ASSESSMENT OF REPRODUCTIVE PERFORMANCE OF SMALLHOLDER DAIRY CATTLE IN RUNGWE DISTRICT, TANZANIA AND POSSIBLE INTERVENTIONS

BY

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ABSTRACT

A study was conducted aimed at establishing causes for suboptimal reproductive performance in smallholder dairy cattle and investigate on possible interventions. Experiment 1 was carried out to identify management, productive and reproductive status of the animals. The data were analysed using descriptive and Chi-square test. Monitoring was done (Experiment 2) to evaluate nutritional, productive and reproductive status of animals. Body weight (BWT), body condition score (BCS), plasma urea nitrogen (PUN), calcium (Ca), phosphorus (P) and copper (Cu) were determined. Several reproductive performance indices were calculated and association between them and the nutritional parameters were determined by Pearson's correlation coefficients. Effect of supplementation on productive and reproductive performance was evaluated (Experiment 3) using similar parameters as in experiment 2. General linear model was applied for analysis of variance of variables in experiments 2 and 3. Chi-square test was used to determine the relationship between proportions of animals in categories of reproductive parameters and diseases in different seasons and treatment groups. Experiment 1 showed that most respondents practised zero grazing, bred animals by natural mating and dried cows 1-3 months precalving without steaming up. On average farmers fed 1.9 kg of concentrate per day for 19.2 days in a month with 23.8 g/day of minerals included in 13.7 days in a month. The observed (Means ± SD) ages at puberty, first mating, first calving (AFC) and CI were 20.5±1.0, 21.5±1.8, 30.8±1.8 months and 526±123 days, respectively. In experiment 2, BWT and BCS (Means ± SEM) were 320.8 ± 3.9 kg and 2.2 ± 0.0, respectively. Concentrations (Means ± SEM) of PUN, plasma Ca, P and Cu were 8.4 ± 0.2, 7.7 ± 0.1, 4.3 ± 0.1 mg/dl and 0.44 ± 0.01 μg/ml, respectively. Ovarian cyclicity resumed before 90 days postpartum in 29.4% of the animals and days to first visual oestrus (DPO) were 178.7 ± 19.6 (Mean ± SEM) with 22.9% of cows showing visual oestrus before 90 days postpartum. Mean (Mean ± SEM) SC and CI were 1.5 ± 1.2 and 485.7 ± 20.1 days, respectively. The DPO was significantly correlated with BWT ($r = -0.315$; $P<0.05$), BCS ($r = -0.424$; $P<0.01$) and body condition score at calving (BCSC) ($r = -0.348$; $P<0.05$) while CI was significantly correlated with BCS ($r = -0.394$; $P<0.05$). Supplementation significantly ($P<0.05$) reduced DPO by 43.6 days and significantly ($P<0.001$) improved BWT, BCS, PUN, and milk yield by 37.9 kg, 0.3, 2.2 mg/dl, and 2.5 L/day, respectively. In addition, supplementation significantly ($P<0.05$) increased BCSC, plasma P, Cu, and calf birth weight by 0.4, 0.6 mg/dl, 0.07 μg/ml, and 2.6 kg respectively. Reproductive performance of the cattle was suboptimal and was attributed to nutritional deficiencies. Concentrate supplementation and body condition scoring were recommended but further research is needed to refine the feeding strategy in relation to plasma P and Cu and to establish the optimum body condition score for dairy cattle production and reproduction in the area. More research is also needed to identify risk factors that contribute to cattle dystocia in Rungwe district.

DECLARATION

I, ANGAZA AMOS GIMBI, do hereby declare to the Senate of Sokoine University of Agriculture that this thesis is my own original work and has not been submitted for a degree award in any university.

Signature...

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DEDICATION

To my beloved late brother John Gimbi who was brutally murdered when I was in the middle of this research. May the almighty God rest his soul in eternal peace.

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AFC	Age at first calving
AI	Artificial insemination
BCS	Body condition score
BWT	Body weight
Ca	Calcium
BCSC	Body condition score at calving
CBwt	Calf birth weight
CCI	Interval from calving to conception
CF	Crude fiber
CI	Calving interval
CL	Corpus luteum
CP	Crude protein
Cu	Copper
DALDO	District agriculture and livestock development officer
DM	Dry matter
DMI	Dry matter intake
DPO	Days from parturition to first visual oestrus
DPOA	Days from parturition to resumption of ovarian cyclic activity
FSH	Follicle stimulating hormone
GnRH	Gonadotropin releasing hormone
HM	Hominy meal

IGF-I	Insulin-like growth factor-I
IVOMD	In vitro organic matter digestibility
L	Litre
LH	Luteinising hormone
ME	Metabolisable energy
MP	Metabolisable protein
MR	Milk response
MUN	Milk urea nitrogen
MY	Milk yield
NE	Net energy
NPN	Nonprotein nitrogen
P	Phosphorus
PGF2α	Prostaglandin F2α
PRA	Participatory Rural Appraisal
PUN	Plasma urea nitrogen
RDP	Rumen degradable protein
RIA	Radioimmunoassay
RP	Reproductive performance
SC	Services per conception
SHZ	Southern highlands zone
SM	Super Maclick® (Coopers Kenya Ltd)
SSC	Sunflower seed cake

SUA	Sokoine University of Agriculture
TNF-α	Tumour necrosis factor α
TShs	Tanzanian shillings
UDP	Undegradable dietary protein

CHAPTER 1

INTRODUCTION

1.1 Background

Rungwe district is located in the southern highlands zone (SHZ) of Tanzania. The SHZ of Tanzania covers several regions, which lay between latitudes 7^0 and 12^0 south and longitudes 30^0 to 38^0 East. It covers an area of 244,224 km^2 with an estimated human population of 7.4 million (1998 projection growing at 3.38% annually). Over 80% of the population is engaged in agriculture. In addition to local zebu cattle, smallholder farmers in the area keep crossbred dairy cattle. Introduction of the improved dairy cattle in the area took place mostly during the last two decades as a result of activities of Southern Highlands Dairy Development Project (SHDDP), Heifer Project International (HPI), Uyole Agricultural Research Centre (UARC), Kitulo and Iwambi Dairy Farming Company farms and Dabaga dairy farm. Missionaries and private farms have also contributed considerably to the introduction of dairy cattle in the area (Mwakyembe, 1996a). However, increase in dairy cattle population has been low compared to projected numbers in Iringa and Mbeya regions. Long calving interval (CI) has been suspected to be a contributing factor (Mwakyembe, 1996b).

Most of available information on reproductive performance (RP) of dairy cattle in SHZ is similar to other parts of Tanzania and Africa (Table 1.1). In most cases the

Table 1.1: Reproductive performance parameters observed in cattle in different types of farms in Africa and Tanzania

Reproductive parameters				Cattle/farm type	Place	Source
[1]AFC (months)	[2]DPOA (days)	[3]CCI (days)	[4]CI (days)			
39.7±0.5			517.6±16.4	Smallholder (Friesian x local breeds)	Highlands-Ethiopia	Shiferaw *et al.* (2003)
36.8±1.3			462.1±38	Smallholder (Friesian x local breeds)	Urban - Ethiopia	Shiferaw *et al.* (2003)
38.8±0.5			463.1±5.3	(*B.Taurus* x *B. indicus*)	Ethiopia	Negussie *et al.* (1999)
	101±7	152±4	444±16	Smallholder (Sanga)	Peri-urban, Ghana	Obese *et al.* (1999)
			475±19.4	Smallholder (Friesian x Red Dane)	Zimbabwe	Francis and Sibanda, (2001)
			538±26.9	Smallholder (Friesian)	Zimbabwe	Francis and Sibanda, (2001)
			412	Friesian	Kenya	Rege, (1991)
			406	Friesian	Kenya	Ojango, (2000)
			490-503	Smallholder (*B.Taurus* x *B. indicus*)	Kagera, TZ	Rugambwa *et al.* (1994)
			453	Smallholder (*B.Taurus* x *B. indicus*)	Northeast Tanzania	Msanga *et al.* (1999)
			477 (335-860)	Smallholder	Highland areas (Mt. Meru), TZ	Kanuya *et al.* (2000)
30.2±0.8			426±18	Large farm (Friesian, Ayrshire and Jersey)	Morogoro, TZ	Mujuni *et al.* (1990a)
			433±8	Smallholder (*B. Taurus*)	Mbeya (SHZ)	Mchau, (1991)
			443±10	Smallholder (*B.Taurus* x *B. indicus*)	Mbeya, (SHZ), TZ	Mchau, (1991)
33-39			375–489	Large farms	Iringa & Mbeya	Kifaro, (1995)
36.7			484.9	Smallholder	Iringa & Mbeya	Balikowa, (1997)
		237±14	517±22		Arumeru, TZ	Kanuya *et al.* (1998)
32.8			404±13 (RS) 466±20 (DS)	(Ayrshire)	Iringa, (SHZ), TZ	Kanuya and Greve, (2000)
			480	Smallholder (*B.Taurus* x *B. indicus*)	Iringa & Mbeya (SHZ)	Mwakalile *et al.* (2002)

[1]AFC = Age at first calving
[2]DPOA = Days from parturition to resumption of ovarian cyclic activity
[3]CCI = Interval from calving to conception
[4]CI = Calving interval

information indicates suboptimal RP in terms of age at first calving (AFC), interval from calving to conception (CCI) and CI. This is in contrast to what is expected in a well-managed dairy herd, where heifers would show first oestrus from 7 to 18 months of age and 65 to 70 % of the cows conceive on first service with an average of 1.3 to 1.7 services per conception (Roberts, 1971). Generally, recommended AFC in a well-managed dairy herd is 24 months (Quigley *et al.*, 1996) and less than 10% of cows are expected to have reproductive problems and CI should be between 360 and 390 days (Roberts, 1971). In order to attain this CI, cows must be pregnant within 85 - 115 days after calving. Arguments against short CIs are sometimes raised in connection to loss of milk. However, recent research shows that cows that get pregnant sooner after calving have higher average MY per day of lactation period and per year. This is because shorter CIs, reduce the prolonged periods of lower daily milk production in later lactation than comparable cows with delayed conception (Little, 2004).

The suboptimal RP of cows in SHZ is probably related to improvements in MY and the increased nutrient demands placed on the improved cattle as reported in other countries. A number of publications have documented decline in reproductive efficiency that has been related to improvements in MY in the United states (Lucy, 2001; Washburn *et al.*, 2002), Australia (Macmillan *et al.*, 1996), Ireland (Roche, 2000) and the United Kingdom (Royal *et al.*, 2000).

Factors causing reproductive decline in Europe and Australia may be different from those in the United States. For example, the rapid adoption of North American genetics and the associated increase in milk production in countries that depend heavily on grazing instead of total mixed ration feeding, may create a situation in which North American genetics are not matched with local management and feeding practices (Macmillan *et al.*, 1996). Although the scope and scale of dairy industry in Tanzania is very different from the developed countries, similar underlying managemental and cow biological factors could be involved in adversely affecting cattle RP in Tanzania as in developed countries.

Variations in RP result largely from influence of environmental (80%) than genetic (20%) factors (Lotthammer, 1989). Mwatawala *et al.* (2003) reported low repeatability for AFC and CI for Boran x Friesian crosses in Kagera, Tanzania suggesting that better improvement of RP can be achieved by manipulation of the environmental factors than genetic constitution of the animals. Possible environmental factors that can contribute to the suboptimal RP include poor nutrition that could be exacerbated by seasonal variations in pasture quality and quantity, low oestrus detection rates, reproductive diseases and disorders and functional abnormalities. It is assumed that the suspected suboptimal RP in Rungwe district is related to improvements in dairy herd genetics brought about by use of *B. taurus* x *B. indicus* crossbreds that does not correspond with local environmental factors. Since dairy farming is an important part of the household economy particularly where land is a limiting factor for agriculture (Mdoe *et al.*, 2000) and sub optimal RP is evident from the reviewed studies it is rational to carry out an on-farm study to investigate on factors that contribute to such performance and develop strategies to improve it. To achieve this 3 experiments were carried out with the following objectives.

1.2 General objective

To establish causes for sub optimal reproductive performance and evaluate the usefulness of regular body condition scoring in monitoring nutritional status in relation to reproductive performance of smallholder dairy cattle in Rungwe district and come up with possible interventions.

1.2.1 Specific objectives

Experiment 1:

- To identify the reproductive status of smallholder dairy cows and heifers in Rungwe district.

Experiment 2:

- To monitor and identify major causes of suboptimal reproductive performance of dairy cows and heifers in Rungwe district.

Experiment 3:

- To assess the effect of supplementation on reproductive performance of dairy cows and heifers in Rungwe district.

CHAPTER 2

LITERATURE REVIEW

Reproductive performance of dairy cattle reared under smallholder conditions is a complex subject. Knowledge of the characteristics of smallholder dairy farming system and dairy cattle reproduction are prerequisites to identification of possible factors that contribute to suboptimal reproductive performance and suggesting possible interventions.

This chapter begins with a review of some characteristics, background and importance of smallholder dairy production as a vehicle for rural development. Then, a review of reproductive performance in cows and heifers is covered with highlights on physiological control of reproduction and detailed review of reproductive events during the postpartum period that are critical in determining efficient reproduction in the cow. The knowledge of normal events of reproduction and their control is necessary in order to be able to identify the abnormal events. A review is then made on possible causes for reproductive failure and previous intervention attempts to improve RP in smallholder dairy cows and heifers in Tanzania and elsewhere in order to identify intervention opportunities for improvement of RP that could be adopted in Rungwe district.

2.1 Characteristics of smallholder dairy cattle production system

Smallholder dairy farming is an important part of farming throughout the developing world. Smallholder farmers follow three main feeding systems for cattle rearing, which are zero grazing (intensive), partial grazing (semi-intensive) and free range (extensive) (Sarwatt, 1986) as cited by Challya, 1998. Zero grazing system has been widely adopted by smallholders in dairy farming due to shortage of land (5 acres/family on average), and relatively sufficient availability of labour (Aminah and Chen, 1989). The system is also used as a means to control communicable diseases by isolation of the crossbred and exotic cattle from the indigenous cattle (De-Wit, 1990). However, zero grazing can contribute to poor animal productivity due to a number of factors. Failure to feed cattle during the night is often encountered in zero grazed animals, which is undesirable since stall-fed milking cows need night feeding like grazing animals (Aminah and Chen, 1989). In addition, failure to recycle soil nutrients is often observed in zero grazing system. In a study carried out in the Northern highlands zone of Tanzania about 28 % of feeds used in the highlands came from the lowlands and the manure obtained from the animals was not taken back to the lowlands (Massawe, 1999). Improved technologies, such as introduction of forage legumes and intensive use of multipurpose trees in the banana/coffee based farming system was proposed to reduce nutrient mining in the highlands (Kitalyi and Massawe, 2000). An additional shortfall of the system is due to inferior nutritive value when cut pasture is offered compared to that received by grazing animals. The protein content of Napier grass grazed by cattle was 17.1%, while that of the same forage being fed to stall kept animal was 7.4% (Vincente-Chandler *et al.*, 1964). Grazing animals are able to choose their own forages and tend to produce more milk (Soetrisno *et al.*, 1985; Wong *et al.*, 1987) and obtain better reproductive performance (Msangi *et al.*, 2001) than stall-fed cows.

Two main characteristics of smallholder farms are their small size in terms of resources and their low-income levels. They also lack the socio-economic power with which to gain access to public and private services (Kinsey, 1994). Although smallholder farmers have the common characteristics of limited resources and income, their farming systems and culture differ widely from place to place (McNamara, 1973 cited by Dillon and Hardaker, 1980). The smallholder dairy herd in Tanzania is made up of about 450,000 crossbred cattle managed on small holdings of 1-2 acres of land (Kurwijila and Boki, 2003) and land is limiting for expansion of arable crop farming (Msechu, 1988). Farmers own mostly between one and five zero-grazed dairy cattle (Kishinhi, 1999; Kurwijila and Boki, 2003). Among the smallholder farmers, milk has always been an important product or by-product of the enterprise (Udo and Cornelissen, 1998; Bebe *et al.*, 2003). Others include manure, form of capital investment and security, meat, skin, draft power and social statuss (Udo and Cornelissen, 1998).

Smallholder dairying is an important avenue for rural development in developing countries through its contribution to increases in livestock and farm productivity, income generation from sales of milk and dairy product, provision of jobs and transfer of money from urban to peri-urban and rural areas. Farming households integrate dairy with crop enterprises to maximize the returns from limited land and capital, with dairy production as means to achieve multiple objectives: to improve food security, support crop production, build capital assets and generate cash income (Paris, 2000; Kristensen *et al.* 2004). Given that smallholder farmers own more than 80% of improved national cattle herds (Kishinhi, 1999), governments and aid organizations started to promote small scale dairying as a powerful means of rural development and of meeting the growing demand for milk. To date, considerable progress has been made in some Asian and African countries, of which India and Kenya are outstanding examples where smallholder dairy production has given good promise (Stotz 1979; Walshe *et al.*, 1991) as a vehicle for rural employment and development. In Kenya, it was estimated that 80% of marketed milk was produced by approximately 3 million dairy cattle (*Bos taurus* cattle and their crosses with *Bos indicus*) of which 2.5 million were found on smallholder farms and that approximately 70% of all the marketed milk was produced by smallholder farmers (Omore *et al.*, 1999). The number of crossbred dairy cattle under smallholder farming system in Tanzania was estimated to be about 450,000, which is consistent with low average per capita milk consumption of about 26 liters when compared to 44 liters in Kenya and the recommended level of 100 liters (Kurwijila and Boki, 2003). The main avenues of improvement in the smallholder sector have been through crossbreeding with European dairy breeds, disease control, improved feeding and development of milk collection, processing and marketing infrastructure.

In Tanzania, the government and donor agencies shifted emphasis from large scale to smallholder dairy development as stipulated in 1983 livestock policy and later the Dairy Development Programme (1989) (Mtumwa and Mwasha, 1995). The emphasis was particularly focused among smallholders in southern and northern highland areas of Tanzania after failures of attempts by the government to stimulate large-scale parastatal dairy farms, ranches and improvement of pastoral systems. This was indicated by collapse of large parastatal dairy farms, ranches and a number of major development programmes aimed at the beef sub sector of the livestock industry, for example the Maasai settlement scheme, the beef cattle grading system and attempts to enforce a 10% destocking policy. Further reasons cited included the large amount of labour and personal commitment required for dairy production, the predominance of smallholdings in the most suitable dairy production zones and the large social benefits from supporting small-scale farmers (Brumby and Sholtens, 1986).

A number of constraints have been facing the smallholder dairy farmers in Tanzania, which include poor quality natural pastures and unavailability and prohibitive prices of hominy meal, oil seed cakes and commercial minerals for supplementation (Urio and Sarwatt, 1986; Safari *et al.*, 2000; Stephen *et al.*, 2002). Other constraints are inadequate supply of good quality replacement heifers (Houterman *et al.*, 1993; Kurwijila *et al.*, 1996), inadequate support services such as artificial insemination (AI), veterinary drugs and equipment (Lyimo, 1994) and dairy products marketing problems (Mdoe and Wiggins, 1996; Stephen *et al.*, 2002). In addition, shortage of finance for investment (Kurwijila *et al.*, 1996), inadequate farmers training, weak decision and implementation ability on farm management have contributed to reduced productivity of smallholder dairy cattle (Lyimo, 1994).

Despite the general constraints to smallholder dairy cattle productivity, the performance of crossbred and grade cattle on smallholder dairy farms in some areas reached a level equal to or surpassing that of large scale parastatal dairy farms in Tanzania (Mchau and Mwakatumbula, 1981). Furthermore, it has been previously shown that in households with improved cattle, the per capita milk consumption was more than twice the national average and that considerable amounts of surplus milk were sold to supplement farm income (Mchau, 1980; Lerenius and Skarback, 1987).

