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Effects of gastrointestinal helminth infections and plane of nutrition on the health and productivity of F1 (West African Dwarf × Sahelian) goat crosses in The Gambia

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Abstract

A two by two factorial design including natural helminth infections (dewormed 'D' or not dewormed 'ND') and different levels of diet (basal 'B' or basal diet plus supplement 'S') was used to assess the effect of helminth infections and plane of nutrition on health and productivity of F1 (West African Dwarf (WAD) × Sahelian) crosses. The pasture composed the basal diet and supplemented animals received cottonseed and rice bran. Feed composition analysis revealed that the pasture did not provide sufficient nutrients for reproduction requirements. Feed supplementation had a significant effect on weight gain of does during pregnancy and lactation, and milk off-take was significantly higher in supplemented does compared to non-supplemented ones (31.3 ± 2.5 l versus 17.7 ± 2.5 l respectively, $P < 0.01$). A peri-parturient rise in strongyle egg output was noted, and diet supplementation tended to reduce faecal egg count and to increase packed cell volume (PCV), mainly during the dry season.

Deworming had a significant effect on red blood cell (RBC) count, PCV and haemoglobin (Hb) concentration, mainly during the period of peak strongyle egg output (season × deworming: $P < 0.001$ for RBC and PCV and $P < 0.05$ for Hb). Helminth infections combined with a basal diet seriously affected weight gain but the interaction of deworming and diet was not significant. In groups receiving the basal diet, dewormed animals had a significantly higher milk yield than those that were not dewormed (23.5 ± 3.3 l versus 12.0 ± 3.7 l, respectively; interaction diet × deworming: $P < 0.05$). The higher daily weight gains of offspring born from dewormed does might be explained by the fact that, in addition to the effect of deworming on milk yield in animals receiving basal diet, the kids were less exposed to helminth eggs, whereas does that were not dewormed constituted a greater source of helminth infection for their kids.

Keywords: Goats; Sahelian; West African Dwarf; F1 crosses; Nutrition; Helminths; Productivity

1. Introduction

West African Dwarf (WAD) and Sahelian goats are the main goat breeds reared in the southern part of Senegal and The Gambia, in West Africa. Sahelian

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goats are mainly located in the arid to semi-arid part of Senegal and are well adapted to the harsh conditions of this agro-ecological zone. They are long-legged animals with a mean daily milk production of 1 kg per animal (Cissé et al., 1994), but they are susceptible to diseases such as helminth infections and trypanosomosis, which are constraints to their rearing in more humid areas. WAD goats are small, prolific animals that are trypanotolerant and well adapted to the humid zone, but with low milk production (Faye, unpublished data). Crossbreeding between Sahelian and WAD breeds occurs naturally or as a strategy of farmers wishing to obtain more productive animals. Such crossbreeding may be a promising strategy for increasing milk production from goats and thus for improving the nutritional status of children who are the main consumers of this milk (Boogaard and Schuppers, 2001, unpublished data). However, the productivity of these F1 crosses and their susceptibility to diseases such as helminth infections still need to be determined. For trypanosomosis, a study carried out by Faye et al. (2002) did not reveal any superior trypanotolerance of WAD goats compared to F1 crosses (West African Dwarf × Sahelian).

The objective of this study was therefore, to assess the effects of natural helminth infections and their interactions with the plane of nutrition on health (haematological changes) and productivity of F1 does.

2. Materials and methods

The experiment took place from July 2001 to February 2002 at the coastal station of the International Trypanotolerance Centre (ITC), Banjul, The Gambia. The tsetse challenge is very low and mainly, if not entirely due to *G. p. gambiensis*, which is likely to be a vector of *T. vivax* and not *T. congolense* infections.

2.1. Animals

Twenty-seven primiparous F1 crosses, born and reared on-station and 2–3 years of age, were used for this experiment. All animals were vaccinated against Peste des Petits Ruminants and pasteurellosis and sprayed with Bayticol® once every 4 weeks. Does were synchronised using the buck-effect and the bucks were kept in the flock for 45 days to optimise servings.

