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

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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 intake (P < 0.05). The reduction in milk intake (P < 0.01) and calf live weight (P < 0.05) were proportionally larger in the S-I than in the B-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., 1999b), 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.
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(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 the 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 2x2 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 1x10⁴ 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

2

3

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.
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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):

<table>
<thead>
<tr>
<th>Pre-partum</th>
<th>Post-partum</th>
<th>Infection</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;br&gt;(23)</td>
<td>8(12)</td>
<td>(4 weeks post-partum)</td>
</tr>
<tr>
<td>&lt;br&gt;(L)</td>
<td>5(10)</td>
<td>1(6)</td>
</tr>
<tr>
<td>&lt;br&gt;(3(10)</td>
<td>5(15)</td>
<td>1(5)</td>
</tr>
<tr>
<td>&lt;br&gt;(9(10)</td>
<td></td>
<td>1(5)</td>
</tr>
</tbody>
</table>

Diet 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 Benoded district. The I group were offered individually 9.4 kg dry matter (DM) per day of concentrate containing groundnut cake and rice bran in the ratios of 1:1 and 0.9 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 forage. To compensate for the lack of fodder, the I group received 4.7 kg DM per day of the concentrate whereas 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 2416 g DM per day of groundnut hay, 1800 g DM per day of andropogon hay, and 2350 g DM per day of concentrate, consisting of equal parts 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 1980 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 poorest quality straw fraction rejected. This was determined from previous trials at ITC where cattle were offered andropogon hay at farinum. 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 2.3 l of milk per day (records from ITC indicate that the average daily milk yield in the first 100 days of lactation is 3.5 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 150 g/kg DM. Each cow received 12 g of local sea salt per day in the concentrate. Water was offered at 11.00 and 15.00 h.

Management and health

Post partum, the cows were dosed orally with a broad-spectrum anthelmintic, 10% fenbendazole (Panacur, Hennepin Chemical) 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 trypanosomiasis infection by tsetse or tsetse flies. One animal was recorded as positive for trypanosomiasis and withdrawn from the trial. As two of the calves yielded Trypanosoma congolense immediately after birth, all calves were dosed with 10% fenbendazole at birth and at 3 weeks of age.

All infected cows were treated with 124 mg/kg body weight dimethoate acaricide (Benren, Hennepin Chemical) at the end of the trial. Cows were withdrawn prematurely and treated with Benren, if their blood PCV fell below 32%.

Measurements and observations

Food intake and refusal. Voluntary DM intake (DMI) was recorded daily by weighing food offered and refused. Subsamples 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 feed 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, in 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-acetate acid coated vacutainers. The samples were examined by the buffy-coat dark ground-glass technique (Murray et al., 1977) to detect presence of trypanosomes and quantity of infection
as a parasitemia score (DG). The PCVs were determined using the standard microhematocrit 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 (1979) 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 Fornal dilution 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 is traditional systems is withdrawn for human consumption.

Reproduction. The resumption of ovarian activity 150 days post partum was monitored using progesterone profiles in plasma. The assay used was a double antibody technique. A microtiter 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, F1922). 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 30 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 (F 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:

\[ Y_{ij} = \text{period} + \text{block} \times \text{diet pre-partum} + \text{diet post partum} + \text{health status} + \text{animal (block \times diet pre \times diet post \times health status)} + \epsilon_{ij} \]

Animal (nested within block, diet pre-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 simple treatment. They cannot be used for comparing different treatments (e.g. the t-tests can be used for comparing the least-squares means of the B-C group in periods 1 and 3 but not to compare the H-C group with the B-C group in period 1).

The call live weight least-squares 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-squares means of food intake, PCV and live-weight change of cows and calves.

Food intake. Pre-partum nutrition (K, L) had no significant effect on total DM intake 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 < 0.001) difference in the daily DM intake between the two post partum diets. In period 1, the mean daily DM of the 5-C and the 5-L groups were 6035 (s.e. 92) g/day DM and 6016 (s.e. 91) g/day DM, while intakes in the B-C and B-L groups were 5052 (s.e. 98) g/day DM and 5119 (s.e. 88) g/day DM, respectively. The difference in DM intake 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
Trypanosomosis infection caused a significant ($P < 0.05$) overall reduction in total DMI post infection (period 3). There were also highly significant interactions ($P < 0.001$) 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 ($P < 0.001$) greater in the S-I group. This resulted in different 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 (s.e. 0.3 g/l g DMI; 3.9 g/l g DMI; 4.3 g/l 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 mid pregnancy and immediately post partum (period 1), 215 (s.e. 5) kg. Pre-partum nutrition had a significant ($P < 0.05$) 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 ($P < 0.05$) 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 ($P < 0.001$)
### Table 2: Individual dietary treatment and *Treponema* infection effects on milk output and composition (standard errors given in parentheses)

