



Influence of an experimental *Trypanosoma congolense* infection and plane of nutrition on milk production and some biochemical parameters in West African Dwarf goats

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Received 17 September 2003; received in revised form 8 September 2004; accepted 29 October 2004

Abstract

The interactions of trypanosomosis and plane of nutrition on health and productivity of multiparous and primiparous West African Dwarf (WAD) does were studied in a multi-factorial experiment including diet (supplementation or basal diet) and infection (infected or control). Experimental does were infected with *Trypanosoma congolense* at the beginning of the second week post-kidding and monitored for 16 weeks after infection. Trypanosome infection significantly reduced packed cell volume (PCV) (control: $30.1 \pm 0.3\%$ versus infected: $22.2 \pm 0.3\%$; $P < 0.0001$). Regardless of infection, the drop in PCV from the pre-infection period to the end of the experiment was more severe in animals under restricted diet (interaction diet \times period, $P < 0.001$). Trypanosome parasitaemia tended to be higher in the supplemented group than in the basal diet group ($P > 0.05$) and multiparous animals had a higher parasitaemia (score: 2.6 ± 0.1) than primiparous animals (score: 2.2 ± 0.1) ($P < 0.05$). Trypanosome infection as well as dietary supplement had a significant effect on lactation length. Milk off-take from trypanosome-infected does was significantly lower than that from the uninfected control group (17.5 ± 3.21 versus 35.5 ± 3.21 , $P < 0.001$) and there was a positive effect of plane of nutrition (supplemented: 32.8 ± 3.21 and basal diet: 20.2 ± 3.51 , $P = 0.01$). The drop in milk off-take due to trypanosome infection was more severe in the supplemented group (control: 46.7 ± 4.71 versus infected: 18.9 ± 4.21) than in the group receiving a basal diet (control: 24.2 ± 5.01 versus infected: 16.1 ± 4.71) (interaction infection \times diet, $P = 0.04$) due to the number of does from the supplemented group that were withdrawn from the experiment. The effect of trypanosome infection on doe's live-weight was only noticeable during the first 8 weeks of lactation and there was no significant effect on offspring growth rate unless the mother died. Plasma total protein (TP), albumin and cholesterol

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concentrations were significantly reduced by the infection but were significantly increased by supplementation. Supplemented does had a higher level of cholesterol and a tendency for a higher parasitaemia. Does of high parity also had a higher cholesterol level than primiparous does and, based on the number of animals that were withdrawn from the experiment, they showed a lower resistance to the infection.

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Keywords: *Trypanosoma congolense*; Nutrition; Milk; West African Dwarf goats; Biochemistry; Lactation

1. Introduction

African Dwarf goats living in tsetse endemic areas are known to be more resistant to trypanosomosis than exotic breeds or breeds living in tsetse free areas (Griffin and Allonby, 1979; Whitelaw et al., 1985; Kanyari et al., 1986; Adah et al., 1993). However, studies carried out in The Gambia and elsewhere have suggested that they are less trypanotolerant than Djallonke sheep (Goossens et al., 1998; Leak et al., 2002). Trypanotolerance in cattle is defined as their ability to control parasitaemia and anaemia (Murray et al., 1982). However, Osaer et al. (1994) found that small ruminants are less able to control the parasitaemia and drop in PCV following trypanosome infection. In addition to anaemia, experimental *Trypanosoma congolense* infection affected reproductive performance of West African Dwarf (WAD) goats (with abortions and stillbirth) but did not have a significant effect on growth or mortality rates (0–30 days) of kids born alive (Goossens et al., 1997). Field or experimental studies have demonstrated that trypanosome infections can affect milk yields of cattle or sheep (Agyemang et al., 1990; Kalu, 1991; Akinbamijo et al., 1994). Some biochemical changes following trypanosome infection have also been reported in castrated male goats and Djallonke ewes (Akinbamijo et al., 1992; Osaer et al., 2000). Increased serum non-esterified fatty acids (NEFA) in trypanosome-infected animals has led to the suggestion that lipolysis is the major mechanism for supplying the high energy demanded by the fever following trypanosome infection (Akinbamijo et al., 1992 quoting Zwart et al., 1991). The combined energy demands of trypanosome infection and lactation may lead to a severe energy shortage and this might be reflected in changes to energy and protein metabolism. The aim of this experiment was to study the effect of trypanosomosis on milk production and plasma metabolites and interactions with the plane of nutrition.

