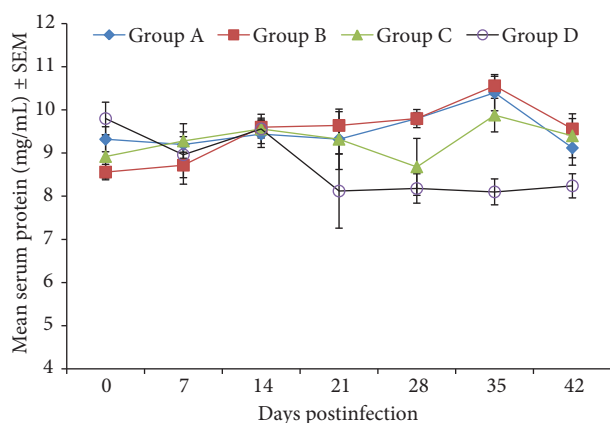


Figure 6. Effect of supplementation on the total serum protein concentration. Group A: infected, supplemented; Group B: uninfected, supplemented; Group C: uninfected, unsupplemented; Group D: infected, unsupplemented.

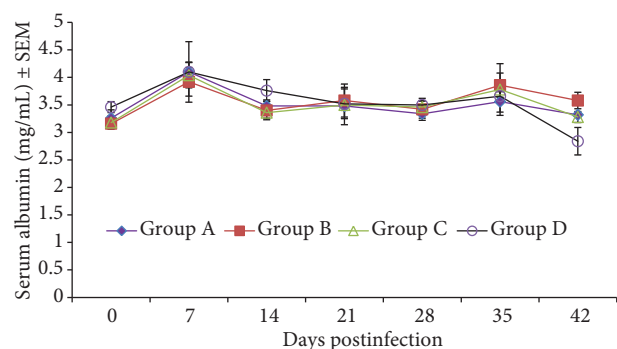


Figure 7. Effect of supplementation on the serum albumin concentration. Group A: infected, supplemented; Group B: uninfected, supplemented; Group C: uninfected, unsupplemented; Group D: infected, unsupplemented.

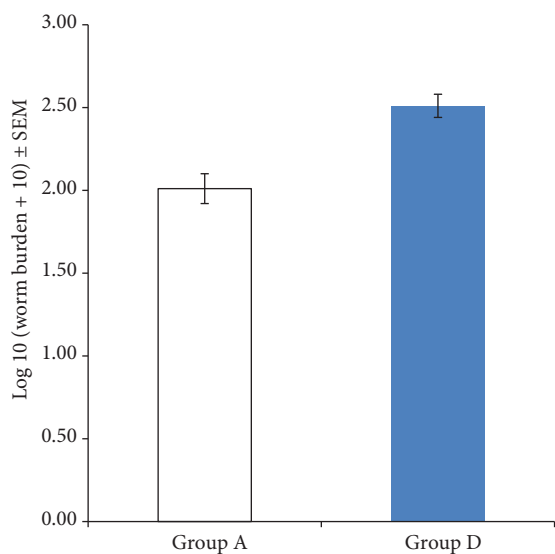


Figure 8. Effect of protein supplementation on the worm burden due to *H. contortus* and *T. colubriformis*. Group A: infected, supplemented; Group D: infected, unsupplemented.

± 101.6, while Group D had 1102 ± 115.68 due to the same worm species, which was also significantly different ($P < 0.05$).

Discussion

The results of this study show that dietary protein supplementation had a positive effect on live weight gain, as seen among the goats in Groups A and B. Conversely, Groups C and D, without protein supplementation, experienced losses in body weight over time. The losses in body weight were probably due to an insufficient amount of metabolizable crude protein in the forage. Although Group D had a lower growth rate than Group C, the difference was not significant. The lower growth rate recorded in Group D may be the result of parasitism. The difference in body weight gain between the 2 infected groups (A and D) was significant. Again, this may be due to the combined effect of malnutrition and parasitism. It is supposed that Group A, which was infected and supplemented, had adequate metabolizable protein for the maintenance and growth of body tissues, whereas Group D, which was suffering from protein deficiency, could not support a gain in body weight. It is therefore apparent that adequate protein nutrition

under mixed GI nematode infections enhanced the capability of goats to withstand the effects of infection. This falls in line with reports on earlier studies in cattle (17) and goats (6).

Goats that had dietary supplementation also had a better BCS throughout the period of the study relative to those in the unsupplemented groups. This is in agreement with an earlier report by Okello and Obwolo (18). BCS is an assessment that reflects the rate of lipogenesis (19). Therefore, the significantly higher BCSs observed in the supplemented groups were probably due to adequate development and later to the conversion of excess nutrients after meeting the normal body requirements. The reduction in BCS toward the end of the experiment might be attributed to falling feed quality due to lignification of the grasses that were fed to the animals as their sole diet, since this was not noticeable in the 2 supplemented groups. This might also partly explain the significant effect of time on the body weights and BCSs of all of the groups. There was a significant negative correlation between worm burden and body weight, and also between worm burden and BCS. This is in agreement with earlier findings (6) and supports the suggestion of Chiejina et al. (20) that both parameters are useful phenotypic markers and correlates of GI nematode infections in Nigerian WAD goats.

The mean PCVs of all of the groups were similar from D0 of infection to D42. In general, the goats were able to withstand the infections, with the possible exceptions of animal numbers 33, 39, and 149, which showed relatively less resilience than the rest of the infected goats. Therefore, the goats showed evidence of overall resilience to the infections in the face of poor dietary intake. Generally, the results of this study showed a negative and weak correlation between worm burden and PCV. This is contrary to all of the previous reports on experimental and field *H. contortus* infections in WAD goats (8,20,21). Those researchers reported highly significant negative correlations between worm burden and PCV.

The observed reduction in voluntary feed intake is a common feature of gastrointestinal nematode infections (22). Thus, the uninfected supplemented goats consumed a significantly higher amount of feed than the infected supplemented goats. Similarly, the uninfected unsupplemented goats consumed a

significantly higher amount of feed than the infected unsupplemented goats. This is in agreement with earlier reports by various researchers (23). Although the mechanisms affecting voluntary feed intake have not been fully elucidated, Dynes et al. (24) demonstrated that the degree of inappetence varies with the level and duration of parasitism and also the level of protein intake. In this study, significant differences were noticed on postinfection D28 among the various dietary groups, which is in line with the findings of Abbot et al. (23) as the goats were trickle-infected over a period of 4 weeks consecutively.

Generally, the results show minor differences between Groups C and D and also between Groups A and B. This is thought to be due to the duration of the experiment. Perhaps if the experiment was extended into the chronic phase of infection, the interaction between nutrition and infection on the performance of the goats could have been better appreciated. Therefore, further studies should be conducted to allow for investigation that would enhance the full range of variation in the responses of the goats to the parasites.

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In conclusion, the results presented in this study showed that improvement of host nutrition via supplementation might contribute to the improvement of the goats' response against worm populations and their general productivity. Therefore, they tend to confirm the bulk of data acquired in sheep. These findings could be applied as a tool in boosting livestock production through adequate nutritional management such as supplementation, especially during the long dry season. Since an extensive management system is common among livestock owners in Nigeria in particular and the tropics in general, dietary supplementation seems to be a promising adjunct to other helminth parasite control programs options.

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