Animal Science 1999, 68: 819-829

1357-7298/99/84210819$20·00

Effects of nutrition *pre-partum* and *post partum* on subsequent productivity and health of N'Dama cows infected with *Trypanosoma congolense*

J. J. Bennison[1]†, O. O. Akinbamijo[2], J. Jaitner[2], L. Dempfle[2], C. R. C. Hendy[1] and J. D. Leaver[3]

[1]*Natural Resources Institute (NRI), Central Avenue, Chatham Maritime, Chatham, Kent ME4 4TB*
[2]*International Trypanotolerance Centre (ITC), PMB 14, Banjul, The Gambia*
[3]*Wye College, University of London, Wye, Ashford, Kent TN25 5AH*

Abstract

This experiment studied the effects of body condition, long- and short-term levels of nutrition and trypanosomosis infection on the productivity of N'Dama cows using a 2 × 2 × 2 factorial cross-over design. Pre-partum, *23 cows received supplements for 6 months (H), the other group of 20 for 2 months (L). Both groups grazed native pastures. Two days* post partum, *half the cows from each group were placed on a basal (B) or supplemented (S) plane of nutrition. The diet of concentrate, groundnut hay and andropogon hay was the same, only the quantities differed. Four weeks* post partum *half the animals in each group were inoculated with* T. congolense *organisms (I), the others acted as controls (C). The trial continued for a further 6 weeks.*
Pre-partum *nutrition (H, L had no effect on dry-matter intake (DMI) but* pre-partum *feeding (H) improved* post-partum *productivity, evident by higher dam live weights ($P < 0·05$), body condition ($P < 0·001$), calf birth weight ($P < 0·05$) and calf live-weight gain ($P < 0·01$).* Post-partum *nutrition had no effect on productivity. Trypanosomosis infection caused a reduction ($P < 0·05$) in total DMI. The decline in groundnut hay and concentrate intake was proportionally ($P < 0·001$) greater in the S-I group than in the B-I group. A low plane of nutrition* pre-partum *depressed milk yield but increased fat concentration ($P < 0·05$). Infection significantly reduced milk offtake ($P < 0·05$). The reduction in milk offtake ($P < 0·01$) and calf live weight ($P < 0·05$) were proportionally larger in the B-I than in the S-I group. Infection caused a decline in milk protein concentration ($P < 0·05$) and protein yield ($P < 0·01$) which was independent of dietary effects. Infection reduced ($P < 0·01$) the packed-cell volume but there were no interactions with diet. None of the cows was pregnant 150 days* post partum *but seven were cycling, 3(5) in the H-S-I group, 2(7) in the H-B-I group, 1(5) in the L-B-I group and 1(5) in the L-S-C group. These results suggest that S-I cows attempted to maintain milk yield at the expense of live weight whereas the B-I cows had insufficient live-weight reserves that could be mobilized. This suggests the nutritional balance and changes in weight at the time of infection might be more important than historical planes of nutrition.*

Keywords: *cattle, N'Dama, nutrition, productivity,* Trypanosoma congolense.

Introduction

While there is clear evidence that improved nutrition increases the ability of cattle to tolerate trypanosomosis infection through the control of anaemia, both from on-station trials (Little *et al.*, 1990; Romney *et al.*, 1997) and field observations (Agyemang *et al.*, 1990b), the responses in trials to short-term nutritional interventions and infection appear to be dependent, in part, on initial live weight (or body condition) of animals. Using rate of packed cell volume (PCV) decline as an indicator, Little *et al.* (1990) found that the initial acute phase response was more severe in N'Dama bulls in a better body condition.

Field studies with the N'Dama have also investigated the impact of trypanosomosis infection on components of cattle productivity, especially milk yield and reproductive performance. Agyemang *et al.*

† Present address: Agrimin Ltd, The Flarepath, Elsham Wold Industrial Estate, Brigg, North Lincs, DN20 0SP.

(1990a) noted marked effects of infection on milk yield. Mael *et al.* (1988) concluded that infection reduced milk production because calves suckling parasitaemic cows had lower pre-weaning growth rates and reduced weaning weights. Agyemang *et al.* (1993) found independent and additive effects of infection and weight change *post partum* on subsequent calving intervals.

One of the major constraints to the improvement of reproductive efficiency in N'Dama cows is the duration and variability in the length of the post-partum anoestrous period. In temperate *B. taurus* cattle breeds, while suckling has an inhibitory effect on the return to cyclicity, the dominant factors affecting calving interval are peri-parturient weight change and body condition which in turn reflect pre-partum levels of feeding (Wright *et al.*, 1992). With *B. indicus* suckling cows weaning has a greater effect on the duration of the post-partum anoestrous period than supplementary feeding (Moore and da Rocha, 1983; McSweeney *et al.*, 1993). There is even less information for tropical *B. taurus* breeds such as the N'Dama. A field study by Agyemang *et al.* (1991) provides the only indication of the independent effects of live weight and live-weight change, suggesting that cows which conceived within 12 months *post partum* showed either rising or high live weight in the 3 months prior to conception.

These observations suggest that milk production, reproductive responses and the control of infection are all associated with both current live weight and short-term live-weight change. Thus, it may be possible to develop a concept of target live weights at different seasons, levels of tsetse challenge, and/or physiological status, with required short-term supplementary feeding interventions to promote productivity when there is trypanosomosis challenge.

The objective of this experiment was to isolate the effects of body condition, long- and short-term levels of nutrition and trypanosomosis infection on the productivity and subsequent reproductive performance of N'Dama cows.

Material and methods

Treatments and animals

In order to investigate the effects of both pre-partum and post-partum feeding and infection on productivity, a 2^3 factorial cross-over design was adopted. In mid November 1994 the oestrous cycles of over 120 N'Dama cows were synchronized using norgestomet and oestradiol valerate (Intervet UK Ltd). They were then artificially inseminated with Jersey or Holstein semen imported from New Zealand. In February 1995, in the mid-dry season, 56 pregnant cows (including nine heifers) were selected from the original group for the trial. Twenty-nine cows received supplementary food (H) for a 6-month period in the dry season to maintain weight and body condition, whilst the other group of 27 only received supplements (L) in the final 2 months of gestation. Both groups grazed daily on poor quality native pasture. This ensured that two groups of animals had different live weights and condition scores by calving in late August/early September 1995 early in the rainy season. The animals continued to graze until calving.