2. Materials and methods

2.1. Experimental design

This experiment was carried out at the coastal station of the International Trypanotolerance Centre (ITC), Banjul, The Gambia. At this location, the apparent density of tsetse flies is very low (0.062 flies/trap/day) on station (ITC, unpublished data). Most flies are of the species *Glossina palpalis gambiensis*, which is likely to be a vector of *T. vivax* rather than *T. congolense* infections (Leak, 1998).

In a controlled multi-factorial experiment, 31 WAD goats (5–6 years old; fourth parity) and 23 primiparous WAD goats (18 months old) were used. Oestrus was synchronised by two injections of prostaglandin F2 α (Estrumate[®], Coopers, Burgwedel, W. Germany) 13 days apart at a dose rate of 125 μ g per animal. Bucks were introduced 24 h after the second administration and left with the does for 4 weeks to facilitate repeat breeding.

Animals that aborted or were not pregnant were withdrawn from the experiment and the remaining does were subdivided into blocks according to their parity and randomly allocated to four different treatment groups 4 weeks before parturition:

1. Basal diet and infected (BI) = 10 animals.
2. Basal diet and uninfected (BC) = 8 animals.
3. Supplemented and infected (SI) = 11 animals.
4. Supplemented and uninfected (SC) = 9 animals.

Artificial trypanosome infection took place 1 week after kidding in order to avoid risk of abortion or early kidding. Assigned animals were infected intravenously with 1 ml of blood containing approximately 10⁵ trypanosomes derived from a cloned stabilate of *T. congolense* (ITC 84). Interactions between experimental infection, parity and nutrition on milk yield were studied.

Blood samples were taken three times a week for the first 2 weeks and thereafter once a week until the end of the experiment (16 weeks post-infection). Packed cell volume (PCV) was determined and parasitaemia was assessed by the dark ground (DG) method (Murray et al., 1977) and scored according to Paris et al. (1982). Blood samples were taken once a week in EDTA tubes for biochemical examination. The parameters that were measured were albumin, total protein (TP), urea, glucose and cholesterol using a Vitros 750 XRC series analyser (Vitros, Ortho-clinical Diagnostics, Inc., USA).

Data on the weights of does and offspring were collected weekly. Following kidding, does were milked morning and evening one day per week from 10 to 100 days post-kidding. For this purpose, offspring were separated from their does the night before.

Rectal temperatures were taken 4 and 2 weeks before kidding, then three times a week for the first 2 weeks after infection, twice a week for the third week and then once weekly until week 7 post-infection.

2.2. Diet

Experimental diets were initiated 3 weeks before parturition. Animals on the basal diet received a ration of groundnut hay (96 g of crude protein and 8.6 MJ of metabolisable energy per animal per day), which covered their maintenance requirement and 50% of their lactating requirement (McDonald et al., 1978). Animals in the supplemented group received a ration of cottonseed, rice bran and groundnut hay (190 g of crude protein and 15 MJ of metabolisable energy per animal, per day), which covered 123% of their maintenance and lactating requirements. During the experimental period, there was no refusal in the basal diet groups. In the supplemented group, there were some refusals of rice bran and groundnut hay and, taking into account the daily intake, the ingested ration provided 159 g of CP and 11.0 MJ of ME to the supplemented/infected does covering 103% CP and 91% ME requirements for maintenance and lactation. The ingested ration by the supplemented/uninfected does (163.8 g of CP and 11.7 MJ of ME) covered 106% CP and 96.7% ME requirements for maintenance and lactation.

2.3. Statistical analysis

Statistical analyses were carried out using SAS[®] (SAS Institute, 2000) procedures. Packed cell volume, rectal temperature, parasitaemia and biochemical parameters were analysed using a general linear model (GLM procedure) as repeated measurements using a mixed model. The model included the following main effects: infection (control versus infected), diet (basal versus supplemented), block, period (period 1 = pre-infection = week – 1; period 2 = acute: weeks 0–5; period 3 = post-acute weeks 6–15), animal (nested within infection, diet and block), interactions infection × diet, period × diet, period × diet × infection. The animal effect was considered as random.

Parameters such as milk off-take, lactation length, daily weight gain (doe and offspring), and birth-weight were analysed in a similar model but without the animal effect. Lactation was considered to be terminated whenever does died or were treated due to the infection. Milk yield was calculated according to the test interval method (TIM) of the International Committee for Animal Recording (ICAR, 2001).