Future prospects for the smallholder dairy farming system is to evolve into medium scale dairy farming system. With increase in demand for milk and milk products as economy improve and urbanization increases, a shift is expected of the smallholder dairy production system in their contribution to milk supply (Ingco *et al.*, 1996). Introduction of specialised dairy breeds and increased level of inputs and the requirements for good market linkages for milk sales and input supply is bound to be high (Shem and Mdoe, 2002). Consequently, the existing smallholder dairy production system offers a good base for further research aimed at developing and promoting appropriate technologies to sustainably support the improvement of dairy industry in Tanzania.

2.2 Reproductive performance in cows and heifers

Reproduction is important as it affects milk production and calf crop in cattle. Milk production is very much dependent on the reproductive performance (RP) of the cow. This is facilitated by high calving rate, fewer services per conception, fewer days open and shorter calving intervals (CIs). Together with milk production, survival of calves and growth rate to maturity, RP is a trait of economic importance in dairy farming (Kiwuwa, 1968). Poor RP is a constraint to success of dairy farming because of economic losses, which result from prolonged CIs and early culling of cows due to reproduction failure. Understanding the RP traits, mechanisms involved in the control of reproductive events and factors affecting them, is a prerequisite to evaluation and working out strategies for management and improvement of RP in cows and heifers.

2.2.1 Reproductive performance traits and some indices of economic importance in cows and heifers

Traits that contribute to the overall RP of a breed include age at first calving (AFC) and calving interval (CI). Breed differences account for about 1 to 8% of total variation in AFC. This is much less compared to the influence of year of birth which is responsible for up to 40% of total variation. The influence of year of birth is linked to variations in availability of feeds and management among years. This suggests that much improvement in this trait can be brought about through improved feeding and management. Season of birth seems to have a small and mostly nonsignificant influence on AFC (Madsen and Vinther, 1975; Buvanendran *et al.*, 1981; Kiwuwa *et* *al.*, 1983). Negussie *et al.* (1999) observed no significant influence of season but a significant effect of year of calving on AFC for a 6-year period and linked the observed variations in AFC to availability of supplementary feed and problems associated with timely availability of frozen semen for AI among the years in Ethiopia.

Calving interval seems to have the same pattern as AFC with year of calving being more important than breed while the influence of season of calving is small. In a study to evaluate the effect of environmental factors and proportion of Holstein blood on days to first insemination and CI of crossbred dairy cattle on smallholder farms in Tanzania (Msanga, *et al.*, 1999), genotype and season of calving had no significant effect on CI. On the other hand, year of calving was reported to have a significant effect on CI, which was attributed to variability in feed availability among years. Similarly, Negussie *et al.* (1999) observed no significant influence of season but a significant effect of year of calving on CI for a 6-year period that was associated with availability of supplementary feed and frozen semen for AI among the years in Ethiopia.

Evaluation of RP in female cattle is carried out using a number of measures some of which are shown in Table 2.1. Calving interval is the measure most commonly used to assess the overall RP in dairy herds (Upham, 1991; Esslemont, 1992; King, 1993). Calving interval is calculated as the duration of the interval between the two most

Table 2.1: Common reproductive indices and their optimal values under ideal circumstances

Reproductive index	Optimal value	Serious problems value
Calving interval (days)	375 - 390	> 420
Days to first observed oestrus	< 40	> 60
Cows observed in heat within 60 days after calving (%)	> 90	< 90
Days open to first breeding	45 - 60	> 60
Services per conception	< 1.7	> 2.5
First service conception rate of heifers (%)	65 - 70	< 60
First service conception rate of lactating cows (%)	50 - 60	< 40
Cows that conceived with less than 3 services (%)	> 90	< 90
Cows with a breeding interval between 18 and 24 days (%)	> 85	< 85
Days open (days)	85 - 110	> 140
Cows open more than 120 days (%)	< 10	> 15
Dry period length (days)	50 - 60	< 45 or > 70
Average age at first calving (months)	24	< 24 or > 30
Abortion rate (%)	< 5	> 10
Culling rate for reproductive problems (%)	< 10	> 10

Source: Wattiaux, 2004

recent calvings for all parturient cows in a herd. This measure has several inherent limitations (Upham, 1991). One major deficiency is that first lactation cows are excluded from the measure, as they have not had two calvings. Second, open cows and cows culled for reproductive failure also do not contribute to the measure. Thus, an apparently acceptable CI might misrepresent actual herd performance because infertile cows and cows with poor fertility are often culled from the herd (Peters and Ball, 1995; Upham, 1991). Hence, a high reproductive culling rate might result in a low average CI, even in herds with serious reproductive problems. Therefore, CI should be interpreted in combination with reproductive culling rate (Esslemont, 1992). The CI is based on historical events (i.e., past calvings), and does not reflect recent changes in RP, which is a disadvantage because proactive assessment and planning of reproductivemanagement require current information on RP. Provided the numbers culled for sterility and the number of abortions are within acceptable limits, CI below 405-420 days could be considered satisfactory (King, 1993).

Reproductive culling represents involuntary culling as the decision to remove the cow from the herd is not based on milk production or genetic merit. This becomes a problem in herds with low pregnancy rates where many cows that are not pregnant at the end of the breeding period are culled and replaced with heifers. Even though some revenue is derived from sale of beef, reproductive culls have a negative impact on profitability. Less than 10-15% of cows calving in a year should be culled for poor reproduction (Ferguson, 1989).

Various factors have been reported to influence days open and CI in dairy cattle. Oestrus detection rate, days to first service and conception rate all combine to influence days open and CI. Average days to first service is affected by the selected voluntary waiting period, heat detection efficiency and herd reproductive health (Smith *et al.*, 2002). Generally, dairy producers set a voluntary waiting period of 45 to 60 days, which enables the minimum days to first service (Young, 2002). The days to first service further sets the minimum CI for a cow and the herd. The average time between calvings will be longer than the minimum CI because not all cows conceive on first service and some cows experience early embryonic death. The conception rate, heat detection efficiency and postpartum breeding policy strongly influence the CI (Smith *et al.*, 2002).

Accurate heat detection is especially important for herds breeding by AI, though it is also important for natural service herds. It provides the basis upon which most reproduction management decisions are made. Detection of the first estrous period following calving provides a reference point upon which to expect subsequent estrous periods. It is also beneficial in determining whether a cow is progressing normally from calving (Smith *et al.*, 2002; Young, 2002). Heat detection is a major factor affecting days open and CI. The percent of heats observed is an indicator of the overall success of a heat detection program. Not only must estrous be observed, but the observation and breeding must be done on a timely basis for conception to occur.

Measures of conception rate include services per pregnancy and percent successful services. Services per pregnancy are available for pregnant cows as well as for all cows. The percent successful services is equal to the number of successful services divided by the number of total services times 100. The goal is to maintain at least a 50% conception rate (Young, 2002). For herds on routine pregnancy diagnosis, reported pregnancies are used to calculate the percent successful. When actual pregnancy data are not reported, the 60-day non-return rate is used (Smith *et al.*, [illegible]).

The non-return rate is an estimate of the percentage of cows, which have become pregnant and did not return for another service within a specified time after insemination. This estimate will be much greater than the actual conception rate if complete records of return to service dates are not kept. In addition, non-return rates are expected to be inflated by approximately 15-20% relative to true conception rate when there is no way to identify cows that were culled after insemination (O'Connor and Dechow, 2002).

The number of services per conception (SC) is directly related to the conception rate in a herd, thus Conception rate = 100/SC. The SC is calculated as the average number of breedings required to produce pregnancy. It is a useful indicator of success of breeding program although it is deficient since it only includes assumed pregnant animals and provides no information on the proportion of females that fail to get pregnant at all, or any indication of how early or late conception occurs in relation to the previous parturition (Young, 2002). The target for number of services per conception is 1.7-2.0 (Table 2.1). Conception rate influences days open because if a cow does not conceive, she will be open an additional estrous cycle that is 21 days. If problem breeders are not culled, SC will continue to rise.

Other indices of economic importance are pregnancy rate and days open. Pregnancy rate is calculated by multiplying oestrus detection rate times conception rate (Wattiaux, 2004). Calving to conception interval also termed as number of days a cow is open is the time from freshening to conception and may be the best indicator of current reproductive efficiency (Smith *et al.*, 2002). It's limitation is that it does not include open animals. A dairy producer's goal for days open is around 100 to 110 days. Days open can be influenced by length of voluntary waiting period and heat detection accuracy (Smith *et al.*, 2002; Young, 2002).

Exceptionally long or short dry periods will adversely affect the profitability of individual cows. A short dry period will not provide adequate rest and time for mammary regeneration, while long dry periods will result in higher feed costs with no income from milk production. Long dry periods can also result in fat cows that are more prone to problems with health and RP (Hafez, 1980; Esslemont, 1992).

2.2.2 Physiology of reproduction in cows and heifers

Events of reproduction in cattle are controlled by chemical messengers called hormones. Hormones are physiological chemical regulators usually produced by endocrine glands in one part of the body that are subsequently carried by either blood or lymph to their site of action or target tissue, where they are recognised and interact with special receptors and cause a change in function of the tissue. Some hormones and their function(s) in the control of reproduction in female cattle are presented in Table 2.2.

2.2.2.1 Puberty

Puberty is the age at which an animal becomes capable of reproducing. The exact

Table 2.2: Hormones that regulate reproduction in cows

Site of Production	Hormone produced	Action
Hypothalamus	Gonadotropin releasing hormone (GnRH)	Releases FSH and LH from pituitary gland.
Pituitary	Follicle stimulating hormone (FSH)	Stimulates follicle development and oestrogen production
	Luteinising hormone (LH)	Induces ovulation, development of corpus luteum (CL), and progesterone production.
	Oxytocin	Stimulates contraction of myoepithelial cells surrounding the alveoli in the mammary gland (milk ejection or 'letdown').
		Stimulates myometrium that is under Oestrogen dominance.
		Transportation of sperms in the reproductive tract.
Ovarian follicles	Oestrogens	Induces oestrus behaviour. Alter fluid production and muscular activity of oviducts, uterus, cervix and vagina. Causes surge in release of LH from pituitary during oestrus.
	Inhibin	Selectively depresses FSH release.
Corpus luteum (CL)	Progesterone	Prepares uterus for pregnancy. Prevents recurrence of oetrus cycles by depressing FSH & LH release.
	Relaxin	Expansion of uterus during pregnancy and relaxation of cervix at parturition.
Uterus	Prostaglandins	Promote luteal regression at end of oestrous cycle or pregnancy
	Embryo proteins	Provide signal that promotes maintenance of CL during early pregnancy.

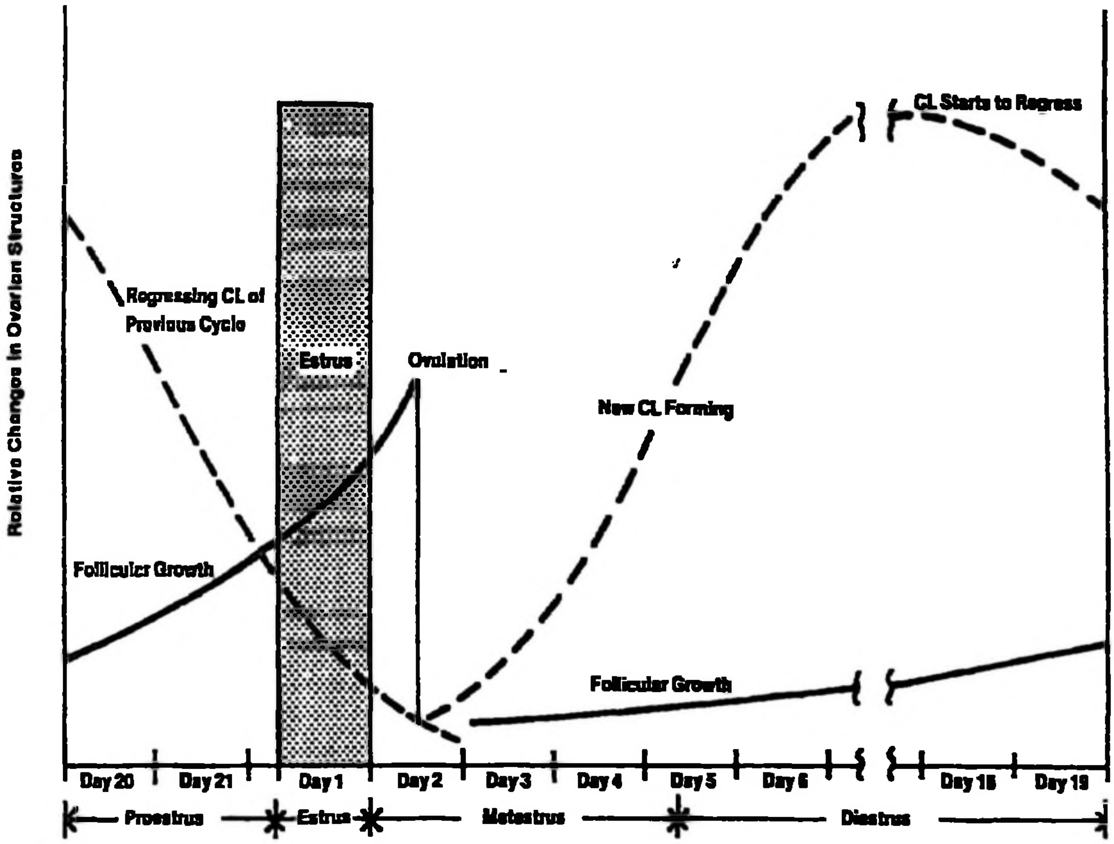
Source: Adapted from Duby and Prange, (2003).

mechanism controlling the onset of puberty is unknown. It is possible that puberty requires maturation of the hypothalamic mechanism controlling the surge mode of LH secretion. There is no distinct correlation between serum levels of GnRH, FSH or oestrogen and the onset of puberty (Hafez, 1980). The onset of puberty is not characterized by any deficiency in circulating levels of gonadotropins nor does ovarian sensitivity appear limiting (Hafez, 1980). In prepubertal heifers, pulsatile secretion of LH with peaks of high amplitude occurs throughout the period of sexual maturation and a definite decrease in magnitude of the LH peaks commences approximately 1 week prior to first ovulation (Gonzalez-Padilla *et al.*, 1975).

2.2.2.2 Oestrous cycle

Once heifers reach puberty, they enter into a cycle of reproductive events that involves mating, pregnancy and calving. Success of mating or AI of cows and heifers depends on timing of the appropriate stage of oestrous cycle. Oestrous cycle is the time interval between two periods of oestrus. Understanding factors regulating the oestrous cycle of female cattle is an essential component of reproductive management of dairy farms. Breeding cows using bulls by hand-mating accentuate this need. Oestrous cycles in cows and heifers normally vary from 18 to 24 days with 21 days considered as average (Figure 2.1). There are two or three waves of follicular growth during each cycle, each comprising of recruitment, selection, development of dominant follicle and atresia of the remaining follicles (Ginther *et al.*, 1996). The dominant follicle of the last wave of the oestrous cycle does not undergo atresia, it secretes large amounts of oestrogens that stimulate a preovulatory luteinizing hormone (LH) surge, causing this follicle to ovulate (ovulation = Day 0) approximately 30 hours after the onset of standing oestrus. Structural and functional changes of the ovulated follicle lead to the formation of the corpus luteum (CL) that grows quickly in size and secretes large amounts of progesterone. In non-pregnant cattle, pulsatile release of PGF2α from the uterus is initiated around Day 16 (Kindahl *et al.* 1981) causing regression of the CL. Circulating progesterone concentrations are then decreased, allowing final growth of a dominant preovulatory follicle, and the cycle is repeated. The pulsatile secretion of PGF2α in cattle was previously proposed to be generated by a positive feedback loop between ovarian and/or hypophyseal oxytocin and endometrial PGF2α (Armstrong and Hansel, 1959; Newcomb *et al.*, 1977). However, recent data suggest that oxytocin may not be essential for the initiation of luteolysis in cattle, but may play a supportive and modulatory role for the amplitude of pulsatile secretion of PGF2α after the initiation of luteolysis (Parkinson *et al.*, 1992; Kotwica *et al.*, 1997; 1999).

It was recently demonstrated that tumour necrosis factor α (TNF-α) stimulates PGF2α



Estrous Cycle:	The interval from the first signs of sexual receptivity at estrus (heat) to the start of the next estrus.
Length:	18-24 days (Avg. 21)
4 Periods:	
1. Proestrus:	1-3 days prior to estrus
2. Estrus (heat):	8-30 hours (Avg. 18) Ovulation occurs 10-14 hours after estrus.
3. Metestrus:	3-4 days after estrus. Some cows may have bloody discharge. Indicates she was in heat 2-4 days earlier, will be in heat again in 16-19 days.
4. Diestrus:	12-15 days, active corpus luteum. Regresses if cow is not pregnant, maintained if she is.

Source: Duby and Prange, (2003).

Figure 2.1: Periods of oestrous cycle and the accompanying changes in follicle and corpus luteum in cows

secretion from bovine endometrial tissue during the follicular and late luteal phase, suggesting that TNF-α could be involved in the initiation of luteolysis in cattle (Miyamoto *et al.*, 2000). Ovarian steroids are also involved in the regulation of prostaglandin secretion in cattle, with progesterone having a direct stimulatory effect and oestradiol modulating this effect (Okuda *et al.*, 2002).

Shorter cycles are abnormal while longer cycles, especially those that are multiples of 18-24 days are probably due to failure to detect oestrus. Cycle lengths of approximately 30-35 days may be false heats that occur after breeding or reflect early death of the embryo. The oestrous cycle is divided into four distinct but continuous phases of proestrus, oestrus, metestrus and diestrus (Figure 2.1). Proestrus is a period of follicular development between regression of CL of the previous cycle and oestrus. The period of oestrus is short, lasting from 6-30 hours. It is the only time that a cow will allow herself to be mounted by a bull or other cows. The behavioural changes that occur at this time are used as primary indicators of oestrus. It has been shown that 70 % of mounting activity occurs between 6 pm and 6 am. In addition, about 25 % of cows have oestrus periods of less than 8 hours. Final maturation of the egg and follicle occurs during this period. During early metestrus the follicle ovulates and the wall of the ruptured follicle develops into a CL during the next 3 days. Diestrus is a period of active progesterone production by the CL and lasts 12-15 days (Hafez, 1980).

2.2.2.3 Pregnancy and parturition

Endocrine levels immediately following conception are the same as those during the oestrous cycle. The increasing levels of progesterone and relatively low levels of oestrogen are essential for sperm transport and subsequent passage of the embryo into the uterus. Alteration of oestrogen:progesterone ratios during this time results either in fertilization failure or interruption of normal placentation (Hafez, 1980; Cunnigham, 1992).

The first change in hormonal patterns during pregnancy is associated with maintenance of the CL and its continued secretion of progesterone. The secretion of pituitary hormones is essential for maintenance of the CL, as hypophysectomy during early pregnancy inevitably results in luteal regression (Hafez, 1980). However, maternal recognition of pregnancy appears to involve blockage of uterine induced luteolysis. Progesterone is essential for the maintenance of pregnancy in the cow and reaches a peak approximately 2 weeks following ovulation and remains at this level until shortly before parturition (Swenson, 1970).

The most dramatic changes in the levels of hormones during pregnancy occur shortly before parturition. The first significant change is an increase in foetal levels of corticoids that appears to trigger initiation of parturition in the cow, concomitant with decrease in maternal levels of progesterone (Swenson, 1970; Hafez, 1980).