Two days *post partum* half of the cows from each group were placed on either a basal (B) or supplemented (S) plane of nutrition. In order to assess the effect of trypanosomosis on milk yield, half the animals in each group were then inoculated intradermally 4 weeks *post partum* with at least 1×10^4 trypanosomes using the *T. congolense* clone known as ITC 84 (I). The remainder were retained as un-infected controls (C). The trial continued for a further 6 weeks.

As calving was spread over 4 weeks the experimental animals were allocated to two blocks to ensure each animal was subjected to the treatments at a similar stage of its lactation. The post-partum feeding part of the trial was divided into three separate periods with each block following the same sequence:

Period	Weeks *post partum*	Health status
1	3 and 4	Pre-infection
2	5 and 6	Pre-patent
3	7 - 10	Post-infection

The data from weeks 1 and 2 *post partum* were discarded as this was assumed to be a diet adaptation period.

In traditional Gambian cattle herds, a proportion of the milk is extracted for human consumption in addition to allowing the calf to suck the dam. A similar practice was adopted in this trial. The cows were milked once a day at 08.00 h, after overnight separation from their calves. The calves sucked twice a day, once to stimulate let-down prior to milking and after milking, and again at 15.00 h. The herdsmen were allowed to use their experience as to the amount of milk extracted from each cow. If the yield was deemed to be inadequate by the herdsmen, all the milk was left for the calf.

A total of 13 animals of the original 56 were withdrawn from the experiment, nine that calved outside a 4-week period; one with a naturally acquired trypanosomosis infection; two with twins;

and one with an N'Dama calf. The following is a summary of the main treatments and the numbers of animals finally used in each subclass of the trial (period 1):

Pre-partum feeding	Post-partum feeding	Infection (4 weeks *post partum*)	
H(23)	B(12)	I(7)	C(5)
	S(11)	I(6)	C(5)
L(20)	B(10)	I(5)	C(5)
	S(10)	I(5)	C(5)

Diets and feeding

Pre-partum. Between February and June (3 to 7 months post conception) all animals grazed native grasslands and crop aftermath on a stretch of salt-flats and rice fields, savannah woodland and large areas of cultivated and fallow croplands in the Bondali district. The H group were offered individually 0·94 kg dry matter (DM) per day of concentrate containing groundnut cake and rice bran in the ratio of 1 : 4 and 0·93 kg DM per day of groundnut hay. The foods were offered in the morning before the animals were released for grazing. The L group had access only to grazing. In the final 2 months of pregnancy (July and August) the cattle were moved to ITC headquarters on the coast where the grazing consisted predominantly of crop residues and short-term bush fallows. To compensate for the lack of fodder, the H group received 4·7 kg DM per day of the concentrate whilst the L group received 1·4 kg DM per day.

Post partum. All animals were individually stall-fed. The ratios of foods offered to cows in the basal (B) and supplemented (S) groups were the same, only the quantity differed. The S group were offered 2418 g DM per day of groundnut hay, 1860 g DM per day of andropogon hay and 2350 g DM per day of concentrate consisting of equal parts (1 : 1) of groundnut cake and rice bran. The B group were offered 1953 g DM per day of groundnut hay, 1488 g DM per day of andropogon hay and 1880 g DM per day of concentrate. The amount of andropogon hay offered was based on the assumption that proportionately 0·7 would be consumed and 0·3 of the poorer quality stem fraction rejected. This was determined from previous trials at ITC where cattle were offered andropogon hay *ad libitum*. The foods were offered in the morning, during milking, with first the concentrate followed by the groundnut hay and then the chopped andropogon hay. The refusals of the andropogon were collected at 16.00 h.

The diets were devised so that the amount offered to the B group was estimated to be equivalent to 1·10 of the daily metabolizable energy (ME) requirement for maintenance and lactation based on a 230 kg animal producing 2·5 l of milk per day (records from ITC indicate that the average daily milk yield in the first 100 days of lactation is 2·3 l/day). Cows in the S group were offered the equivalent of 1·38 of the estimated daily ME requirement for maintenance and lactation. The crude protein (CP) content of both diets was approximately 135 g/kg DM. Each cow received 12 g of local sea salt per day in the concentrate. Water was offered at 11.00 h and 15.00 h.

Management and health

Post partum, the cows were dosed orally with a broad-spectrum anthelmintic, 10% fenbendazole (Panacur, Hoechst) at 7·5 ml per 100 kg live weight; and every 2 weeks, to the end of the trial 1% flumethrin pour-on (Bayticol; Bayer) was used to eliminate tick infection and reduce the chances of a possible natural trypanosome infection by tsetse or tabanid flies. One C animal was recorded as positive for trypanosomosis and withdrawn from the trial. As two of the calves voided *Toxocara vitulorum* immediately after birth, all calves were dosed with 10% fenbendazole at birth and at 3 weeks of age.

All infected cows were treated with 7·0 mg/kg body weight diminazene aceturate (Berenil, Hoechst) at the end of the trial. Cows were withdrawn prematurely and treated with Berenil, if their blood PCV fell below 15%.

Measurements and observations

Food intake and refusal. Voluntary DM intake (DMI) was recorded daily by weighing food offered and refused. Sub-samples from the food offered and refused were taken daily, pooled over a 7-day period, dried in an oven at 60°C until constant weight, ground through a 1-mm screen and stored for analysis.

Analysis of food samples. The following determinations were made on the weekly pooled samples of food offered and refused: DM; organic matter (OM); nitrogen using the Kjeldahl method; neutral-detergent fibre (NDF); acid-detergent fibre (ADF) using the methods of Van Soest (1982).

