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A Cross-sectional Study of Reproductive Performance of Smallholder Dairy Cows in Coastal Tanzania

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ABSTRACT

A retrospective cross-sectional study was conducted on 200 randomly selected smallholder farms from a mixed dairy farming system in Tanga, Tanzania, between January and April 1999. We estimated the frequency and determinants of long calving interval (LCI), retention of fetal membrane (RFM), dystocia, and abortion in smallholder crossbred cattle and explored birth trends. The mean calving interval was 500 days and birth rate was 65 per 100 cow-years. Dystocia was reported to affect 58% of calvings, and 17.2% of animals suffered RFM. Using mixed effect models, the variables associated with LCI, RFM and dystocia were breed, level of exotic blood and condition score. Zebu breeding was associated with LCI (odds ratio (OR) = 2.3, $p = 0.041$) and Friesian breeding with lower odds for RF (OR = 0.26, $p = 0.020$). Animals with higher levels of exotic blood had lower odds for evidence of dystocia (OR = 0.45, $p = 0.021$). Evidence of dystocia was significantly associated with poor condition score ($\beta = -1.10$, $p = 0.001$). Our observations suggest that LCIs are common in smallholder dairy farms in this region and a likely source of economic loss. Dystocia, RFM, poor condition score and mineral deficiency were common problems and were possibly linked to LCI.

Keywords: dairy cows, reproduction performance, smallholders, Tanzania

Abbreviations: A, abortion; AEZ, agroecological zone; BR, birth rate; D, dystocia; LCI, long calving interval; OR, odds ratio; RFM, retention of fetal membrane; TDDP, Tanga Dairy Development Programme

INTRODUCTION

Smallholder dairying is an important source of human food, regular household income and employment in Tanzania (Ministry of Agriculture and Livestock Development, 1983; Leslie *et al*., 1999). The efficiency of smallholder dairy farming is influenced greatly by the reproductive performance of the dairy cows (Mdoe, 1993). In studies on

reproductive performance of stall-fed dairy cows in humid coastal and other areas of Tanzania, the average calving intervals in such herds ranged from 420 to 680 days (Donald, 1985; FAO, 1989; De Wolf, 1993; Southern Highlands Dairy Development Programme, 1997; Kanuya *et al.*, 2000; Msanga *et al.*, 2000; Lyimo *et al.*, 2004). These intervals are considerably longer than the standard recommendation of 430 days under tropical conditions (Mujuni, 1991; Kanuya, 1992). Underlying causes of the long calving intervals are rather difficult to establish and evaluate; however, they do confirm the existence of poor reproductive performance. For adequate evaluation of the reproductive performance of stall-fed cows, well-kept records are required (Gaines, 1989). In many smallholder farms, such records are either incomplete or not kept at all.

The purpose of the present study was to assess the reproductive performance of stall-fed cows in the humid coastal area of Tanga, Tanzania. The primary objective was to identify and quantify factors that are potentially associated with long calving intervals in the herds with a view to developing strategies aimed at improving reproductive performance.

MATERIALS AND METHODS

Study site

This cross-sectional field study was conducted in Tanga Region, located between latitudes 4°21′ N and 6°14′ S, and longitude 36°11′ W and 38°26′ E, in north-east Tanzania. The study area comprises the humid coastal, hinterland and highland zones of the region at an altitude between 200 and 2000 m above sea level. Characteristics of the region are described in detail by Swai (2002); briefly, the study sites comprise five administrative districts (Tanga, Muheza, Pangani, Lushoto and Korogwe) and the land is classified into five 'agroecological zones' (AEZ) based on elevation, soil types, rainfall (amount and pattern), water retention ability and crops grown (National Coconut Development Council, 1981). The climate of the region is tropical heterogeneous with a bimodal rainfall pattern (the short rains falling from September to November and the long rains from March to May). The mean annual rainfall varies from 500 to 1400 mm/year depending on altitude. The topography of the area ranges from coastal plain to inland upland slopes. Soils are sandy in the coastal belt, clay to loamy in the hinterland, and leached mineral laterite in the highlands. The relative humidity in the daytime ranges from 70% on the coast to 40–50% in the highlands for most of the year. Temperatures range typically from a low of 15°C between June and August and a high of 35°C between December and March. Most areas within the region receive 2300–3100 hours of sunshine a year.

