Blood Metabolites and Their Relationship to Dairy Cattle Productive and Reproductive Performance in Smallholder Farms in Morogoro, Tanzania

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Abstract

Sixty four dairy cows (B. taurus x B. indicus crosses) belonging to 40 peri-urban smallholder farms were investigated for relationship of their blood metabolites, body condition score (BCS) and body weight to milk yield and reproductive performance. Feed availability and quality were monitored monthly. Plasma concentrations of selected metabolites [albumin, globulin, beta-hydroxybutyrate (BHB), inorganic phosphorus, urea] and packed cell volume (PCV) were measured at one month before calving, at 30 days and 60-90 days postpartum (DPP). Milk yield, BCS and body weight were taken once a month. The reproductive status was monitored by measuring milk progesterone (P4) concentrations and rectal palpation. Average daily food intake was 9.8±0.3 kg DM/day. Cows calved in good BCS (4-6), had mean milk yield between 6.4±0.44 and 7.3±0.66 L/day in the first 90 days of lactation and delayed calving to conception interval (126.1±6.3 days). There was no relationship between apparent feeding level, and therefore change in body weight and BCS, with milk yield and reproductive performance (P>0.05). The mean body weight and BCS dropped within one month after calving, which gradually recovered within the second month postpartum. A large proportion of cows (22-38%) had low PCV values (<27%) before calving to 60-90 DPP an indication of anaemia possibly due to low feed intake and probably diseases. Blood metabolite values remained more or less constant before calving and during the first 60-90 DPP. 24% of cows had high BHB values (>1 nmol/L) before calving, indicating a negative energy balance in late gestation. Globulin levels were high (>50 g/L) in 20% of the cows during the 60-90 DPP period suggesting probably an inflammatory reaction within the body. The differences between metabolite concentration among animals were small and they were not significantly related to productive and reproductive performance (P>0.05). The use of metabolic profile testing identified under-nutrition as the potential constraint to productivity in dairy cows in smallholder farms in Morogoro.

Keywords: Smallholders, dairy cattle, blood metabolites, productive and reproductive performance.

Introduction

A large proportion of the estimated 400,000 improved dairy cattle in Tanzania is owned by smallholder farmers in peri-urban and rural areas. In the peri-urban farms, crosses of Tanzanian zebu and exotic dairy breeds of cattle are kept on zero grazing system and fed cut grass with limited supplementation. The productivity of the dairy cows is much below their potential productivity.

The smallholder dairy sector contributes substantially to the national economy. It produces approximately 15% of the total milk, while the

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remaining 85% comes from the indigenous cattle population (MDB, 1993). The contribution of the smallholder dairy sector could be improved if the constraints affecting the sector were identified and controlled. Success in commercial dairy farming depends on the efficiency of milk and calf production that also depends on fertility (Janson, 1980; Smith and Akinbamijo, 2000).

Undernutrition has been identified as the major constraint on productivity in dairy cattle in the tropics (Preston and Leng, 1987). In normal dairy herd situations, direct assessment of energy balance in individual cows is cumbersome, but changes in BCS provide an indirect measure. The severity and duration of undernutrition is primarily related to dry matter intake, which in turn, determines the body condition at calving. There is a direct correlation between fertility and BCS (Butler, 2000; Schwalbach *et al.*, 1997).

Metabolic profile testing has generally been used as part of a multidisciplinary approach for dairy herd management and nutrition in temperate climates (Whitaker *et al.*, 1995). The technique can be used for identifying constraints on productivity in small herds in environment less favourable for milk production (Kelly *et al.*, 1988). Blood levels of selected metabolites [Beta-hydroxybutyrate, (BHB), inorganic phosphorus, urea, albumin and globulin] can be measured, at specific times of nutritional changes, in conjunction with information on body weight and condition score, milk production, feeding and reproduction. Comparisons with optimum values, the degree of variation from the latter allows one to obtain information about nutritional constraints on productivity (Whitaker *et al.*, 1995). The use of selected nutritional metabolite determinations, body condition and weight for estimating nutritional status and predicting cow performance and progesterone RIA for evaluating reproductive status and identifying breeding management problems have proved to be useful and practical tools to evaluate and monitor production systems (Garcia, 1999; Whitaker *et al.*, 1999).