2.2. Experimental design

In this study, a two by two factorial design was used which included natural helminth infections (dewormed 'D' or not dewormed 'ND') and diet (basal 'B' or basal diet plus supplement 'S'). This resulted in four treatment combinations: dewormed and supplemented (D_S), dewormed and basal diet (D_B), not dewormed and supplemented (ND_S), not dewormed and basal diet (ND_B). Animals were allocated to three experimental blocks based on their live-weight (1: average weight = 21 kg; 2: average weight = 24 kg; 3: average weight = 28 kg) and thereafter, randomly allotted to the different treatment groups.

Two months following introduction of the bucks (beginning of July), and coinciding with the beginning of the rains, faecal samples were taken fortnightly for the first 2 months and thereafter at weekly intervals until the end of the experiment in order to estimate the strongyle egg output using the McMaster technique with a sensitivity of 100 eggs per gram (EPG) (Thienpont et al., 1995).

Animals assigned to the deworming groups were treated with fenbendazole (Panacur®, Hoechst Roussel, N.V., Brussels) at a dose of 10 mg/kg. A strategic deworming scheme, which consisted of treatments at the end of July, mid-September and end of October was followed.

Haematological parameters were calculated at weekly intervals during the rainy season until the early dry season (July–November) using an automated blood cell counter (ABX MINOS ST Haematology Analyser, Levallois, France). Parameters recorded were: red blood cell (RBC) count, haemoglobin (Hb) concentration, mean corpuscular volume (MCV) and mean corpuscular haemoglobin concentration (MCHC).

Packed cell volume (PCV) was used to estimate anaemia and was measured by the capillary microhaematocrit centrifugation method at weekly intervals during the rainy season and fortnightly for the rest of the experiment. Blood samples were also checked for trypanosome infections using the dark ground (DG) method (Murray et al., 1977) to make sure that the anaemia noted was only due to gastrointestinal nematode infections.

After kidding, birth-weights of the offspring were recorded and offspring were weighed at weekly intervals. Does were weighed weekly, starting from the third month of pregnancy up to the end of the experiment.

Starting 10 days after kidding, does were hand-milked on 1 day per week for 100 days. Monthly milk samples were collected for the determination of fat and protein content by the Gerber and the formaldehyde titration methods, respectively.

The following formula was used to compute the lactation record for milk yield (MY) according to the test interval method (TIM) of the ICAR (International Committee for Animal Recording, 2001):

$$MY = \sum_{i=1}^{n} W_i Y_i$$

where $W_1, \ldots, W_n$ = interval, in days, between recording dates, $W_1 = (\text{day}_1 - \text{kidding date})$, $W_i = (\text{day}_i - \text{day}_{i-1})$; Y_i = mean milk yield from day_{i-1} to $\text{day}_i = (y_i + y_{i-1})/2$, y_i = milk yield at ith sampling on day_i of the lactation, y_{i-1} = milk yield at $i-1$th sampling on day_{i-1} of the lactation; for W_1, $Y_1 = y_1$.

2.3. Feeding

Animals were released during daytime and allowed to graze for at least 6 h. In addition, the supplemented groups received 200 g of cottonseed and 200 g of rice bran per animal per day during pregnancy. This supplementation started at the beginning of the second half of pregnancy (July 2001) until the end of the experiment (February 2002). After parturition, due to a high rate of refusal of rice bran, the supplement was changed to 300 g of cottonseed. During the rainy season (September) and the dry season (March), grass samples were collected from the pasture for nutritional analysis.

The composition of the different feeds is presented in Table 1. The reproductive requirements of the animals were calculated according to formulae derived from McDonald et al. (1978) and Rivière (1977). The supplement provided 45.5% of digestible crude protein (DCP) and 34.0% of the metabolisable energy (ME) requirements for maintenance and pregnancy and 45% DCP and 43.1% of ME requirements during lactation. The pasture provided 64% of DCP and 125% of ME requirement for maintenance and pregnancy, and 46% of DCP and 140% of ME requirements for lactation.