Water intake. Voluntary water intake was recorded daily throughout the trial by measuring, to the nearest 0·5 l, the amount drunk from a bucket. Water intake was expressed relative to voluntary DMI (g/g DMI).

Haematological measurements. Blood samples were collected weekly with ethylene diamine tetra-acetic acid coated vacutainers. The samples were examined by the buffy-coat dark ground/phase parasitological technique (Murray *et al*., 1977) to detect presence of trypanosomes and quantify the intensity of infection as a parasitaemia score (DG). The PCVs were determined using the standard microhaematocrit technique. The plasma was separated and stored for subsequent progesterone analysis.

Live weight and condition score. Weekly records were maintained of cow body weights to the nearest kg, the calves were also weighed on a weekly basis to the nearest 0·5 kg.

The condition scores of the cows were recorded on a weekly basis to the nearest half unit based on a five-point scale adapted for N'Dama cattle from scales devised by Pullen (1978) and Richards *et al.* (1986) where a score of 1 is thin and 5 obese.

Milk yield and composition. Milk yields (ml) were measured daily and the concentration of milk fat and protein analysed twice weekly using the Gerber and Formol titration tests. An estimate of the daily milk fat and protein yield (g) was calculated by multiplying concentration with average milk yield. However, it should be noted that this represents yield from the fore-milk that in traditional systems is withdrawn for human consumption.

Reproduction. The resumption of ovarian activity *ca.* 150 days *post partum* was monitored using progesterone profiles in plasma. The assay used was a double antibody technique. A microtitre plate was coated with affinity isolated Anti-Rat IgG (Sigma, R5130). Into each well, 20 µl of plasma samples, progesterone standards or controls were dispensed and 100 µl of an anti-progesterone antibody (Monoclonal Antibody 2H4 Sigma, P1922). The plate was then covered and incubated at room temperature in the dark for 2 h. After decanting the plate and washing four times, a 150 µl of enzyme labelled progesterone (supplied by Weihenstephan, Germany) was added and incubated for a further 20 min in the dark. The substrate reaction was stopped by adding 50 µl of 2 mol/l sulphuric acid. The optical density was then measured at 450 nm with an automatic microtiter plate reader (a high optical density indicates the sample has a low progesterone concentration). The values were then plotted against a curve derived from the standards to give an estimate of the progesterone concentration (µg/l). The results were then corrected using a factor (F) that is based on the difference between the observed and known values of the controls. Progesterone values within the range of 4 to 8 µg/l indicates the animal is either pregnant (if consistently high) or in the luteal phase.

Statistical analysis

The data were analysed using the GLM procedure of the Statistical Analysis Systems Institute (1994) whereby:

$$Y_{ijklmn} = \text{period}_i + \text{block}_j + \text{diet } \textit{pre-partum}_k + \text{diet } \textit{post partum}_l + \text{health status}_m + \text{animal (block} \times \text{diet pre} \times \text{diet post} \times \text{health status})_{njklm} + e_{ijklmn}$$

Animal (nested within block, diet *pre-* and *post partum* and health status) was regarded as random and the other variables as fixed. The interactions between experimental period, diet and health status were tested.

The results presented for food intake and cow productivity are least squares means. The accompanying standard errors are based on the MS(error) term of the analysis of variance which essentially gives an estimate of within animal variation. Thus, the standard error can only be used for comparing periods within a single treatment. They cannot be used for comparing different treatments (e.g. the s.e. can be used for comparing the least-squares means of the H-C group in periods 1 and 3 but not to compare the H-C group with the L-C group in period 1).

The calf live weight least-square means could not be estimated because animals were withdrawn in period 3. Instead, the actual means and s.e. of the means are presented.

A separate analysis was used for the DG scores in periods 2 and 3. The values from each week were summarized as one observation per animal in each period. The analysis of variance then tested the main effects of diet, infection and the interaction between diet and infection.

Results

Food intake, live weight and condition score

Table 1 presents treatment least-square means of food intake, PCV and live-weight change of cows and calves.

Food intake. Pre-partum nutrition (H, L) had no significant effect on total DMI or on intake of the separate components of the diet in any post-partum period. Consequently, the results presented refer solely to the post-partum diet. As planned, there was a significant ($P < 0{\cdot}001$) difference in the daily DMI between the two post-partum diets. In period 1, the mean daily DMI of the S-C and the S-I groups were 6035 (s.e. 102) g/day DM and 6016 (s.e. 91) g/day DM while intakes in the B-C and B-I groups were 5052 (s.e. 98) g/day DM and 5119 (s.e. 88) g/day DM, respectively. The difference in DMI between the B and S groups in period 1 was predominantly due to the animals consuming all of the groundnut hay and concentrate offered. There was no significant difference in andropogon hay intake, despite the

Table 1 *Individual dietary treatment and* T. congolense *infection effects on food intake, PCV and live-weight change (standard errors given*

	H-C	H-I	L-C	L-I	S-C	S-I	B-C	B-I	Significance of main effects: Diet *pre-partum*	Diet *post partum*	Infection
Live [illegible]ght period 1 (kg)	227 (1·0)	219 (0·8)	209 (0·9)	207 (0·9)	225 (1·0)	216 (0·9)	211 (0·9)	211 (0·9)			
Live weight period 3 (kg)	226 (0·8)	211 (0·6)	210 (0·7)	204 (0·7)	227 (0·7)	210 (0·7)	209 (0·7)	206 (0·7)			
Condition score period 1	2·3 (0·07)	2·3 (0·06)	1·7 (0·06)	1·7 (0·07)	2·2 (0·07)	2·2 (0·06)	1·8 (0·07)	1·7 (0·06)			
Condition score period 3	2·5 (0·05)	2·0 (0·04)	1·9 (0·05)	1·6 (0·05)	2·3 (0·1)	1·9 (0·1)	2·0 (0·05)	1·6 (0·05)			
Daily dry-matter intake (DMI) (g DM) period 3											
[illegible]ut hay					2365 (27)	1869 (26)	1940 (27)	1895 (25)		***	
Andropogon hay					1644 (28)	1121 (27)	1382 (27)	1101 (26)			
Concentrate					2248 (34)	1827 (32)	1877 (34)	1832 (32)		**	
Total DMI					6257 (74)	4817 (20)	5199 (72)	4827 (68)		***	
Calf live weight (kg) period 1	23·4 (0·6)	23·0 (0·9)	21·6 (0·9)	21·0 (0·9)	22·5 (0·8)	21·8 (1·0)	22·8 (0·8)	22·4 (1·0)	**		
Calf live weight (kg) period 3	28·3 (0·7)	25·4 (1·2)	24·1 (1·3)	22·5 (1·3)	26·4 (1·0)	24·4 (1·3)	26·5 (1·3)	23·9 (1·3)			
PCV (%) period 1	30·4 (0·8)	29·5 (0·6)	27·8 (0·7)	27·0 (0·7)	29·7 (0·8)	28·0 (0·7)	28·5 (0·7)	28·5 (0·7)	**		
PCV (%) period 3	29·9 (0·6)	24·0 (0·5)	27·9 (0·5)	22·6 (0·6)	29·1 (0·6)	23·1 (0·5)	28·8 (0·5)	23·5 (0·5)			**

