The effect of dietary protein on the productivity of West African Dwarf (WAD) goats infected with *Haemonchus contortus*

P.A. Nnadi,*, T.N. Kamalu, D.N. Onaha

1. Introduction

West African Dwarf (WAD) goats are the most widely distributed and popular small ruminants in the humid tropical zone of West Africa. Their production should be favoured by traits such as early maturity, which ensures rapid turnover and/or cash flow, and lower nutrient need and capital cost per head than in cattle, pig or poultry production. They primarily serve as a measure of wealth and ready source of income under emergency situations such as payment for medical bills, funeral costs, school fees etc. The basic product, meat, is popular as no cultural or religious taboos are attached to its consumption. However, efforts to improve the productivity of WAD goats are

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ABSTRACT

The effects of increased dietary protein on the performance of West African Dwarf (WAD) goats infected with *Haemonchus contortus* were investigated. 28 pubertal 9–12-month-old female goats were divided into two equal groups A and B and fed on high and low protein diets, respectively, from day 1 of pregnancy (day of mating) to 6 weeks post-partum. Each animal was trickle infected with a total of 2400 infective larvae of *H. contortus* over 4 weeks starting from day 1 of pregnancy and the prepatent period recorded. Live weights and body condition scores were measured weekly and the changes determined by subtracting the initial value from each of the subsequent values. Birth and weaning weights of kids as well as stillbirths and foetal losses were also determined. High protein diet improved the ability of goats to resist worm establishment and patency, which was manifested as significant increase in the prepatent period in group A than in the low protein diet group B (*p* < 0.001). Also high protein diet resulted in significantly higher increase in body weight during pregnancy (*p* < 0.01). During lactation both groups rapidly lost weight although body weight increase relative to preinfection value remained significantly higher in group A than in group B (*p* = 0.05). Between weeks 3 and 13 post infection, the body condition scores increased but were significantly higher in group A than in group B (*p* < 0.001). From weeks 16 to 27, the body condition scores remained significantly higher in group B than group A although both experienced severe losses during lactation. Group A delivered significantly heavier kids than group B (*p* < 0.001) and had no foetal losses as occurred in the latter. However, the level of supplementation had no influence on weaning weights as there was no significant difference in the weaning weights of kids of both group (*p* > 0.05). It is concluded that lactation demand for dietary protein is higher than that for gestation since both body weights and body condition scores deteriorated in both group during lactation, and that improved dietary protein enhances resistance to parasite establishment (increased prepatent period) and resilience in terms of kidding performance, birth weight and survival of neonates.

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constrained by two major factors. First, most are produced by local peasant farmers in small units using cut-and-carry grass and forages whose nutritional quality fluctuates between seasons and the animals are frequently inadequately fed. Second, WAD goats are susceptible to many important endemic diseases among which are gastrointestinal (GI) helminths, especially *Haemonchus contortus* and *Trichostrongylus colubriformis* (Chiejina, 1987; Fakae, 1990; Fakae et al., 1999). Estimated losses associated with these parasites are higher than those due to peste des petits ruminants (PPR), a foremost disease of importance in goats in the area (Akerejola et al., 1979). It has been shown, that the prevalence of these GI parasites among traditionally managed goats could be as high as 100% (Fakae and Chiejina, 1993) and losses may include, but not limited to, decreased kid survival and live weight gain, decreased milk/meat production and reproductive performance in adult female animals (Holmes, 1993).