3. Statistical analysis

Statistical analyses were carried out using SAS® (Statistical Analysis Systems Institute, 2000) procedures. Haematological traits (PCV, RBC, Hb, MCV, MCHC) and strongyle egg output were analysed using a general linear model (GLM procedure) as repeated measurements using a fixed model. The following main effects were included: deworming (dewormed versus not dewormed), diet (supplemented versus basal), season (season 1, early to mid-rainy season: July–September; season 2, late rainy season: October; season 3, early dry season: November–December and season 4, mid-dry season: January–February), block (1–3) and does (nested within deworming, diet and block). The interactions between deworming × diet, season × deworming, season × diet and season × deworming × diet were also included in the model. Before analysis, faecal

Table 1
Dry matter composition of feed offered and pastures

	Dry matter (%)	Crude protein (%)	Digestible crude protein (%)[a]	IVDOM (%)	Metabolisable energy (MJ/kg)[b]
Pasture (rainy season)	63.8	8.3	4.4	67.1	16.9
Pasture (dry season)	93.5	7.8	3.8	49.3	15.4
Cotton seed	93.7	22.6	13.7	66.0	16.2
Rice bran	95.1	5.5	2.6	48.0	13.5

OMD = 5.3 + 0.071 × IVDOM + 0.035 × NDF (Riveros and Argamenteria, 1986). TDN, total digestible nutrients; ADF, acid detergent fibres; OM, organic matter; OMD, estimated in vivo organic matter digestibility; IVDOM, in vitro degradable organic matter; NDF, neutral detergent fibres.

[a] DCP = TDN × CP (TDN = 4.898 + (1.044 − 0.0119 × ADF) × 89.796) (Ishler et al., 1996).

[b] ME (MJ/kg) = 0.015 × OM × OMD (MAFF, 1984).

egg output (epg) and RBC count were subjected to logarithmic transformations to approximate normal distribution. Kid birth-weight and growth rate up to 90 days (calculated from linear regression analysis) were tested in a model including treatment status of the doe (deworming, diet), litter size of the doe (only for kid birth-weight) and sex. For doe growth rate, mean daily weight gain was calculated from linear regression analysis for the pregnancy and lactation periods and analysed for each period in a model including deworming, diet, block and the interaction diet × deworming. A similar model was used for analysing the 100-day milk yield. Litter size was omitted since only 2 animals out of 19 were suckling two kids. The milk yield was considered to be equivalent to milk off-take, as milking is carried out only in the morning.

Twenty-one does kidded successfully from the end of September to the end of October, but the kids of two does died during the first week following kidding. Six does remained empty, four of which were from the not dewormed group. The deworming effect was omitted and the pregnancy status was included for the comparison between helminth egg output of pregnant-lactating does and empty does.

Tests for significance were based on *F*-tests, whilst means for the different variables were given as least square means ± standard error unless stated otherwise.

4. Results

4.1. Helminth egg excretion

During the whole study period, deworming significantly reduced strongyle egg output ($P < 0.001$). In not dewormed pregnant and lactating animals, the strongyle egg output (least square mean of log-transformed) tended to be higher in animals under basal diet compared to the supplemented ones (6.1 ± 0.6 versus 5.2 ± 0.5, respectively) (Fig. 1), but neither the effect of diet nor the interaction between