Utero-ovarian venous levels of oestrogen begin to increase in the cow 3 weeks prepartum. There is a rapid increase in oestrogen during the last 10 days that reaches a peak 1 to 4 days prior to parturition. Utero-ovarian levels of PGF2α remain constant until 48 hours before calving, where there is an exponential increase that peaks at parturition. The final stage of labour is accompanied by a surge in oxytocin, which probably acts in combination with PGF2α to cause expulsion of the foetus (Swenson, 1970; Hafez, 1980).

2.2.3 Postpartum changes in cows

Postpartum phase is the most critical period in determining efficient reproduction in the cow (Arthur *et al.*, 1989). Restoration of reproductive functions has to compete with the carry-over effects of the previous pregnancy and delivery and with the requirements for milk production. The postpartum period in the cow starts with parturition and continues until when uterine involution is completed with resumption of regular cyclic ovarian activities (Mario, 1982). The interval from parturition to first observed oestrus varies from 30 to 76 days in dairy cattle (Roberts, 1971). A study in Tanzania (Mujuni *et al.*, 1996) showed that cows undergoing normal postpartum, had mean (±s.d.) interval of 31± 12 days from calving to complete uterine involution and 46 ± 17 days to resumption of normal ovarian cyclicity.

2.2.3.1 Anatomical changes

Incomplete uterine involution is a barrier to fertility during the early normal postpartum period and completion of uterine involution is critical to development of early postpartum functions. The process of uterine involution involves reduction of the uterus size and re-establishment of normal endometrium (Wagner, 1968; Samuel, 1977). Infertility during the first 20 days after calving is caused by physical barrier to sperm transport by noninvoluted uterus (Short *et al.*, 1990), which may also be a barrier to implantation due to hostile uterine milieu. In addition, involuting uterus may be involved in shortening the luteal phase (Lauderdale, 1972) causing short early postpartum oestrous cycles, possibly through release of PGF2α from the endometrium. The functional capabilities of early postpartum CL are normal, but the CL is caused to regress prematurely by abnormally high PGF2α concentrations from the uterus (Short *et al.*, 1990). Short oestrous cycles contribute to postpartum infertility during the first 30 to 40 days after calving. Most oestrous cycles after 40 days have normal length, although some evidence exists that short oestrous cycles will occur later (Lishman *et al.*, 1979). Qureshi (2000) observed decreased rate of postpartum uterine involution with increasing zinc intake.

2.2.3.2 Dry matter intake and nutritional requirement changes

Dry matter intake postcalving can be explained by events during late gestation and the postpartum period. Dry matter intake (DMI) begins to decline around three weeks before calving in cases of single foetus in cattle. The DMI may be decreased by 10 to 30% compared with intake during early dry period (Bertics *et al.*, 1992), which is believed to be due to high circulating oestrogen around calving (Grummer, 1997). Furthermore, nutrient partitioning favours the foetus and placenta in advanced pregnancy and foetal growth during the last trimester is exponential and nutrient demands by foetus and placenta are at their greatest (Van Saun, 1991; Bell, 1995; Chandler, 1995). During the last four weeks of gestation the uterus and its contents increase in weight by 27% (Bereskin and Touchberry, 1967). This creates a very large increase in the gestational requirement of nutrients before parturition. The increased gestational requirement coupled with a decline in DMI make it necessary to feed a nutrient dense ration for three weeks before calving. Limited feed intake during the late gestation leads to negative energy balance that results in a high ratio of growth hormone to insulin in blood of cows, which promotes mobilisation of long chain fatty acids from adipose tissue. Fatty acids released from adipose tissue circulate as nonesterified fatty acids (NEFA), which are a major source of energy to the cow during this period (Emery *et al.*, 1992). Amino acids from the diet or from breakdown of skeletal muscle also contribute to glucose synthesis.

Maintaining positive energy balance in early lactating dairy cows is difficult, especially with low energy forages. After calving, high metabolic activity, initiation of milk synthesis and rapidly increasing milk production greatly increases demand of glucose for milk lactose synthesis, at a time when feed intake has not reached its maximum. Postpartum cows prioritise their metabolisable energy (ME) toward production of milk and then toward regaining body condition before reproductive processes. When the diet provided fails to meet the nutrient requirements of the animal, body reserves and tissues are mobilised to meet the requirements and this leads to loss in BWT and BCS (Buskirk *et al.*, 1992).

In the United States of America, most cows reach peak milk production around 35 days in lactation and do not reach energy balance until 70 to 85 days into lactation. Most cows in early lactation, because of their slow response to increasing DMI, are usually in negative energy balance from 1 or 2 days after calving until 70 to 85 days into lactation (Larry and Joe, 1994). Msangi *et al.* (2004) observed an overall improvement in energy balance as lactation progressed, mainly as a result of increased ME intakes in crossbred dairy cattle in Tanga. All cows were in positive ME balance after 15 weeks following parturition (Msangi *et al.*, 2004).

2.2.3.3 Endocrinological changes

Postpartum cows will begin to cycle once LH pulsatility reaches a critical level. The increase in LH pulsatility stimulates the maturation of a dominant follicle (Mihm and Austin, 2002). The dominant follicle produces estradiol 17-ß that reaches a threshold level to trigger an LH surge. The cow will have an LH surge and ovulate as long as the LH surge mechanism (positive feedback of estradiol) is established. Hypothetically, mechanisms that increase LH pulsatility through their actions on the hypothalamus and pituitary also coordinate an increase in the responsiveness of the ovary to LH (Butler, 2000; Lucy, 2000).

The most important postpartum process is recovery of ovarian activity and re-initiation of cyclicity. Recovery of the hypothalamus and pituitary from effects of the previous pregnancy and resumption of FSH and LH secretion is important for initiation of postpartum ovarian cyclicity in cattle. It has been observed by Karg and Schallenberger (1982) that the hypothalamus of the post parturient cow is usually refractory and needs about 2 weeks from calving to become active and accelerate GnRH to elicit increased secretion of FSH but without significant increase in LH. The LH surge mechanism for ovulation must also be re-established during the postpartum period. Cows begin normal LH pulsatility 1-2 weeks after parturition and recover the LH surge mechanism shortly thereafter (Lucy, 2003). Labhsetwar *et al.* (1964) observed more FSH and less LH immediately after calving than 20 - 21 days after calving. Follicle stimulating hormone is needed for follicular growth in postpartum cows but is not viewed as limiting for reproduction because most anoestrus cows have relatively high concentrations of FSH (Lucy, 2003). Follicular development begins shortly after calving with a transient increase in FSH, a follicular wave and development of a dominant follicle. The first postpartum dominant follicle undergoes one of three fates (Beam and Butler, 1999), which are ovulation, atresia and turnover followed by new wave emergence or cyst formation. A principal component of the mechanisms that dictate occurrence of any of the three events is the secretion of LH during the early postpartum period. Low LH pulsatility is associated with follicular turnover and anoestrus, moderate LH pulsatility is associated with ovulation, and extreme LH pulsatility and lack of an LH surge is associated with the development of cystic ovaries (Silvia *et al.*, 2002).

Concerning ovarian hormones, postpartum oestrogen profile as observed by Labhsetwar *et al.* (1964) showed a marked decrease in its concentration in urine 3 days after calving. Arije *et al.* (1974) and Keller *et al.* (1977) observed a fall of oestrogen and progesterone concentrations in systemic plasma and milk in the first week after calving. At time of ovulation oestrogen reaches a high level to suppress FSH production thereby stimulating the release of preovulatory surge of GnRH and LH (Diehl and Day, 1974; Braun, 1980).

During the postpartum period progesterone levels are minimal in the cow, only about 1.0 ng/ml of plasma but increase to peak at about 3.7 ng/ml after 63 days. Levels decline later to about 1.0 ng/ml at about 2 days before oestrus (Labhsetwar *et al.*, 1964; Dickey *et al.*, 1975). Progesterone inhibits oestrus but at low doses it favours ovulation possibly indirectly through its effect on LH release (Stabenfeldt, 1974). Progesterone profiles can be used to monitor ovarian function and cyclicity and are more useful than rectal palpation in this respect (Sprecher *et al.*, 1989; McLeod and William, 1991). Radioimmunoassay (RIA) is an effective method for measuring progesterone concentration in milk samples first described by Heap *et al.*, (1973). The technique has since then been applied extensively in monitoring reproductive functions in animals.

Changes in metabolic hormones Insulin and Growth hormone (GH), insulin-like growth factor (IGF-I) and leptin are dynamic in postpartum cows and reflect the shifting metabolic status of the animal. Blood concentrations of insulin, IGF-I, and leptin decrease shortly after calving (Butler, 2000; Lucy, 2000; Block *et al.*, 2001). Insulin and IGF-I concentrations gradually increase postpartum whereas leptin remains low in lactating cows (Lucy, 2000). Insulin, GH through IGF-I and leptin play a role in control of secretion of FSH and LH through their influence on GnRH release.

The lack of ovarian activity in underfed postpartum cows (Tegegne *et al.*, 1992; Das *et al.*, 1999) appears to be due to suppression of the pulsatile release of LH from the anterior pituitary gland, which in turn is controlled by release of GnRH from the hypothalamus. Energy balance may function by modulation of pulsatile LH secretion presumably at hypothalamic-pituitary level, and alteration of ovarian responsiveness to LH signalling through some metabolic compound(s) (Randel, 1990; Canfield and Butler, 1991). The endocrine signals most likely to inform the reproductive axis regarding a negative energy balance are Insulin, IGF-I and leptin (Williams *et al.*, 2002; Meikle *et al.*, 2004). The blood concentrations of insulin, IGF-I, and leptin are greater in cows in positive energy balance. Their actions may be on GnRH neurons, on the neuronal pathways that impinge upon GnRH neurons, or on the pituitary gonadotroph (Williams *et al.*, 2002). The endocrine control arises from tissues that respond to the metabolic or nutritional status of the animal (e.g., insulin from the pancreas; IGF-I from the liver; leptin from adipose tissue). The same metabolites and hormones that influence GnRH secretion and ultimately LH and FSH secretion may act directly on the ovary to influence the sensitivity of the ovary to LH and FSH. Ovarian cells treated with either insulin or IGF-I have greater numbers of gonadotropin receptors and greater activation of second messenger pathways in response to gonadotropins (Lucy, 2000). There is also the potential for insulin and IGF-I effects that are completely independent of LH and FSH. Although the interaction of metabolic hormones with the ovary has been described for insulin and IGF-I (Butler, 2000; Lucy, 2000; Monget *et al.*, 2002), it is likely that a variety of hormones, metabolites, and nutrients act on the ovary and change the ability of the ovarian cells to grow or respond to gonadotropins.

Another link between the energy balance and reproductive axis is through its effect on development and function of ovarian follicles. A low energy diet decreases the follicular growth rate, mainly because of the decrease in IGF-I concentrations that are essential for follicular development (Adashi *et al.*, 1985). Beam and Butler (1997) observed that follicles which emerged after energy balance nadir had a greater steroidogenic output and incidence of ovulation than follicles that had emerged before the energy balance nadir although the initiation of a follicular wave occurred regardless of early postpartum negative energy balance.

2.2.4 Factors affecting reproductive performance in cows and heifers

Factors that affect reproductive performance would invariably cause infertility that is diminution or absence of ability to produce offspring. Factors that contribute to infertility can be nutritional, parity, suckling and milk yield, managemental, functional disorders, infections, congenital morphologies and climatic environmental factors. The incidence and importance of the causes of infertility varies from one location and/or animal to another. In a sample of 510 Gir cattle in India, functional abnormalities were responsible for 59.4% of the cases of reproductive disturbance, compared to 23.3% attributed to pathological causes, 8.8% to anatomical factors and 4.8 to old age (senility) (Kodagali, 1974). In northern highland of Tanzania, the observed cumulative incidence risk of some causes of infertility were 16%, 1.7%, 2.5%, 4.2%, 1.7% and 6.1% for abortion, dystocia, prolapse, retained foetal membranes, milk fever and cyclic non-breeders, respectively (Kanuya *et al.*, 2000).

2.2.4.1 Nutritional factors

There is strong relationship between nutrition, reproductive and productive performance in cattle. It is estimated that about 80 % of the variance in fertility is due to environmental factors, of which more than 50 % is explained by nutrition, when severe infections and male fertility are excluded. Even predisposition to infectious diseases can be caused or increased by nutritional failures (Lotthammer, 1989). Therefore balanced feeding is fundamental to milk production as well as health and fertility.

Adverse effects on RP have been observed in cases of either excessive or deficient nutrition in heifers and cows. The primary dietary components that should be considered in providing for good reproduction are energy, protein, minerals and vitamins.

a. Energy and protein

Energy is one of the essential nutrients required by dairy cattle. The need for energy is met first and at the expense of other nutrients, if necessary. For example, if the energy requirement is not satisfied and protein is available, the animal will break down dietary protein to satisfy their energy needs before using it to meet their protein or amino acid requirements. Additionally, the quantitative demand and subsequent total cost for energy exceeds all other nutrients in the diet (Cecava, 1995).

The two main sources of energy in the diet are carbohydrates (starch and the fibrous components of the plant) and fats. Protein may also be used as an energy source when other sources are limiting, but this is an expensive and inefficient source of energy.

The first and primary function of energy is for the support of maintenance, which includes processes associated with body temperature regulation, metabolism and normal physical activity (NRC, 1996). Seventy percent of the ME intake of the mature cow is used for maintenance (Jenkins and Ferrell, 1983) while a growing heifer uses nearly 40% of her ME intake to meet maintenance requirements (NRC, 1996). The balance is available for productive function that is growth, lactation and reproduction.

Usually energy is the first limiting nutrient for high milk yield (MY) and reproduction because of low energy in forages. Energy balance plays a major role in initiation of ovulatory ovarian cycles in postpartum dairy cattle (Canfield *et al.*, 1990). Cows fed a high-energy diet after calving conceive sooner than those with a lower energy intake (Tegegne *et al.*, 1992; Das *et al.*, 1999).

Protein is an essential nutrient to dairy cattle. Proteins are complex organic compounds composed of amino acids, which serve as the basic "building blocks" within the body. Deposition of protein is necessary for growth. Protein is a primary cell component and is used by nearly every organ or system in the body, as it is an essential constituent of hormones, enzymes, and genetic material. Various quantities of ingested feed protein are degraded by ruminal microorganisms to smaller peptides and amino acids. Some of these proteins, peptides and amino acids may pass through the rumen and be absorbed directly by the small intestine. However, the vast majority are converted to ammonia and reconverted to microbial protein that will be later digested and absorbed by ruminants for their own usage. This is a relatively inefficient process, but it does allow cattle to utilize non-protein nitrogen (NPN) compounds such as urea to meet a portion of their protein requirement, provided there is adequate energy in the diet (Moore *et al.*, 1991).

For many years, nutritionists have formulated diets based upon CP. Crude protein is a measure of all nitrogenous compounds in a feed and is easily measured and estimates are readily available for most feedstuffs. More recently requirements for metabolisable protein (MP) in cattle have been generated (NRC, 1996). Metabolisable protein (MP) is the true protein absorbed by the intestine, which is supplied by microbial protein and undegraded intake (bypass) protein. The MP system is designed to account for the protein or nitrogen needs of the microbes as well as the protein needs of the animal (Ensminger and Perry, 1998). However, there is limited information for many feedstuffs regarding their percentage of rumen degradable protein (RDP) and undegradable dietary protein (UDP).

Protein to energy ratio has been shown to be important in dairy cattle diets in order to optimise fermentative digestion in the rumen. Production of volatile fatty acids and synthesis of rumen microbial proteins are determined in the first instance by the supply of fermentable ME (total ME minus ME in lipids and fermentation acids) (AFRC, 1993). In addition to fermentable ME, RDP is necessary in amounts sufficient to sustain optimum microbial fermentation. Requirements are for 9-12 g of effective RDP per MJ fermentable ME consumed (AFRC, 1993) depending on the feeding level. For ruminal microbes to efficiently capture nitrogen from RDP, energy supply must be synchronised with the rate at which nitrogen substrates become available for microbial growth. From non-fat dietary sources, 8-11 g of microbial CP are yielded per MJ of ME (Schelling, 1996). If a diet is deficient in protein, rumen ammonia levels will be too low for optimum microbial growth. This will reduce the level of carbohydrate digestion in the rumen and restrict the intake of feed by the animal (Butler, 1998).

The importance of protein to energy ratio has also been indicated in mammary gland development and subsequent milk production. VandeHaar (1998) evaluated 11 mammary gland development experiments and observed that mammary gland development was inversely related ($r^2 = 0.71$) with the CP to energy ratio of the diet. Furthermore, the CP:ME ratio of the diet accounted for 76% of the variation in milk yield from these studies. These data suggest that mammary gland development and milk yield are impaired when heifers are fed low protein, high-energy diets. On the other hand, it has been suggested that milk yield is affected adversely by excessive intake of RDP and that energy expenditure for urea synthesis might be partially responsible for the depressed milk yield of cows fed with surplus CP (Higginbotham *et al.*, 1989). These data also suggest that when high-energy diets are fed, increasing dietary protein may be warranted. In another study (Radcliff *et al.*, 1997; 1998), heifers weighing 125 kg were fed a diet containing 5.5 MJ/kg of net energy (NE) and 16.3% CP or a diet containing 7.7 MJ/kg of NE and 19.3% CP. Findings showed that body protein percent and amount of mammary tissue were not depressed by feeding a high energy, high gain (1.2 kg/d) diet. However, high energy, high protein diet resulted in significantly reduced calving age, and reduced first lactation yield by approximately 3.6 kg/d. The reduction in milk yield could not be well explained by reductions in mammary development and likely was the result of body composition differences at calving. While not conclusive, these data (Radcliff *et al.*, 1997, 1998) suggest protein to energy ratios in heifer diets may be important.

Protein deficiencies in lactating cows may increase the incidence of silent heats (cow releases the egg but she is not seen in heat) and lower conception rates while at the same time decreasing feed intake and milk production. Cows that are deficient in protein increase milk production within a couple of days when additional protein is added to the diet. First-calf heifers may be more sensitive to protein deficiencies than mature cows. Heifers that are raised on a protein-deficient diet lack the skeletal growth in relation to their size, especially in the pelvic area. These heifers are older when they start cycling, have a higher frequency of difficulty calving, and may not milk as well once they enter the milking herd (Donna *et al.*, 1997). Nevertheless, excessive protein intake may lead to decreased fertility in dairy cows (Randel, 1990). Some studies have shown that excessive RDP decreases reproductive efficiency. In a study to evaluate reproductive responses of cows and heifers fed two diets (16 and 19% CP), which met undegradable protein requirements but differed in RDP, cows (n = 33) and heifers (n = 32) were randomly assigned within parity to diets at calving and remained on diets for 20 days after first breeding. First service conception rate was lower (31% vs. 48%) and plasma urea higher in animals fed the high protein diet. The data suggest that feeding excess CP as RDP elevated plasma urea concentrations and decreased first service conception rate (Canfield *et al.*, 1990).

Concentrations of urea nitrogen in blood, plasma, serum, urine, or milk have been recognised for several years as useful measures of changes in protein status or protein nutrition of ruminants (Hammond, 1983; Hof *et al.*, 1997). Plasma urea nitrogen concentrations are well-known to be influenced by protein and energy intake under conditions of normal liver and kidney functions, (Oltner and Wiktorsson, 1983). Other factors include sampling time, days in milk, and method of analysis (Butler *et al.*, 1995; Gustafsson and Palmquist, 1993). Predictions of protein status of ruminants by plasma urea nitrogen allows dairy producers to evaluate adequacy of their cows' nutrition program although they are not as sensitive as desired to factors such as body weight (BWT) and parity (Huntington and Archibeque, 1999).