Study farms and husbandry practices

Farms for the study were identified from the Tanga Dairy Development Programme (TDDP) database. Two hundred farms from a sampling frame of 3001 smallholders,

distributed in five out of the six districts in Tanga Region, were randomly selected for the study, which began in October 1998. Most of the cattle (>90%) are stall housed throughout the year. Dairy stock kept included crosses of *Bos taurus* (Friesian, Ayrshire, Jersey, Simmental) and *Bos indicus* (Tanzania Shorthorn Zebu, Boran, Sahiwal) at levels of exotic blood that varied from 50% to 85%. The location of each farm in each administrative district was also classified as rural, urban or peri-urban. Urban farms were those occurring within towns, peri-urban farms were those peripheral to towns but within a 15 km of the town centre, and rural farms were those occurring at 15 km or more from a town centre. The location of farm by administrative district and AEZ could influence availability of feed supplements, breeding services etc. by affecting access to suppliers. Farm locations by administrative district, AEZ and farm class were considered as explanatory variables during data analysis.

Data collection

A pre-tested, structured questionnaire (PSQ) administered on each farm at each visit was used to collect farm data and information on farm management practices. Data collected by the questionnaire included details of the type of animal housing (cowshed with and without roof, kraal); whether the animal had access to minerals; whether the animal had grazed or been zero grazed; whether the cattle owner had attended any dairy husbandry training; the herd size; feeding regime; breeding regime; age of the cow; breed; filial generation (classified as F_1, F_2 and F_3 based on the level of exotic genes from breeding records); source of animals (home-bred or brought-in); calving dates; and any histories of arbortion, dystocia and retention of fetal membrane. Details of these variables are shown in Table I. All the information collected (excepting calving dates) related to farm and animal events occurring in, or relevant to, 1998. This involved detailed tracing of all animals on the farm, and examination of any written records, so that all ages of the cattle, calving dates, date of deaths and other movements of cattle on and off the farms agreed chronologically.

Using a tape measure, live weight estimates were calculated using the following formula as modified by Msangi and colleagues (1999): BW = 4.0914HG + 1.674BL – 459.75 (BW, body weight; HG, heart girth; BL, body length). Body condition scoring of the cows to the nearest half point was done using a 0–5 scale described by Msangi (2001), which was developed from the methods of Lowman and colleagues (1973) and Pullan (1978).

Estimation of inorganic phosphorus concentration

Blood samples were collected from all animals into 10 ml plain Vacutainer tubes (Becton Dickinson, Cowley, Oxford, UK) by jugular venepuncture. Following centrifugation, aliquots of sera were submitted to Sokoine University of Agriculture (SUA) for estimation of inorganic phosphorus concentration using Randox Inorganic Phosphorous kits (Randox Laboratories Ltd, Crumlin, UK).

Definition of reproduction parameters

The smallholder dairy farm as defined by TDDP is a dairy unit having fewer than 10 animals of any ages and sex.

Birth rate (BR) was defined as the proportion of total number of births in 1998 to total number of cows alive in 1998 (French *et al.*, 2001).

Calving interval (CI) was defined as the average interval between the two most- recent consecutive calvings for each cow in each herd.

Long calving interval (LCI) was considered to occur if the calving interval was beyond the standard recommended 430 days under tropical condition (Mujuni, 1991; Kanuya, 1992).

Abortion (A) was defined as the expulsion of one or more calves at <271 days after natural mating or artificial insemination (Roy, 1983).

Retention of fetal membranes was considered to occur if fetal membranes remained unexpelled at least 12 h after calving or abortion.

Dystocia (D) was considered to occur if parturition was assisted either by the farmer or by a field officer.