P[illegible] 1 refers to the pre-infection period, weeks 3 and 4 and period 3 refers to the post-infection period weeks 7 to 10.
F[illegible] significant [illegible]

different amounts offered each day because the B groups consumed a greater proportion of the poor quality stem fraction in an attempt to compensate for the restricted ration offered. Using the pre-infection period 1 as an example again, the B groups consumed 0·85 of the andropogon hay offered whereas the S groups consumed 0·75. The CP and NDF content of the andropogon offered and refused was 38 g/kg DM *v.* 20 g/kg DM and 764 g/kg DM *v.* 860 g/kg DM respectively.

Trypanosomosis infection caused a significant ($P < 0{\cdot}05$) overall reduction in total DMI post infection (period 3). There were also highly significant interactions ($P < 0{\cdot}001$) between period, diet and infection particularly with regard to the changes in groundnut hay and concentrate intake. Between periods 1 and 3, the relative decline in andropogon hay intake was similar for both the B-I and the S-I groups. However, the decline in intake of groundnut hay and concentrate was proportionally ($P < 0{\cdot}001$) greater in the S-I group. This resulted in similar levels of intake between the two infected groups in period 3 although differing amounts were offered (see Table 1).

Mean daily water intake relative to DMI, varied significantly between periods 1 and 2 and between periods 2 and 3 (4·3 (s.e. 0·07) g/g DMI; 3·98 (s.e. 0·07) g/g DMI; 4·3 (s.e. 0·05) g/g DMI). There were no direct or interaction effects of diet and infection on water intake.

Live weight. The overall mean live weight of the herd was 248 (s.e. 5) kg in mid pregnancy and immediately *post partum* (period 1), 215 (s.e. 0·5) kg. Pre-partum nutrition had a significant ($P < 0{\cdot}05$) effect on live weight which continued throughout the experimental period.

Neither post-partum nutrition nor infection had significant effects on live weight, although lower weights occurred with animals on the basal diet and with those infected with trypanosomosis. However, the relative change in live weight between periods 1 and 3 was affected by a significant ($P < 0{\cdot}05$) interaction between the diets *pre-partum* and *post partum*. Live-weight losses in the B groups were similar, irrespective of the diet *pre-partum*. However, the relative change in live weight in the S animals *post partum* varied according to their *pre-partum* plane of nutrition. Cows on the H plane of nutrition *pre-partum* tended to lose weight, whereas those that received a L level either maintained or slightly increased their weight.

Trypanosomosis had no direct effect on live weight although there was a significant interaction ($P < 0{\cdot}01$)

Table 2 *Individual dietary treatment and T. congolense infection effects on milk offtake and composition (standard errors given in parenthesis)*

	Diet *pre-partum*				Diet *post partum*				Significance of main effects		
	H-C	H-I	L-C	L-I	S-C	S-I	B-C	B-I	Diet *pre-partum*	Diet *post partum*	Infection
Milk offtake period 1 (ml)	819 (29)	701 (23)	609 (27)	663 (26)	868 (28)	699 (25)	559 (28)	666 (24)	0·06	0·06	
Milk offtake period 3 (ml)	579 (21)	231 (17)	332 (19)	208 (20)	566 (20)	265 (19)	345 (20)	174 (19)			
Milk fat concentration, period 1 (g/kg)	19·1 (0·1)	20·8 (0·1)	21·1 (0·1)	21·7 (0·1)	21·9 (0·1)	20·6 (0·1)	18·3 (0·1)	21·8 (0·1)			
Milk fat concentration, period 3 (g/kg)	21·8 (0·1)	23·4 (0·1)	25·6 (0·1)	26·9 (0·1)	25·5 (0·1)	23·5 (0·1)	21·9 (0·1)	26·8 (0·1)			
Milk fat yield, period 1 (g/day)	15·7 (1·0)	15·0 (0·8)	12·6 (0·9)	14·3 (0·9)	18·2 (1·0)	14·7 (0·9)	10·1 (1·0)	14·6 (0·8)			
Milk fat yield, period 3 (g/day)	9·8 (0·9)	12·8 (0·7)	8·7 (0·7)	5·8 (0·9)	13·9 (0·7)	7·4 (0·8)	7·6 (0·7)	5·0 (0·8)			
Milk protein concentration, period 1 (g/kg)	30·6 (0·1)	31·0 (0·1)	31·1 (0·1)	29·6 (0·1)	31·1 (0·1)	31·3 (0·1)	30·6 (0·1)	29·3 (0·1)			
Milk protein concentration, period 3 (g/kg)	29·6 (0·1)	27·1 (0·1)	28·6 (0·1)	26·1 (0·1)	30·3 (0·1)	28·0 (0·1)	27·9 (0·1)	25·1 (0·1)			
Milk protein yield, period 1 (g/day)	25·0 (0·9)	21·7 (0·7)	19·0 (0·8)	19·4 (0·8)	26·5 (0·9)	21·6 (0·8)	17·5 (0·9)	19·5 (0·8)			
Milk protein yield, period 3 (g/day)	17·4 (0·7)	7·1 (0·6)	9·6 (0·6)	6·1 (0·8)	17·4 (0·6)	8·5 (0·7)	9·7 (0·6)	4·7 (0·7)			**

Period 1 refers to the pre-infection period weeks 3 and 4 and period 3 refers to the post-infection period weeks 7 to 10.
F ratios significant at * $P < 0·05$; ** $P < 0·01$; *** $P < 0·001$.

between period, post-partum nutrition and infection, caused by a weight gain in the S-C group and a weight loss in the S-I group. There was no significant interaction between pre-partum nutrition and infection but there was a supporting trend for the H-I group to lose relatively more weight.