Chemotherapy is the usual helminth control option among local producers but dearth of veterinary services in rural communities and scarcity/high cost of drugs when available have greatly limited chemotherapy as an effective helminth control option for rural producers. This situation is further compounded by increased parasite resistance to anthelmintic drugs (Waller, 1997). However, studies in sheep have shown that improved dietary protein increased resistance to the pathogenic effects of *H. contortus* infection and reduced the mean faecal egg and total parasite counts (Abbott et al., 1986a,b; Bown et al., 1991). Also, it has been shown that two of the most promising and feasible alternatives to chemotherapy in helminth control are improved nutrition (Bown et al., 1991; Van Houtert et al., 1995; Donaldson et al., 1998) and selection for genetic resistance (Woolaston, 1992). It would, therefore, seem that improvement in the dietary protein of WAD goats using local and easily available and affordable protein source may be the best and most relevant option for parasite control and improvement in productive performance in the rural area. This is further supported by the works of Barger (1996) and Coop and Holmes (1996).

Thus, given the high prevalence of GI parasites in goats in the area (Fakae and Chiejina, 1993), there is the need to formulate and test a high quality feed, which might be understood, affordable, and easily adaptable by the small scale, rural goat producers to help them combat the effects of the disease. Ordinarily, protein supplementation is achieved by adding high quality nuts and seeds such as groundnut (*Arachis hypogaea*), cotton seed (*Gossypium hirsutum*) and Soya bean (*Glycine max*.) cakes (GNC, CSC and SBC, respectively) (Ademosun, 1994). However, these are expensive and seasonal and therefore, do not constitute a realistic option (Waller, 1997). On the other hand, palm kernel cake (PKC) is derived from the extraction of oil from the seeds of oil palm tree (*Elaeis guineensis*). It is available all the year round, cheap, and has a high crude protein (CP) content of about 18%. It has been shown that its use to increase dietary protein significantly improved body weight gain, body condition score and kid birth weight in healthy pregnant WAD goats (Nnadi et al., 2007a) and decreased faecal egg output in WAD goats infected with *H. contortus* (Nnadi et al., 2007b). In this study we investigated the effect of improved dietary protein using PKC on the resilience (ability to maintain production/reproduction despite parasitism) of WAD goats infected with *H. contortus* during pregnancy and lactation.

2. Materials and methods

2.1. Animals, care, housing and feeding

Pubertal female and two male WAD goats aged 9–12 months and weighing between 7.5 and 12.5 kg were purchased from flocks belonging to various traditional goat keepers in Nsukka area of Enugu State and used for the study. After acquisition, the animals were weighed and faecal samples routinely examined for GI helminth eggs using the floatation technique (Hansen and Perry, 1990). Blood samples were also collected via jugular venipuncture and examined for haemoparasites. Thereafter they were drenched with an insecticide powder (Asuntol® Bayer, Leverkusen, Germany) as a measure against ectoparasitic infestation. They were also treated with the anthelmintics, Febendazole (Panacur®, Hoechst, Germany) at the dose rate of 7.5 mg/kg body weight.

All the female animals were housed and acclimatized in a large fly-proof concrete floored pen for 2 weeks. During this period, they were observed for evidence of clinical signs such as high temperature, diarrhoea or lack of appetite. Their blood and faeces were analysed a second time during the second week for evidence of parasitic infection. Only female animals (28 in number) negative for GI and haemoparasite infections in the two analyses were eventually selected and used for the study. Also during acclimatization, all the clinically normal and parasite-free animals were vaccinated against PPR using the tissue culture rinderpest vaccine as recommended by the manufacturer, the National Veterinary Research Institute (NVRI), Vom, Nigeria. During the same period the animals were given water and diet consisting of PKC and Bambara nut chaff in the ratio of 1:1 *ad libitum* and, cut-and-carry forage/grass comprising of *Panicum maximum* and *Andropogon mucunoides* once a day. The proximate analyses of the ingredients used in formulating the diets in percentage dry matter (DM%) is presented in Table 1 while the dry matter intake (NRC, 1976) and calculated nutrient levels per animal in the low and high protein diet groups are presented in Table 2.