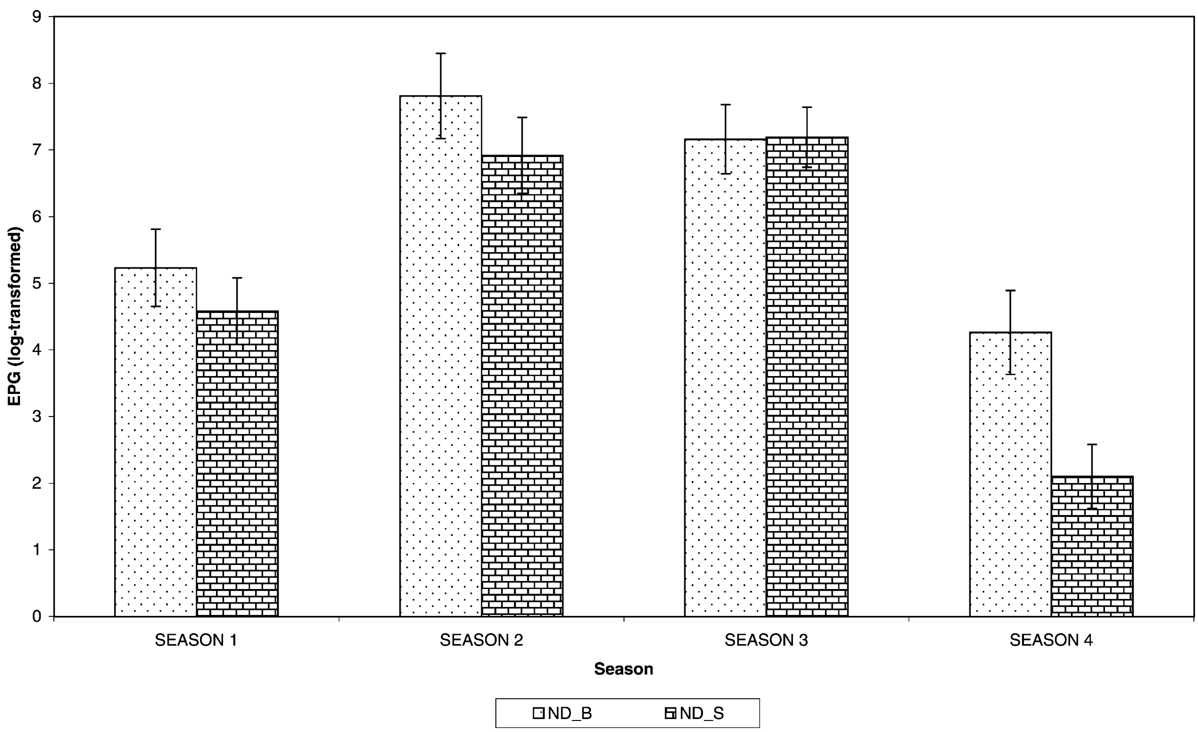

Fig. 1. Log-transformed strongyle egg output (±standard error) of not dewormed (ND) F1 goats supplemented (S) or not supplemented (B) for the different seasons.

diet and deworming were significant ($P > 0.05$). The interaction between diet, deworming and season was also not significant.

There was a significant effect of season ($P < 0.001$) with a significant increase of strongyle egg excretion during the late rainy season (peak kidding period) compared to the mid-rainy season; the peak being reached in the early dry season. There was a significant individual effect ($P < 0.0001$), indicating that some animals were better able to cope with helminth infections than others.

One animal from the not dewormed and basal diet group was treated with fenbendazole at 10 weeks post-kidding due to a very high strongyle egg output, low PCV and low milk production. Four offspring of the not dewormed group were also treated due to high strongyle egg outputs associated with diarrhoea.

The arithmetic means of the egg output of the pregnant and not dewormed does were four and seven times higher than those of the not dewormed and empty does during the pregnancy and lactating periods, respectively (Table 2). Overall, there were significant differences in egg output between pregnant and not dewormed and empty and not dewormed females ($P < 0.001$).

4.2. Influence of deworming and diet on haematological parameters

Regardless of deworming and diet, there was an effect of season, with significantly lower PCV, RBC count and Hb concentration occurring in the late rainy season and early dry season than in the mid-rainy season ($P < 0.0001$).