For the analysis of the offspring daily weight gain, the effect of the survival status of the doe was also tested. In this case, the infection effect was omitted. This gives four categories of offspring:

1. Offspring born from control does which survived throughout the experiment.
2. Offspring born from infected does which survived throughout the experiment.
3. Offspring of does which exited in the second month following infection.
4. Offspring of does which exited in the third month following trypanosome infection.

3. Results

3.1. Rectal temperature, parasitaemia and packed cell volume

During the experiment, infected animals had a significantly higher mean rectal temperature than the controls (38.96 ± 0.05 °C versus 38.11 ± 0.04 °C, $P < 0.0001$).

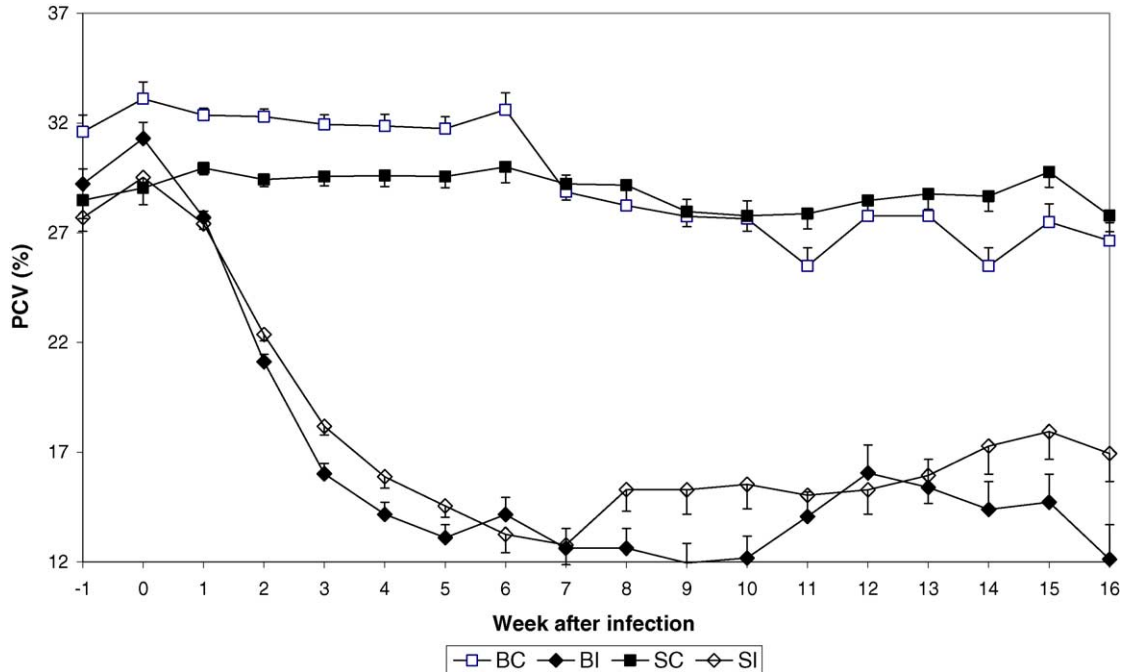


Fig. 1. Weekly mean packed cell volume (%) of trypanosome-infected does (I) and their uninfected controls (C) receiving basal diet (B) or supplement (S).

Trypanosome parasitaemia tended to be higher in the supplemented group (score: 2.5 ± 0.1) than in the basal diet group (score: 2.3 ± 0.2) ($P > 0.05$). Multiparous does had a higher parasitaemia (score: 2.6 ± 0.1) than primiparous ones (score: 2.2 ± 0.1) ($P < 0.05$).

Fig. 1 shows the effect of infection and diet on PCV. During the infection period, trypanosome infection caused a significant ($P < 0.0001$) drop in PCV with an average of $30.1 \pm 0.3\%$ for the control group versus $22.2 \pm 0.3\%$ for the infected group.

Average PCV values over the whole infection period dropped with 11.3% in the animals under the restricted diet compared to 7.1% for the supplemented animals (interaction diet \times period: $P < 0.001$). However, the interactions diet \times infection and diet \times infection \times period were not significant and there was no block effect.

From weeks 1 to 12 post-infection, thirteen animals from the infected group were withdrawn from the experiment due to very low PCV, high parasitaemia and clinical signs of trypanosomosis (Table 1). In the first parity group, 2 animals out of 7 were withdrawn

(28.6%) whilst in the higher parity group, 11 out of 14 were withdrawn (78.6%). Among the 13 animals withdrawn, 5 belonged to the basal diet group and 8 to the supplemented group.