Statistical analysis

Descriptive statistics for the animal and farm level explanatory variables examined in the study were developed using Epi-Info version 6.04d (Centers for Disease Control, Atlanta, GA, USA). The unit of analysis was individual potential breedable females (cows and heifers >30 months old) that were on the farm in 1998. The outcome (dependent) responses investigated were LCI, and evidence of RFM and D as binary variables. Explanatory (independent) variables investigated were AEZ and Administrative district in which the farm occurred (as factors), farm class (rural, urban or peri-urban), history of farmer training, feeding of minerals, sex of the owner of the animal, cattle breed, filial generation, source of animals, condition score, weight of animal and level of plasma phosphorus. Associations between dependent and independent variables were investigated in two steps by logistic regression (using Egret for Windows version 2.0, Cytel Software Corporation, MA, USA) with 'farm' as a random effect because cows on one farm may not be statistically independent of one another (Kristula *et al.*, 1992). In the first step, relationships between each independent and outcome variable were individually investigated. In the second step, any variables that were significantly associated at the $p<0.25$ level were included in multivariable models producing, by forward and backward substitution and elimination, the most parsimonious models in which all independent variables remained significant at the $p<0.05$ level.

RESULTS

Descriptive statistics

All selected farms were visited and farmers were interviewed (100% voluntary response rate) during the period January to April 1999. A total of 308 breedable cows kept on 175 farms (87.5%) were examined. Twenty-five farms (12.5%) had no breedable cows during the actual survey period. The average number of breedable cows per farm was 2 (range 1–6) and the average age of study cows was 6 years (range 3–13 years). The mean ($\pm$SE) body weight (kg) of the cows was 322 ± 3.30 kg (range 176–468) and mean body condition score was 2.24 ± 0.03 (range 0.5–4.5). The mean blood inorganic phosphorus concentration (mg/100 ml) was 2.5 ± 0.05 (range 0.61–8.75). The proportions of cows in each category of each variable investigated during the study are shown in Table I.

Fertility

The estimated overall birth rate was 65 per 100 cow-years. Crude birth rates by district are shown in Table II. Of the 201 cows that gave birth in 1998, 117 (58.2%) and 35 (17.4%) were associated with dystocia and retention of fetal membrane, respectively. Animals that had dystocia were significantly associated with retention of fetal membrane ($\chi^2 = 29$, $p < 0.001$). Evidence of abortion was reported from only 2 cows (0.9%). Of the calves born alive, 104 (51.7%) were males and 97 (48.2%) females. The calving interval ranged from 303 to 1065 days with a mean of 500 ± 12.2 days. The median condition score was 2 (range 0.5–4.5).

Temporal pattern of birth

The temporal patterns of births are shown in Figure 1. Births were reported to occur in all months of the year, with a higher proportion being born in August. No significant seasonal pattern was found, however.

Factors influencing long calving interval, dystocia and retention of fetal membrane

The factors that were found to be associated with LCI, RFM and D in the most parsimonious multivariable regression models are shown in Table III. Animals with Friesian genes were significantly less likely to be associated with retention of fetal membrane than animals of other taurine breeds (OR = 0.26, $p < 0.05$). Animals with Tanzanian Shorthorn Zebu (TSHZ) blood were more likely to suffer a long calving interval compared to other *Bos indicus* breeds (OR = 0.26, $p = 0.020$ for Friesian; OR =2.3, $p = 0.041$ for TSHZ).

TABLE I
Proportions of cows in each category of each variable investigated during the study (n = 308)

Variable	Category	Number (%) of animals
Animal-level variables		
Source of animal	Homebred	95 (30.8)
	Brought-in	213 (69.1)
Filial generation	F_1	151(49.0)
	F_2	150 (48.7)
	F_3	7 (2.2)
Breed	Ayrshire cross	81 (26)
	Friesian cross	258 (82.7)
	Jersey cross	5 (1.6)
	TSHZ cross	247 (79.2)
	Boran cross	50 (16.1)
	Simmental cross	3 (1.1)
	Sahiwal cross	5 (1.6)
LCI (n =133)	>430 days	81 (60.9)
	<430 days	52 (39.1)
Age	>3–5 years	135 (43)
	>5–8 years	110 (35)
	>8–12 years	55 (17.8)
	>12 years	8 (2.5)
Condition score	0.5–2.0	174 (56.4)
	>2.0–3.0	116 (37.6)
	>3.0–4.5	18 (5.8)
Farm-level variables		
Farm location	Korogwe	29 (9.4)
	Lushoto	39 (12.6)
	Muheza	81 (26.2)
	Pangani	9 (2.9)
	Tanga	150 (48.7)
AEZ	5	157 (50.9)
	6	54 (17.7)
	7	56 (18.2)
	12	38 (12.3)
	14	3 (0.9)