2.2. *Haemonchus contortus*

A strain of *H. contortus* recently isolated from WAD goats in Nigeria (Musongong et al., 2003) was passaged in young female goats. The adult female animals (28 in number) were vaccinated against PPR using the tissue culture rinderpest vaccine as recommended by the manufacturer, the National Veterinary Research Institute (NVRI), Vom, Nigeria. During the same period the animals were given water and diet consisting of PKC and Bambara nut chaff in the ratio of 1:1 *ad libitum* and, cut-and-carry forage/grass comprising of *Panicum maximum* and *Andropogon mucunoides* once a day. The proximate analyses of the ingredients used in formulating the diets in percentage dry matter (DM%) is presented in Table 1 while the dry matter intake (NRC, 1976) and calculated nutrient levels per animal in the low and high protein diet groups are presented in Table 2.

Table 1

<table>
<thead>
<tr>
<th>Feedstuff</th>
<th>CP (%)</th>
<th>Fibre (%)</th>
<th>ME (%)</th>
<th>EE (%)</th>
<th>Ca (%)</th>
<th>P (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. m/A. spp.</td>
<td>5.15</td>
<td>40.70</td>
<td>1.78</td>
<td>3.00</td>
<td>0.40</td>
<td>0.30</td>
</tr>
<tr>
<td>BNC</td>
<td>13.10</td>
<td>25.00</td>
<td>2.19</td>
<td>45.00</td>
<td>0.09</td>
<td>0.01</td>
</tr>
</tbody>
</table>

BNC, Bambara nut chaff; Ca = calcium; CP = crude protein; EE = ether extract; ME = metabolisable energy; P = phosphorus; PKC = palm kernel cake; P. m/A. spp. = *Panicum maximum/Andropogon* species.
Table 2
Daily dry matter intake and calculated nutrient levels per animal in the low and high protein diet groups.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Plane of nutrition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HDP</td>
</tr>
<tr>
<td>Mean live weight of does (kg)</td>
<td>10.00 ± 1.76</td>
</tr>
<tr>
<td>Mixed grass intake (g)</td>
<td>720.00</td>
</tr>
<tr>
<td>Bambara nut chaff (g)</td>
<td>150.00</td>
</tr>
<tr>
<td>Palm kernel cake (g)</td>
<td>150.00</td>
</tr>
<tr>
<td>Total dry matter intake (g)</td>
<td>1002</td>
</tr>
<tr>
<td>Crude protein intake (g)</td>
<td>82.80</td>
</tr>
<tr>
<td>Metabolisable energy</td>
<td>1.906</td>
</tr>
<tr>
<td>intake (Mcal/kg)</td>
<td></td>
</tr>
<tr>
<td>Ether extract (g)</td>
<td>70.20</td>
</tr>
<tr>
<td>Crude fibre (g)</td>
<td>341</td>
</tr>
</tbody>
</table>

Once in two worm-free donor goats. Faecal cultures were prepared from the infective larvae (L3) routinely harvested as described by MAFF, 1977 and modified by Musongong et al. (2003). These were then used to infect the experimental goats as described below.

2.3. Mating, infection and prepatent periods

After acclimatization, the 28 female goats (does) were divided into two equal groups (A and B) of 14 animals each and housed separately. The two bucks were also housed separately. A modification of the male effect (Whitten, 1956) was used to induce oestrus cycle among the pubertal does. The does were mated following the detection of classical signs of heat. Direct observation of mating was used to determine stages of pregnancy, with the day of mating recorded as day 0 of pregnancy.

Both groups were trickle infected with 200 H. contortus L3 on day 1 of pregnancy using a stomach tube. This was repeated three times per week for 4 weeks with each animal eventually receiving a total of 2400 infective larvae. Trickle infection was employed as it best simulates natural condition where infection is picked up gradually over time in the course of grazing. It also avoids the elaborate immunological response associated with large infection doses that may result in rapid immune expulsion of larvae (Sykes, 1982). Patency (establishment of the L3 and maturity to reproducing adults in the abomasums) and prepatent period (day eggs first appear in faeces) were used as the measure of resistance to infection and were determined by daily faecal analysis for the presence of H. contortus eggs using the flotation technique.