Condition score. The mean condition score of the herd was 3·5 (s.e. 0·1) in mid pregnancy and immediately *post partum* (period 1) 2·0 (s.e. 0·03). Both pre-partum nutrition and post-partum nutrition had a significant effect (to at least $P < 0·05$) on the condition score of the animals throughout the trial. While the interaction between period, diet *pre-partum* and diet *post partum* just failed to reach statistical significance ($P < 0·06$), the change in condition score supported the observed changes in live weight, i.e. pre-partum nutrition had no influence on condition score in the B group whereas in the S group cows on the H plane of nutrition *pre-partum* tended to lose condition while those on the L plane exhibited no change.

Trypanosomosis infection reduced body condition, but the effect was not significant.

Milk offtake, milk composition and calf live weight
Table 2 summarizes individual treatment least-square means for milk offtake and composition. It should be noted that the results represent samples collected from fore milk and not samples of total yield.

Milk offtake and milk composition. There were non-significant trends ($P < 0·06$) for milk of offtake to be greater in cows given either the H plane of nutrition *pre-partum* or S *post partum*. Infection significantly reduced average daily milk offtake ($P < 0·05$). The interactions between pre-partum and post-partum nutrition and pre-partum nutrition and infection were not statistically significant. However, there was a significant interaction ($P < 0·01$) between post-partum nutrition and infection. The reduction in milk offtake was proportionally larger in the B-I than in the S-I group.

The L *pre-partum* plane of nutrition significantly ($P < 0·05$) increased milk fat concentration but there was no difference in fat yield because the group tended ($P < 0·06$) to produce less milk. The diet *post partum* had no significant effect on milk fat concentration or yield although, during the course of the trial, the concentration of milk fat increased ($P < 0·001$) from 20·7 (s.e. 0·06) g/kg in period 1 to 24·4 (s.e. 0·05) g/kg in period 3. Trypanosomosis infection had no direct effect on fat concentration but interacted with diet *pre-partum* and *post partum*, causing the largest increase ($P < 0·001$) in the L-B-I group (their mean in period 3 was 33·1 (s.e. 0·17) g/kg compared with 23·2 (s.e. 0·17) g/kg in period 1). While the fat concentration increased, the mean daily fat yield declined ($P < 0·001$) from 14·4 (s.e. 0·45) g/day in period 1 to 8·47 (s.e. 0·37) g/day in period 3. Again, trypanosomosis had no direct effect but interacted with diet; the decline being proportionally greater ($P < 0·05$) in the B-I group, with an associated trend ($P < 0·06$) in the H-B-I group.

The changes in milk protein concentration and yield followed a different pattern from milk fat. As the milk yield declined during the course of the study, milk protein concentration also significantly ($P < 0·001$) declined (period 1 = 31 (s.e. 0·1) g/kg; period 3 = 28 (s.e. 0·1) g/kg). This resulted in a significant ($P < 0·001$) reduction in milk protein yield (period 1 = 21·3 (s.e. 0·41) g/day; period 3 = 10·1 (s.e. 0·34) g/day. The yield of milk protein was more sensitive to the dietary changes than milk fat. Improved nutrition significantly ($P < 0·05$) increased milk protein offtake with diet *pre-partum* and *post partum* interacting and the highest protein yields were observed in the H-S group. Infection caused an overall decline in milk protein concentration ($P < 0·05$) and protein yield ($P < 0·01$). There were no interactions between infection and diet on milk protein concentration or yield.

Calf birth weight. The overall mean birth weight of the calves was 19·4 (s.e. 0·56) kg. Male calves weighed significantly ($P < 0·05$) more than females, 20·6 (s.e. 0·89) kg compared with 18·4 (s.e. 0·63) kg. Breed had a significant effect ($P < 0·001$) on birth weight, the Holstein crossbreds being heavier than the Jersey crossbreds, 21·3 (s.e. 0·82) kg and 17·8 (s.e. 0·54) kg respectively. Pre-partum nutrition also had a significant effect ($P < 0·05$) on birth weight. The calves produced by cows on the H level *pre-partum* weighed 20·1 (s.e. 0·78) kg compared with a mean of 18·4 (s.e. 0·68) kg for calves in which the dam received the L level of supplementation.

Calf live weight. Pre-partum nutrition of the dam had a significant ($P < 0·01$) effect on calf live weight throughout the experiment, whilst diet *post partum* had no significant effect. Infection of the dam had a negative effect ($P < 0·05$) on calf live weight. There was also a significant ($P < 0·05$) interaction between period, diet *pre-partum* and infection, where the adverse effects of trypanosomosis were greater in the H-I group. Conversely, the significant ($P < 0·05$) interaction between period, diet *post partum* and infection demonstrated that effects of infection in the dam on calf live weights were proportional greater in the group given the B diet. Breed had no significant effect on live-weight gain.

Progesterone profiles

None of the cows was pregnant but seven cows appeared to be cycling, the remaining 35 were anoestrus. Of the seven cycling cows, three (5) were in the H-S-I group, two (7) in the H-B-I group, one (5) in the L-B-I group and one (5) in the L-S-C group. Of these cows, one animal in each group had lost her calf

Herd health

PCV and DG. Pre-partum nutrition had a significant ($P < 0·001$) effect on the PCV throughout the experimental period whilst the diet *post partum* had no significant effect. Infection significantly ($P < 0·01$) reduced the mean PCV but there were no interactions between diet *pre-partum* or *post partum*. The effects of diet and infection on PCV were additive and independent.