TABLE I (continued)

Variable	Category	Number (%) of animals
Farm class	Urban	118 (38.3)
	Peri-urban	54 (17.5)
	Rural	136 (44.2)
Attended a training course	Yes	197 (63.9)
	No	111 (36.0)
Housing	Cowshed with roof	263 (85.3)
	Cowshed without	31 (10.2)
	Kraal	14 (4.5)
Fed minerals	Yes	287 (93.1)
	No	21 (6.8)
Gender of owner	Male	272 (88.3)
	Female	36 (11.6)
Grazing history in 1998	Zero grazing	275 (89.2)
	Grazing	33 (10.7)

TABLE II
Birth rates by district for cattle on smallholder dairy farms in Tanga, Tanzania

District	Number of births	Cow time in years	Birth rate per 100 cow-years	SE
Tanga	102	152.2	67	0.2
Muheza	48	80.9	59	0.3
Lushoto	28	38.2	73	0.9
Korogwe	15	26.0	57	1.1
Pangani	8	8.6	93	6.2
Overall	201	305.9	65.7	0.1

SE, standard error of the mean

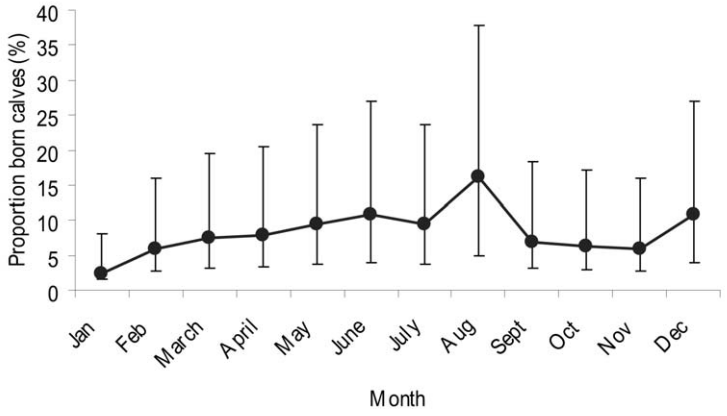

Figure 1. The proportion of calves born (±95%CI) by months of the year on smallholder dairy farms, Tanga, 1998 (n = 201)

TABLE III
Factors associated with long calving intervals, the incidence of dystocia and retention of fetal membrane in dairy cattle in Tanga in a multivariable logistic regression models adjusted for farm effects

Variable	β (SE)	Wald P	LRS	LRP	Odds ratio (95% CI)
Outcome variable: evidence retention of fetal membrane					
Constant	–1.91 (0.58)				
Friesian vs non-Friesian	–1.33 (0.63)	0.035	5.3	0.020	0.26 (0.07–0.91)
Random effect	1.76 (0.67)				
Outcome variable: evidence of dystocia					
Constant	–0.36(0.24)				
Condition score	–1.10(0.27)	<0.001			0.33(0.19–0.56)
Breeding:					
F_2 vs F_1	–0.79(0.34)	0.021	28.3	<0.001	0.45(0.22–0.89)
F_3 vs F_1	0.14 1.05	0.889			1.15(0.14–9.08)
Random effect	1.23(0.38)				
Outcome variable: evidence of long calving interval					
Constant	0.06 (0.35)				
Zebu vs non-Zebu	0.85 (0.42)	0.041	4.1	0.041	2.3 (1.03–5.38)
Random term	0.00 (0.61)				

LRS, likelihood ratio statistic; LRP, likelihood ratio p-value; OR, odds ratio; CI, confidence interval
Wald P, wald statistic (t value χ^2 @ 1 df

Evidence of dystocia varied significantly with levels of exotic genes, with F_2 being significantly protective compared to F_1 (OR for F_2 vs F_1= 0.45, p = 0.021; OR for F_3 vs F_1 = 1.15, p = 0.889). Evidence of dystocia was significantly associated with poor condition score (β for score –1.10, p = 0.001).