2.4. Doe and kid performance

Body weight, body condition score, successful gestation and kidding of healthy kids at term and, kid birth and weaning weights were used as indices of performance (resilience) of the does to parasitism during pregnancy and lactation. The does were weighed weekly using a spring balance (Five Goats\(^\text{\textregistered}\), India) from week 0 of pregnancy to 6 weeks post-partum. Successive changes in the body weight of each doe were determined by subtracting the initial value (week zero value) from each of the subsequent weekly values until week 27 when the study was terminated. Similarly, the body condition score of each doe was assessed weekly using the method of Houdijk et al. (2000) and weekly changes determined as for the body weight. Each doe was closely monitored during pregnancy for signs of abortions or stillbirths and for other signs that might be related to the helminth infection. Following kidding, each kid was weighed within 12 h of birth and again at 6 weeks of age to determine the birth and weaning weights, respectively.

2.5. Statistics

All data were subjected to descriptive statistics and further analyses were carried out using 3-way factorial analysis of variance (ANOVA) (Steel and Torrie, 1980). Main effects included infection, which was at two levels: infected and uninfected; time, which consisted of 27 weeks and feed types: HPD and LPD. The analyses were carried out in such a manner that the various interactions between the main effects would be revealed. Where positive interaction occurred, further analysis was carried out to determine the exact period during the course of study. Kid birth and weaning weights for the two groups were analyzed using the Student’s t-test (Steel and Torrie, 1980).

3. Results

3.1. Clinical observations

Most of the does were in apparent good health throughout the period of study. However, at weeks 4 and 5 post infection one doe in the HPD group and three in the LPD group showed symptoms of clinical haemonchosis in the form of pasty, semi-solid faeces that lasted for five days. The group on LPD consumed less forage than the HPD group within the first 9 weeks of the study and subsequently developed complete inacceptance during week 15 of pregnancy which later resulted in the defecation of stringy/mucoid faeces.

3.2. Prepatent period

Patency (establishment of infection and maturity to adult stage) occurred in all the animals irrespective of the diet type received. However, HPD increased the ability of the does to resist early establishment of H. contortus infection with the result that it took a significantly longer period of time for Haemonchus eggs to be detected in the faeces of group A than in the faeces of group B does (\(p < 0.001\)). The mean prepatent periods of the two groups are as shown in Fig. 1. It is pertinent to note that in this study, the daily faecal egg counts were also significantly lower in the HPD than LPD group (\(10 ± 22.36 \text{ vs } 220 ± 103.68, 250. ± 180.28 \text{ vs } 490 ± 143.18, 280 ± 116.79 \text{ vs } 520 ± 75.83, 200 ± 117.26 \text{ vs } 510 ± 121.97 \text{ and } 190 ± 129.5 \text{ vs } 750 ± 221\)) on weeks 3, 8, 16, 24 and 27, respectively, for HPD and LPD. This is in conformity with the results of our previous study report (Nnadi et al., 2007b).
3.3. Doe performance

The weekly gain expressed as mean weekly change in body weights of group A (HPD) and group B (LPD) does during pregnancy and lactation is presented in Fig. 1. In comparison to the preinfection/ pregestation values, both groups had significant progressive gain ($p < 0.01$) in body weight during pregnancy (weeks 1–20) and, to a lesser extent ($p < 0.05$), during the period of lactation (weeks 21–27). That notwithstanding, the increase was significantly higher in group A than in group B does ($p = 0.01$) during gestation. Similarly, the increase was, to a lesser extent, also significantly higher in group A than group B during lactation ($p = 0.05$), although the overall kinetic picture during this period was that of a progressive loss in body weight. Overall, however, group A gained significantly higher body weight than group B from the period of gestation through lactation ($p < 0.01$) and did not lose as much weight as group B during lactation.