Overall, deworming significantly increased red blood cell counts ($16.4 \pm 0.0\,\mathrm{mm}^{-3}$ for dewormed animals versus $16.2 \pm 0.0\,\mathrm{mm}^{-3}$ for not dewormed animals, $P < 0.05$). There was a significant interaction between season and deworming ($P < 0.001$); deworming significantly increased RBC only in the late rainy season, but this effect was more marked in the early dry season ($16.4 \pm 0.0\,\mathrm{mm}^{-3}$ for dewormed animals compared with $16.1 \pm 0.0\,\mathrm{mm}^{-3}$ for not dewormed animals). The effect of deworming on Hb concentration was only significant in the early dry season (dewormed 8.2 ± 0.2 g/dl and not dewormed 6.9 ± 0.3 g/dl, season × deworming: $P < 0.05$). The effect of deworming on MCV, MCHC was not significant. Diet had no significant effect on RBC, HB concentration, MCV or MCHC.

The combined effects of deworming and supplementation are shown in Fig. 2. Deworming significantly increased PCV only during the late rainy to early dry season with the greatest difference being recorded in the early dry season (dewormed $24.8 \pm 0.3\%$ and not dewormed $21.1 \pm 0.4\%$; season × deworming: $P < 0.001$). Supplementation tended to increase PCV during the dry season (supplemented $25.3 \pm 0.5\%$ compared to basal $22.3 \pm 0.5\%$, season × diet: $P = 0.07$). The effect of plane of nutrition on PCV was more pronounced in not dewormed animals (supplemented $24.9 \pm 0.6\%$ versus basal $21.5 \pm 0.9\%$) compared to dewormed ones (supplemented $25.6 \pm 0.8\%$ versus basal $23.2 \pm 0.6\%$) during the dry season (interaction diet × deworming × season, $P < 0.05$). In not dewormed does, supplemented ones had significantly higher PCV than does under basal diet at early dry season and mid-dry season. In dewormed does, supplemented ones had higher PCV than does under basal diet only at mid-dry season.

4.3. Influence of diet and deworming on milk production and composition

Regardless of treatments, the mean milk off-take (100 days) of F1 does was 24.5 ± 2.5 l. The plane

Table 2
Mean strongyle faecal egg output and range of pregnant and empty does (not dewormed group)

	Pregnancy period		Lactating period	
	Mean EPG	Range	Mean EPG	Range
Pregnant does ($n = 9$)	966.7	0–11,200	3193.6	0–74,400
Empty does ($n = 4$)	241.7	0–1600	448.7	0–2500

EPG: eggs per gram.

