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The Development of Feeding Strategies to Improve Reproductive Performance and Milk Yields of Cows in High Potential, Mixed Farming Systems

Determinants of Milk Yield in Crossbred Dairy Cows on Smallholder Farms in Coastal North East Tanzania

Abstract

A 2-year longitudinal survey was carried out to investigate factors affecting milk yield in crossbred cows on smallholder farms in and around an urban centre. Sixty farms were visited at approximately 2-week intervals and details of milk yield, body condition score (BCS) and heart girth measurements were collected. Fifteen farms were within the town (U), 23 farms were approximately 5 km from town (SU), and 22 farms approximately 10 km from town (PU). Sources of variation in milk yield were investigated using a general linear model by a stepwise forward selection and backward elimination approach to judge for important independent variables. Factors considered for the first step of formulation of the model included location (PU, SU and U), calving season, BCS at calving, at three months postpartum and at six months postpartum, calving year, herd size category, source of labour (hired and family labour), calf rearing method (bucket and partial suckling) and parity number of the cow. Daily milk yield (including milk sucked by calves) was determined by calving year ($P<0.0001$), calf rearing method ($P=0.044$) and BCS at calving ($P<0.0001$). Only BCS at calving contributed to variation in volume of milk sucked by the calf, lactation length and lactation milk yield. BCS at 3 months after calving was improved on farms where labour was hired ($P=0.041$) and BCS change from calving to 6 months was more than twice as likely to be negative on U than SU and PU farms. It was concluded that milk production was predominantly associated with BCS at calving, lactation milk yield increasing quadratically from score 1 to 3. BCS at calving may provide a simple, single indicator of the nutritional status of a cow population.

Introduction

Smallholder dairying schemes are common throughout much of the developing world; frequently the activity is found in a peri-urban context, local conurbations providing a ready market for a perishable commodity. In East Africa, numerous projects have developed, many incorporating heifer-in-trust credit schemes that have increased the take-up of smallholder dairying by a greater proportion of the community. Smallscale dairying has developed in north-east Tanzania around the town of Tanga, encouraged and assisted by a bi-laterally funded development programme (Tanga Dairy Development Programme; TDDP). Systems are typical of such enterprises in much of east and southern Africa. Herd sizes of crossbred cows are small, (typically one milking cow, one dry cow and two followers; Msanga, 1997). The majority of cows are confined, forage in the form of indigenous herbs and grasses being cut and carried from fallow and uncultivated land, or more rarely use is made of cultivated grasses from farmed plots. Concentrate is usually in the form of maize bran. Cows suckle their calves (initiating milk letdown and then taking residual milk, or sucking one teat) although some urban farmers bucket rear calves. The mean weaning age reported by Msanga (1997) was 4.6 (SD=1.8) months.

Although feed resources are generally inexpensive, the high labour demand together with the costs of maintaining animal health makes such systems uneconomic if high milk yields cannot be maintained (Mdoe and Wiggins, 19--). The objective of the study described here was to quantify and identify the key determinants of milk yield in dairy cows kept in smallholder farms in and around a large conurbation.

Materials and Methods

The study was carried out in Tanga District in the northeastern corner of Tanzania. Choice of sites was based on their location in relation to Tanga township (approximate population 289,000 in year 2000) that is a potential market for milk and milk products and is a source of inputs. Selection of farmers was done from TSDDP's list of reporting farmers in three sites in and around Tanga town: villages around Pongwe (approximately 10 km from the urban centre and described as 'peri-urban PU); villages around Mafuriko (approximately 5 km from the urban centre and described as 'sub-urban' SU); and Tanga town itself (described as 'urban' U). Farmers were blocked within district by their records of milk yield and calving interval into ‘best’, ‘average’ and ‘worst’. Sixty farmers, all with crossbred cows and using cut-and-carry feeding systems, were randomly selected, with 22 from villages around Pongwe, 23 from villages around Mafuriko and 15 from Tanga town.

A longitudinal survey was carried out from October 1995 to September 1997. Each farmer received a monitoring visit at approximately 14-day intervals giving a total of 48 sequential observations for each variable from each of the participating farms. Records of milk yield, lactation length, calf growth, and cow body condition score were obtained.

Records of daily milk yield and lactation length

The amount of milk extracted by hand milking on the previous day to the visit as shown from the farmer’s records or recalled by the farmer was recorded on the day of each visit. The amount of milk sucked by a calf was estimated from its liveweight gain (see below), assuming that 1 kg of liveweight gain is equivalent to 9 kg of milk (Drewery *et al,* 1959; Msanga, 1997). Daily total milk yield before weaning was therefore the summation of saleable milk (milk extracted by hand) and the daily estimate of milk consumed by the calf. Total lactation yield was computed and the mean daily milk yield calculated from the lactation yield. Records used to estimate mean daily total milk yield included those of partial lactations of at least seven months. Shorter lactations were not necessarily due to cows stopping milking but more likely the result of data collection terminating while cows were still in milk. Type of calf rearing (bucket or partial suckling) was also noted.