The mean DG scores in period 2 (pre-patent) and period 3 were 3·6 (s.e. 0·3) and 2·6 (s.e. 0·3) ($P < 0·05$), respectively. There was no significant effect of diet *pre-partum* or *post partum* on the degree of parasitaemia, nor was there any interaction.

Not all the cows were able to sustain a trypanosomosis challenge. In period 3, five cows were withdrawn and treated with Berenil; one each from the L-B, the H-B and L-S groups and two from the H-S group. A further animal died in the L-S group, although its PCV was 17% at death. Trypanosomosis infection in the dam had a severe effect on the health of the calves, particularly the Holstein crossbreds. In period 3, four of the 12 Holstein cross calves died (one Jersey cross calf from a cow in the L-S-C group also died). They succumbed to a range of ailments including pneumonia and coccidiosis. While anaplasmosis organisms were not detected in a blood smear, post-mortem findings in two animals included an enlarged gall bladder, liver discolouration and an abnormal heart. Furthermore, five calves (three Holstein crosses and two Jersey crosses) from infected cows suffered from diarrhoea but recovered after being injected with Tribrissen 48% (400 mg Sulfadiazin) and rehydrated. Trypanosomes were not detected in the blood of any of the sick calves.

Discussion

The principal objective of this trial was to isolate the effects of body condition, long- and short-term levels of nutrition and trypanosomosis infection on the productivity of N'Dama cows. It should be noted that the cows entered the post-partum experimental phase in a moderate to lean condition, rather lower than had been planned originally. At conception, the cows were in excellent condition with optimum live weights following an intensive period of supplementation during the preceding 6 months prior to oestrous synchronization and artificial insemination. From late-gestation to parturition both the H and L groups lost weight markedly despite supplementation and differential feeding. The main reason for the dramatic fall was the increasingly impoverished grazing around the ITC centre in Kerr Seringe during the mid-to-late dry season which coincided with the final 2 months of pregnancy. Urban expansion, land enclosure and the consequent demand for croplands has considerably reduced the amount of native grasslands and bush fallows for grazing. Supplementation could only partially compensate for this deficit. It is possible that the crossbred calves placed an additional nutritional demand on the dam compared with a purebred N'Dama calf. The average birth weight of an N'Dama calf is 17·5 (s.e. 0.1) kg (Agyemang *et al.*, 1991) compared with 21·7 (s.e. 0·5) for the Friesian crossbreds and 18·4 (s.e. 0·5) kg for the Jersey crossbreds. As a result the mean post-partum live weight of 215 (s.e. 0·5) kg was lower than the mean of 226 (s.e. 1·1) kg established by Agyemang *et al.* (1991) as the average for the Gambian N'Dama.

Nutrition pre *and* post partum

Pre-partum nutrition had no effect on post-partum food intake which was expected because the animals were unable to express true levels of voluntary food intake. As planned, there was a significant ($P < 0{\cdot}001$) difference in the daily DMI between the two post-partum diets, particularly in period 1. The ratios of different foods were identical in the B and S diets; only the quantity differed.

Despite the considerable decrease in live weight and body condition during pregnancy, improved pre-partum nutrition (H) significantly improved productivity during the post-partum period. The responses included higher dam live weight ($P < 0{\cdot}05$) and body condition score ($P < 0{\cdot}001$), calf birth weight ($P < 0{\cdot}05$) and calf live-weight gain ($P < 0{\cdot}01$). The latter, when combined with a corresponding trend for an increase in milk offtake ($P < 0{\cdot}06$), indicates a beneficial effect on milk production.

Generally, post-partum nutrition had no significant effect on calf live-weight gain, milk yield ($P < 0{\cdot}06$) or dam live-weight change. However, the uninfected cows in the S group tended to gain weight whereas there was little change within the uninfected B group. The significant interaction between diets ($P < 0{\cdot}05$) provided evidence that the live-weight response of lactating cows was related to short- and long-term changes in the plane of nutrition. The relative change in live weight of the animals on the B diet *post partum* was not affected by pre-partum supplementation whilst, within the S group, cows that had received the H diet *pre-partum* lost weight compared with those on the L plane which maintained live weight ($P < 0{\cdot}05$).

If milk production is deemed to be an important production objective, these results indicate that it would be preferable to supplement during gestation rather than during lactation. Although the S group received proportionately 1·25 of food offered to the B group, the difference was not sufficient to produce a significant milk yield response. Yet this observation is consistent with those of other experiments reported in the literature. With temperate beef breeds, improved nutrition *pre-partum* generally increases live weight and milk yield, whereas the response to post-partum nutrition is less predictable and dependent on a number of factors including length of observation period, breed, body-condition and pre-partum nutrition (Bartle *et al.*, 1984; Laflamme and Connor, 1992; Marston *et al.*, 1995). In the tropics, Little *et al.* (1991 and 1994) reported significant milk yield responses in N'Dama cows supplemented *post partum* with the equivalent of 140 to 170 g CP per day compared to those grazing only native pasture. Increasing the level of CP supplementation above 200 g CP per day did not produce a further increase in milk yield. In the trial reported here, the groundnut cake (in the concentrate) supplied 440 g CP per day to the B group and 550 g CP per day to the S group. Assuming the N'Dama has the genetic potential, the results suggests that if there is sufficient CP in the diet then the ME concentration of the diets need to be increased in order to elicit further increases in milk yield. The provision of protein *post partum* might have assisted in the mobilization of the body reserves in the H pre-partum group to meet the deficit in energy. Ørskov *et al.* (1981) demonstrated that feeding fish meal with a low rumen degradability led to the mobilization of body reserves and stimulated milk yields in energy-deficient cows, although a comparable increase did not occur with groundnut meal, a highly degradable source of protein.