Dietary protein nutrition or utilization and the associated effects on ovarian or uterine physiology have been successfully monitored with urea nitrogen in plasma or milk (Butler, 1998). Diets high in protein content elevate plasma urea nitrogen and uterine secretions (Jordan *et al.*, 1983; Canfield, *et al.*, 1990). In a study to evaluate effects of dietary CP on constituents of plasma and uterine secretions at various stages of oestrous cycle of high producing postpartum Holstein cows, eighteen cows were assigned randomly to isocaloric diets containing either 12 or 23% CP on Day 40 postpartum. Uterine secretion and coccygeal blood samples were collected at oestrus, Days 5 and 15 of the first oestrous cycle after 50 days postpartum, and at the subsequent oestrus. The 23% CP diet resulted in higher concentrations of ammonia in blood as well as urea in blood plasma and uterine secretion than the 12% diet (Jordan, *et al.*, 1983). In addition to their association with diets high in protein content, elevations in blood or milk urea nitrogen concentrations have also been associated with low fertility (Butler *et al.*, 1996; Rajala-Schultz *et al.*, 2001). In a study to evaluate the association between milk urea nitrogen and fertility of dairy cows, cows with milk urea nitrogen levels below 10.0 mg/dl and between 10.0 to 12.7 mg/dl were 2.4 and 1.4 times more likely to be confirmed pregnant, respectively than cows with milk urea nitrogen values above 15.4 mg/dl (Rajala-Schultz *et al.*, 2001). Furthermore, plasma and milk urea nitrogen concentrations > 19 mg/dl were associated with approximately a 20 percentage point decrease in pregnancy rate after AI in lactating dairy cattle (Butler *et al.*, 1996). Based on this study, it was concluded that plasma and milk will yield similar results for monitoring urea nitrogen in dairy cows. When poor herd conception rates are present and the concentrations of serum urea nitrogen on a herd basis exceed 20 mg/dl, the ration should be evaluated on the basis of RDP and UDP (Ferguson *et al.*, 1988). Table 2.3 gives some suggested levels for CP, RDP and UDP in lactating dairy cow diet for different stages of lactation.

Table 2.3: Suggested levels of protein by stage of lactation

Stage of Lactation	CP (%DM)	UDP (%CP)	RDP (%CP)
0-6 weeks	18	45	55
6-12 weeks	17	40	60
>12 weeks	15	36	64

Source: Adapted from Ferguson and Chalupa, (1989).

Larry and Joe (1994) evaluated many studies where cows were fed diet with high proteins and showed that type and amount of protein fed explained much of the variation in conception rate. Age and dietary concentration of energy were identified as modifiers of the impact of protein on reproduction.

Although the exact mechanism by which feeding large amounts of protein affects fertility is not completely known, alterations in the hypothalamic-hypophyseal-ovarian axis may be responsible for many of the effects of protein on reproduction (Ferguson and Chalupa, 1989). Factors that have been indicated to contribute to the adverse effects of high protein diets on RP include exacerbation of negative energy balance and reduced plasma progesterone concentrations when cows are fed rations that are high in RDP (Butler, 1998) and toxic effects of ammonia and its metabolites on oocyte growth or maturation, fertilisation or early embryo development (Sinclair *et al.*, 2000; De Wit *et al.*, 2001; Ocon and Hansen, 2003).

Occurrence of the first postpartum ovulation determines to a great extent how soon the cow conceives and is directly related to body condition at calving and body weight loss. The percentage change in cow's bodyweight during the first 2 weeks after calving is inversely related to number of days to first ovulation (Butler, *et al.*, 1981). Patil and Deshpande (1981) found that Gir cows that gained weight in the first three months after parturition showed heat during that period, while those that lost weight remained anoestrus. Body weight loss is dependent on the level of milk production and total dry matter and energy intake. Therefore, it is important that cows calve in proper body condition and are fed diets that are properly balanced with high quality forage in order to achieve sufficient dry matter intake (DMI) to shorten the time the cow is in negative energy balance. Smith *et al.* (1984) observed increased days to first ovulation and days to first service with increased loss of body condition during first 5 weeks postpartum. The first service conception was also adversely affected by body condition loss (Table 2.4). In addition, Silke *et al.* (2002) observed greater extent of embryonic loss in cows that lost body condition between days 28 and 56 of gestation compared with cows that either maintained or improved in body condition.

Table 2.4: Relationship between body condition loss during first 5-week postpartum and reproductive performance

Variable	Body condition loss group		
	BCL1	BCL2	BCL3
Number of cows	17	64	12
Days to first ovulation	27^{a}	31^{a}	42^{b}
Days to first service	48^{ab}	41^{a}	62^{b}
First service conception, (%)	65^{a}	53^{a}	17^{b}
Services per conception	1.8	2.3	2.3

Source: Smith *et al.*, (1984)

BCL1=Less than 0.5 body condition loss; BCL2=0.5 to 1.0 body condition loss; BCL3=body condition loss greater than 1.0
Values with different superscript within each row are significantly different; P<0.05

Changes in live weight and body condition are usually used to assess the nutritional status of cattle. Body condition score (BCS) or changes in body condition although subjective, is a reliable technique of evaluating nutritional status in cattle (Kunkle and Sand 1990; De Vries and Veerkamp, 2000). The technique assesses the deposition of fat under the skin on the hipbone, tail head area, gluteal muscle, spinous process and the lower rib cage. A numerical score is given which is an indication of body reserves and hence, nutritional status of the animal. It relies on manual palpation to feel the quantity of subcutaneous fat cover under the mentioned areas. The technique is simple to perform, requires no specialised facility and unlike body weight, it is independent of skeletal frame size and gut fill (Peters and Ball, 1995). Although subjective, with practice a high level of repeatability both between measurement and between scorers can be obtained (Patton *et al.*, 1988; Mukasa-Mugerwa, 1989; Peters and Ball, 1995). Wherever applied the technique has proved to be worth using for estimating cattle performance.

Body condition at calving affects RP through its effect on the days to first postpartum ovulation (Smith *et al.*, 1984), rate of tissue mobilisation in early lactation and on uterine health and motility (Titterton, 1994). Because of the strong relationship between body condition loss in early lactation and RP, body condition scoring is a useful tool for predicting RP. For dairy cattle, the recommended BCS on a 1 to 5 scale at calving is 3.5 to 4.0 with acceptable body condition score loss after calving not to exceed 1 score. A decrease in BCS of more than 1.0 point during the first 5 weeks postpartum was associated with lower fertility at first service (Butler and Smith, 1989; Britt, 1992). Therefore, animals calving with a score of 3.5 should not be less than 2.5, five to seven weeks postpartum. Body condition scores desired for different stages of lactation are shown in Table 2.5.

Table 2.5: Desirable body condition scores by stage of lactation

Stage	Score (1-5 scale)
Drying Off	3.5 - 4.0
Calving	3.5 - 4.0
One Month Postpartum	2.5 - 3.0
Mid Lactation	3.0
Late Lactation	3.0 - 4.0
Heifer at Calving	3.5

Source: Wildman *et al.*, (1982)

b. Minerals

(i). Influence of calcium, phosphorus and copper on reproductive performance

In many areas of the world cattle production depends almost exclusively on forages to provide all required nutrients. Under these circumstances, animal productivity is often seriously limited due to deficiencies or imbalances of essential nutrients. There is evidence to show that growth and reproduction rates may deteriorate even when other constraints such as inadequate supply of energy and protein, diseases and parasites have been rectified. This has been attributed to mineral deficiencies, toxicities or imbalances in animal diets (Underwood, 1981). Despite existence of substantial knowledge of functional roles of many minerals, it is rarely possible to relate this information to observed pathological consequences of deficiency. Adoption of preventive measures should be prompted by biochemical evidence of marginal deficiencies in animals rather than soils or pastures (Suttle, 1986).

Calcium (Ca) is a constituent of skeleton and teeth and an essential constituent of living cells and tissue fluids. It is involved in nerve impulse transmission, muscle contraction and blood coagulation. Calcium is found in relatively large quantities in milk, and is involved in activity of several enzyme and second messenger systems. Forages are generally satisfactory sources of Ca for grazing livestock, particularly when they contain leguminous species. The average temperate grass sward will meet the Ca requirements of sheep, but a contribution from legumes is needed for the dairy cow. Cultivar differences in Ca content can be marked, but it is the maturity of the sward that has the more widespread influences. The leaf generally contains twice as much Ca as the stem, and pasture Ca concentrations are therefore increased by applying nitrogenous fertilizer and decrease with advancing maturity (Underwood and Suttle, 1999).

Calcium and phosphorus (P) supplementation in diets is required, but animals can adjust any temporary imbalances, due to extensive skeletal reserves provided they are in overall balance over longer periods (ARC, 1990). The priority of all mammals is to maintain Ca concentrations in plasma and extracellular fluids close to 10 mg/dl in the face of large fluctuations in demand and lesser fluctuations in supply (Hurwitz, 1996). During hypocalcaemia, conservation of Ca facilitated by the endocrine system at the kidney, mobilization of Ca from bone, and increased absorption from the digestive tract have high physiological priority (Horst, 1986). When the ionic concentration of Ca in blood falls, parathyroid hormone is secreted (Brown, 1991) and activates vitamin D_3 (Borle, 1974). Vitamin D_3 is hydroxylated to 25-hydroxy-D3 (25-OHD_3) in the liver and further in the kidney to two compounds, 24,25-$(OH)_2D_3$ or 1,25-$(OH)_2D_3$. In the intestinal mucosa, 1,25-$(OH)_2D_3$ opens up Ca channels and facilitates uptake and transfer, with the help of calcium-binding protein, calbindin (Hurwitz, 1996). In addition, bone-resorbing cells (osteoclasts). respond indirectly to 1,25-$(OH)_2D_3$ via cytokines released by osteoblasts (Norman and Hurwitz, 1993) to increase bone resorption. Supplementation of Ca to cattle has been performed with variable responses. Hernandez *et al.* (1999) found no significant effect of administration of $CaCl_2$ gel 24 and 48 hr after parturition, on serum normalized Ca, total Ca, Mg, or P concentrations or on incidence of metritis, days to first insemination, and pregnancy status after first insemination in dairy cows with retained foetal membranes. On the other hand, Garcia-Bojalil *et al.* (1998) supplemented Ca salts to 15.7% degradable protein diet and observed doubling of number of corpora lutea, reduced time to first rise in progesterone by day 6 and doubling of number of normal luteal phases. Furthermore, hypocalcemia has been associated with a negative effect on subsequent ovulation (Jonsson *et al.*, 1999).

In adult cattle the normal plasma Ca range is 9.6-12.3 mg/dl (Kaneko, 1989) and Ca concentrations < 10 mg/dl (McDonald *et al.*, 1997) and < 8.6mg/dl Rosol *et al.* (1995) cited by Phiri *et al.* (2000) are considered as indicative of Ca deficiency in plasma.

Marginal bands for assessing low Ca status in periparturient dairy cows and young ruminants as recommended by Underwood and Suttle, (1999) are 5.0-8.0mg/dl and 5.9-8.9mg/dl, respectively. Mean values within bands indicate possible and values below bands probable dysfunction in some individuals while individual values below bands indicate need for wider sampling and possibility of dysfunction.

Phosphorus is closely associated with Ca in skeleton. It also occurs in phosphoproteins, nucleic acids and phospholipids. It plays a role in energy metabolism in formation of sugar-phosphates and adenosine di- and tri- phosphates. Phosphorus deficiency is the most common mineral deficiency of cattle in the world (McDowell, 1985) particularly in grazing cattle where P supplementation is not a common practice (Underwood and Suttle, 1999). Phosphorus is often insufficient in tropical forages to support optimum microbial fermentation and protein synthesis (Leng, 1990; van Houtert, 1993). Microbial protein synthesis requires a continuous supply of P for nucleic acid formation, and requirements are for at least 2 g P per kg feed DM (Gunn and Ternouth, 1994). With the exception of common salt, P is probably the nutrient most frequently given as a supplement to grazing ruminants (Cohen, 1980). Phosphorus deficiency has been associated frequently with reduction in appetite, retarded growth, less efficiency in feed utilisation, decreased milk production, delayed sexual maturity and depressed oestrus signs. Favourable effect of P in RP is not always easy to demonstrate and studies to evaluate the effect of P in production and reproduction have given mixed results. Some research reports (Call *et* *al.*, 1978; Little, 1980; Butcher *et al.*, 1979; Pott *et al.*, 1987) indicated that there was normal reproduction and production, even when dietary P concentrations were below those commonly recommended. Glauber (1993) supplemented P to Argentine Friesian pluriparous cows using phosphate injections (Unspecified dose of Calfostan) 25±10 days postpartum. There were no significant differences in RP between the treated and untreated groups. Similarly, Wu *et al.* (2000) observed no relation between dietary P content and RP. However, some reports indicated dramatic increase in fertility levels and growth in cattle in many parts of the world after P supplementation (McDowell, 1976; Engels, 1981; Bauer *et al.*, 1982; NRC 1984). In addition, impaired RP was among clinical signs of P deficiency observed by Call *et al.* (1986) within 6 months in cows given 5.1 to 6.6 g of P/day. Phosphorus has also been suspected to be among the causes of ovarian inactivity in communal farming area on a sentinel herd of Mashona cows and heifers in Zimbabwe (Ogaa *et al.*, 1992). The protein content of herbage falls with phosphorus, so that protein deficiency, and frequently also energy deficiency, are exacerbating factors in the malnutrition of livestock in phosphorus deficient areas (Underwood, 1981).

The normal range of plasma P in cows is 4 mg/dl to 8 mg/dl (Forar *et al.*, 1982) and concentrations of < 6 mg/dl indicate deficiency of the mineral (McDonald *et al.*, 1997) while values within bands of 3.1-4.7 and 4.0-5.9mg/dl indicate possibility of future losses and values below the band indicate a probability of impaired health or performance if P supplies are not improved in cows and calves, respectively (Underwood and Suttle, 1999).

Calcium and P are two closely associated elements in cattle. The recommended Ca:P ratio for ruminant diets is 2:1 (NRC, 1996). An excess of P interferes with absorption of Ca by binding to the Ca binding protein, making the protein unavailable for Ca (Horst, 1986). Likewise, high levels of Ca in the diet may reduce the absorption of P when its levels are low due to either precipitation of P in non-absorbable forms within the intestine as the pH rises or due to the homeostatic mechanisms concentrating on regulating plasma Ca (Ternouth and Sevilla, 1990). However, studies have shown that dietary Ca:P ratio of between 1:1 and 7:1 result in nearly equal performance, provided the animal's P intake meets its requirements (McDowell, 1992). The Ca and P interactions only have a nutritional significance when the supply of one element is limiting and the other is excessive (Underwood and Suttle, 1999).

Copper (Cu) plays a role in many enzyme systems e.g. cytochrome oxidase. It is also present in ceruloplasmin, which is concerned with release of iron from cells into plasma. Blood copper levels of less than 0.5 µg/ml or liver tissue concentrations below 25 ppm on a dry matter basis are considered deficient (Smart *et al.*, 1981) although Cu concentrations < 1 µg/ml are considered deficient by others (Blood and Radostits, 1989). With the possible exception of P, Cu is the mineral most likely to be deficient in grazing cattle (McDowell, 1985).

The exact mechanism by which copper deficiency causes infertility is not clear, but is probably related to one or more of the enzyme systems requiring copper. Copper may play a role in regulating synthesis of LH (Xin *et al.*, 1993), hence indirectly affect ovulation and RP. Low fertility, associated with delayed or suppressed oestrus has been observed in cows grazing on Cu deficient pastures in several widely separated areas (Underwood, 1977; Underwood and Suttle, 1999). Cows fed 50 ml of 1% copper sulphate solution daily from day 7 after calving had shorter calving to conception interval (68.5 days) than the control group (112.4 days), and required fewer matings per conception (2.7 vs. 3.1) (Manickam and Balagopal, 1993). Increasing Cu intake in Nili-Ravi buffaloes (Qureshi *et al.*, 2000) decreased postpartum uterine involution time and ovulation intervals.

Herd (1994) identified delayed or suppressed oestrus and embryo death, often between day 30 and 50 of gestation, to be common symptoms of copper deficiency in beef cattle. Louisiana researchers (Kappel *et al.*, 1984) reported that dairy cows with higher serum Cu concentrations had significantly low days to first service (56 vs. 70), fewer services per conception (1.1 vs. 4.4), and fewer days from calving to conception (58 vs. 183) compared to cows with low serum Cu levels.

A number of studies have shown that Cu also plays a role in immune function of the body. Xin *et al.* (1991) showed that immune function in cattle was impaired even though there was no evidence of anaemia or depression in growth. Cattle that were marginally deficient in Cu had reduced superoxide dismutase activity and decreased neutrophil bacteriocidal capability. These animals were less efficient at killing *Staphylococcus aureus*, an organism that often causes mastitis in cattle. This could explain the observation that dairy herds, which are marginal in their Cu status often seem to have a higher incidence of mastitis. Gengelbach *et al.* (1997) observed higher TNF-α, a cytokine involved in regulating the immune response in plasma of Cu adequate calves before and after a respiratory disease challenge. Minatel and Carfagnini (2002) reviewed literature on Cu deficiency and immune response in ruminants and concluded that Cu deficiency alters innate immune response in ruminants, principally affecting neutrophil functions and acute phase protein ceruloplasmin which may increase susceptibility of ruminants to bacterial and fungal infection. There is no proven clear deleterious effect of Cu deficiency on specific immune response in ruminants yet.

Copper availability in most feedstuffs fed to farm animals is between 1% and 15% (Hemken *et al.*, 1993). Grains are lower in Cu than are forages. Most forages will contain Cu at levels equal to or above the NRC recommended requirements for ruminants. However, as plants mature and the phytate and lignin content increases, bioavailability of the Cu decreases rapidly.

There is no clear consensus as to what tissue concentrations of Cu indicate deficiency in cattle. This may be because the Cu status in ruminants partly depends on the nutritional interrelationships between Cu, molybdenum, zinc and sulphur (Smith and White, 1997). Blood and Radostits (1989) regard plasma Cu concentrations < 1 µg/ml to be indicative of Cu deficiency in cattle while others consider concentrations <0.6 μg/ml as indicative of Cu deficiency (Minatel and Carfagnini, 2002). Values below a marginal band of 0.19-0.58 μg/ml indicate high probability of current or future dysfuction and impairment of health or production while values above the band indicate minimal likelihood of Cu supplementation being beneficial (Underwood Suttle, 1999).

(ii). Mineral status of pasture, cattle and some wild ruminants in Tanzania

In Tanzania, marginal levels of Ca, and low levels of P, and Cu, have been reported in pastures (Table 2.6). Critical dietary levels for Ca, P, and Cu in DM are 0.30%, 0.25% (McDowell *et al.*, 1983), and 5 mgCu/kg (Cunnigham, 1992), respectively.