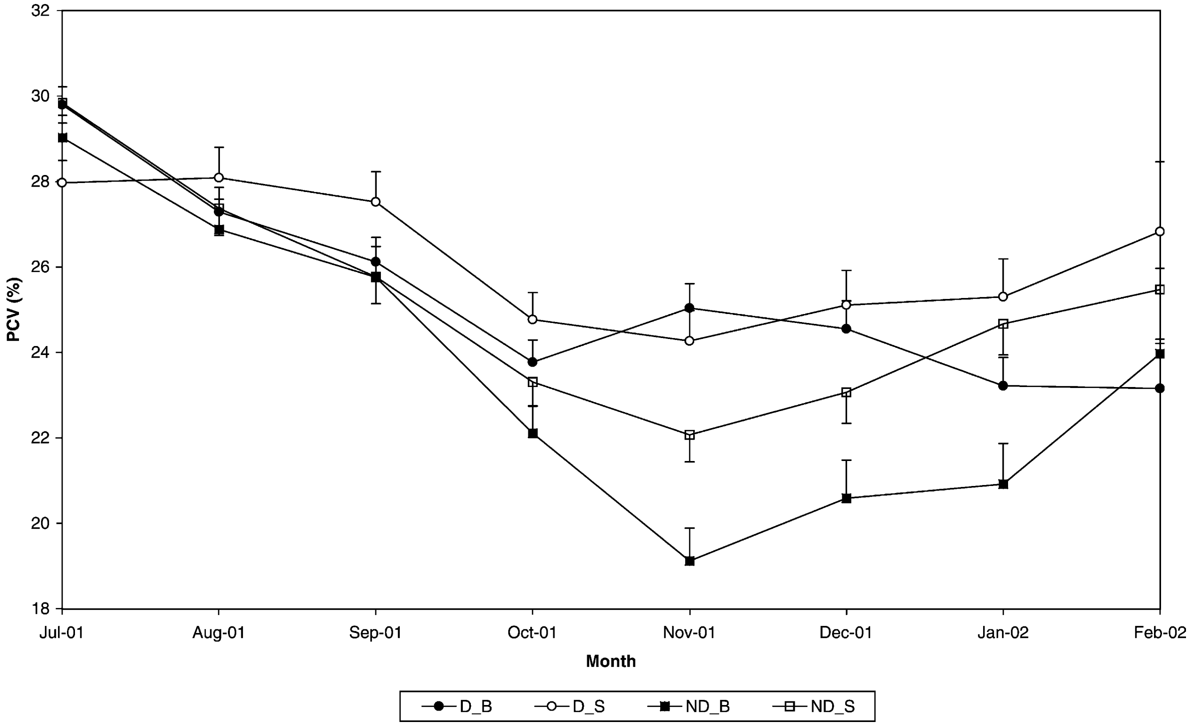

Fig. 2. Monthly PCV levels (least square means ± standard error) of F1 goats dewormed (D) or not dewormed (ND) and supplemented (S) or not supplemented (B).

of nutrition significantly affected milk off-take (supplemented 31.3 ± 2.5 l and basal diet 17.7 ± 2.5 l, $P < 0.01$). This effect was more noticeable in not dewormed (supplemented 33.1 ± 3.3 l and basal diet 12.0 ± 3.7 l) than in dewormed ones (supplemented 29.6 ± 3.7 l and basal diet 23.5 ± 3.3 l). A positive effect of deworming on milk off-take was only noticeable in animals receiving a basal diet with a significant interaction diet × deworming (dewormed 23.5 ± 3.3 l versus not dewormed 12.0 ± 3.7 l, interaction: $P < 0.05$).

Regardless of treatment, the mean milk fat and protein percentage of the F1 does was 3.7 ± 0.3 and 3.3 ± 0.1%, respectively. Overall, neither diet nor deworming significantly affected milk fat percentage. However, in animals that were not dewormed, milk fat percentage was significantly higher in supplemented animals compared to those receiving a basal diet (4.1± 0.3% versus 3.2±0.4%, respectively, interaction diet× deworming: $P < 0.05$).

4.4. Live-weight

Supplemented does had a significantly higher daily growth rate than does under basal diet during pregnancy (22.7 ± 6.2 g versus 5.0 ± 5.8 g, respectively; $P < 0.05$) and there was no effect of litter size. Dewormed does tended to exhibit a higher daily weight gain than those that were not dewormed (19.9 ± 5.8 g versus 7.8 ± 6.3 g, $P > 0.05$). The interaction between diet and deworming was not significant, but daily weight gain tended to be higher in dewormed and supplemented animals. Animals in the group that was not dewormed and which received a basal diet were the only ones in which there was a negative weight gain during pregnancy (Fig. 3).

During lactation, diet also significantly influenced daily weight gain ($P < 0.05$). The supplemented group showed a slight weight gain whilst those receiving basal diet lost weight (10.4 ± 5.5 g versus −9.9 ± 5.2 g, respectively). There was no ef-