The changes in fat concentration tended to mirror the change in milk yield; a low plane of nutrition *pre-partum* depressed milk yield but increased fat concentration. The mean fat concentration in this trial was unexpectedly low. For example, the pre-infection mean was 20·7 (s.e. 0·06) g/kg which compares with a mean of 51 g/kg quoted by Agyemang *et al.* (1991). A subsequent test with a standard milk of known fat content showed that there was no obvious fault in laboratory technique. It is probable that the fat concentration appeared to be depressed because the sample was collected from fore-milk.

Trypanosomosis infection

Trypanosomosis infection induced a significant ($P < 0{\cdot}05$) decline in DMI which is consistent with the findings in most of the literature (Reynolds and Ekwuruke, 1988; Akinbamijo *et al.*, 1992; Romney *et al.*, 1997). Infection also had a negative effect on calf live weight and milk yield, which again is a well established feature of the disease (Agyemang *et al.*, 1990a). However, there is less information on the effects of trypanosomosis on the composition of milk. This trial showed that trypanosomosis has a negative effect ($P < 0{\cdot}01$) on the milk protein yield, which is independent of dietary effects. The cause of the decline is uncertain although the diversion of blood proteins and amino acids to mount an immune and erythrokinetic response is one possibility.

The significant ($P < 0{\cdot}01$) decline in PCV in response to trypanosomosis is a characteristic feature of the disease and a primary criterion for assessing its severity. The S post-partum diet had no beneficial effect on PCV which is contrary to other reports (Agyemang *et al.*, 1990b; Little *et al.*, 1990; Romney *et al.*, 1997). It would appear that improved anaemia control occurs in experiments where the concentration of protein in the diets is increased. In this study, the CP concentration of the two post-partum diets was similar, as was the actual food intake post-infection. This result suggests that improved anaemia control is related to the short-term level of protein intake. The higher levels of CP intake in period 1 (pre-infection) conferred no benefit for the S-I group in subsequent periods.

Interactions between diet and trypanosomosis

The only significant interaction between period, pre-partum nutrition and trypanosomosis was a differential response in calf live weights. In this instance, infection had a proportionately greater ($P < 0{\cdot}05$) effect on calves from cows that received the H plane of nutrition *pre-partum*. In contrast, there were a number of highly significant interactions between period, post-partum nutrition and trypanosomosis, particularly with regard to the relative change in food intake between period 1 (pre-infection) and period 3 (post infection). The decline in DMI was proportionately greater ($P < 0{\cdot}001$) in the infected cows supplemented *post partum*. When the different components of the diet were analysed, the animals in S-I group rejected larger amounts of groundnut hay ($P < 0{\cdot}001$) and concentrates ($P < 0{\cdot}001$) than the B-I animals. The decline in andropogon intake was similar for both groups. The net effect was one of similar levels of DMI between the S-I and B-I groups in period 3. Trypanosomosis appeared to induce two distinct responses. First, the degree of anorexia is related to previous levels of intake. Secondly, that rejection of foodstuffs is not restricted to the poor quality components of the diet is contrary to the observations of Romney *et al.* (1997) where infected heifers tended to reject only andropogon hay.

It is also interesting to note that despite the similarity in intake between the B-I and S-I groups the relative changes in productivity were significantly different. The S-I group lost proportionately more weight than those in the B-I group while the adverse effects of trypanosomosis on milk offtake ($P < 0{\cdot}01$) and calf live weight ($P < 0{\cdot}05$) were proportionately greater in the B-I groups. These results suggest that S-I cows maintained milk yield by utilizing live weight, whereas the B-I cows had insufficient live-weight reserves with consequent detrimental effects on the calf and milk yield.

The milk fat yield and concentration was significantly affected by an interaction between trypanosomosis and diet. The decline in fat yield was proportionately greater in the B-I treatment. This result, combined with the milk yield and live-weight response supports the observation that animals on the B diet were unable to utilize body reserves to maintain milk and milk fat yields, unlike those of the S group. It is uncertain whether the reduction in milk yield increased the susceptibilty of the calves to secondary infections but their poor health appeared to dominate their performance.

The loss of a calf influenced the return to cyclicity, as four of the seven cyclic cows belonged to this subgroup. However, there appeared to be some evidence of an interaction between H plane of nutrition *pre-partum* and infection upon reproductive performance. Five of the 12 cows in this treatment subgroup were cycling. Wright *et al.* (1992) concluded that the dominant factors affecting calving interval are peri-parturient weight change and body condition although weaning is thought to have a greater effect in *B. indicus* breeds (Moore and da Rocha, 1983; McSweeney *et al.*, 1993). It is possible that infection, which induced a reduction in milk yield, simulated a weaning response in the animals with higher body condition at calving. If this theory is correct, it raises the question of the extent to which milk yield recovered when the animals were treated with Berenil at the end of the trial.

Conclusion

In this trial there was no interaction between pre-partum nutrition and a trypanosomosis infection *post partum* However, there were significant interactions between diet at the time of infection and relative change in productivity. These results suggest that nutritional balances and changes in live weight already occurring at the time of infection might be more important than current live weight. This raises the question of whether a concept of target live weights can be promoted. The study has not entirely answered this question. There still may be desirable target live weights at different physiological states, or seasons. However, target live weights might be difficult for a smallholder to attain whereas live-weight change is a more realistic option that can be incorporated in simple food management strategies.

Acknowledgements

The authors wish to thank Drs B. Goossens, F. Sanyang, H. Wagner of the International Trypanotolerance Centre in The Gambia for providing veterinary support and undertaking the AI of cows. We are also grateful for the help given by ITC laboratory technicians and livestock assistants. This research was jointly funded by the Livestock Production Programme of the Department for International Development (DFID) and the European Union (DG XII).

References

Agyemang, K., Clifford, D. and Little, D. A. 1993. An assessment of the biological and economic efficiency in conversion of milk to growth in N'Dama calves. *Animal Production* **56:** 165-170.