Blood plasma concentrations of Ca, P and Cu in cattle and wild ruminants in Tanzania are shown in Table 2.7. The higher plasma mineral concentrations in wild ruminants than cattle might be due to differences in milk production as a result of natural selection of wild animals to the wild environment and artificial selection of cattle for milk production resulting in loss of high quantities of minerals in higher quantities of milk by cattle when compared to the wild ruminants. The figures in Table 2.7 indicate deficient and lower plasma Ca and P in SHZ than other locations despite similar levels of the minerals in pastures. The lower plasma concentrations of Ca and P in SHZ could be a reflection of low bioavailability or low level of mineral supplementation. The season when the concentrations were determined would also have some influence

Table 2.6: Levels of calcium, phosphorus and copper in pastures and concentrates in Tanzania

Type of pasture	Comments	Levels of minerals			Source
		Ca (%)	P (%)	Cu (ppm)	
Range grasses	Regenerating green leaves	0.26	0.17	7.80	*Rodgers, (1975)
Range grasses	Green leaves	0.36	0.11	3.82	Rodgers, (1975)
Range grasses	Dry leaves	0.40	0.05	3.80	Rodgers, (1975)
Digitaria milanjiana	Dry whole plant	0.41	0.05	6.2	Rodgers, (1975)
-	Dry season-Malya	0.19	0.06	2.6	Mwakatundu, (1977)
-	Rainy season-Malya	0.31	0.20	4.0	Mwakatundu, (1977)
-	Dry season-Morogoro	0.65	0.21	12.0	Mwakatundu, (1977)
-	Rainy season-Morogoro	0.28	0.28	7.0	Mwakatundu, (1977)
Pasture	Dry & short rains-Morogoro	0.49	0.26	12.17	Sendalo *et al.* (1988)
-	Dry season-Mpwapwa	0.22	0.10	2.90	Mwakatundu, (1977)
-	Rainy season-Mpwapwa	0.21	0.19	5.0	Mwakatundu, (1977)
-	Dry season-Tanga	0.39	0.16	4.0	Mwakatundu, (1977)
-	Rainy season-Tanga	0.23	0.22	3.75	Mwakatundu, (1977)
-	Dry season-Tengeru	0.57	0.32	5.26	Mwakatundu, (1977)
-	Rainy season-Tengeru	0.34	0.67	6.75	Mwakatundu, (1977)
-	Dry season-West Kilimanjaro	0.12	0.18	2.81	Mwakatundu, (1977)
-	Rainy season-West Kilimanjaro	0.40	0.40	5.80	Mwakatundu, (1977)
-	Dry season-Iwambi (SHZ)	0.33	0.07	2.6	Mwakatundu, (1977)
-	Rainy season-Iwambi (SHZ)	0.29	0.23	3.0	Mwakatundu, (1977)
Hay	Uyole (SHZ)	-	-	4.6	Maro *et al.*, (1980)
Silage	Uyole (SHZ)	-	-	2.6	Maro *et al.*, (1980)
Pastures	Uyole (SHZ)	-	-	3.8	Maro *et al.*, (1980)
Concentrates	Uyole (SHZ)	-	-	5.6	Maro *et al.*, (1980)
Pasture	Dry season-Rungwe (SHZ)	0.34	0.19	-	Mussa, (1998)
Pasture	Rainy season-Rungwe (SHZ)	0.31	0.22	-	Mussa, (1998)
Pasture	Dry season-Iringa (SHZ)	0.38	0.18	6.8	Pereka and Phiri, (1998)
Pasture	Rainy season-Iringa (SHZ)	0.64	0.31	7.6	Pereka and Phiri, (1998)
Pasture	Dry season-Iringa (SHZ)	0.24	0.18	1.72	Phiri *et al.*, (2000)
Pasture	Wet season-Iringa (SHZ)	0.33	0.31	3.52	Phiri *et al.*, (2000)
Hay	Iringa (SHZ)	0.36	0.36	1.45	Phiri *et al.*, (2000)
Concentrate (maize bran: SSC 3:1	Iringa (SHZ)	0.14	0.54	7.3	Phiri *et al.*, (2000)

*All results from Rodgers (1975) refer to studies in Selous game reserve, southeast Tanzania.

Table 2.7: Blood concentrations of calcium, phosphorus and copper in wild ruminants and cattle in Tanzania

Location and type of ruminant	Levels of plasma/serum minerals			Source
	Ca (mg/dl)	P (mg/dl)	Cu (mg/l)	
Impala	14.2	15.35	7.5	[1]Rodgers, (1975)
Wildebeest	14.8	10.66	7.1	Rodgers, (1975)
Hartebeest	13.8	6.85	6.7	Rodgers, (1975)
Sable	14.3	15.4	7.7	Rodgers, (1975)
Hippopotamus	16.9		3.9	Rodgers, (1975)
Buffalo	15.6		9.0	Rodgers, (1975)
Cattle-Rainy season-Malya	10.67	5.92	0.69	Mwakatundu (1977)
Cattle-Dry season-Morogoro	10.2	6.44	0.91	Mwakatundu (1977)
Cattle-Rainy season-Morogoro	10.2	5.93	1.00	Mwakatundu (1977)
Cattle-Dry season-Mpwapwa	10.3	5.1	0.92	Mwakatundu (1977)
Cattle-Dry season-Tanga	10.95	7.17	0.44	Mwakatundu (1977)
Cattle-Dry season-Tengeru	11.17	5.6	0.52	Mwakatundu (1977)
Cattle-Dry season-West Kilimanjaro	10.3	5.51	1.09	Mwakatundu (1977)
Cattle-Dry season-Iwambi (SHZ)	9.37	5.67	1.28	Mwakatundu (1977)
Friesian female calves-Uyole (SHZ) Unsupplemented	-	-	6.5	Maro *et al.*, (1980)
Friesian female calves-Uyole (SHZ) Supplemented with copper	-	-	8.0	Maro *et al.*, (1980)
Crossbred pregnant heifers-Iringa (SHZ)	8.56	3.81	-	[2]Phiri *et al.*, (1997)
Crossbred pregnant cows- Iringa (SHZ)	8.56	3.96	-	Phiri *et al.*, (1997)
Crossbred lactating cows- Iringa (SHZ)	8.80	2.91	-	Phiri *et al.*, (1997)
Crossbred steers- Iringa (SHZ)	7.60	5.57	-	Phiri *et al.*, (1997)
Crossbred heifers-Iringa (SHZ)	-	-	0.93	Phiri and Pereka, (1998)
Crossbred cows-Iringa (SHZ)	-	4.84	-	Phiri *et al.*, (2000)

[1]All results from Rodgers (1975) refer to studies in Selous game reserve, southeast Tanzania.

[2]The experiment was carried out during the end of rain season (April, 1997).

since mineral levels in pasture vary with seasons. Considering a Cu cut-off point of 1 µg/ml, the figures in Table 2.7 show marginal and low values of plasma Cu except for calves at Uyole in Tanzania. The available information for SHZ therefore indicates marginal levels of Ca and low levels of P and Cu in pastures as well as deficiencies in plasma Ca and P concentration and marginal plasma Cu status. Hence, Ca, P and Cu deficiency could be among the factors contributing to suboptimal RP in Rungwe district. Furthermore, Cu deficiency in Rungwe district could be exacerbated by the fact that it is located in the rift valley area. Copper deficiency observed and described by various authors in Kenya, Ethiopia and Djibouti has been closely associated with the pedogeological area of the rift valley. Geo- morphological characteristics of rift valley, particularly molybdenum and sulphur excess in the volcanic region are suspected to account for the marked Cu deficiency in the area (Faye *et al.*, 1991).

(iii). Evaluation of mineral status in cattle

Langlands (1987) indicated that tissues and blood are more reliable means of evaluating mineral status of grazing ruminants than forages due to soil contamination, variability in diet selection or availability of ingested nutrients. Underwood and Suttle (1999) indicated that mineral concentrations of serum or tissues consistently higher or below the 'normal' concentrations or ranges provide suggestive but not conclusive evidence of dietary deficiency or excess of particular minerals. He also indicated that the choice of tissue or fluid for analysis depends upon the mineral element under

Table 2.8: Recommended substrates and components for detection of some mineral deficiencies and toxicities

Minerals	Substrates and components						
	Diet	Blood	Saliva	Urine	Milk	Liver	Bone
Calcium	Ca	Ca					Ca
Cobalt	Co	Vitamin B_{12}				Co	
Copper		Cu				Cu	
Iodine		Thyroxine		I	I		
Magnesium	Mg	Mg					
Manganese	Mn						
Phosphorus	P	P					P
Selenium	Se	Glutathione peroxidase					
Sodium	Na		Na + K	Na			
Zinc	Zn	Zn	Zn				

Source: Adopted from Underwood and Suttle, (1999).

investigation (Table 2.8). Although serum and plasma Cu concentrations are often measured, blood levels may not show the deficiency until severe symptoms develop (Hemken *et al.*, 1993). Liver Cu concentration is the most sensitive indicator of changes in Cu status and its determination is recommended when liver biopsies can be obtained. However, liver biopsy is time-consuming, invasive, and expensive. Ceruloplasmin concentrations and superoxide dismutase activity in the blood or red blood cells can be useful indicators of Cu status.

c. Influence of supplementation of smallholder dairy cattle on productive and reproductive performance

Nutritional interventions using various levels of locally available sources of feeds to supplement smallholder dairy cattle has been shown to improve productive and reproductive performance and proved economically viable in a number of countries.

Supplementation with tree legume leaves (*Sesbania sesban*) in Malawi (Kumwenda, 1999), fish silage blocks made out of fish waste and molasses in Morocco (Guerouali, 1999), and strategic pre- and postpartum supplementation with cotton seed cake in Mauritius (Boodoo *et al.*, 1999) brought about major improvements in milk production, body weight and body condition score and/or reproductive performance parameters.

In Tanzania, several supplementation trials have been reported in smallholder crossbred dairy cattle using variable supplemental ingredients. However, most studies were short term and aimed more at evaluation of effects of energy, protein and mineral supplementation in milk production and composition than reproductive performance. Urassa (1999) reported an increase in milk production of 1.5 L/day when crossbred cows were supplemented with 4 kg of maize bran, 2 kg of cotton seed cake and 100g of Bayslick® minerals per day for 17 days in various districts of Tanga region. Supplementation of cows with 4 kg of concentrate per cow per day (68% maize bran, 31% sunflower meal and 1% Super Maclick®) showed average improvements in live weight (5.2kg), body condition score (0.1) and milk yield (1.5 L/cow/day) during 12 weeks of treatment in peri-urban and urban areas of Morogoro (Mlay *et al.*, 2005).

Msangi *et al.* (2004) evaluated the effect of short term (8^{th} to 9^{th} weeks of lactation), high concentrate (7 kg/cow/day) supplementation using a concentrate made up of 67 parts maize bran to 33 parts coconut cake per kg plus 100g dried bone meal in productive and reproductive performance in Tanga. All crossbred cows receiving the supplement achieved a positive energy balance during the period of supplementation. However, despite promoting early ovulation the short-term supplementation did not enhance early visual oestrus. In addition the supplement had no effect on milk production and body condition scores (Msangi *et al.*, 2004).

Dry season supplementation of on-station cows receiving *ad libitum* grass hay and 6 kg/day of maize bran with urea molasses mineral blocks for 49 days, increased milk production from 6.7 to 11.2 L/day and DMI from 10.1 kg/day to 12.0 kg/day while supplementation with molasses urea mix increased daily milk yield from 6.7 to 8.8 L/day in Morogoro (Nkya *et al.*, 1999b). On-farm supplementation with urea molasses mineral blocks for 53 days increased milk yield by 1.7 L/day in dry season and was cost-effective (Nkya *et al.*, 1999b).

Smallholder dairy cows 3-6 months post calving supplemented for 12 weeks with maize bran mixed with sunflower meal had higher milk yield than those supplemented with maize bran only during the dry season in urban and peri-urban areas of Morogoro. The economic return for sunflower meal incorporation in the concentrate was found to be very high (Mlay *et al.*, 2005).

Supplementation with 0.8 kg/cow/day of concentrate comprising of maize bran (70%), cottonseed cake (28%) and minerals (2%), during dry season improved milk yield (34%), and maintained body condition (2.8-3.1). In relation to reproductive performance post-partum anoestrus period was reduced from 86.3 ± 6.6 to 71.2 ± 5.3 days and calving to conception from 102.4 ± 5.1 to 80.4± 4.7 days. Feeding 0.8 kg was cost effective if there was an increase in milk yield by more than 1.0 L/day (Nkya *et al.*, 1999a).

Maro *et al.* (1980) observed increased live weight gains and serum Cu due to Cu supplementation in 4-10 months dairy calves in Mbeya Tanzania.

2.2.4.2 Parity

Studies have reported longer intervals from parturition to first ovulation in the first and second parity cows than later parities. Izaike (1990) observed significantly longer duration from calving to first ovulation in the first and second parities than in the seventh and ninth parity and Bellows *et al.* (1982) reported longer postpartum interval for first-calf heifers than mature cows.

2.2.4.3 Suckling and milk yield

Suckling is a very important factor affecting milk yield of especially cows that are kept together with calves. Cows suckling calves had longer intervals from parturition to first postpartum oestrus than cows milked twice daily or cows receiving no milking or suckling stimuli after 24 hours postpartum (Saiddudin *et al.*, 1968). Janowski *et al*, (1986) established that a 4-week suckling period weakened the cow's reproductive processes, and hence delayed ovarian function and consequently first oestrus. The postpartum oestrus interval was shorter by 13 days in restricted than in continuously suckling cows (Tegegne *et al.*, 1992). Carruthers and Hafs (1980) and Peters (1984) suggested that suckling may prolong the postpartum interval of dairy and beef cows by reducing the frequency and perhaps the amplitude of GnRH secretion. The inhibitory effects of the calf on LH secretion are mediated in part by the endogenous opioids (Schillo, 1993). The presence of a calf enhances an opioidergic neuropathway, which is inhibitory to GnRH secretion, whereas its absence reduces the input from this system (Whisnant *et al.*, 1986). The long anoestrus period in the nursing cow might partly be due to an elevated level of prolactin as well, which appears to depress the secretion and release of GnRH, or due to the pituitary being less responsive to GnRH during nursing (Vandeplassche, 1982). Increasing nutritional level in restricted suckling cows tends to improve the postpartum anoestrus period, but the positive effects of supplementation cannot completely compensate for the negative effects of suckling (Das *et al.*, 1999).

High milk yield negatively affects RP in dairy cows (Fonseca *et al.*, 1983). Negative correlations between milk produced in the first 30 days of lactation and days to first service (r = -0.23) and conception (r = -0.22) as well as SC (r = -0.15) have been reported in Tanzania (Mujuni *et al.* 1990b). The effect of milk yield is more pronounced in high yielding dairy cows where milking frequency is three times a day (Hafez, 1980). Frequent milking may in some way have the same negative effect as that of a suckling calf on the dam's reproductive system, by blocking LH secretion through the enhancement of the opioidergic neuropathway inhibitory to GnRH secrection (Izaike, 1990; Mwaanga and Janowski, 2000). High milk yield might also influence RP due to low energy balance caused by preference of milk production over reproduction and the animal's inability to take-in sufficient energy-giving food (Butler *et al.*, 1981) corresponding to its daily needs for both milk production and reproductive activities. Furthermore, increase in milk yield can also affect reproduction by delaying uterus involution (Izaike, 1990).

2.2.4.4 Specific and non-specific diseases and disorders

The common specific infectious diseases that interfere with reproduction are Brucellosis, Trichomoniasis, Campylobacteriosis, Leptospirosis, Salmonellosis, Infectious bovine rhinotracheitis, Bovine virus diarrhoea, Infectious bovine epididymitis and vaginitis complex, and Mycoplasmosis (Roberts, 1971).

The non-specific diseases and disorders are diverse conditions that are similar in that they all can result in impaired reproductive function. Conditions that simulate pregnancy, such as pyometra, severe metritis, foetal maceration or mummification cause anoestrus. These conditions damage the endometrial lining of the uterus and reduce secretion of luteolytic prostaglandin. The average number of days to first insemination and conception were 100 and 157 days, respectively for metritic cows and 83 and 106 days, respectively for normal cows. In addition, more inseminations per conception were needed for metritic cows (2.06) than for normal cows (1.52) in Holstein cows (Lourens, 1995). Although anoestrus can, to some degree, be overcome by treatment, it is more practical to ensure that animals are well managed and are fed to maintain good condition during critical periods, i.e. prior to mating and during lactation, in order to avoid anoestrus.

Retained foetal membranes cause significant economic losses, as many affected cows develop metritis and may suffer from infertility (Coleman *et al.*, 1985), and reduced milk yield (Lucey *et al.*, 1986). The high risk for retained foetal membranes after twinning, dystocia, parturition induction, and premature births are well recognized and understood but the associations of the trait with nutritional factors are less so. Prevention of retained foetal membranes in cows in practice is limited unless deficiency of selenium is a major cause of the disease. Prevention of subclinical hypocalcemia, and ensuring a proper BCS at calving could reduce the problem.

Parturient paresis is a problem of economic importance not only due to immediate production losses and the possibility of fatality, but also as a significant risk factor for the occurrence of conditions such as prolapsed uterus, metritis, retained foetal membranes, dystocia and abomasal disorders (Houe *et al.*, 2001). The main cause of parturient paresis has been attributed to hypocalcaemia. With initiation of lactation, most cows experience some degree of clinical or subclinical hypocalcaemia (Beede, 1995; Risco, 1995). The hypocalcaemia results from sudden flow of Ca from blood into colostrum. In most cows, activation of Ca homeorhetic mechanisms restores normal blood Ca early in the postpartum period (Goff, 1992; Risco, 1992). If the system malfunctions resulting in inefficient Ca absorption from the gut and poor Ca resorption from bone (Oetzel and Barmore, 1992), increases in severity and duration of hypocalcemia occur predisposing the cow to periparturient disorders like parturient paresis. Parturient paresis affects 3-10% of the intensively fed dairy herds in the developed countries and similar proportions of affected animals fail to respond to treatment (Littledike *et al.*, 1981).

Both stillbirth and parturient paresis are determinants of uterine prolapse. The increased risk for uterine prolapse in cows with stillbirth could result from the mechanical stress associated with dystocia. The stress leads to weakening of the uterine and later to prolapse. The association or uterine prolapse with parturient paresis implies that a loss in uterine muscle tone caused by a drop in blood calcium level is a major factor in the etiology of the disease.

Dystocia can delay return to estrus, decrease conception rates, increase days from first breeding to conception and days open, as well as increase calf losses and cow mortality (Maizon *et al.*, 2004).

Mastitis affects the farmer economically through reduced milk quality and quantity, premature culling and replacement of chronic cases (Shitandi *et al.*, 2004). Mastitis has also been shown to increase days to first breeding and days open (Maizon *et al.*, 2004) possibly as a consequence of reduced appetite, DMI and hormones that drive oestrous cyclicity (Studer, 1998). Other suggested possible mechanisms through which mastitis impairs reproduction are increased $PGF2\alpha$, body temperature, and/or immune response that can decrease the length of the luteal cycle or embryonic development. Furthermore, increased cortisol from mastitis inhibits LH and FSH secretion, which decreases follicle development, maturation of the oocyte, or ovulation rate (Olive *et al.*, 2000). In addition, embryonic losses can be increased by chronic mastitis among other factors (Ferguson, 1989).

Impact of diseases and disorders on RP is not entirely consistent. This fact reflects the complex nature of the interaction between diseases/disorders and reproductive performance of cattle. The problem is confounded by different definitions of some of the fertility disorders in different studies (Ouweltjes *et al.*, 1996). Using meta-analysis methods to evaluate effect of disease on reproduction in dairy cows, Fouricho *et al.* (2000) found no effect of stillbirth, parturient paresis, mastitis and displaced abomasum in intensive farming farms. Retained foetal membranes and dystocia were associated with 2 to 3 more days to first service and with a 4 to 10% lower conception rate at first service, resulting in 6 to 12 more days to conception. Metritis was associated with 7 more days to first service, 20% lower conception rate at first service, resulting in 19 more days to conception. Cystic ovaries were associated with 26 more days to first service and with an 18% lower conception rate at first service, resulting in 41 more days to first conception. Abortion was associated with 70 to 80 more days to conception (Fouricho *et al.*, 2000).

Maizon, *et al.* (2004) observed increased days open in cows with dystocia, stillbirth, retained placenta, metritis, or other diseases occurring in the first 45 days after calving, and in cows with metritis, mastitis, or other diseases occurring after 45 days.