<table>
<thead>
<tr>
<th></th>
<th>Diet pre-partum</th>
<th>Diet post-partum</th>
<th>Significance of main effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I-C</td>
<td>H-I</td>
<td>L-C</td>
</tr>
<tr>
<td>Milk output period 1 (ml)</td>
<td>815 (9)</td>
<td>781 (7)</td>
<td>852 (7)</td>
</tr>
<tr>
<td>Milk output period 2 (ml)</td>
<td>579 (21)</td>
<td>213 (17)</td>
<td>322 (19)</td>
</tr>
<tr>
<td>Milk fat concentration, period 1 (g/kg)</td>
<td>19.1 (0.4)</td>
<td>23.0 (0.1)</td>
<td>21.5 (0.6)</td>
</tr>
<tr>
<td>Milk fat concentration, period 2 (g/kg)</td>
<td>21.8 (0.1)</td>
<td>23.4 (0.1)</td>
<td>23.0 (0.1)</td>
</tr>
<tr>
<td>Milk fat yield, period 1 (g/day)</td>
<td>157 (10)</td>
<td>150 (10)</td>
<td>124 (10)</td>
</tr>
<tr>
<td>Milk fat yield, period 2 (g/day)</td>
<td>9.6 (0.9)</td>
<td>12.0 (0.7)</td>
<td>9.7 (0.7)</td>
</tr>
<tr>
<td>Milk protein concentration, period 1 (g/kg)</td>
<td>30.0 (0.1)</td>
<td>31.0 (0.1)</td>
<td>31.1 (0.1)</td>
</tr>
<tr>
<td>Milk protein concentration, period 2 (g/kg)</td>
<td>29.0 (0.3)</td>
<td>29.0 (0.1)</td>
<td>29.0 (0.1)</td>
</tr>
<tr>
<td>Milk protein yield, period 1 (g/day)</td>
<td>15.0 (2.0)</td>
<td>21.7 (0.7)</td>
<td>19.0 (0.8)</td>
</tr>
<tr>
<td>Milk protein yield, period 2 (g/day)</td>
<td>17.4 (0.7)</td>
<td>7.1 (0.6)</td>
<td>9.6 (0.6)</td>
</tr>
</tbody>
</table>

Period 1 refers to the pre-infection period weeks 3 and 4 and period 2 refers to the post-infection period weeks 5 to 10.

F ratios significant at: * P < 0.05, ** P < 0.01, *** P < 0.001.

The L. pre-partum plane of nutrition significantly increased milk output (P < 0.001) in all groups with increased milk output. There was no significant effect of diet on milk output. There was no significant difference in milk fat concentration or yield between dietary treatments. The infection had no significant effect on milk fat concentration or yield. Milk protein concentration and yield were not significantly different between dietary treatments. Milk protein yield was significantly different between dietary treatments (P < 0.05). The infection had a significant effect on milk protein yield (P < 0.001). There was no significant difference in the effect of diet on milk protein concentration or yield. The infection had no significant effect on milk protein concentration or yield. The effect of diet on milk protein concentration or yield was not significant. The infection had no significant effect on milk protein concentration or yield. The infection had no significant effect on milk protein concentration or yield. The infection had no significant effect on milk protein concentration or yield. The infection had no significant effect on milk protein concentration or yield. The infection had no significant effect on milk protein concentration or yield. The infection had no significant effect on milk protein concentration or yield. The infection had no significant effect on milk protein concentration or yield. The infection had no significant effect on milk protein concentration or yield.
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Prongestone profiles

None of the cows was pregnant but seven cows appeared to be cycling, the remaining 35 were anoestrous. Of the seven cycling cows, three (5) were in the H-S1 group, two (7) in the H-BI group, one (5) in the L-BI 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. 0.5) (P < 0.005) 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 discoloration 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 Tribriessen 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

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 144 (s.e. 0.45) g/day in period 1 to 84.7 (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-I group. Infection caused an overall decline in milk protein concentration (P < 0.05) and 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. 0.62) 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.

in a range of body condition, weight, treatment level or infection severity, there was no interaction between post-partum effect and infection severity. There were no significant interactions between treatment and sex within each herd.
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 change. 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 < 0.001) 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 < 0.05) and body condition score (P < 0.001), calf birth weight (P < 0.05) and calf live-weight gain (P < 0.01). The latter, when combined with a corresponding trend for an increase in milk off-take 
(P < 0.06), indicates a beneficial effect on milk production.

Generally, post-partum nutrition had no significant effect on calf live-weight gain, milk yield 
(P > 0.06) 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 < 0.05) 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 < 0.05).

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., 1985). 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 suggest 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. Orskov et al. (1981) demonstrated that feeding fish meal with a low rumen degradability led to the mobilization of body reserves and an augmented milk yield 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
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The significant \( (P < 0.01) \) decline in PCV in response to trypanosomosis is a characteristic feature of the disease and is a primary criterion for assessing its severity. The \( S \) post-partum diet had no beneficial effect on PCV which is contrary to other reports (Agymag 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 \( (P < 0.05) \) effect on calves from cows that received the H plane of nutrition pre-partum. In contrast, there were no statistically 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 \( (P < 0.001) \) 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 \( (P < 0.001) \) and concentrates \( (P < 0.001) \) 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 off-take \( (P < 0.01) \) and calf live weight \( (P < 0.05) \) 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 susceptibility 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 retain whereas live-weight change is a more realistic option that can be incorporated in simple food management strategies.

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