DISCUSSION

The mean annual birth rate of 65 per 100 cow-years was comparable to birth rates reported in studies of smallholder mixed local/dairy cattle in highland (Iringa) and Lake Zone regions of Tanzania, where calving rate is also considered as an important livestock production parameter (De Wolf, 1993; Southern Highland Dairy Development Programme, 1997).

The mean birth rate estimated from this study was higher than the recently reported 54/100 cow-years from smallholder farms from Zimbabwe (French *et al.*, 2001). As a consequence, the calving interval of 500 days was markedly lower than the 687 days in the Zimbabwe study. There was no evidence of significant variation in birth rates among different districts, which is consistent with findings in other tropical regions of Africa (Agyemang and Nkhonjera, 1990).

The mean calving interval of 500 days was longer than that previously reported for cows kept in smallholder units and government farms in Tanzania (Kifaro, 1985; TDDP, 1999; Kanuya *et al.*, 1997, 2000) as well as those reported from other sub-humid regions of the tropics (Agyemang and Nkhonjera, 1990; Shehata *et al.*, 1995; Obese *et al.*, 1999; Masama *et al.*, 2003) and temperate parts of the world (Aeberhard *et al.*, 1997). Such a long calving interval implies that farmer's income suffers because of the low calf crop and the low level of production associated with extended lactations (Kanuya *et al.*, 2000).

Dystocia was reported to be a common problem affecting more than 50% of births. Whether this represents true levels of dystocia or overzealous interference by inexperienced farmers is unclear. Nevertheless, assisted calvings are likely to result in deleterious effects on the subsequent fertility of the cows (Elbs Bott and Distl, 1994), often via postpartum uterine infections in the cows (Dohmen *et al.*, 2000). Dystocia may also increase the likelihood of RFM (Schnitzenlehner *et al.*, 1998), which is consistent with our observations that animals with more exotic blood (which for the most part was Friesian) were less likely to suffer dystocia, and Friesian crosses were less likely to suffer RFM. Many animals had poor condition score (median 2), suggesting that malnutrition of the dairy cows is widespread on the farms. The relationship between poor condition score and dystocia is consistent with other studies (Obese *et al.*, 1999), although we are cautious about interpreting relationships between events and measurements that are temporally separated. Retained placenta was reported in 17.4% of the cows. This finding is comparable to the 18% estimated in peri-urban smallholders dairy cows in Morogoro and Dar-es-salaam (Nkya and Swai, 1990). This prevalence is, however, higher than the range of 5–12% in normal populations of calving cows reported by Younquist (1988) and Moller and colleagues (1967). Retained placenta is a further potential cause of LCI via a greater likelihood of uterine infections

in the cows (Zaiem *et al.*, 1997; Bruun *et al.*, 2002). Only 0.9% of cows were reported to have aborted, a finding somewhat different from observations in other areas of Tanzania (9% in smallholder dairy farms in Dar-es-salaam and Morogoro: Nkya and Swai, 1990), and also lower than the 5% level that is considered normal (Gaines, 1990).

Most farms (93%) in the study reported feeding minerals, but only nine animals had levels of plasma inorganic phosphorus at or above the 4–5 mg/100 ml level that is considered normal in bovine species (Blood *et al.*, 1997). Blood collected from the jugular vein can yield more variable phosphorous levels than blood collected from the vessels in the tail (Blood *et al.*, 1997). Nevertheless, the mean 2.5 mg inorganic P/100 ml of blood collected from the study animals suggests that deficiency may be widespread on farms of the study region. A general problem of malnutrition of the dairy cows may be the underlying cause of phosphorus deficiency on the farms. Phosphorus deficiency could lead to sub-oestrus, impaired fertility and, hence, extended calving interval (Blood *et al.*, 1997).

Apart from breed and condition score effects, none of the other farm-level variables investigated was found to be associated with long calving interval, dystocia or retention of placenta, suggesting that other unmeasured farm- (or farmer-) related factors may be important determinants of reproduction performance in the smallholder units. These could include attributes of farmer training such as awareness of heat signs or early detection of heat signs, but also delayed mating due to the poor availability of breeding bulls or artificial insemination. Most of the studied cows were zero grazed, so failure or inaccuracy of oestrus detection by owners or attendants associated with confinement of the cows may be partly responsible for the long calving intervals.