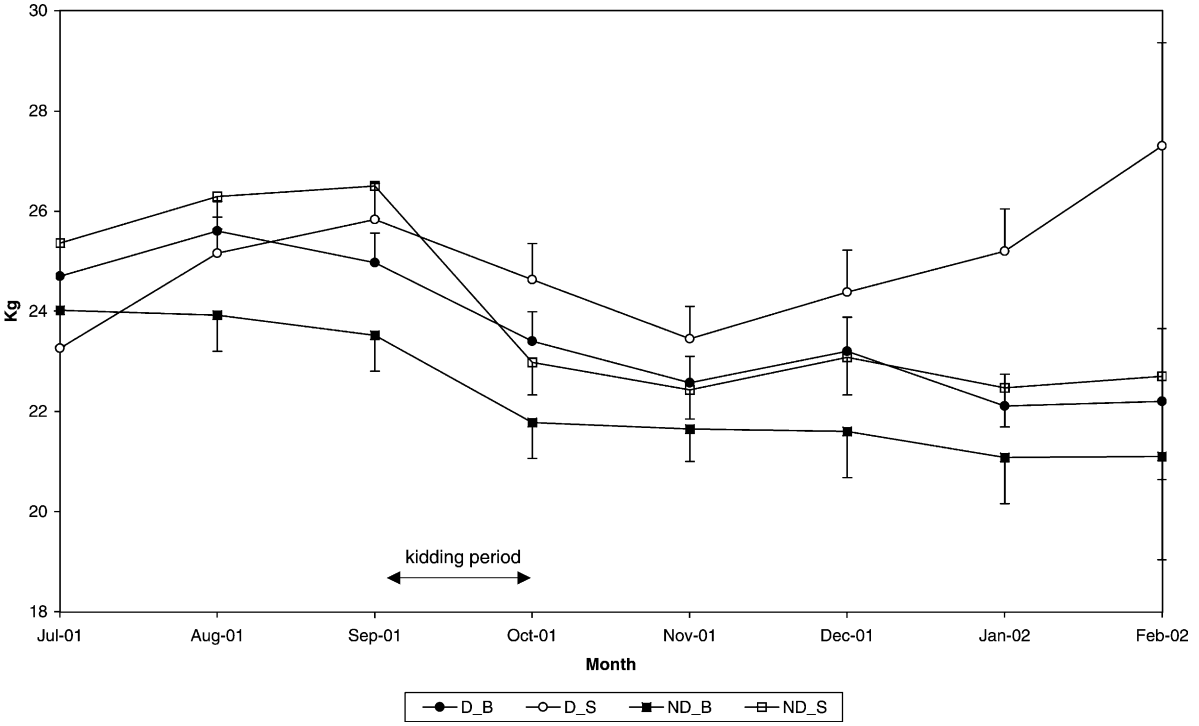

Fig. 3. Mean body weight changes (least square means ± standard error) in F1 goats dewormed (D) or not dewormed (ND) and supplemented (S) or not supplemented (NS).

Table 3
Effect of the level of nutrition and deworming status of the does on offspring daily weight gains (least square means ± S.E.) from 0 to 90 days

	Deworming			Level of nutrition		
	Dewormed	Not dewormed	Significance	Supplemented	Basal	Significance
0–45 days	86.0 ± 9.0	75.3 ± 8.7	$P > 0.05$	87.5 ± 9.0	73.8 ± 8.9	$P > 0.05$
45–90 days	64.0 ± 5.3	39.9 ± 5.3	$P < 0.01$	64.3 ± 5.3	39.6 ± 5.3	$P < 0.01$
0–90 days	72.5 ± 6.0	57.5 ± 5.8	$P = 0.07$	73.5 ± 6.0	56.5 ± 6.0	$P = 0.05$

fect of deworming and the interaction between diet and deworming was not significant. However, the combination of basal diet and not deworming led to negative weight changes, whilst supplemented and dewormed animals had the highest weight gain (Fig. 3).

Neither diet nor deworming had significant effects on offspring birth-weight. Single kids had higher birth-weights than twins (2.0±0.1 g versus 1.4±0.1 g, respectively, $P < 0.001$).

Diet and deworming of does influenced the daily weight gain of kids, mainly between days 45 and 90 of life; the period which follows peak strongyle egg excretion and which also coincides with the dry season (see Table 3). There was no significant interaction between diet and deworming but the highest daily weight gain was recorded in offspring from dewormed and supplemented does.