Metabolic profile testing was able to identify undernutrition as the major constraint at critical periods of dairy cow's reproductive life in Philippines (Alejandrino *et al.*, 1999). However, in studies conducted on dual-purpose cows in Venezuela (Parra *et al.*, 1999), and on grazing dairy cows in Brazil (Abdalla *et al.*, 1999), and in Sudan (Idris *et al.*, 1999) it was found out that blood metabolite profiles were not consistently related to productive or reproductive variables.

The objective of the present study was to determine whether blood metabolite concentrations are associated with cow productivity and fertility with the aim of establishing the suitability of the test as an aid to identifying constraints to productivity of smallholder dairy cows under semi arid areas in the tropics.

Materials and methods

Location

The study was conducted in Morogoro municipality in Tanzania, which has a typically hot and semi arid climate. Mean minimum and maximum day temperatures are 15°C and 32°C respectively. The mean total rainfall of 1000 mm falls during the period of long rains (March to May) and short rains (November to December). The rest of the year is dry. The relative humidity for the area ranges between 46-66%.

Study design

Sixty-three smallholder dairy farms participated in a survey conducted between October 1993 and March 1995 in which an interview questionnaire was used to gather information regarding farm management practices. Data was also collected on mating and calving dates, milk production, feeding regime, feed availability and record keeping. At the end of the survey, 40 farms keeping approximately 60 dairy cows were randomly selected for the study that lasted to April 1998. The selection criteria were zero grazing of cows, keeping some form of records, had one or more cows in late gestation and willingness to participate in the study. Blood metabolites, productive (milk yield, BCS, body weight) and reproductive performance (calving to first P4 rise, calving to conception) were determined in three different stages depending on the calving date: pre-calving (-30 to -1 DPP), calving (4-21 DPP) and post-calving (60-90 DPP). Calving intervals were determined for cows that had two or more calvings during the study period.

The five blood metabolites were selected on the grounds of stability after collection, ease of analysis and known relevance to likely nutritional constraints. BHB level was used as a measure of energy balance. Urea level was used to assess protein intake. Albumin and globulin values were measured to assess long-term protein status as well as presence of chronic inflammatory disease, respectively. Inorganic phosphate levels in blood provided an indication of dietary phosphate intake (0.28% in DM). Reference values for the metabolites were taken from Whitaker *et al.* (1995).

Animals and management

The cattle were crosses between Zebu and European dairy (Ayrshire, Friesian and Jersey) breeds. Animals in all the farms were zero grazed, fed brought fodder consisting of local grasses with limited supplementation. The major feeds for the dry season were dry grass, maize stovers and rice straws. Almost all animals received at milking times supplement based mainly on maize bran in equal amounts. Early weaning was practised. Cows were normally milked twice a day. Breeding was throughout the year through artificial insemination (AI) or natural service or both. The owner or herdsman at milking, feeding and cleaning times did oestrus detection.

Measurements and sample collection

Once a month the amount of food offered in a day was weighed and divided by the number of cows having access to it to provide an assessment of average daily food intake. Representative feed samples were taken monthly for laboratory analysis. Similar feed sample from farms in a given location was pooled and a sample randomly selected.

Data for Body condition score (BSC), body weight and blood samples for metabolite analysis were collected one month before calving (-30 Day Pre Partum). The measurements were taken again one month post calving and 60-90 days post calving (60-90 Day Post Partum). Milk samples for P4 analysis were collected once a week starting two weeks after calving until confirmation of pregnancy by rectal palpation that was done monthly. Cyclic ovarian activity was deemed to have started at the first of two consecutive samplings where progesterone was > 1 nmol/L. Reproductive parameters studied included calving to first rise in milk progesterone, calving to conception, services per conception and calving interval.

Blood samples for metabolites were collected from tail vein one month before calving and then monthly, in vacutainers containing heparin anti-coagulant and transported in a cool box for laboratory analysis.

Laboratory analysis

Feed samples were analysed for dry matter (DM), crude protein (CP), and ash content according to methods described by AOAC (1990).