3.2. Lactation length, milk off-take

When the experiment was terminated, animals in BC, BI and SI groups were already dry, whilst three out of nine does from the SC group were still giving a daily milk yield above 100 ml. Diet had a significant effect on lactation length (supplemented: 140.3 ± 14.7 days

Table 1

Number of does withdrawn from the experiment according to parity and treatment group

	Parity 1	Parity 5	Total
Basal diet – infected	2 (4)	3 (6)	5
Supplemented – infected	0 (3)	8 (8)	8
Total	2 (7)	11 (14)	13

Numbers in parentheses (*n*) represent the number of experimental animals at the beginning of the experiment.

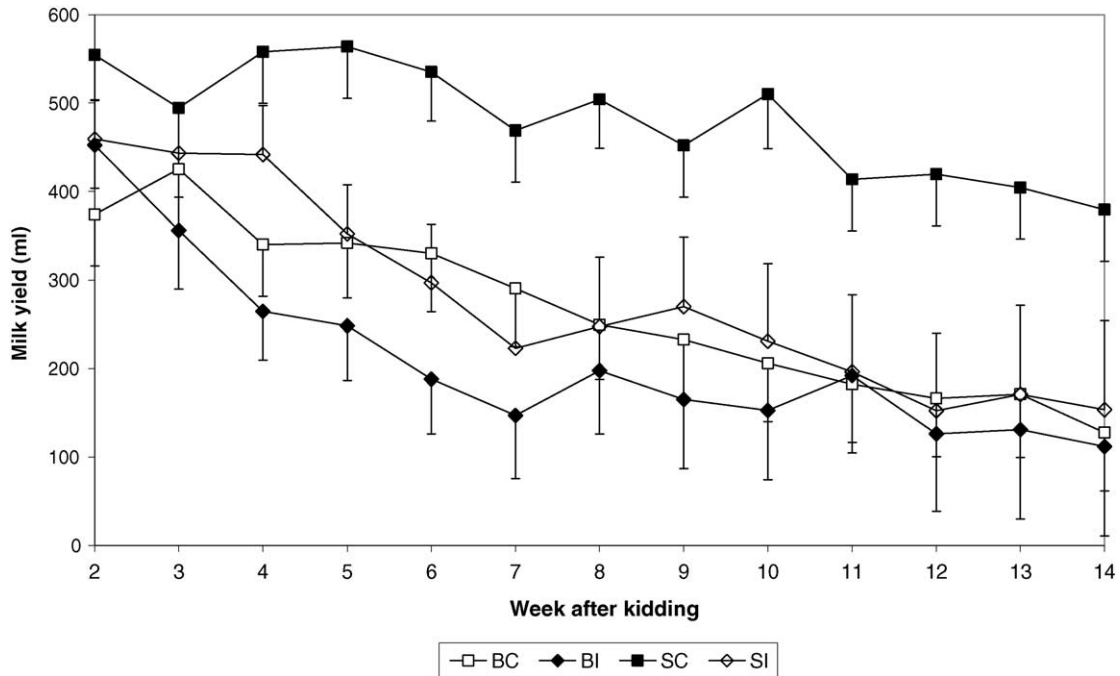


Fig. 2. Weekly milk yield of trypanosome-infected does (I) and their uninfected controls (C) receiving basal diet (B) or supplement (S).

versus basal: 93.6 ± 14.8 days, $P < 0.05$). Trypanosome infection also had a significant effect on lactation length (infected: 73.0 ± 14.1 days versus uninfected: 160.8 ± 15.4 days, $P < 0.01$). Uninfected and supplemented does had a lactation length of 200.6 ± 21.1 whilst uninfected does receiving a basal diet had a lactation length of 121.0 ± 21.6 . However, the interaction between trypanosome infection status and diet was not significant.

The lactation curves of the different experimental groups are shown in Fig. 2. Peak milk off-take was reached in the first 2 weeks of lactation. Milk off-take of trypanosome-infected does was significantly lower than that of the controls (17.5 ± 3.21 versus 35.5 ± 3.21 , respectively, $P < 0.001$).

Regardless of infection, plane of nutrition also affected milk off-take (supplemented: 32.8 ± 3.21 versus basal diet: 20.2 ± 3.51 , $P = 0.01$). Declining mean milk off-take (from kidding to 100 days lactation) due to infection was more severe in the supplemented group (control: 46.7 ± 4.71 versus infected: 18.9 ± 4.21) than in the group receiving a basal diet (control: 24.2 ± 5.01 versus infected: 16.1 ± 4.71)

(interaction infection \times diet, $P = 0.04$). Regardless of treatment, milk off-take of first parity does was significantly lower than of fifth parity does (21.7 ± 3.91 versus 31.3 ± 2.91 , respectively, $P < 0.05$). On average, morning and evening milk yield accounted for 2/3 and 1/3 of the daily milk yield, respectively.