Body condition score and liveweight gain

Body condition scoring of the cows to the nearest half point was done using a 0-5 scale incorporating methods described by Lowman *et al* (1973) and Pulan (1978). Live weight was estimated by measuring heart girth as the circumference of the chest just behind the forelimbs (cm). Liveweight was determined from the equation

$$\text{Live weight} = (0.1416 \times \text{heart girth} - 5.0564)^2$$

This expression had been developed from heart girth measurements and live weights of crossbred cows at Tanga Livestock Research Centre (Msangi *et al,* 1999). The rate of liveweight change was established by regression equation.

Daily rainfall was recorded using facilities at the nearby Tanga airport and monthly average rainfall was calculated to establish the annual rainfall pattern.

Data handling and statistical analysis

All data was transferred from field notebooks to a database (Microsoft Access'97 for Windows 1997) and when necessary a spreadsheet (Microsoft Exel'97 for Windows 1996) was used for arrangement and computation before importation to a statistical package for analysis.

Sources of variation were analysed using a general linear model (GLM) (Statistical Analysis System (SAS), 1999) by a stepwise forward selection and backward elimination approach to judge for important independent variables to be used in the adopted models (Hosmer and Lemeshow, 1989). In this approach all independent variables were included for the first step of formulating a general model. The variable was retained in the model when found to be close or to satisfy a $P<0.05$ significance level. However, factor(s) previously excluded could also be re-tested and once shown to have the least P value were again considered for re-inclusion. Interaction of factors already showing significance and thought to be relevant depending on the dependent variable dealt with were tested for inclusion in a model.

Factors considered for the first step of formulation of the model included location (PU, SU and U), calving season (dry and wet seasons based on the rainfall pattern across the period of the survey), body condition score at calving, at three months postpartum and at six months postpartum, calving year (Year 1 = 1995/96, Year 2 = 1996/97), herd size category (small = 1-3 animals; medium = 4-6 animals; large = 7 animals), source of labour (hired and family labour) calf rearing method (bucket and partial suckling) and parity number of the cow.

Data on body condition score at calving, three-months postpartum and six-months postpartum, together with body condition score changes between these periods were analysed using a logistic regression model by 'stepwise selection' procedure (Hosmer and Lemeshow, 1989). The procedure included in the regression equation only those terms that contribute significantly to the variation in the dependent variable. Terms not contributing significantly were removed from an initial large equation.

Results

Of the sixty farmers recruited to the study, only two withdrew. Data was collected from 125 cows.

Rainfall over the survey period showed the characteristic bimodal distribution although little rain fell during the short rains of 1996. The total amount of rainfall received in 1995/96 was 1281 mm and in 1996/97 was 901 mm.

Daily total milk yield

Factors used in the adopted model were body condition score at calving, calving year, site, calf rearing method, source of labour and site x source of labour. Daily total milk yield was significantly influenced by the independent variables calving year ($P<0.0001$), calf rearing method ($P=0.044$) and body condition score of the cow at calving ($P<0.0001$).

In calving year 1995/96, the wetter of the two years, cows had a mean milk yield of 9.5±0.74 compared to 7.3±0.75 litres/d for the second year. Cows that suckled their calves yielded significantly more milk (9.8±0.33 litres/d) in comparison to cows where calves were bucket reared (7.1±1.32 litres/d); these cows also appeared to have more variable yields than cows suckling calves. The relationship between daily total milk yield and body condition score of the cow at calving is best described by the polynomial expression

$$y = -1.769x^2 + 8.973x - 0.196 \ (R^2 = 0.196; P<0.0001)$$

where y = daily total milk yield (litres) and x = body condition score of the cow at calving. The relationship between mean daily total milk yield and body condition score at calving (i.e. the relationship for the population) was

$$y = -2.457x^2 + 12.509x - 5.520 \ (R^2=0.988; P<0.0001)$$

Table 1 shows least squares means (LSM) total daily milk yield for cows in body condition score 1-3. The results show a cubic relationship, yield rising steeply from body condition score 1 to body condition score 2-2.5 before beginning to decline again.