Fig. 2 represents the mean weekly changes in the body condition scores of both groups during the study. The body condition scores increased significantly ($p < 0.01$) in group A between weeks 2 and 16, after which there was significant progressive loss ($p < 0.01$) which persisted...
until the end of the experiment. Similarly, group B showed a fluctuating but lesser increase than group A in body condition scores from weeks 2 to 21, after which there was also a progressive decrease until the end of the experiment. However, there was no statistically significant difference in the body condition scores of both groups during pregnancy, lactation and overall \((p > 0.05)\), irrespective of the differences and kinetics of the scores in the two groups.

**3.4. Kidding performance**

All the does carried the pregnancy to term and kidded at week 20. No abortions or stillbirths were observed in either group. However, group B had three kids with very low birth weights, which were born alive but died soon after. Thus, group B in the end weaned 11 kids (78.6%) as against 14 kids (100%) weaned by group A. Comparisons show that the mean birth and weaning weights were higher in group A kids than group B kids. However, whereas the mean birth weight of the group A kids was significantly higher than that of group B kids \((p < 0.001)\), there was no statistically significant difference \((p > 0.05)\) between the mean weaning weights of group A and B kids.

**4. Discussion**

Most studies that have examined the interactions between protein nutrition and the resistance/resilience responses of small ruminants to gastrointestinal nematode parasitism have been done in sheep, with very few in goats \((\text{Etter et al., 2000; Hoste et al., 2005, 2007})\). Moreover, even the few that have been done in goats have concerned growing kids and lactating does \((\text{Hoste et al., 2005, 2007})\) and none has assessed doe performance during pregnancy and lactation. The objective of this study, therefore, was to investigate the effect of the level of protein supplementation primarily on the resilience (ability to maintain body weight, body condition, normal gestation, parturition of healthy kids and sufficient milk production and weaning of kids of high birth weight) of WAD goats with clinical \(H. contortus\) infection during pregnancy and lactation, and secondly on their ability to resist the establishment of the infection. The prediction was that parasitism will establish more easily and have a more severe effect in pregnant does fed on low protein diet because the scarce protein resource would be competed for between the host’s body maintenance needs, reproductive efforts and immune efforts against the parasites.

The results of the study showed that WAD does maintained on feed with high protein supplementation were able to mount a measure of resistance against early establishment of the infection as evidenced by prolonged prepatent period (the period between infection and evidence that the parasite has established and attained adulthood, i.e. egg out put in faeces). Inadequacy of metabolisable protein (MP) among the LPD does was probably responsible for their inability to mount sufficient immunological response against early parasite establishment, thus the shorter prepatent period of the parasite in them. This is largely in agreement with our earlier report in which goats given high protein diet had significantly lower faecal egg out put and number of adult worms recovered post mortem \((\text{Nnadi et al., 2007b})\). However, the observation differs with those of \text{Abbott} (1982) and \text{Abbott et al.} (1985a,b), where the level of protein intake had no effect on parasite establishment. However, they used a single primary infection dose as against trickle infection doses of \(L_3\) in this study. It should be noted however, that in our study the HPD group did not completely suppress parasite establishment but succumbed as the dose of infection built up, suggesting that high protein diet may not play any role in the resistance of infection. However, \text{Coop and Holmes} (1996) stated that the main effect of protein supplementation is to increase the rate of acquisition of immunity and resistance against re-infection following recovery from primary infection. It would, therefore, appear that with increasing build up of infective larvae over time the earlier resistance by HPD group was overcome resulting in eventual parasite establishment but a delay in the prepatent period. This seems to be a better simulation of the situation with natural infections under field (grazing) conditions.