3.3. Live-weight

During the post-partum period, all does lost weight whether they were infected or not, supplemented or receiving a basal diet. The effect of infection on daily weight gain was significant during the first 4 weeks of the lactation period (control: -45.0 ± 15.0 g/day and infected: -97.0 ± 14.0 g/day, $P = 0.015$), approached significance during the second month (control: -17.5 ± 11.0 g/day and infected: -51.6 ± 13.5 g/day, $P = 0.06$) and was not significant during the third month of lactation. Although animals on the basal diet lost more weight than supplemented ones throughout the experiment, the effect of diet on live-weight was more noticeable during the first 4 weeks of lactation but did not reach statistical significance (supplemented:

–52.7 ± 14.4 g/day and basal: –89.2 ± 15.4 g/day, $P=0.08$). Neither was the interaction diet × infection significant. Regardless of treatment, weight loss was more pronounced in high parity animals than in primiparous does, but only during the first 4 weeks of lactation (–126.1 ± 12.3 g/day versus –15.8 ± 18.0 g/day, respectively, $P < 0.0001$).

3.4. Offspring performance

Seventy-nine (79%) percent of the high parity does had twins compared to 33.3% of the first parity does. Kids born single had higher birth-weights (mean: 2.0 ± 0.1 kg) than twins (mean: 1.5 ± 0.1 kg) ($P < 0.01$). Kids born from high parity does tended to have heavier birth-weights (1.9 ± 0.1 kg) than kids born from low parity does (1.6 ± 0.1 kg) ($P = 0.08$). Neither diet nor sex influenced kid birth-weight.

Offspring born from does that died between the fourth and eighth week of trypanosome infection had a lower daily weight gain than the offspring of does which survived (Table 2). From birth to the age of 4 weeks, offspring of does, which subsequently died had a lower daily weight gain (although not significant) than offspring whose mother survived.

From birth to 4 weeks, kids from supplemented does tended to have a higher daily weight gain than those from unsupplemented does (48.8 ± 12.2 g versus 35.2 ± 11.9 g, respectively, $P = 0.06$). From 8 to 12 weeks, a significant effect of maternal plane of nutrition on daily weight gain of kids was only observed in the control groups (interaction diet × infection, $P = 0.03$). Kids from supplemented does grew faster than those from unsupplemented does (35.9 ± 9.1 g versus 17.2 ± 9.0 g).

Kids born single had a significantly higher daily weight gain than twins but only during their first 4 weeks (54.9 ± 12.8 g versus 29.2 ± 11.9 g, respectively, $P < 0.01$). Kids born from high parity does also had a significantly higher daily weight gain than those born from first parity does during their first 4 weeks of life (53.8 ± 11.1 g versus 30.8 ± 13.2 g, respectively, $P < 0.05$).

3.5. Biochemical analysis

3.5.1. Total plasma protein

Trypanosome infection reduced total protein concentration with a least squares mean of 71.8 ± 0.5 g/l versus 75.5 ± 0.5 g/l for the control group ($P < 0.01$). Supplemented does had a higher total protein level than animals receiving a basal diet (75.9 ± 0.5 g/l versus 71.5 ± 0.4 g/l, $P < 0.01$). The interaction between diet and infection was not significant.

3.5.2. Plasma albumin concentration

Trypanosome infection caused a decline in the plasma albumin concentration with a least squares mean of 30.1 ± 0.3 g/l for the control group versus 26.1 ± 0.3 g/l for the infected animals ($P < 0.0001$). There was also a positive effect of diet with 29.5 ± 0.3 g/l for supplemented group versus 26.7 ± 0.3 g/l for the basal diet group ($P < 0.001$). The interaction between diet and infection was not significant.