Our studies suggest that, in common with other tropical countries, long calving intervals are common on smallholder dairy units and are a likely source of economic loss. Potential factors associated with long calving interval included breed effects, but the observed poor nutrition, mineral deficiency, high levels of dystocia (or at least farmer intervention at calving) and retained placenta may all interact as management causes of long calving intervals. Larger prospective, longitudinal studies would be required for a comprehensive and specific investigation of potential causes of sub-fertility in this farming system.

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Étude croisée des performances reproductives des vaches laitiéres de petits cultivateurs en Tanzanie Côtière

Résumé – Une étude rétrospective croisée a été entreprise sur 200 fermes de petits cultivateurs choisies au hasard appartenant à un système mixte de fermes laitières au Tanga, en Tanzanie, entre janvier et avril 1999. Nous avons estimé la fréquence et les déterminants d'un long intervalle de vêlage (LCI), de la rétention de la membrane foetale (RFM), de la dystocie et de l'avortement sur le bétail croisé de petits cultivateurs et avons exploré les tendances de la naissance. L'intervalle moyen du vêlage a été de 500 jours et le taux de naissance de 65 par 100 vaches-années. La dystocie a été signalée comme affectant 58% des vêlages et 17.2% des animaux souffraient de RFM. En utilisant des modèles à effet mixte, les variables associées au LCI, à la RFM et à la dystocie ont été la race, le taux de sang exotique et le score de la condition. La race des zébus a été associée au LCI (rapport des cotes (OR) = 2.3, $p = 0.041$) et la race frisonne à des cotes plus basses pour la RF (OR = 0.26, $p = 0.020$). Les animaux ayant des taux de sang exotique plus élevé avaient des cotes plus basses pour les signes de dystocie (OR = 0.45, $p = 0.021$). Les signes de dystocie ont été significativement associés à un score de piètre condition (bêta = –1.10, $p = 0.001$). Nos observations suggèrent que des LCI sont fréquents dans les fermes laitières de petits cultivateurs dans cette région et qu'ils sont une source probable de perte économique. La dystocie, le RFM, un score de piètre condition et une carence en minéraux ont été des problèmes fréquents et éventuellement liés à un LCI.

Estudio intersectorial del rendimiento reproductivo de las vacas lecheras en granjas pequeñas de la zona costera de Tanzania

Resumen – Se llevó a cabo un estudio intersectorial retrospectivo en 200 granjas pequeñas seleccionadas al azar, pertenecientes a un sistema agrícola lechero mixto en Tanga, Tanzania, entre enero y abril de 1999. Estimamos la frecuencia y los factores determinantes de los largos intervalos entre partos (LCI, en inglés), la retención de la membrana fetal (RMF), la distocia y los abortos en el ganado cruzado de granjas pequeñas, y exploramos las tendencias de los nacimientos. El intervalo medio entre partos fue de 500 días y la tasa de nacimientos 65 por 100 vacas-años. Se informó que la distocia afectaba a un 58% de los partos, y que un 17.2% de los animales sufrían RMF. Utilizando modelos de efectos mixtos, se vio que las variables asociadas con LCI, RMF y distocia eran la raza, el nivel de sangre exótica, y la condición corporal. La raza Cebú se asoció a un LCI (razón de probabilidades (OR) = 2.3, $p = 0.041$) y la raza Friesian con razones más bajas para RMF (OR = 0.26, $p = 0.020$). Los animales con niveles mayores de sangre exótica tenían menores probabilidades de evidencia de distocia (OR = 0.45, $p = 0.021$). La presencia de distocia se asoció de modo significativo con la pobre condición corporal (beta = –1.10, $p = 0.001$). Nuestras observaciones sugieren que los largos intervalos entre partos (LCI) son habituales en las pequeñas granjas lecheras de esta región y una fuente probable de pérdida económica. La distocia, la retención de la membrana fetal (RMF), la deficiente puntuacion corporal, y la deficiencia mineral resultaban problemas habituales y estaban posiblemente relacionados con los LCI.