Table 1: Least squares means of total daily milk yield and yield of milk sucked by a calf in crossbred cows of body condition scores 1 to 3 at calving

Body condition score at calving	Total daily milk yield (litres/day)	SE	Yield of milk taken by calf (litres/day)	SE
1		0.95	2.2^{a} (16)	0.34
1.5		0.78	2.4^{a} (34)	0.24
2		0.83	3.1^{b} (34)	0.23
2.5		0.74	3.5^{b} (20)	
3	9.8^{c} (9)	1.13	3.0^{a} (8)	

LSMs within columns with different superscript letters are statistically significantly different

Figures in parenthesis represent animal numbers (n) contributing to the LSM

Milked sucked by calves

Overall mean yield of milk sucked by calves was estimated as 2.8 (SD=1.16) litres per day. Factors included in the final model were body condition score of the cow at calving, calving season, calving year, site, source of labour, and the interaction between site and labour source. The only factor to contribute significantly to the variation was body condition score of the cow at calving (P=0.006). The polynomial expression

$$Y=-0.486x^2 + 2.483 + 0.06\ (R^2=0.826;\ P=0.0007)$$

describes the relationship where Y = mean yield of milk sucked by the calf (litres) and x = cow body condition score . Table 1 shows LSM yield of milk sucked by calves for cows in body condition score 1-3. The trend is similar to that for total daily milk yield.

Lactation length

Lactation length (for complete lactations only; n=75) ranged between 148 and 492 days with an overall mean of 329 (SD=71.9) days. Factors included in the final model were body condition score of the cow at calving, source of labour and site. Only body condition score at calving contributed significantly to the variation in the number of days in milk (P=0.053). The relationship between the number of days in milk (Y) and body condition score (x) is linear (P=0.0.017), described by the equation

$$Y=36.1x + 256.1 \ (R^2=0.076)$$

The relationship between the mean number of days in milk and body condition score was

$$Y=41.4x + 247.4 \ (R^2=0.743)$$

Table 2 shows LSM lactation lengths against body condition scores 1-3.

Lactation milk yield

Analysis of variance of lactation milk yield used data from only those cows with complete lactation records (n=75). The overall mean lactation yield was 2295 (SD=864.8) litres. Factors included in the final model were body condition score at calving, source of labour and site. Only body condition score at calving contributed significantly to the variation (P=0.0004). Regression analysis indicated a positive quadratic relationship (P=0.00003) between lactation milk yield (Y) and body condition score at calving (x)

$$Y = -338.1x^2 + 2075.6x - 382.2 \ (R^2 = 0.237)$$

For mean lactation milk yield and body condition score at calving the relationship is

$$Y = -278.6x^2 + 1867.7x - 253.2 \ (R^2 = 0.970)$$

Table 2 shows LSM lactation milk yields for cows in body condition score 1-3.

Table 2: Least squares means of days in milk and lactation yield in crossbred cows of body condition scores 1 to 3 at calving

Body condition score at calving	Days in milk	SE	Lactation milk yield (litres)	SE
1	284^a (7)	30.0	1360^a (7)	325.6
1.5	312^a (20)	18.1	1829^a (20)	196.1
2	351^a (25)	15.1	2526^b (25)	163.2
2.5	321^a (15)	19.1	2570^b (15)	207.1
3	383^b (8)	20.1	2878^b (8)	282.8

LSMs within columns with different superscript letters are statistically significantly different

Figures in parenthesis represent animal numbers (n) contributing to the LSM

Body condition score and condition score changes of cows from calving to six months postpartum

The overall mean body condition score of cows at calving (n=125) was 1.8 (SD=0.55), declining to 1.4 (SD=0.53) and 1.2 (SD=0.49) at 3 and 6 months postpartum, respectively. Results from logistic regression analysis showed that the body condition score of cows at calving was not associated with any of the factors included in the model (^{2}=7.150; df=6; P=0.307). At three months of lactation, the analysis singled out source of labour as the only factor influencing the body condition score (^{2}=4.178; df =1; P=0.041). The odds ratio estimate at 95% confidence limit (hired *v* family = 2.066) indicated that better body condition score three months after calving was twice as likely for cows tended by hired labour (n=90) compared to those tended by family labour (n=34). At six months of lactation, body condition score was not associated with any of the factors included in the model (^{2} = 10.849; df = 6; P=0.093).

Body condition score change from calving to six months was influenced by site (^{2}=6.117; df=2; P=0.047). The odds ratio estimate at 95% confidence limit for U *v* PU and U *v* SU was 2.1 and 2.6 respectively, indicating that cows on U farms were more than twice as likely to lose body condition score during the first six months of lactation than cows on PU and SU farms.