3.5.3. Plasma glucose concentration

Overall, neither infection nor diet significantly influenced plasma glucose concentration (PGC). However, there was a significant interaction between

Table 2

Offspring daily weight gain (g/day) according to the survival status of their does throughout the experiment (survived, exited in the second or third month of infection)

	Age of the offspring		
	0–4 Weeks	5–8 Weeks	9–12 Weeks
Control does survived	54.8 ± 10.6 ^a	43.1 ± 5.1 ^b	39.4 ± 4.9 ^f
Infected does survived	61.3 ± 10.3 ^a	56.1 ± 8.6 ^c	43.8 ± 7.7 ^g
Infected does exited in the 2nd month	38.3 ± 11.8 ^a	24.8 ± 7.4 ^d	14.5 ± 6.7 ^h
Infected does exited in the 3rd month	36.2 ± 14.6 ^a	31.2 ± 9.8 ^e	30.6 ± 8.8 ⁱ

^aNot statistically different. ^bStatistically different from ^d($P = 0.03$). ^cStatistically different from ^d($P < 0.01$). ^eNot statistically different from ^e($P = 0.06$). ^fStatistically different from ^h($P < 0.01$). ^gStatistically different from ^h($P < 0.01$). ^{f-h}Not statistically different from ⁱ($P > 0.05$).

infection and period with infected does having a significantly higher PGC than controls during the chronic phase of the infection (56.0 ± 1.2 mg/dl versus 50.6 ± 0.9 mg/dl, respectively, $P=0.02$). Five out of eleven adult goats (45.4%) that were withdrawn from the experiment during the acute phase of the infection had a very low glucose level between 10 and 16 mg/dl at the time of exit.

3.5.4. Plasma cholesterol concentration

There was a significant decline of plasma cholesterol concentration in infected animals compared to uninfected ones (83.6 ± 1.5 mg/dl versus 112.0 ± 1.6 mg/dl, respectively, $P<0.0001$). Supplementation significantly increased plasma cholesterol concentration (supplemented: 123.2 ± 1.6 mg/dl versus not supplemented: 72.4 ± 1.4 mg/dl). Regardless of infection, fifth parity does also had a higher cholesterol concentration than primiparous ones (108.6 ± 1.3 mg/dl versus 87.0 ± 1.8 mg/dl, respectively, $P=0.01$).

In infected does, cholesterol concentration was significantly higher in multiparous does than in primiparous ones between week 0 and week 3 post-infection ($P<0.01$). The interaction between diet and infection was not significant.

3.5.5. Plasma urea concentration

Trypanosome infection tended to decrease plasma urea concentration with mean level of 45.6 ± 1.0 mg/dl for controls versus 41.5 ± 0.9 mg/dl for infected group ($P=0.09$). Plane of nutrition increased plasma urea concentration with 46.1 ± 1.0 mg/dl for the supplemented group versus 40.9 ± 0.9 mg/dl for the basal diet group ($P=0.01$). The interaction between diet and infection was not significant.

4. Discussion

4.1. Trypanotolerance

First parity goats were more able to control parasitaemia and had a higher survival rate than multiparous animals. Given that milk yield and kid performance were better in the multiparous does, the low degree of trypanotolerance of the latter as compared to first parity ones could be due to the age effect or

to the level of production or the combination of these two factors. Indeed, there is generally an age-associated decline in the competence of the immune system vis-à-vis diseases (Albright and Albright, 1994). Concerning trypanosomosis, Osaer et al. (1999) found that ewe lambs developed less severe anaemia than older ewes following *T. congolense* infection. Young calves were also reported to be more resistant to trypanosomosis than adult cattle and Andrianarivo et al. (1996) reported a higher erythropoietic potential in trypanosome-infected young calves. In WAD goats, the results of some experiments carried out by Van Dam (1996) suggested a negative relation between age and dry matter intake (DMI) ratio following trypanosome infection indicating that older animals would suffer more from anorexia during infection. One of the probable explanations was that the pathological signs during trypanosomosis are more pronounced in adult animals, compared to young animals. The DMI ratio was not estimated during our study. However, if we consider the suggestion of Van Dam (1996), a lower DMI in infected adult animals will contrast with their higher requirements. This would mean a higher negative energy balance in this category of animals and could partly explain why, during our study, 45.4% of the adult does (5 out of 11) that were withdrawn from the experiment had a very low glucose level although three out of these five animals were supplemented.

Furthermore, it is known that some stress factors such as inter-current infections or physiological status (pregnancy, lactation) can affect the expression of trypanotolerance. Indeed, Agyemang et al. (1991) found that pregnancy and lactation tended to predispose trypanotolerant N'Dama cows to trypanosome infections and that the interaction between reproductive status and trypanosome infection appeared to affect their ability to maintain PCV levels and body weights. In the present study, multiparous does were more under stress, firstly because 85% of them were suckling twins compared to only 25% of first parity does and secondly they had a higher milk yield.