Days to first breeding increased in cows with stillbirth, retained placenta, milk fever, mastitis, foot and leg problems, or other diseases occurring before day 45, and in cows with metritis, mastitis, foot and leg problems, or other diseases occurring after 45 days. Days to first breeding decreased in cows treated for ovulatory dysfunctions either before or after 45 days. Days from first breeding to conception increased in cows with dystocia, stillbirth, retained placenta, metritis, or ovulatory dysfunctions occurring before first breeding, and in cows with mastitis occurring after first breeding.

Little information has been published on effects and incidences of reproductive diseases and disorders on dairy cattle in Tanzania. Mujuni and Mgongo (1994) reported complete failure of lactation, short lactation lengths and reduced milk yield in cows that experienced abortions, stillbirths and premature calvings in Morogoro. In addition the number of days to first service, services per conception and CI were longer than in control group.

In a study to evaluate factors associated with reduced dairy cattle RP in smallscale farms of peri-urban Dar es Salaam and Morogoro, the prevalence of abortion and retention of foetal membranes was 9.9% and 18.3%, respectively. Animals that aborted had significantly longer CI and were more associated with foetal membrane retention than those that never aborted. The study indicated that delayed maturity, abortion in association with retained placenta which prolong CI, poor management (confinement, poor oestrus detection and record keeping) and inadequate nutrition contribute to reduced reproductive efficiency in the small scale dairy farming (Nkya and Swai, 1999).

The first reported incidence rates for endometritis and ovarian inactivity in Tanzania were 35.3 and 32.5 per cent, respectively (Mujuni *et al.*, 1996). The occurrence of ovarian inactivity was significantly higher in cows with endometritis. The findings implied that endometritis and ovarian inactivity are interrelated, probably through a common causal factor.

In a study to assess the reproductive performance of dairy cattle in smallholder herds kept under zero-grazing management systems, the prevalence of clinical mastitis was found to be 4.2% (Kanuya *et al.*, 1998) and the cumulative incidence risk of abortion, dystocia, prolapse, retained fetal membranes, mastitis, milk fever and cyclic non-breeders were 16.0, 1.7, 2.5, 4.2, 5.0, 1.7, and 6.1%, respectively in a rural highland area of northern Tanzania (Kanuya *et al.* 2000). In a study in dairy cows on smallholder and large scale farms in Morogoro urban and periurban areas Shem *et al.* (2001) reported 62% and 4% of cows as sub-clinical and clinical mastitis cases, respectively. Levels of infection were higher on smallholder farms (75%) than on large-scale farms. Studies conducted in the Lake zone of Tanzania, (Msanga *et al.*, 1989) showed that the average annual incidence of sub-clinical mastitis varied between 40% and 71.6%. A study carried out on smallholder dairy herds in Dar es salaam region revealed that 3.8% of the lactating cows had clinical mastitis and 90.3% had sub clinical mastitis (Kivaria *et al.*, 2004). In a study to investigate status of inflammatory mastitis in smallholder dairy bovine udders in the Rift Valley of Kenya over a seven-month period, the prevalence of clinical mastitis was 19.6 % (Shitandi *et al.*, 2004).

2.2.4.5 Functional disorders

The causes of functional infertility include cystic and inactive ovaries with anoestrus, early embryonic mortality with repeat breeding, and prolonged gestation. Anoestrus often reflects a hormonal disturbance and accounted for 47.8% of cases while repeat breeding, where cows require three or more services to conceive, accounted for 11.5% of cases (Kodagali, 1974). Singh *et al.* (1981) also found functional infertility to be more common than infertility due to infectious diseases (76 vs. 24%).

Ovarian cysts are a product of ovulation aberrations. They develop from follicles that fail to ovulate and instead continue to grow in size. Ovarian cysts are distinguished from mature Graafian follicles by their size, wall thickness and their association with uterine pathological conditions (Whitmore *et al.*, 1974; Bierschwal *et al.*, 1975). Two ovarian disorders, namely ovarian cysts and ovarian inactivity (true anoestrus) were reported to account for more than 30% of all reproductive disorders detected in dairy cattle (Munro *et al.*, 1982; Francos and Meyer, 1988). High milk yield, lactation number and close confinement of animals have been associated with ovarian cysts and occur most frequently in the second to fifth lactation (Hardie and Ax, 1981).

2.2.4.6 Congenital morphological abnormalities

Congenital causes of infertility include developmental abnormalities of the ovaries, oviducts, uterus, cervix, vagina and vulva (Mukasa-Mugerwa, 1989). In Tanzania, various gross abnormalities were observed in the reproductive organs of about 16% of Small East African zebu heifers and cows slaughtered at Morogoro abattoir, and the major reproductive abnormality was various degrees of fibrous adhesion between the ovary and the infundibulum and mesosalpinx (Assey *et al.*, 1998).

2.2.4.7 Climatic factors

Climatic elements such as season, temperature, humidity, and light interact to affect reproduction. Either abnormally high or low temperatures reduce RP. High temperatures shorten duration and lower behavioural expression of oestrus in the cow (Gangwar, *et al.*, 1965) and a greater percentage of cows come into heat at night when no one is available to observe them. In addition, hot climatic conditions often cause anoestrus in cows because adrenal glands secrete large amounts of progesterone (Wiersma and Stott, 1969). Heat stress during the dry period resulted in reduced milk yield and more days open in subsequent lactation (Moore *et al.*, 1992). Furthermore, heat stress has been shown to reduce embryo development and increase embryonic mortality (Thatcher, 1974; Wolfenson *et al.*, 2000). Heat stress reduces uterine blood flow (Roman-Ponce *et al.*, 1978), oocyte quality, luteal function, and endometrial function (Wolfenson *et al.*, 2000), milk yield and overall RP (Armstrong, 1994).

2.2.4.9 Managemental factors

Equal attention must be given to nutrition and reproduction management, which includes proper heat detection and timing of service. Poor oestrus detection is the major limitation to achieving a pregnancy in cycling cows when they are inseminated by AI or bred by hand mating (Barr, 1975; Britt *et al.*, 1986; Senger, 1994) resulting into delayed breeding and prolonged CIs. In well managed herds, only about 60% of dairy cows were detected correctly in oestrus when observed two or three times daily (Laing *et al.*, 1988) while 80% detection rate has been suggested as a realistic target (Esslemont, 1979). With continuous observation, the detection rate may increase to 95% in the second and later postpartum ovulations (Villa-Godoy *et al.*, 1988).

In another study however, oestrus was observed for only 75% ovulations, even when continuous videotaping was used. Slippery slatted floor was suspected to partially account for the reduced oestrus detection efficiency (Lucy, 2003). Alejandrino *et al.* (1999) reported failure of accurate oestrus detection as a factor contributing to calving intervals longer than 400 days in smallholder crossbred cattle in Philippines. Important challenges for detecting oestrus are accurately recognising signs of oestrus and identifying all possible periods of oestrus in breeding cows and heifers. The intensity and duration of oestrus depend on behaviour of individual cows as well as social interactions among cows (Lucy, 2003) hence confinement and isolation housing can contribute to decrease in oestrus expression for zero grazed animals because of deprivation of interactions among cows.

Nkya and Swai (1999) revealed that confinement, poor oestrus detection and record keeping were among other factors that contributed to dairy cattle reduced reproductive efficiency in smallholder farmers in peri-urban Dar es Salaam and Morogoro. A cow will not be detected to stand if no other cow is available to mount. Mounting activity is stimulated strongly by estrogen and inhibited by progesterone (Allrich, 1994). Thus, mounting frequency is considerably greater for cows in proestrus or estrus than for cows that are out of estrus or in midcycle with a functional CL (Helmer and Britt, 1985). Once four or more sexually active animals are in estrus in the same pen, standing and mounting activity will normally be maximized (Hurnik *et al.*, 1975) and should increase efficiency of detected estrus. For that reason, if no synchronization of estrus or ovulation is used, no fewer than 20 nonpregnant cows should be penned together to maximize the efficiency of detected estrus (Stevenson, 2003).

A number of environmental conditions either stimulate or restrict interactions among cows and influence whether they show estrus (Stevenson, 2003). Cows that are eating or are crowded in holding pens or alleys do less mounting. Cows also show less mounting activity when housed on slippery alleys, frozen ground, or any surface that makes footing tenuous (Britt *et al.*, 1986).

Oestrus may also be affected by light intensity in the stall (De Kruif and Brand, 1978) and light intensity should be such that a newspaper can be easily read in every part of the barn. Cows in estrus are more likely to mount one another if the other cows are loose rather than tied. Perhaps this indicates that freedom to interact before mounting is important for maximum expression of mounting activity. Cows that have foot problems show less mounting activity regardless of whether the problem is structural, subclinical, or clinical (Leonard *et al.*, 1994). Many of the foot problems that affect mounting activity might be alleviated by proper foot care such as using foot baths and regular hoof trimming.

Poor distribution and accessibility to bulls might also contribute to suboptimal RP in smallholder dairy cattle. Swai *et al.* (1993) pointed out failure to detect heat and failure to take cows to bulls for mating among others, as reasons for low herd size increase and low milk yield in Tanga. Small number of bulls (3 bulls per over 120 cows) leading to difficulties in accessing bulls for timely mating was reported in smallholder farmers in Turiani division (Safari *et al.*, 2000). Similarly, Kishinhi (1999) suspected lack of bulls to be among the factors leading to longer calving intervals among cows under smallholder management system when compared to large-scale system in Tanzania.

2.3 Overview and conclusions from literature review

Smallholder dairy farming has been identified by the Tanzanian government and aid organizations as a means of rural development and meeting the growing demand for milk. Milk for sale and home consumption has been an important product among others for keeping cattle in the smallholder dairy farming systems in developing countries. Efficient production of milk and calf crop is very much dependent on efficient reproduction of cattle, hence the importance of optimum reproduction for optimum milk and calf production, and enhanced contribution to rural development.

Rungwe district in the southern highlands zone of Tanzania is among the areas with high potential for dairy cattle farming and the existing smallholder dairy herd offers sufficient base for further research aimed at improvement of dairy industry in Tanzania. Using a number of measures that eventually affect the calving interval of cows, one can evaluate the reproductive performance. Evaluation of reproductive performance is usually carried out during the postpartum phase, which is a critical period when sexual restoration has to compete with the carry-over effects of the previous pregnancy and delivery and with the requirements for milk production. The process of reproduction in cattle is complex and affected by many environmental and genetic factors. However, environmental factors exert more influence on reproductive performance than genetic factors, a fact suggesting that much improvement in reproduction can be brought about through improved management including proper feeding.

Available information on smallholder dairy cattle in Rungwe district and the southern highlands of Tanzania in general indicates suboptimal reproductive performance of cows and heifers, but little published information is available on specific factors that could be adversely affecting the reproductive and apparently no evaluation has been done on the effects of improved nutrition to RP of smallholder dairy cattle and its economics in Rungwe district. It is imperative and reasonable from the reviewed literature therefore to undertake an on-farm research to identify the main specific causes of suboptimal reproductive performance in the area and develop an intervention strategy to improve the reproductive performance as a contribution to further enhance rural development in Rungwe district and similar areas in Tanzania.

CHAPTER 3

MATERIALS AND METHODS

3.1 Experiment 1: Field baseline survey

3.1.1 Study area

The study was conducted in smallholder farms in Rungwe district. The district is divided into four administrative divisions that are Tukuyu, Ukukwe, Pakati and Busokelo. The district headquarters are in Tukuyu, which is the largest town in the district located along the Mbeya-Malawi highway. The second largest town also located along the same highway is Kiwira in Ukukwe division. Pakati division comprise mostly of rural areas far from Tukuyu with poor transportation and communication infrastructure, except for Ushirika that is a village situated along the Tukuyu-Kyela road.

The district is located between longitudes 33^0 20' E and 34^0 00'E and latitudes $8^0$50'S and $9^0$20'S. It has an area of 2,211 km^2 of which 2,201 km^2 is dry land and the remaining area consists of rivers. About 75% of the dry land is arable. The land in the district is volcanic and mountainous plateau with numerous steep valleys and hills. Its altitude varies from about 1,000 m to 2,958 m above sea level at the peak of mount Rungwe. It receives an annual precipitation of 1,700 mm to 2,400 mm, distributed almost throughout the year except in August and September. Average temperature is between 23^0C and 25^0C. The area is suitable for production of different species of livestock and crops. The human population was 307,270 in 2002 census (URT, 2002).

3.1.2 Experimental design and sampling

A cross sectional research design as described by Babbie (1990) was used for baseline survey. Multistage, purposive sampling was done whereby 3 divisions were selected in the district depending on the availability of dairy cattle keepers and accessibility to the locations. Two wards were chosen from each of the selected divisions and 2 villages were randomly picked from each of the chosen wards. Six farmers were selected from each of the villages depending on their availability and willingness to participate in this study. The sample therefore consisted of 72 smallholder farmers.

3.1.3 Data collection

Data were collected by use of formal and informal interviews as well as direct observations. Communication with farmers was done in Swahili language and the information gathered was translated into English. A pre-prepared guide to informal interview was used for individual key informants and group discussions (Appendix I) while pre-tested structured questionnaires (Appendix II) were used during formal interviews.

Information collected by informal interviews included overviews on sources of income, types of dairy cattle kept and reasons, rearing systems, basal feeds and feed supplements used, milk production and marketing as well as health and reproductive management practices. Two group discussions, each lasting for about 2.5 hours were conducted in each division. The groups' sizes were 6 and 7, 6 and 8, and 6 farmers in Tukuyu, Ukukwe and Pakati, respectively. Participatory Rural Appraisal (PRA) technique was used during group discussions. The PRA tools used included pair wise ranking and matrix score. Pair wise ranking was used to rank basal feeds according to their importance. Farmers made a list of basal feeds that was used to construct the pair wise matrix. For each pair, the participants determined which of the two feeds is preferred using a consensus-oriented discussion. Scores for each basal feed from the matrix were then used to rank them. Ranking of sources of income in order of importance was done by matrix scoring using pebbles. The farmers made a list of sources of income and each farmer was given a number of pebbles equal to the number of items on the list to use for scoring.

In addition to group discussions, informal interviews with key informants were carried out. The key informants interviewed were the district livestock development officer (DALDO), Chairman of Tukuyu farmers' cooperative union (Umoja wa Wafugaji Tukuyu-UWATU), livestock field extension officers and veterinary service and input suppliers.

Individual formal farmer interviews lasted for 70 to 90 minutes and data collected included details of household structure and land ownership of the farmers, number of reared dairy cattle per household, age at attainment of puberty in heifers, age at first mating in heifers, calving intervals, methods of mating and heat detection. Additional data included types and availability of forages and feed supplements, common diseases and disease control measures, milk yield per cow and availability of bulls.

3.1.4 Data analysis

Percentages, means, ranges and standard deviations were calculated from data on household structure, number of different classes of cattle per household, dairy cattle feeding, milk production and reproductive indices for each division. Chi-square test was used to compare the overall observed and expected CI using SPSS© 12.0.1 for windows (SPSS, 1989-2003).

3.2 Experiment 2: Field monitoring experiment

3.2.1 Experimental design and sampling

A longitudinal monitoring experiment with multistage, purposive sampling carried out in the 3 divisions where the baseline survey was conducted (Section 3.1.2). Three wards were selected and included 2 wards that were initially used in the baseline survey and 1 ward randomly selected from the remaining wards in the selected division. Two villages were randomly picked from each of the selected wards. Three farmers were then chosen from each of the villages based on their informed consent to use the animals. A sample of 54 animals (about 7 months pregnant) was obtained from the farmers (one animal per farmer). The animals were obtained in two periods such that half of them were expected to calve between April and June 2002 (rainy season) and the other half from August to early October 2002 (dry season). The number of animals and the parity that they belonged in parentheses were 15 (1), 12 (2), 12 (3), 6 (4), 2 (5), 3 (6), 2 (7) and 2 (8). The animals were individually identified by ear tags and natural permanent body marks. Monthly rainfall data to indicate the rainy and dry seasons for the year 2002 were obtained from Tukuyu meteorological station, which is located within the study area.

3.2.2 Experimental animals, their management and feeding

Animals used were pregnant dairy cows and heifers reared by smallholder farmers in Rungwe district. The animals were crossbreds, mainly between Friesian (*Bos taurus*) and indigenous Tanzania Short Horn Zebu (*Bos indicus*) cattle.

All the experimental animals were reared by the farmers themselves under zero grazing system. It was assumed that differences in cattle management practices from one household to another was small and insignificant. Animals were fed mainly on natural pastures as basal diet. Cultivated fodder comprising of Napier grass (*Pennisetum purpureum*), *Desmodium spp.* and Guatemala grass (*Tripsacum laxum*) was also provided but they always constituted less than half of the basal diet, and their availability depended on the season, the size of household's fodder plots and number of animals kept per farm. Banana pseudostems and leaves were increasingly used during the dry season due to shortage of natural and cultivated pastures. Maize stover, bean and groundnut straw, and sweet potato vines were also used when available. The animals were fed 3 to 5 times a day between 0800 h and 2000 h with no food offered during the night. Home made supplementary feeding, comprising of hominy meal, sunflower seed cake and commercial minerals was provided mostly to lactating cows. The supplement composition and amount fed varied depending on availability of ingredients and no consideration was made to season of the year, level of production or stage of reproductive cycle of the animal. The concentrate was fed twice a day during milking. Daily hand-milking was done early in the morning (0500 – 0730 h) and in the evening (1500 – 1800 h).

Health management involved check-ups and treatments by local veterinary field officers. A cow was said to have retained placenta when the foetal membranes failed to separate from the mother's side for more than 24 hours after parturition.

3.2.3 Sample collection and measurement of variables

Daily milk yield (MY) was measured volumetrically using calibrated jars and recorded on special forms provided to farmers. Milk samples were collected once every 5 days from 14 to 90 days post calving for determination of progesterone concentration. Milk samples were also collected when heat signs were observed on days different from the days scheduled for sampling. About 5 ml of composite milk samples were collected from each cow during morning milking session on scheduled days for sampling. Sodium azide tablets (500 mg) were used for milk preservation and the milk samples were then stored at –2 to –8°C for subsequent progesterone radioimmunoassay (RIA).

Blood samples were collected monthly (starting about 60 days precalving to 90 days post calving) by jugular venipuncture using 6ml EDTA vacutainer tubes (BD Vacutainer Systems, Plymouth, UK). The samples were then centrifuged at 2000 revolutions per minute for 15 minutes to obtain plasma that was kept frozen at -20^0 C for subsequent Calcium (Ca), Phosphorus (P), Copper (Cu) and plasma urea nitrogen (PUN) concentrations determination.

Monthly individual body weights (BWTs) were estimated by use of weigh band (We-Bo. Denmark) distributed by Kruuse Denmark. A 5-kg tension was applied on the weigh band with a spring balance to minimize variations among measurements. Body condition scores (BCSs) were determined monthly using the method of Lowman *et al.* (1973) and tested by Msangi *et al.* (1999) under Tanzania conditions as described in detail in Appendix III. Reproductive disorders/diseases e.g. abortions, stillbirths and retained foetal membranes were recorded throughout the experimental period. Only clinical mastitis cases were recorded during this study.

3.2.4 Laboratory analyses

3.2.4.1 Milk progesterone

Progesterone concentrations in milk were determined using self-coating milk progesterone radioimmunoassay (RIA) kit (FAO/IAEA Programme, 1999 Bench protocol, version – ScRIA 3.1) (Appendix IV). The method is based on the principle of reversible and non-covalent binding of milk progesterone by monoclonal lyopholised antibody (6H11/14) employing radioactivity labelled progesterone (radioactive tracer: progesterone-11-α-hemisuccinate-2[^{125}I] iodohistamine) to measure the fraction of the milk progesterone bound to a sub-stoichiometric amount of the antibody. Preparation of coating buffer, diluent buffer, antibody stock solution, milk standards and washing solution was done a day before commencing a series of assays.