Packed cell volume (PCV) was measured on whole blood immediately after collection by microhematocrit technique. Samples were centrifuged within 24h and plasma subsequently removed.

Analysis of the metabolites was carried out on plasma samples using Randox kits (Randox Laboratories Ltd, UK) and manually operated colorimeter. The methods used were BHB by end point UV enzymatic 3-hydroxybutyrate dehydrogenase (3-HBDH) NAD+ dependent (cofactor); Urea by Urease-Berthelot (enzymatic kinetic); Total protein by Biuret; Albumin by Bromo Cresol Green; Globulin by the difference between total protein and albumin; and inorganic phosphorus by Molybdate.

Milk samples for progesterone were preserved with sodium azide and centrifuged, the skim milk was separated from the fat and kept frozen at -20°C until radioimmunoassay (RIA) was carried out for progesterone level using FAO/IAEA solid-phase self coating RIA kits (FAO/IAEA, 1997).

Statistical analysis

The blood metabolite values, body condition scores, body weights, milk yields and ovarian cyclicity (Productive parameters)were analyzed as dependent variables whereas the periods of data collectoin acted as classes of the independent variable in a one way analysis of variance. The General Linear Models (GLM) procedure of SAS (1990) was used in analyzing the data assuming the data was described by the following model:

$$Y_{ij}=\mu +P_i+E_{ij}$$

Where μ = general mean
P_i = effect of the ith period of data Collection
E_{ij} = error term

Results

Out of the 40 farms in the study, only 11 (27.5%) kept proper production (milk yields), reproduction (dates for oestrus, breeding, calving), and husbandry interventions (rectal palpation, treatment) records. The remaining 29 farms (72.5%) kept partial/incomplete records, which indicates generally poor record keeping.

Table 1: Percentage dry matter (DM%) content and chemical composition (crude protein (CP) and ash on DM basis) of the major feeds for dairy cattle in Morogoro

Feed Material	DM (%)	CP	Ash
		(% DM)	
Green grass	22.5 ± 2.4	10.7 ± 1.0	12.8 ± 1.9
Grass hay	88.3 ± 3.9	8.0 ± 0.9	7.3 ± 2.0
Dry grass	93.0 ± 4.5	3.1 ± 0.5	5.7 ± 0.7
Maize stover	93.6 ± 0.7	2.7 ± 0.5	6.8 ± 0.4
Maize bran	90.9 ± 0.5	11.3 ± 1.1	2.4 ± 0.1

An estimate of individual average intake ranged between 6.8 and 18.6 kg with an average of 9.8±0.3 kg DM/day. Chemical composition of the major feeds and supplement is given in Table 1. The amount of protein in the dry grass (standing hay) and maize stovers was low (3.1 and 2.7 %DM, respectively). Table 2 shows findings on milk yield, body weight and BCS for the cows during the observation period. From the table it is evident that the mean milk yield was not significantly higher in the second month compared to the first month after calving (P>0.05).

Table 2: Least squares means ± standard errors for milk production, body weight and body condition score (BCS) in relation to pre and post calving periods

Parameter	Pre and post calving periods			
	One month Pre-calving (n=25)	One month post-calving (n=20)	2-3 months post-calving (n=19)	P value
Milk yield (L/d)	-	6.4 ± 0.44	7.3 ± 0.66	ns
Body weight (kg)	242 ± 10.3	319 ± 11.5	323 ± 13.2	ns
BCS(1-9)	5.7 ± 0.10	5.3 ± 0.10	5.5 ± 0.10	ns

n=Number of cows in parentheses
ns-Not statistically significant (P>0.05)

The mean body weight of cows declined over the first month of lactation with slight gains thereafter. Mean BCS dropped within one month of calving and over the second month started to recover gradually. Change in BCS (<0.5) and body weight (19-23 kg) during the last month of pregnancy and first month postpartum showed no significant relationship with milk yield and reproductive performance (P>0.05).

Blood metabolite levels remained more or less constant before calving and in the first three months postpartum. The results of the analysis for the five metabolites and PCV are presented in Table 3.