Discussion

The estimates of lactation milk yield compare reasonably well with previously published results obtained from this geographical region. For example, Msanga *et al* (2000) analysed TDDP records of total lactation yield and found mean yields of 2332 (SD=283.0; n=713) for cows with only first lactation records and 2477 (SD=840.1; n=373) for cows with multiple lactation records. However, the mean lactation milk yield for cows in the present study did include an estimate of milk sucked by the calf for the majority of cows. Lactation length is also reasonably comparable to the estimates of Msanga *et al* (2000); first lactations were represented by 331 (SD=77.0; n=713) days in milk while cows with multiple records had lactations of 324 (SD=74.0; n=373) days. Not only are these means close to that of the present study but the SDs are also very similar. Thus it seems that the 95% confidence intervals for lactation length lie around 180 and 476 days. Short lactations presumably result from cows drying off or milk yield becoming so insignificant that the cow is dried off. Deliberately extended lactations may be a strategy employed by farmers to counter long calving intervals, given that crossbred cows kept in smallholder dairying systems frequently have flat, persistent lactation 'curves' (Tanner *et al,* 1998).

A consistent factor affecting milk yield and lactation length was body condition of the cow at calving. The relationships, although statistically significant, were generally of poor fit when individual animals were considered but were much more precise for the population. Cows were generally in poor condition, few being seen above body condition score 3. Moreover, cows appeared to continue to lose body condition up to at least the sixth month of lactation. Attempts to identify factors influencing body condition found source of labour had some influence at three months after calving. Hired labour presumably provided additional manpower to collect forage that may have assisted cows to support lactation without recourse to mobilising excessive body tissue. Loss of body condition from calving to six months appeared to be influenced by site. Cows kept on the U site seemed to be at particular disadvantage. This may well have been because of the difficulties encountered in obtaining forage in the urban environment. An alternative explanation is that, because of the greater use of AI by U farmers, U cows tended to have greater *Bos taurus* inheritance and were therefore more prone to partition feed to milk rather than body tissue. Although both source of labour and site had some influence on body condition score and body condition score change, neither contributed significantly to measurements of milk production.

Only body condition score at calving (rather than at three or six months after calving) contributed to variations on milk yield and lactation length. It is well established that body tissue contributes to the nutrient requirements for lactation in well nourished cows (Garnsworthy, 1988). In the data set presented here, daily milk yield rose steeply from body condition score 1 to body condition score 2-2.5 before declining again. The nature of the response may reflect the variable genetic make-up of the cows in the study. Msanga *et al,* (2000) categorised the crossbred animals in the study area as 50, 62 and 75% Holstein inheritance. Increasing Holstein inheritance may be associated with a greater preponderance to partition feed to milk rather than body tissue. Hence cows in better body condition at calving (body score 3 and above) may have less Holstein inheritance and therefore less potential for milk production. An alternative explanation is proposed by Garnsworthy and Topps (1982) who fed cows differentially to achieve variations in body condition score at calving. They found that thin cows at calving had greater dry matter intakes and higher milk yields than fat cows. In the present study, thin cows at calving did not produce more milk than fatter cows. However, the thin cows of this study probably did not have the opportunity to express voluntary feed intake and were therefore denied the opportunity of increasing nutrient intake for milk synthesis.

Body condition score at calving not only affected milk yield but also lactation length. Lactation milk yield, being a function of daily yield and days in milk, therefore particularly benefits from improvements in body condition score at calving. Raising the body condition score of the cow at calving from 1 to 2 almost doubles the lactation milk yield. It seems unlikely that this very substantial increase in milk yield associated with increasing body condition score can be attributed solely to additional tissue resources catabolized for milk synthesis. Cows calving in better condition are likely to be better fed and the better feeding may well persist throughout lactation. The greater milk yields associated with year 1 of the study when there was greater rainfall most probably reflects the greater availability of forage.

Cows that suckled calves were associated with higher milk yields. The estimation of the yield of milk sucked by the calf requires some consideration. The mean daily yield was estimated as 2.8 litres. Bryant and Msanga (1998), using similar techniques and animals in on-station studies, found the mean daily volume of milk taken by calves to be 2.4 litres when calves were allowed to suck residual milk only. Suckling resulted in greater lactation persistency and greater lactation milk yields. Similar findings were published by Urgate and Preston (1972) and Sahn (1994). However, when calves are suckled for long periods then inevitably they will be consuming solid food in addition to milk. The provision of concentrate specifically for calves appeared to be rare and forages were generally of low quality. Therefore, although the estimate of milk sucked by calves probably lacks precision, it is likely to be a reasonable value.

In conclusion, the main determinant of lactation milk yield was found to be body condition score of the cow at calving. It seems likely that this provides an indicator of the better feeding of cows throughout their lactations, if not throughout their lifetimes. Body condition score of individual cows is not a good predictor of subsequent lactation performance. However, the major contribution made by body condition score at calving to variation in milk production parameters suggests that it should provide a single, simple indicator of nutritional adequacy when applied to a population of cows.

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