3.2.4.2 Blood plasma urea

Urea in blood plasma was determined using a NED Dye method kit (Span Diagnostics Ltd, Surat, India) (Appendix V). In this method urea condenses with O-Phthalaldehyde and Naphthyl ethylene diamine to form an orange coloured complex. The rate of formation of this complex is directly proportional to urea concentration.

spectrophotometer. A buffer was prepared by dissolving 7.456 g KCl in 950 ml distilled water and pH was adjusted to 1.80 with 1.0 N HCl. The flask was then filled to 1000 ml. Calcium reagent 1 was made by dissolving 0.820 g 8-hydroxyquinoline + 0.025 g 0-cresolphathaleine complexone in 480 ml KCl-HCl buffer. The pH was adjusted to 1.80 and the flask filled to 500 ml mark. Calcium reagent 2 was made by dissolving 14.26 g 2-amino-2-methyl-1-propanole in 180 ml distilled water. The pH was adjusted to 10.3 with 3 N HCl-solution and flask was filled to 200 ml. Plasma (90 µl) was added to 3.0 ml acidic calcium reagent 1 and incubated for a period of four minutes to ensure the release of protein bound calcium. Calcium reagent 2 was added that formed an alkaline medium wherein cresolphthalein complexone formed a coloured complex with calcium ions, which was measured at 574 nm. The 8-hydroxyquinoline in the reagent binds the magnesium ions, thus minimizing their interference in the calcium assay. The standard solution was made from Tritisol Ca-solution, which was used to prepare the standard curve.

3.2.4.5 Blood plasma phosphorus

Phosphorus concentration was determined by spectrophotometer method (Kessler and Wolfman, 1964) (Appendix VII). The method determines inorganic phosphorus by measurement of vanado-phosphomolybdate complex formed in acid. The absorbance of the coloured complex is directly related to the concentration of P and it is measured by the spectrophotometer. A reagent was prepared by dissolving 0.110 g NH_4VO_3 in approximately 80 ml of distilled water that was magnetically stirred. Then, 4.0 g

$(NH_4)_6Mo_7O_{24}$, $4H_2O$ were added and dissolved. Finally, 10 ml 6 N HCl were added and the flask filled to 100 ml. One volume of blood plasma was added to 4 volumes of 10% TCA solution, mixed on a whirl mixer and centrifuged for 5 minutes at 3000 rpm. Two hundred µl of supernatant were pipetted into 200 µl of the reagent. One and half ml of water was added, the mixture mixed on a whirl mixer and allowed to stand for 2-6 hours (minimum and maximum) in the dark before reading at 420 nm on spectrophotometer. Standard curve was prepared using KH_2PO_4 as P source.

3.2.5 Derived reproductive performance parameters

Following calving, farmers were involved in oestrus detection and hand-mating the animals. The date of conception was obtained retrospectively after confirmation of pregnancy. Pregnancy confirmation was done by rectal palpation at about 60 days after breeding. Reproductive performance parameters were derived as follows:

- Days from parturition to resumption of ovarian cyclic activity (DPOA) were determined by RIA of milk progesterone. Increase in progesterone concentration after calving above 1 ng/ml or more for 2 consecutive sampling days was considered an indication that ovulation had taken place (Terqui *et al.*, 1982).
- Oestrus detection rate was calculated as the proportion of visible heats recorded by farmers expressed as a percent of those cows registered as being in oestrus by use of milk progesterone assay.
- Days from parturition to first visual oestrus (DPO) were calculated from farmers' records. The results were arbitrarily classified into 3 categories according to how

soon the first visual oestrus was observed after calving. The DPO categories of < 90 days, 90 – 150 days and >150 days were used.

- The number of services per conception (SC) was calculated after confirmation of pregnancy.
- Calving interval (CI) was calculated as an interval between two most recent consecutive calvings.

3.2.6 Statistical models and analysis

All data were analysed using SPSS 12.0.1 for windows (Copyright© SPSS Inc, 1989-2003). Data exploration was carried out for all variables for identification of outliers and assessment of distribution. The statistical outliers that were not within normal range of biological values for a particular variable were omitted.

The model used for analysis of the effect of month of reproductive cycle and season on BWT, BCS, PUN, plasma Ca, P and Cu was:

$Y_{ij} = \mu + S_i + M_j + e_{ij}$

Where: Y_{ij} = Observation from an animal during the i^{th} season and j^{th} month of reproduction cycle.

μ = Overall mean.

S_i = Effect of i^{th} season of calving.

M_j = Effect of j^{th} month of reproductive cycle

e_{ij} = Random error term.

The data analysis was done using the procedure of general linear model, multifactorial between subjects analysis of variance. During the analysis of variance, dependent variables were BWT, BCS, PUN, plasma Ca, P and Cu, whereas the month of reproductive cycle and season were fixed factors (Appendix IXa). Following a significant effect of month of reproductive cycle on any variable, post hoc procedure was carried out for multiple comparisons among marginal means by Hochberg's test at alpha = 0.05

The model used for analysis of the effect of season on body condition score at calving (BCSC), MY, DPO, SC and CI was:

$Y_{ij} = \mu + S_i + e_{ij}$

Where: Y_i = Observation from j^{th} animal during i^{th} season.

μ = Overall mean.

S_i = Effect of i^{th} season of calving.

e_{ij} = Random error term.

Univariate analysis of variance was done separately for BCSC and MY (Appendices IXb and IXc) while DPO, SC and CI were run together using the general linear model (Appendix IXd). During the analysis of variance season was set as a fixed factor and MY, BCSC, DPO, SC and CI as dependent variables.

Procedure of descriptive statistics was run to produce a contingency table for percentages of animals that showed postpartum cyclicity before and after 90 days during rainy and dry seasons. Another contingency table was produced for percentages of animals in different DPO categories in both the seasons. Pearson's chi-square test was used to determine the relationship between different categories in the contingency tables and Cramer's V test was applied to quantify the strength of relationships (Appendices IXe and IXf).

A bivariate correlations procedure was used to compute Pearson's correlation coefficients between DPO, SC, CI, BWT, BCS, BCSC, plasma Ca, P, Cu, PUN, MY and parity (Appendix IXg).

Cumulative incidence risk of the various reproductive disorders/diseases was calculated using the population at risk as a denominator. Each animal could have each disorder only once. Overall associations between occurrence of reproductive diseases and disorders for the two seasons and for sex of the calf were tested in contingency tables by Pearson's chi-square test and strengths of associations were tested by Cramer's V test (Appendices IXh and IXi).

3.3 Experiment 3: Supplementation experiment

3.3.1 Experimental design and sampling

A longitudinal study with multistage, purposive sampling was set where the same 3 divisions were picked as in experiments 1 and 2, and then 3 wards were selected from each of the 3 divisions. Two villages and 4 farmers per village were chosen from each of the selected ward. A total of 72 animals (about 7 months pregnant) were purposefully selected from the farmers and alternately allocated as obtained into control and supplemented treatment groups. The animals were selected in such a way that half the group were expected to calve between March and June 2003 (rainy season) and the other half between August and early October 2003 (dry season) in the two treatment groups. The number of animals and the parity that they belonged in parentheses were 17 (1), 22 (2), 14 (3), 5 (4), 7 (5), 4 (6) and 3 (7).

Identification of animals and recording of monthly rainfall for the year 2003 were done as described in experiment 2 (Section 3.2.1).

3.3.2 Experimental animals, their management and feeding

Animals used were similar to those in experiment 2 and both treatment groups of animals were under farmers' management practices as described in section 3.2.2 except for animals in the supplemented group, which were given a concentrate in addition to normal basal diet and other feeds supplied by farmers. Literature from Rungwe district (Table 3.1) and tables of nutrient requirements for dairy cattle (ARC, 1990) were used to estimate the amount of metabolisable energy (ME), crude protein

(CP), calcium (Ca) and phoshorus (P) available in pastures. Nutrients deficits at dry matter intake (DMI) of 2.5% of cattle body weight (Mussa, 1998) in Rungwe district were computed (Table 3.2). The specifications for nutrients requirements used were for pregnant and lactating animals weighing 320.8 kg and producing 8.4 L of milk per day as observed during the monitoring experiment.

Table 3.1: Nutritive value of natural pastures in Rungwe district

	Wet season	Dry season	Mean
Dry matter (DM) (%)	13.62	39.19	25.11
Metabolisable energy (ME) (MJ/kgDM)	8.17	7.74	7.95
Crude protein (CP) (%)	8.42	12.51	10.46
Calcium (Ca) (%)	0.31	0.34	0.33
Phosphorus (P) (%)	0.22	0.19	0.21

Source: Mussa, (1998).

Table 3.2: Estimated nutrient balance per day for cows fed on pastures in Rungwe district

		Two months before calving to calving			
Source	**DMI (kg)**	**ME (MJ)**	**CP (g)**	**Ca (g)**	**P (g)**
Pasture	8.55	68.0	894.3	28.3	18.0
Requirements		52.9	396.5	33.0	20.0
Balance		+15.1	+497.8	-4.7	-2.0
		Calving to two months after calving			
Pasture	8.55	68.0	894.3	28.3	18.0
Requirements		104.0	1083.3	32.4	21.0
Balance		-36	-189.0	-4.1	-3.0

The supplement was made to cover the deficits to enable the animals approximately meet the daily allowances for ME, CP, Ca and P (ARC, 1990). The ME and CP contents of ingredients were assumed to be 13.8 MJ/kg and 116 g/kg for hominy meal (HM) and 12.6 MJ/kg and 219 g/kg for sunflower seed cake (SSC), respectively (Bwire and Wiktorsson, 1996).

The supplement was formulated to contain 13.4 ME (MJ/kg), 138.1 g/kg CP, 2.3 g/kg Ca, 1.3 g/kg P and 19 mg/kg Cu using hominy meal (76%), sunflower seed cake (23%) and commercial mineral supplement (1%), which was Super Maclick® (Coopers Kenya Ltd) (Appendix VIII). The supplement was fed at a rate of 7 g/kgBwt/day for 2 months before calving and 10 g/kgBwt/day after calving during the rainy season and 8 g/kgBwt/day for 2 months before calving and 11 g/kgBwt/day after calving during the dry season. Hominy meal was obtained from local milling machines in the areas under study while sunflower seed cake and Super Maclick were purchased from local farm input traders. The costs of purchased supplemental ingredients as well as milk prices were recorded in Tanzanian shillings (TShs).

3.3.3 Sample collection and measurement of variables

Fourty basal feed samples from feeding troughs were randomly collected from the 3 wards (20 during rainy season and 20 during dry season). About 1kg of each sample was weighed, dried indoors for 7 days and then sent to the Department of Animal Science and Production, Sokoine University of Agriculture (SUA), Tanzania for laboratory analyses. Calf birth weights (CBwts) were estimated by use of weigh band (We-Bo. Denmark) distributed by Kruuse Denmark. A 5-kg tension was applied on the weigh band with a spring balance to minimize variations among measurements.

Other collected samples and measured variables were similar to those described in experiment 2 (Section 3.2.3), except that initial measurements of BWT, BCS, plasma Ca, P, Cu and PUN were made approximately a month before the start of supplementation for animals in both the control and supplemented animals.

3.3.4 Laboratory analyses

3.3.4.1 Feed analyses

The feed samples were analysed for dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE), Ca, P and Cu and in vitro organic matter digestibility (IVOMD). Proximate analysis was done according to procedures of AOAC (1990). The IVOMD was done using the two-stage technique (Tilley and Terry, 1963). Metabolisable energy (ME) MJ/kgDM content of the feed was computed according to MAFF (1975) standards as:

ME (MJ/kgDM) = 0.16 x DOMD Where DOMD = Digestible organic matter in dry matter = 0.92 x IVOMD

Other laboratory analyses carried out were similar to those described in experiment 2 (Section 3.2.4).

3.3.5 Derived reproductive performance parameters

Calculations of derived reproductive parameters were similar to those described in experiment 2 (Section 3.2.5).

3.3.6 Prediction of dry matter intake and nutrient balances

Mean daily dietary nutrient balances before and after calving were estimated using predicted DMI and tabulated dietary nutrient requirements (ARC, 1990) for an 8 to 9 months pregnant and lactating animal weighing 287.1 kg and producing 12.0, 11.9, and 10.9 L of milk per day during the first, second and third months postcalving, respectively as observed during the supplementation experiment. The Predicted DMI was calculated as follows:

- Total ME (MJ) intake = Tabulated ME (MJ) requirements ± ME (MJ) balance

  ME (MJ) balance was calculated from monthly BWT change observed during the experiment, where 0.25kg BWT change is proportional to 8 MJ change (ARC, 1990).
- ME from pasture = Total ME intake - ME from supplement
- Pasture DMI (kg) = ME (MJ/kgDM) from pasture x 1kg/Q (MJ/kgDM), where Q is the ME content of pastures samples collected from the study area.

The pasture and supplement DMIs and nutrient concentrations were used to calculate the total nutrients available from pasture and supplement. The nutrient concentration values used for the supplement were the same as calculated during supplement formulation while those for the pastures were obtained from analysis of pasture samples collected from the study area. Nutrient balance was obtained by subtracting nutrient requirements from the total nutrients available from pasture and supplement.

3.3.7 Estimation of economics of supplementation

An economic analysis of the supplementation strategy was performed using farmers and experimental supplementation rates and mean BWT and MY values obtained during the current study. The analysis was performed to cover the entire experiment 3 period, which was 60 days before calving to 90 days postcalving for an animal weighing 287.1 kg and producing mean MY of 11.6 L/day during 90 days postpartum when compared to the same animal under average farmer's supplementation levels producing 9.1 L/day. The milk price used in calculations (170/-) was quoted from the largest farmers cooperative union in Rungwe district, (Umoja wa wafugaji Tukuyu-UWATU) in 2003, where most farmers sold their milk. For economic analysis calculations, it was assumed for the farmer's level of supplementation that an average of 1.9kg of supplement was offered per day for 19.2 days in a month for 2 months pre- and postcalving as observed during the baseline study. It was also assumed that 4,000/- and 3,000/-per month was spent on transport of concentrate ingredients for the supplemented and control animals, respectively. It was further assumed that the calf was offered 4, 3 and 2 L of milk per day during the first, second and third months of age, respectively.

The average costs in Tanzanian shillings (TShs) of concentrate ingredients purchased during the year 2003 were as shown in Table 3.3. The economic analysis (Appendix X) involved calculations to determine the following:

Table 3.3: Average cost (TSh/kg) of purchased supplementary feed ingredients

Ingredient	N	Mean	Std. Deviation	Minimum	Maximum	Range
HM	16	76.07	17.48	55.56	100.00	44.44
SSC	14	92.31	7.19	83.33	100.00	16.67
SM	13	1538.46	112.09	1400.00	1700.00	300.00

- The costs of concentrate ingredients and the mixed concentrate per kilogram.
- Total supplementation costs (60 days pre- and post-calving) and total MYrevenue for 90 days post-calving for a 287.1kg experimentally supplemented cow and cows maintained under average farmers' supplementation levels.
- Marginal profit at 90 days postcalving after supplementation for 2 months pre- and postcalving.

3.3.8 Statistical models and analysis

Data were analysed using SPSS 12.0.1 for windows (Copyright© SPSS Inc, 1989-2003) and data exploration was carried out in a similar manner as described in experiment 2 (Section 3.2.6).

The model used for analysis of effect of supplementation on BWT, BCS, PUN, plasma Ca, P and Cu was:

$Y_{ij} = \mu + T_i + b(X_{ij} - X) + e_{ij}$

Where: Y_{ij} = Observation from j^{th} animal assigned to i^{th} treatment.

μ = Overall mean.

T_i = Effect of i^{th} treatment.

b = Regression of Y_{ij} on X_{ij}.

X_{ij} = Initial observation from j^{th} animal assigned to i^{th} treatment.

X = Overall mean of the covariate

e_{ij} = Random error term.

The procedure of general linear model, multifactorial between subjects analysis of variance was employed and covariates of the measured variables were incorporated in the analysis of variance to adjust for initial observations. On analysis of variance, treatment was a fixed factor while BWT, BCS, PUN, plasma Ca, P and Cu and their initial observations were included as dependent variables (Appendix IXj).

The model used for analysis of effect of supplementation or parity on BCSC, CBwt and MY as well as the effect of parity on BWT, BCS, PUN, plasma Ca, P and Cu was:

$Y_{ij} = \mu + T_i + e_{ij}$

Where: Y_{ij} = Observation from j^{th} animal assigned to i^{th} treatment or that belongs to i^{th} parity.

μ = Overall mean.

T_i = Effect of i^{th} treatment or i^{th} parity.

e_{ij} = Random error term.

Univariate analysis of variance using the general linear model was done for each variable with treatment as a fixed factor and MY, BCSC, CBwt and DPO as dependent variables (Appendices IXk and IXl) during analysis of effect of supplementation on BCSC, CBwt, MY and DPO.

The effect of parity was estimated from pooled data collected in both experiments 2 and 3 because parities 6 and above had too few observations in experiment 3. Data for parities 6 and above were pooled during the analysis to increase the number of observations in those parities. The effect of parity on BWT, BCS, PUN, plasma Ca, P and Cu, was evaluated using the procedure of general linear model, multifactorial between subjects analysis of variance with parity as a fixed factor and BWT, BCS, PUN, plasma Ca, P and Cu as dependent variables (Appendix IXm). Following a significant effect of a parity on any variable, post hoc procedure was carried out for multiple comparisons among marginal means by Hochberg's test at alpha = 0.05. For analysis of effect of parity on BCSC, CBwt and MY, univariate analysis of variance using the general linear model was done for each variable with parity as a fixed factor and MY, BCSC and CBwt as dependent variables (Appendix IXn).

Contigency tables for percentages of animals that showed postpartum cyclicity before and after 90 days, and animals in different DPO categories for treatment and parity factors were produced using the procedure of descriptive statistics. Pearson's chi-square test and Cramer's V test were used to determine the relationship between different categories in the contingency tables and to quantify the strength of relationships, respectively (Appendices IXo and IXp).

Cumulative incidence risk of reproductive disorders/diseases and an overall association between occurrence of reproductive diseases and disorders for the treatment groups was calculated as described in section 3.2.6 of experiment 2 (Appendix IXq).

CHAPTER 4

RESULTS

4.1 Results from baseline survey (Experiment 1)

4.1.1 Household structure and land ownership

The average interviewed smallholder household in Rungwe was headed by a male (Table 4.1). Majority of the farmers (94.4%) had formal education, many of them (59.7%) having primary education. A large proportion of the farmers had formal primary education, and only few (5.6%) lacked formal education. The heads of households were on the average 56.7 years old with the age ranging between 23-83 years. Most households had on the average 7 children and owned 5 acres of land including plots away from the homestead. It was revealed during group discussions that head of households were responsible for making decisions and carrying out daily cattle management activities such as cutting and carrying forages, feeding, milking, selling of milk, selling of animals and purchase of inputs. Children contributed to labour for dairy activities after school hours and during holidays.

4.1.2 Sources of income

Dairy cattle ranked number one as a source of income in Tukuyu and Ukukwe divisions, followed by crop production while the reverse was observed in Pakati division (Table 4.2). Other sources of income are listed in Table 4.2.