A significant proportion of cows had anaemia (PCV<27%), 22% before calving and 38% one

Table 3: Least squares means (± standard error) for blood metabolite concentrations before and after calving

Metabolite	One month Pre-calving (n=25)	One month Post-calving (n=20)	2-3 months post- calving (n=19)	Optimum range	% cows outside [1]optim. ranges
β-BHB (nmol/L	0.47 ± 0.03	0.38 ± 0.04	0.41 ± 0.04	>0.6 - 1.0	24
Range	0.22 - 1.11	0.20 - 0.99	0.25 - 0.86		
Urea (nmol/L)	5.8 ± 0.28	6.2 ± 0.40	6.5 ± 0.27	<3.6	17
Range	1.8 - 6.4	2.0 - 8.7	2.4 - 11.3		
Phosphorus (nmol/L)	1.73 ± 0.10	1.48 ± 0.1	1.76 ± 0.1	<1.4	0
Range	1.38 - 2.16	1.32 - 2.75	1.28 - 2.97		
Albumin (g/L)	33.4 ± 0.50	35.2 ± 0.65	36.0 ± 0.53	<30	12
Range	30-48	24.50	25-49		
Globulin (g/L)	43.6±1.42	42.2 ± 1.26	46.6 ± 1.63	<50	20
Range	32 - 69	26.72	24.66		
PCV (%)	33.4 ± 0.62	32.9±, 0.66	34.0 ± 0.75	24-46	38
Range	26-32	23-30	25 -33		

β-BHB - β-hydxybutyrate; PCV - Packed cell volume
[1]optimum
n-Number of cows in parenthesis

to 2-3 months after calving. In 24% of the cows sampled before calving BHB values were above reference value (0.6-1.0 nmol/L). Only 7% cows had high BHB values at two months after calving. Urea levels were below the reference value (3.6 nmol/L) in 17% of the cows. Almost all the inorganic phosphate levels were within optimum among animals were small and hence had no significant influence on productive and reproductive performance.

Ten cows (15.6%) resumed cyclic ovarian activity within 30 days after calving. There was a time lapse of up to 38 days from first postpartum P_4 rise (cyclic ovarian activity) to

Table 4: Means (± standard deviation) for the reproductive parameters of dairy cows

Reproductive parameter	Number of cows	Mean	Range
Calving to first progesterone peak (days)	52	56.6 ± 3.3	26 - 118
Calving to first service (day)	46	94.4 ± 5.7	63 - 144
Calving t conception oestrus (day)	48	126.1 ± 6.3	66 - 154
Services per conception	46	1.7 ± 0.1	1 - 5
Calving interval (days)	33	398.8 ±16.6	334 - 528

nge (1.4 nmol/L).

Albumin values were in the region of optimum range (30 g/L) with only 12% being low. About 20% of cows had high globulin results (>50 g/L). The differences between metabolite concentration subsequent mating. It required on average 1.7±0.1 services for a conception. Days from calving to first P_4 rise. to conception, services per conception and calving interval are shown in Table 4.

Discussion

Majority of the farms had poor production, reproduction, and husbandry intervention records. Similar observation of poor records from village level to the Ministry was made by Batamuzi *et al.* (1988).

During the wet season cut green grass was more readily available than in the dry season. In the dry season forages become scarce and of low quality, making the level of nutrition not adequate for the cows to produce milk to their potential. In addition, the slow recovery in body condition reflected the lack of stored energy to be mobilised at the critical period of animals' reproductive life suggesting under nutrition. These observations are in agreement with those made by Plaizier *et al.* (1999), and Preston and Leng (1987) that necessitated their recommendation for the dry season supplementation with protein supplements. There was no significant relationship between apparent feeding levels and performance, most likely due to the different types of calf rearing, particularly suckling and weaning policies employed by farmers.

Several studies have shown that the rate of decrease in BCS during postpartum period is positively correlated with postpartum interval (Oroso and Wright. 1992). In the present study, body condition and weight changes were not significantly correlated to reproductive variables measured. Body weight is more associated with puberty, at which a threshold value of weight, more than age is assumed to explain the onset of sexual activity (Schillo *et al.*, 1992). Cyclicity of heifers or of postpartum cows seems to be mostly associated with changes (gains or losses) in weight. Animal body reserves can be estimated by BCS and only its change >0.5 unit may markedly influence postpartum interval to first ovulation, conception rate and calving interval (Butler and Smith, 1989). Body weight and BCS changes were 19-23 kg and <0.5 respectively. In addition, the dairy farmers in the study area have the advantage of accessibility to technology advice and resources due to their proximity to the Agricultural University and therefore managed their animals better.