High protein diet also increased resilience (better weight gain, body condition, pregnancy and kidding/lactation performance) and also enabled the reproducing WAD does to better cope with some of the clinical consequences of parasitism such as reduced feed intake and GI symptoms. This is in agreement with previous reports in sheep \((\text{Bueno et al., 1982; Abbott et al., 1988; Parkins and Holmes, 1989})\) and in goats \((\text{Etter et al., 2000; Hoste et al., 2005, 2007})\). It is likely that increased resilience enabled HPD does to eat better and consequently gained significantly higher body weights than the LPD does throughout the period but more so during pregnancy. This probably also accounted for both the better body condition of this group during pregnancy and the production of heavier kids at parturition. However, both dietary groups experienced reduction in body weight and body condition scores during lactation though the loss in body weight was more in the LPD group. In contrast, the loss in body condition score seems to be more dramatic in the HPD than the LPD group. Two things may probably account for this. First, the HPD does produced and weaned slightly heavier kids whose sucking demand was probably higher than the LPD kids. The weaning of heavy kids is an indirect index of high or low milk production and it has been shown that high milk producers lose more body condition than low producers in the face of parasitism during lactation \((\text{Etter et al., 2000})\). Second, it is conceivable that the HPD group placed a higher priority on producing more milk and feeding their kids over the effort to channel protein resources toward the maintenance of their body condition, including weight gain. Generally, it is believed that protein supplementation provides adequate nutrient supply of MP and stabilizes fluctuations in live weight and body condition during lactation as has been shown in sheep \((\text{Kahn et al., 2003})\). In this study, it would appear that the level of supplementation was inadequate in both cases to provide adequate level of MP during lactation. Our results therefore suggest that the observed deterioration in body weight and body condition by both groups during lactation is an indication that higher MP is required for lactation and...
suckling of kids than is required for pregnancy and foetal development.

The significantly heavier birth weight of HPD kids is also indicative of the resilience of the does and dietary sufficiency of MP during pregnancy which guaranteed adequate foetal development. The reverse, which is scarcity of MP in LPD and birth of low birth weight kids, seems to be the case for LPD does. Scarcity of MP among the LPD does did not only manifest in low kid birth weights but also in birth of some kids with weights below survival threshold and which eventually died. Weaning weights as mentioned above are usually subject to milk yield and higher yields have been found among supplemented ewes (Houdijk et al., 2000). Both groups lost body condition and weight during lactation and this was a sign of penalty for insufficient MP supply in their diets at this period. It is therefore possible that the HPD does weaned heavier kids than the LPD does because of better milk production or ability to mobilize from their higher tissue reserve for lactation than the LPD group. However, it should be noted that the difference in the weaning weights of the HPD and LPD kids was not significant. Thus resilience in terms of ability to feed and wean kids of comparable weight was therefore not significantly affected by the level of protein supplementation in infected lactating and nursing does. In fact, this is in agreement with Kahn et al. (2003) and Bown et al. (1991) who demonstrated that in periods of greater MP requirement, increased supply provides little benefit to resistance/resilience to nematode parasites but may improve the body mass reserve and foetal weight.

In conclusion, the results of this study showed that increased dietary protein supply to pregnant WAD goats was protective against early parasite establishment, body weight losses and deterioration in body condition score during pregnancy and significantly enhanced kid birth weights and post-partum survival. In contrast, during peri-partum and lactation these protective indices in terms of body condition and body weight were lost possibly due to higher nutrient demand than could be met by the dietary protein levels. However, the level of supplementation had no significant effect on the weaning weights of kids in both groups. From our study, there seems to be a great potential and merit in the use of low cost and easily available PKC as a protein source in local production of WAD goats for the amelioration of the deleterious effects of pathogenic gastrointestinal nematode parasite infections in the area. This notwithstanding, there is still the need for further studies in this regards especially in evaluating the effects of higher dietary protein supplementation than was used in the present study in ameliorating the effects of haemonchosis in a larger population of breeding WAD does. Also, considering the availability and low cost of the ingredients used as protein source in the diet, the over all benefit from its use is enormous from the productive point of view.

References