Over 62% of the does withdrawn from the experiment were supplemented with cottonseed and they also belonged to the oldest sub-set and tended to have the highest parasitaemia. A similar tendency was reported by Katunguka-Rwakishaya et al. (1997) in Ugandan goats supplemented with cottonseed cake. O'Kelly (1984) found that supplementation with whole

cottonseed decreased the resistance of *Bos taurus* cattle to the tick *Boophilus microplus* and resulted in a decrease in the number of lymphocytes. Cottonseed is rich in protein but also in fat and some studies carried out in mice have revealed that diets rich in some poly-unsaturated fatty acids can modulate the immune response, leading to reduction of lymphocyte proliferation, cytokine synthesis and natural killer cell activity (Puertollano et al., 2001; Puertollano et al., 2003). Several studies in humans reviewed by Calder (2001) reported a decrease in immune response following consumption of some poly-unsaturated fatty acids.

The supplementation with cottonseed also led to a higher blood cholesterol and the tendency for a higher parasitaemia in adult does may also be linked to their higher level of cholesterol during the first 2 weeks of infection. Indeed, it was suggested that higher blood cholesterol concentration supports higher parasitaemia due to the fact that cholesterol supports the growth and differentiation of trypanosomes (Katunguka-Rwakishaya et al., 1993).

Regardless of infection, young does had a low level of cholesterol and none of those which were infected and supplemented were withdrawn contrasting with results obtained in adults does. On the other hand, two out of four young does under restricted diet were withdrawn. This might mean that the primiparous does under a restricted diet were unable to meet their requirements for growth, lactation and fever generated by the infection leading to stress that exacerbated the course of the infection.

4.2. Doe's live-weight

Feeding of lactating goats is more critical during the first 4 weeks of lactation, the period covering the peak lactation, when there is an increased requirement whilst the intake although increasing is still low (Jarrige, 1988). This could explain the weight loss often noted in lactating animals resulting from a mobilisation of body reserves following the negative energy balance due to the discrepancy between intake and requirements. The higher weight loss in multiparous does during the first 4 weeks of lactation suggests that goats with a higher milk yield tend to use their adipose reserves more extensively to satisfy the energy requirements for milk production.

During the post-partum period, weight loss was significantly higher in trypanosome-infected does than in uninfected controls. Weight loss is a feature of trypanosomosis and has been explained by the decline in dry matter intake and catabolisation of body reserves to meet the increased requirements for maintenance (Verstegen et al., 1991). The effect of the infection on live-weight was only significant during the acute phase and could indicate that the infected animals were able to control the negative effect of the infection during the chronic period. Another explanation could be that following infection, a selection pressure during the acute phase resulted in most susceptible animals being withdrawn from the study whereas the more trypanotolerant ones remained.

4.3. Milk off-take and offspring performance

Infected does had a shorter lactation length than uninfected ones. The lactation length was also shorter in does under basal diet. A shorter lactation length was also reported in naturally trypanosome-infected N'Dama cows that calved in late dry season (Fall et al., 1999). At farm level, an average lactation length of 127.2 days was reported (Jaitner, 2001, personal communication) and this is similar to what was observed during our study in uninfected does receiving a basal diet. The course of the infection was more severe in supplemented and infected does compared to their control counterparts. Indeed, over 62% of the exit animals were supplemented and infected and they were from the high milk producers (parity 5). This explains the great difference in milk off-take between infected and control animals in this group. It also explains the fact that no difference on milk off-take was found when the supplemented and infected group was compared with the basal and infected group. A negative effect of trypanosomosis on milk yield has been reported in dwarf ewes during late lactation (Akinbamijo et al., 1994) and in N'Dama cows (Agyemang et al., 1990; Bennison, 1997).

Whereas the plane of nutrition did not significantly affect live-weight of does, it significantly increased milk yield, suggesting that when supplemented at a certain level, lactating does tended to maintain milk yield at the expense of live-weight. This is similar to the results of Little et al. (1991) quoted by Bennison (1997) who suggested that this was an example of the

partitioning of nutrients by lactating females primarily towards milk production at the expense of bodyweight regeneration. In contrast, Bennison (1997) found that forage supplements in N'Dama cows were used primarily to control maternal weight rather than increase milk output.