Agyemang, K., Dwinger, R. H., Jeannin, P., Leperre, P., Grieve, A. S., Bah, M. L. and Little, D. A. 1990a. Biological and economic impact of trypanosome infections on milk production in N'Dama cattle managed under village conditions in The Gambia. *Animal Production* **50:** 383-389.

Agyemang, K., Dwinger, R. H., Touray, B. N., Jeannin, P., Fofana, D. and Grieve, A. S. 1990b. Effects of nutrition on the degree of anaemia and live weight changes in N'Dama cattle infected with trypanosomes. *Livestock Production Science* **26:** 39-51.

Agyemang, K., Little, D. A., Bah, M. L. and Dwinger, R. H. 1991. Effects of postpartum body weight changes on subsequent reproductive performance in N'Dama cattle maintained under traditional husbandry systems. *Animal Production Science* **26:** 51-59.

Akinbamijo, O. O., Hamminga, B. J., Wensing, T., Brouwer, B. O., Tolkamp, B. J. and Zwart, D. 1992. The effect of *Trypanosoma vivax* infection in West African Dwarf goats on energy and nitrogen metabolism. *The Veterinary Quarterly* **14:** 95-100.

Bartle, S. J., Males, J. R. and Preston, R. L. 1984. Effect of energy intake on the postpartum interval in beef cows and the adequacy of the cow's milk production for calf growth. *Journal of Animal Science* **58:** 1068-1074.

Laflamme, L. F. and Connor, M. L. 1992. Effect of postpartum nutrition and cow body condition at parturition on subsequent performance of beef cattle. *Canadian Journal of Animal Science* **72:** 843-851.

Little, D. A., Dwinger, R. H., Clifford, D. J., Grieve, A. S., Kora, S. and Bojang, M. 1990. Effect of nutritional level and body condition on susceptibility of N'Dama cattle to *Trypanosoma congolense* infection in The Gambia. *Proceedings of the Nutrition Society* **49:** 209A (abstr.).

Little, D. A., Riley, J. A., Agyemang, K., Jeannin, P., Grieve, A. S., Badji, B. and Dwinger, R. H. 1991. Effect of groundnut cake supplementation during the dry season on productivity characteristics of N'Dama cows under village husbandry conditions in The Gambia. *Tropical Agriculture, Trinidad* **68:** 259-262.

Little, D. A., Wassink, G. J., Agyemang, K., Leperre, P., Janneh, L. and Badjie, B. 1994. Feed supplementation of lactating N'Dama cows under village husbandry. *Tropical Agriculture, Trinidad* **71:** 223-228.

McSweeney, C. S., Kennedy, P. M., D'Occhio, M. J., Fitzpatrick, L. A., Reid, D. and Entwistle, K. W. 1993. Reducing post-partum anoestrous interval in first calf *Bos indicus* crossbred beef heifers. II. Responses to weaning and supplementation. *Australian Journal of Agricultural Research* **44:** 1079-1092.

Mael, J. H. H., Coulibaly, L., Defly, A., D'Ieteren, G. D. M., Feron, A., Grundler, G., Hecker, P., Itty, P., Mawuena, K., Morkramer, G., Mulungo, M., Nagda, S. M., Paling, R. W., Pelo, M., Rarieya, J. M., Schuetterle, A., Sheria, M., Thorpe, W. and Trail, J. C. M. 1988. Factors influencing live weight in a range of Network situations. In *Livestock production in tsetse affected areas of Africa. Proceedings of a meeting of International Centre for Africal International Laboratory for Research on Animal Diseases, Nairobi, Kenya, 1987*, pp. 219-230.

Marston, T. T., Lusby, K. S., Wettemann, R. P. and Purvis, H. T. 1995. Effects of feeding energy or protein supplements before or after calving on performance of spring-calving cows grazing native range. *Journal of Animal Science* **73:** 657-664.

Moore, P. C. and da Rocha, C. M. 1983. Reproductive performance of Gyr cows: the effect of weaning age of calves and post-partum energy intake. *Journal of Animal Science* **57:** 807-814.

Murray, C. M., Murray, M., Murray, P. K., Morrison, W. I., Payne, C. and McIntyre, W. I. M. 1977. Diagnosis of African trypanosomiasis in cattle. Improved parasitological and serological techniques. In *Fifteenth meeting of the International Scientific Council for Trypanosomiasis Research and Control.* Publication no. 116, OAU/STRC, The Gambia, pp. 247-255.

Ørskov, E. R., Reid, G. W. and McDonald, I. 1981. The effects of protein degradability and food intake on milk yield and composition in cows in early lactation. *British Journal of Nutrition* **45:** 547-555.

Pullen, N. B. 1978. Condition scoring of White Fulani cattle. *Tropical Animal Health and Production* **10:** 118-120.

Reynolds, L. and Ekwuruke, J. O. 1988. Effect of *Trypanosoma vivax* infection on West African dwarf sheep at two planes of nutrition. *Small Ruminant Research* **1:** 175-188.

Richards, M. W., Spitzer, J. C. and Warner, M. B. 1986. Effect of varying levels of postpartum nutrition and body condition at calving on subsequent reproductive performance in beef cattle. *Journal of Animal Science* **62:** 300-306.

Romney, D. L., N'Jie, A., Clifford, D. J., Holmes, P. and Gill, M. 1997. The influence of nutrition on the effects of infection with *Trypanosoma congolense* in trypanotolerant cattle. *Journal of Agricultural Science, Cambridge* **129:** 83-89.

Statistical Analysis Systems Institute. 1994. *SAS/STAT guide for personal computers. Version 6.1 for Windows*. SAS Institute Inc., Cary, NC.

Van Soest, P. J. 1982. *Nutritional ecology of the ruminant*. O and B Books, Corvallis, Oregon.

Wright, I. A., Rhind, S. M., Whyte, T. K. and Smith, A. J. 1992. Effects of body condition at calving and feeding level after calving on LH profiles and the duration of the post-partum anoestrous period in beef cows. *Animal Production* **55:** 41-46.

(*Received* 9 *June* 1998—*Accepted* 2 *December* 1998)