5. Discussion

During this study, the helminth egg output started to increase in October (peak kidding period) and was at its highest in November (early dry season). The peri-parturient rise of helminth egg output noted during this study has been extensively reported in many different breeds of sheep and goats (Vlassoff et al., 1999). In ewes and probably in does also, this peri-parturient rise may be explained by a peri-parturient relaxation (PPR) in immunity leading to a breakdown of the regulation of the helminth population by the normal immune mechanisms (Coop and Kyriazakis, 1999). This peri-parturient rise in egg output has serious epidemiological implications, since the rise in faecal egg output can increase the number of infective larvae in the pasture, thus increasing the probability of newborn animals being infected. Supplementation tended to reduce strongyle egg output during pregnancy and lactation, in agreement with previous reports of lowered helminth egg output or worm burden following supplementation of reproducing or growing animals (Blackburn et al., 1991; Coop and Kyriazakis, 1999).

Helminth infections caused significant levels of anaemia (estimated from PCV, RBC and Hb measurements) particularly during the period of peak strongyle egg output, which coincided with the early dry season. This was likely due to infection with *Haemonchus contortus*, which is the predominant pathogenic helminth species infecting small ruminants in The Gambia (Fritsche et al., 1993; Kaufmann, 1996). The fact that MCV and MCHC were not affected indicates a normocytic and normochromic anaemia. The fact that deworming did not significantly improve PCV during pregnancy may be because the *Haemonchus* burden was low during that period. Indeed, a strong correlation between faecal egg count, PCV, and worm burden following *Haemonchus* infection has been reported (Chiejina et al., 2002) and during this study, haematological parameters and egg output suggested that the peak infection with abomasal adults might have been reached during the late rainy season as reported previously (Fritsche et al., 1993). It is also possible that experimental animals had an acquired resistance, which broke down due to the stress and reduced immunity following parturition. This could explain the higher strongyle egg output at that time. An acquired immunity to gastrointestinal helminths in goats has been reported previously (Vlassoff et al., 1999; Chiejina et al., 2002).

A further consequence of gastrointestinal helminth infections can be reduction in voluntary feed intake and efficiency of feed utilisation which, combined with an endogenous loss of protein into the gastrointestinal tract, leads to a reduction in soft tissue deposition and milk production. Several studies have reported the negative effects of helminth infection on milk yield in ruminants (Cobon and O'Sullivan, 1992; Chartier and Hoste, 1994; N∅dtvedt et al., 2002), however, during this study, this effect was only noticed in animals receiving a basal diet. In the supplemented group, the level of production was similar between dewormed and not dewormed animals. This suggested that at certain levels of supplementation, parasitised animals can withstand the disease and maintain the same level of milk production as dewormed ones.

The significantly lower weight gain of offspring from does that were not dewormed could have been due to the reduced milk yield of those does (especially those under basal diet) combined with the fact that the latter were also a source of helminth infection for their offspring. Indeed, anthelmintic treatment of does can significantly increase survival rates of their kids (Osaer et al., 2000).

The live-weight changes observed in pregnant and lactating animals under basal diet, confirm that the pasture could not provide the nutrients necessary to meet their reproductive requirements, thus leading to endogenous catabolism. A combination of restricted diet with helminth infections aggravated the weight loss in animals that were not dewormed. It has been suggested that under parasitic challenge, if food resources are scarce, the limited resources should be allocated to the maintenance of body protein function (repair, replacement of damaged tissue) of parasitised animals instead of the reproductive effort (pregnancy/lactation), growth and expression of immunity (Coop and Kyriazakis, 1999).

From this study, it was clear that helminth infections, associated with a low plane of nutrition, could affect health and productivity of reproducing animals, especially during the stressful lactation period. Parasitised animals, especially those under basal diet, constituted a higher source of infection for their offspring and the associated effect of reduced milk production due to an inadequate nutrition, affected offspring performance.

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