Overall, trypanosome infection had no significant effect on offspring daily weight gain up to 90 days, although milk off-take was affected. This is in agreement with previous studies in sheep (Akinbamiyo et al., 1994; Osaer et al., 1998, 1999). In contrast, Bennison (1997) found a direct negative effect of the infection of the dam on calf live weight. The exit of the infected does had a significant effect on offspring growth rate if it occurred when kids were 8 weeks old. They grew less during that period and the next 4 weeks. If does died during the third month, no significant effect on kid growth rate was recorded. Indeed, kid growth is mainly if not exclusively determined by milk production during the first weeks of life. The sudden weaning following death of their mother was stressful to offspring and the latter had to rely mainly on groundnut hay whilst their digestive system was not well prepared for the assimilation of this type of feed explaining, among others, their poor performance.

4.4. Biochemical changes

Trypanosome infection significantly reduced total plasma protein, cholesterol and albumin. A significant decline in plasma TP and albumin was also reported by Katunguka-Rwakishaya et al. (1999) and Osaer et al. (2000). Akinbamiyo et al. (1992) reported an increase in TP during the last period of the infection in WAD goats and this was attributed to a probable rise in gamma globulin concentration. An increase of serum total protein mainly due to the increase of the gamma globulin fraction was also reported by Van Dam (1996) in West African Dwarf goats and this was linked to the initiation of the immune response. The decline in albumin could also be due to the initiation of the immune response and synthesis of immunoglobulins as well as to a probable haemodilution (Katunguka-Rwakishaya et al., 1992; Anosa and Isoun, 1976). A significantly lower level of albumin has also been reported in *T. evansi*-infected camels whilst no alterations of urea and total protein concentration were noticed (Chaudhary and Iqbal, 2000). During our study, supplemented does

had higher plasma TP and albumin levels than females receiving a basal diet whereas Osaer et al. (2000) found no effect of diet on the plasma concentrations of these parameters. Katunguka-Rwakishaya et al. (1993, 1995) found that protein supplements reduced the rate of decline of albumin post-infection in much the same manner as high energy levels did to plasma total protein. Urea concentration was unaffected by the infection during our study, which is in accordance with the results of Katunguka-Rwakishaya et al. (1999), whilst an increased serum or plasma urea level following trypanosomosis has been reported by Van Dam (1996). Our results tend to suggest, as speculated by Katunguka-Rwakishaya et al. (1999), that trypanosome infection is not associated with excessive protein breakdown. However, a negative relationship was found between energy intake and urea levels (Katunguka-Rwakishaya et al., 1999) suggesting that low level of energy intake can lead to protein breakdown with increased urea levels. The severity of the course of a trypanosome infection and the level of energy of the ration could therefore modulate the plasma urea levels in trypanosome-infected animals and could explain the disparity of the reported results.

Supplementation with cottonseed led to a higher blood cholesterol concentration. This is in line with the results of Belibasakis and Tsirgogianni (1995) who found that supplementation of cows with cottonseed increased the blood concentrations of triglycerides, cholesterol and phospholipids.

In infected goats, blood concentrations of NEFA, β -hydroxybutyrate, glucose and insulin reflect the animals' energy status (Van Dam, 1996). Thus, the glucose level is often decreased in animals with a negative energy balance (Van Dam, 1996 quoting Payne, 1989). During our study, only plasma glucose concentration was measured and it was found to increase in infected animals during the chronic phase of the infection. Van Dam (1996) also reported an increased glucose level in infected WAD goats showing a positive energy balance. However, 45.4% of the does that were withdrawn from the experiment during the acute phase of the infection had a reduction of 68.4–80.2% of their glucose level compared to that of control does at the time of exit. Following trypanosome infection, hypoglycaemia was considered only important in hyperacute infections characterised by enormous numbers of trypanosomes

in the circulation (Katunguka-Rwakishaya et al., 1999 quoting Hudson, 1944).

5. Conclusions

Trypanosome infection significantly affected milk off-take but offspring daily weight gain was only reduced when does died. Does supplemented with cottonseed and rice bran were not able to better withstand the disease than does under basal diet. Trypanosome infection also significantly reduced total plasma protein, cholesterol and albumin. However, there was a positive effect of plane of nutrition on all the biochemical parameters except glucose. Primiparous does appeared to be more resistant than multiparous does to trypanosome infection.

Acknowledgments

This study was carried out with financial support of the Belgian Directorate General for Development Cooperation (DGDC, Brussels). The authors gratefully acknowledge the technical personnel of ITC for their help in various ways. Sofie Albertijn of the Department of Clinical Sciences of the Institute of Tropical Medicine in Antwerp (Belgium) is also gratefully acknowledged for carrying out the biochemical analysis.

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