The fact that 24% of the cows had high BHB values before calving indicates negative energy balance in these animals. The energy balance was restored to within optimum range in the first 2-3 months after calving. Only 7% of the cows sustained negative energy balance that eventually re-established optimum energy balance after three months after calving. Farmers tend to supplement their lactating cows with some form of supplement in order to get more milk.

The levels of inorganic phosphorus in the blood was within optimum range, implying that phosphorus content in feeds was adequate to fulfil the estimated requirement of 0.28% in DM (NRC, 1989) and therefore required no phosphate supplementation.

The high level of globulin observed in 20% of the cows probably indicates the presence of some chronic inflammatory disease process on top of the physiological uterine involution. Chronic diseases such as mastitis, metritis and lameness cause raised globulin in temperate climates (Whitaker *et al.*, 1993). Mastitis, lameness, metritis, helminthiasis, trypanosomiasis and tick borne diseases are prevalent in Tanzania (Mujuni. 1992; Shoo *et al.*. 1992; Mgasa. 1989; Matovelo *et al.* 1987). There was no attempt made to investigate particular disease conditions that were possibly involved.

Only 12% of the cows had low albumin values, which indicates that the remaining majority (88%) of the cows tested maintained satisfactory protein status. This implies that dietary protein unlikely constrained productivity. This is true for the wet periods of the year when quality green fodder is readily available, as opposed to the dry season when the availability and quality of feeds become scarce. In the dry season farmers supplement their cows with some form of supplement so as to increase milk production.

The fact that urea levels were low in 17% of the cows indicates that daily dietary intake of rumen degradable protein was adequate and most likely never constrained productivity in the majority (83%) of the animals. Most of the low urea results occurred in the dry season when green fodder was less readily available, and in cows tested before calving, when the appetite was at its lowest.

The extended mean intervals from calving to first P_4 peak (56.6±3.3 days) and calving to first detected oestrus (94.4±5.7 days) show that either first ovulation after calving was not accompanied by overt oestrus or that oestrus detection was poor. Cows are usually tethered indoors. Lack of accurate oestrus detection was due to the fact that the farmers are part time crop farmers or employed.

The observed blood metabolite levels did not significantly associate with milk production and reproduction during the first three months postpartum. The observation is in agreement with the results reported in tropical and sub-tropical environments by Abdalla *et al.* (1999), Alejandrino *et al.* (1999), Idris *et al.* (1999), and Parra *et al.* (1999). This can be explained by the fact that cows under nutritional stress (inadequate nutrient intake) and in early lactation have the ability to adapt their output and their biochemistry to the available feed (Marie, 1999). Furthermore, it has been noted that the use of blood metabolic profiles is dependent on specific situations (breed, production system, management), and the metabolic parameters may not always be indicative of reproductive status of the herd (Tegegne *et al.*, 1993; Parker and Blowey, 1976).

However, the test was most useful as an aid to management. Whitaker *et al.* (1999) made similar observation in that the blood metabolite profile tests provided information that was either available by other means, not available with the same precision by other means or not available early enough to help adjustments to be made for the benefit of a herd. Therefore, the test can confirm the constraints present or not present, which is as important because this allows intervention to be precisely directed.

Conclusion

The study revealed poor record keeping by the dairy farmers. Underfeeding in late gestation was the potential constraint to dairy cow productivity in smallholder farms in Morogoro. The use of the blood metabolic profile test was able to identify low PCV and high BHB and Globulin values in a large proportion of cows which suggest anaemia due to low feed intake and probably diseases in critical periods of animal's reproductive life. Giving the animals adequate feed, and where necessary feed supplement, especially in the dry season, should be given serious consideration by farmers. Investigation to identify diseases that may be affecting performance is desirable.

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