Table 4.1: Gender, education level, marital status, age of head of household, and number of children and acres per family in Rungwe district

Variables	Division							
	N	Overall	N	Tukuyu	N	Ukukwe	N	Pakati
HH's gender								
Female (%)	9	12.5	5	20.8	3	12.5	1	4.2
Male (%)	63	87.5	19	79.2	21	87.5	23	95.8
HH's education								
None (%)	4	5.6	2	8.3	1	4.2	1	4.2
Primary (%)	43	59.7	13	54.2	10	41.7	20	83.3
Secondary (%)	23	31.9	9	37.5	11	45.8	3	12.5
College (Diploma) (%)	2	2.8	0	0	2	8.3	0	0
HH's marital status								
Monogamist (%)	57	79.2	19	79.2	20	83.3	18	75.0
Polygamist (%)	5	6.9	1	4.2	1	4.2	3	12.5
Single female (%)	5	6.9	2	8.3	1	4.2	2	8.3
Widow (%)	5	6.9	2	8.3	2	8.3	1	4.2
	72	**100.0**	**24**	**100.0**	**24**	**100.0**	**24**	**100.0**
HH's age (years)	72	56.7±14.6 (23-83)	24	57.9±13.3 (37-80)	24	57.5±12.3 (37-75)	24	54.8±18 (23-83)
Number of children per family	72	6.9±3.3 (0-14)	24	7.5±3.1 (3-14)	24	6.7±3.0 (1-14)	24	6.5±3.9 (0-13)
Land owned (acres/family)	72	5.0±3.1 (0.5-13)	24	4.1±2.6 (0.5-10)	24	5.9±3.6 (1-13)	24	5.1±2.8 (0.5-12)

Numbers in parentheses indicate the range for a given mean ± SD

HH = Head of household

Table 4.2: Sources of income as ranked by farmers according to relative importance in Rungwe district

Source of income	Division							
	Tukuyu		Ukukwe		Pakati		Overall	
	Score	Rank*	Score	Rank	Score	Rank	Score	Rank
Dairy cattle	20	1	25	1	16	2	61	1
Crop production	17	2	24	2	17	1	58	2
Remittances	5	6	10	7	8	5	23	7
Wages/Salaries	10	4	15	4	2	8	27	5
Timber	7	5	13	6	4	7	24	6
Gardening	13	3	14	5	9	4	36	3
Handcrafts	2	8	8	8	6	6	16	8
Other petty businesses	4	7	17	3	10	3	31	4

*1 and 8 denote the most and least important sources of income respectively

4.1.3 Number and classes of dairy cattle per household

Dairy cattle breeds kept included mostly crosses of Friesian, and to a lesser extent Ayrshire and Jersey to indigenous Tanzania Short Horn Zebu cattle. In most cases, it was found that cows, heifers and female calves predominated in numbers (Table 4.3). Comparatively, few households kept bulls and bull calves. On average, each household kept a total of 2 dairy cattle with the highest and smallest number of dairy cattle per household being found in Ukukwe and Pakati divisions, respectively.

4.1.4 Availability of feeds and feeding

Basal diet for dairy cattle in Rungwe consisted of indigenous natural pastures, cultivated fodder and crop residues. The cultivated fodder most commonly comprised

Table 4.3: Mean (± SD) number of different classes of dairy cattle reared per household

Class of cattle	Division			
	Overall	Tukuyu	Ukukwe	Pakati
Cows	1.3±0.8 (0-4)	1.3±0.7 (0-2)	1.3±0.7 (0-2)	1.3±1.0 (0-4)
Heifers	0.3±0.5 (0-1)	0.4±0.5 (0-1)	0.4±0.5 (0-1)	0.2±0.4 (0-1)
Female calves	0.4±0.6 (0-3)	0.4±0.5 (0-1)	0.6±0.7 (0-3)	0.3±0.5 (0-1)
Bull calves	0.2±0.4 (0-1)	0.2±0.4 (0-1)	0.1±0.3 (0-1)	0.2±0.4 (0-1)
Bulls	0.1±0.4 (0-1)	0.1±0.3 (0-1)	0.2±0.4 (0-1)	0.1±0.3 (0-1)
Average animals per household	2.2±1.2 (1-6)	2.1±1.1 (1-4)	2.5±1.2 (1-6)	2.0±1.2 (1-5)

Numbers in parentheses indicate the range for a given mean

of Napier grass (*Pennisetum purpureum*), Guatemala grass (*Tripsacum laxum)* and *Desmodium spp.* Farm crop residues formed part of the basal diet when available and they consisted of banana pseudostems and leaves, maize stover, sweet potato vines as well as bean and groundnut straws Respondents throughout the district ranked natural pastures as the most important of the basal diet components while cultivated pastures and crop residues were ranked second and third, respectively. Findings from group discussions showed that natural pastures ranked first as basal diet because they were the most available and relied upon for long periods in a year. Banana pseudostems and leaves were more available than sweet potato vines, maize stover, bean and groundnut straws because in contrast to year round banana farming, the others are products of annual crops. Banana pseudostems and leaves played an important role in feeding dairy cattle during dry season when both natural pastures and cultivated fodder were scarce. There was no strict timetable and frequency of feeding the animals, though majority of respondents fed them at least three times a day. First feeding was done between 0800 and 1100 h and last feeding between 1800 and 2000 h by most farmers with no food offered during the night. Farmers provided drinking water to cows' satisfaction at least 3 times a day in 20 L buckets. Few farmers offered continuous supply of water provided in water troughs.

4.1.5 System of rearing cattle, drying off, supplementary feeding and milk production of dairy cattle in Rungwe district

Most respondents (94.4%) practiced indoor rearing of the animals (zero grazing), where grasses were cut and carried to feed the animals (Table 4.4). The remaining farmers practised a mixed system (semi-outdoor), where animals were occasionally tethered during certain periods of a day and/or whole day.

Across the divisions, all interviewed farmers dried off their pregnant animals for 1 to 3 months before calving. However, there was usually no deliberate effort of steaming up such animals, although 16.4% of respondents would supplement them during this period. Most respondents (94.4%) across the divisions provided some sort of supplementary feeding to dairy cattle (Table 4.4), however, 12.5% of respondents in Pakati division did not supplement their animals. Provision of supplementary feeding was subject to availability of concentrate and largely limited to lactating cows. On average, farmers could afford to feed 1.9 kg of concentrate per day for 19.2 days in a month. Home made concentrates of varying physical and chemical composition, and amounts of ingredients were used for supplementary feeding though the most common

Table 4.4: **Rearing system, dry period, supplementation of cattle, milk yield and consumption patterns as reported by farmers in Rungwe district**

Variables	N	Overall	Division: Tukuyu	N	Ukukwe	N	Pakati	N
Rearing system								
Zero grazing (%)	68	94.4	95.8	23	95.8	23	91.7	22
Mixed (%)	4	5.6	4.2	1	4.2	1	8.3	2
PC[1] Drying off								
Yes (%)	59	100	100	19	100	22	100	18
No (%)	0	0	0	0	0	0	0	0
Dry period length (months)	59	2.1±0.3 (1-3)	2.1±0.3 (2-3)	19	2.1±0.3 (2-3)	21	2.0±0.4 (1-3)	19
Provision of supplement								
Yes (%)	68	94.4	100	24	95.8	23	87.5	21
No (%)	4	5.6	0	0	4.2	1	12.5	3
PC supplementation (C-2)[2]								
Yes (%)	10	16.4	23.8	5	14.3	3	10.5	2
No (%)	51	83.6	76.2	16	85.7	18	89.5	17
[3]PP supplementation								
Yes (%)	59	100	100	20	100	21	100	18
No (%)	0	0	0	0	0	0	0	0
Supplementation rate (kg/day)	58	1.9±0.4 (1-3)	2.0±0.4 (1.5-3.0)	20	1.9±0.3 (1.5-2.5)	20	1.7±0.4 (1.0-2.5)	18
Days concentrate supplemented per month	58	19.2±5.0 (10-30)	21.7±4.8 (10-30)	20	18.4±5.1 (7-28)	20	17.3±4.4 (10-28)	18
Mineral mix supplementation rate (g/day)	54	23.8±13.4 (10-70)	25.5±15.4 (10-70)	19	24.5±12.8 (10-50)	18	21.1±11.8 (10-40)	17
Days minerals supplemented per month	58	13.7±7.0 (0-30)	17.9±5.9 (8-30)	20	15.2±5.6 (5-28)	20	7.4±5.1 (0-15)	18
Milk yield (L/day)	61	7.9±2.9 (5-18.5)	9.1±3.6 (5.5-18.5)	20	7.7±3.0 (5-14.5)	20	7.0±1.7 (5-11.5)	21
Milk consumed at home (L/day)	61	1.3±0.6 (0.5-3.0)	1.3±0.5 1.0-2.5)	20	1.5±0.6 (0.5-3.0)	20	1.1±0.5 (0.5-2.5)	21

[1]PC = Precalving
[2]C-2 = 2 months precalving
[3]PP = Postpartum

ingredients were hominy meal, sunflower seed cake and commercial minerals. The most commonly used mineral mix was Super Maclick® (Coopers Kenya Ltd). The supplement composition varied from a concentrate including all the named ingredients to only hominy meal. About 23.8 g/day of mineral mix were included in the concentrate for an average of 13.7 days in a month. The same concentrate was usually provided to dairy cows and calves. Supplementary feeding was rarely given according to level of production or stage of lactation. When available, amount of concentrate offered ranged between 1 and 3 kg per day divided between the morning and evening milking sessions. Dairy cattle in Tukuyu were provided with the highest amount of concentrate (2.0 kg) per day, for the longest duration of 21.7 days/month for concentrate and 17.9 days/month for minerals. The cattle in Tukuyu division also produced more milk (9.1 L/day) than those in other divisions. Percentage of respondents supplementing dairy cattle was highest and lowest in Tukuyu and Pakati divisions, respectively. Findings in Pakati showed the lowest amount of concentrate (1.7 kg) offered per day, shortest duration of 17.3 days/month for concentrate and 7.4 days/month for mineral provision. The lowest milk yield of 7.0 L/day as well as lowest amount of milk consumed at home were observed in Pakati.

4.1.6 Diseases and disorders of dairy cattle in Rungwe district

Across the divisions, retained foetal membranes, mastitis, pyrexia of unidentified origin, abortion and anoestrus were commonly observed (Table 4.5). Uterine prolapse and dystocia were less commonly observed. From group discussions it was learnt that most farmers sprayed their animals with acaricides for tick control. Frequency of acaricide application varied among farmers, from once fortnightly to once in three months. Deworming was not routine and was done only when conditions were critical. Intramammary infusion treatment of dry cows for prevention of mastitis was not practised.

Table 4.5: Number of disease conditions observed by respondents for a period of 12 months (July, 2000 to June 2001) in Rungwe district

Diseases and disorders	Division			Total
	Tukuyu	Ukukwe	Pakati	
Retained foetal membranes	4	3	3	10
Mastitis	3	4	2	9
Pyrexia of unidentified origin (PUO)	3	3	2	8
Abortion	2	3	2	7
Anoestrus	3	2	2	7
Uterine prolapse	2	2	2	6
Dystocia	2	2	2	6
Stillbirth	1	2	2	5
Foot and mouth disease (FMD)	2	2	1	5
Lumpy skin disease (LSD)	3	1	1	5
Parturient paresis	1	2	1	4
East coast fever (ECF)	0	1	2	3
Calf gastrointestinal worms	0	0	2	2
Calf bloat	2	0	0	2
Calf diarrhoea	1	0	0	1
Liver flukes	0	0	1	1
Contagious bovine pleuropneumonia (CBPP)	0	1	0	1

4.1.7 Dairy cattle breeding and reproductive performance

All interviewed farmers practiced year round breeding of cattle using natural mating (hand mating) as a method for breeding. Findings during group discussions showed that farmers had broad knowledge on oestrus detection obtained through courses organised by non-governmental organisations' projects (mainly SHDDP and HPI), government extension field staff and fellow farmers. The method used by respondents for oestrus detection was by visual observation of signs of oestrus. They normally observed their animals for oestrus signs at least twice a day. Generally, farmers kept records, which included age at first heat and dates of heat, service and calving.

There was no evidence of variations in ages at puberty, first mating and first calving between divisions although they were a bit higher in Pakati (Table 4.6). Calving interval was shortest in Tukuyu (495 days) and longest in Pakati (603 days) division. The CI varied between 365 and 1095 days with an overall mean of 526 days across the divisions. This was significantly ($P<0.05$) longer than the range of 375 to 390 days that is expected in a well-managed herd.

Table 4.6: Means (± SD) for reproductive performance indices, distance to bull and cost of bull service

Variables			Division					
	N	Overall	N	Tukuyu	N	Ukukwe	N	Pakati
Age at puberty (months)	59	20.5±1.0 (16.8-25-5)	21	20.1±1.8 (16.8-23.0)	21	20.3±1.8 (17.0-23.5)	17	21.3±1.8 (17.0-25.5)
Age at first mating (months)	58	21.5±1.8 (17.5-26.2)	20	21.1±1.7 (17.5-23-7)	21	21.2±1.8 (17.5-24.5)	17	22.3±1.6 (19.5-26.2)
Age at first calving (months)	58	30.8±1.8 (26.8-35.5)	20	30.4±1.7 (26.8-33.0)	21	30.5±1.8 (26.8-33.8)	17	31.6±1.6 (28.8-35.5)
Calving interval (days)	56	526±123 (365-1095)	20	495.3±81.0 (395-675)	21	500±75.9 (365-615)	15	603.4±183.0 (380-1095)
Distance to bull (km)	72	1.2±1.0 (0.0-4.5)	24	1.3±0.9 (0.0-3.0)	24	1.0±1.0 (0.0-4.5)	24	1.4±1.1 (0.0-3.5)
Cost of bull service (x1,000Ths)	72	2.4±0.7 (1.5-4.0)	24	2.8±0.8 (2-4)	24	2.4±0.5 (2-4)	24	2.0±0.3 (1.5-2.5)

Note: *Numbers in parentheses indicate the range for a given mean*

4.2 Results from field monitoring activities (Experiment 2)

4.2.1 Monthly rainfall pattern for year 2002

Monthly rainfall pattern recorded at Tukuyu weather station during the year 2002 is shown in Figure 4.1. The highest amount of rainfall was recorded in April and the lowest between July and September.

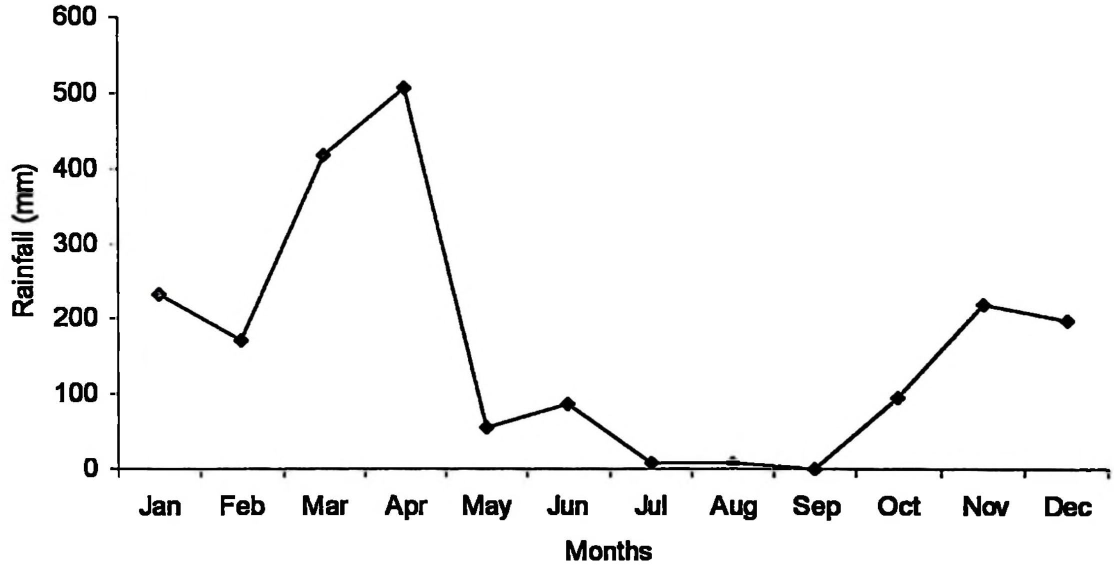


Figure 4.1: Monthly rainfall pattern recorded at Tukuyu meteorological station in the year 2002

4.2.2 Effect of stage of reproductive cycle on body weight and body condition score

The trend for BWT showed an increase from two months precalving to one month precalving followed by a progressive decrease up to two months postcalving (Table 4.7). There was a slight increase in BWT between two to three months postcalving.

The highest rate (kg/month) of loss of BWT was a month before and after calving and the animals were significantly ($P<0.01$) heavier during the period of 2 months precalving than the period of 3 months postcalving. The trend for BCS was characterised by progressive loss of body condition throughout the experiment except for the slight increase from two months to three months postcalving. The BCS values were significantly higher precalving than postcalving ($P<0.001$).

Table 4.7: Means (± SEM) for BWT, BCS, PUN, and plasma minerals between 2 months prepartum (C-2) and 3 months postpartum (C+3)

Variables	Months before and after calving (C=Calving)												P-value
	C-2		C-1		C		C+1		C+2		C+3		
	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	
BWT(kg)	54	343.7 ± 10.6^{a}	54	347.0 ± 9.5^{a}	48	323.0 ± 10.0^{ab}	53	311.7 ± 9.9^{ab}	52	303.9 ± 9.4^{b}	51	304.0 ± 11.0^{ab}	**
BCS	54	2.5 ± 0.1^{a}	54	2.4 ± 0.1^{ab}	48	2.2 ± 0.1^{bc}	53	2.1 ± 0.1^{c}	52	2.0 ± 0.1^{c}	51	2.1 ± 0.1^{c}	***
PUN(mg/dl)	39	7.6±0.5	47	8.2±0.5	42	8.0±0.5	43	8.6±0.5	48	8.7±0.5	35	8.6±0.5	ns
Ca(mg/dl)	54	7.8 ± 0.2^{ab}	54	7.9 ± 0.2^{ab}	47	8.1 ± 0.2^{a}	53	7.5 ± 0.2^{ab}	52	7.6 ± 0.2^{ab}	51	7.4 ± 0.3^{b}	*
P(mg/dl)	54	2.7 ± 0.3^{b}	54	4.2 ± 0.2^{a}	47	5.1 ± 0.2^{a}	53	4.9 ± 0.2^{a}	52	4.5 ± 0.2^{a}	51	4.9 ± 0.3^{a}	***
Cu(µg/ml)	53	0.46±0.03	54	0.43±0.03	47	0.42±0.03	53	0.45±0.03	52	0.46±0.03	51	0.43±0.03	ns

Means with different superscript within each row are significantly different; ** = P<0.01; *** = P<0.001; *P<0.05

ns = Not significantly different (P>0.05)

4.2.3 Effect of stage of reproductive cycle on plasma urea nitrogen

The PUN increased from two months precalving to one month precalving then decreased up to calving (Table 4.7). There was a rise in PUN for one month following parturition after which the values appeared more or less stable. The observed variations in PUN among the months were however not significant ($P>0.05$).

4.2.4 Effect of stage of reproductive cycle on plasma calcium, phosphorus and copper concentration

Plasma Ca remained more or less stable throughout the experimental period except for a significant ($P<0.05$) rise around the calving period and a decline three months after calving (Table 4.7). Mean plasma P concentration significantly ($P<0.001$) increased from two months before calving to one month before calving after which it remained relatively stable. The highest concentration of P in plasma coincided with the calving period. Plasma Cu decreased from two months before calving and reached its lowest point at calving (Table 4.7). The values then increased for two months postcalving before decreasing towards the third month postcalving. The variations in plasma Cu concentrations were not significant ($P>0.05$) among the months.

4.2.5 Effect of season on body weight and body condition score

During rainy season, body weight (BWT) increased for a month from two months before calving then declined for a month before and after calving (Figure 4.2). There was a further decrease in BWT between the first and second months after calving followed by an increase towards the third month. A similar trend was observed during the dry season except that the BWT decreased from two to one month precalving and continued to decline from the second to third month postcalving. The animals were significantly ($P<0.001$) heavier during the rainy than in dry season (Table 4.8). A trend similar to that of BWT was observed in BCS values in both the rainy and dry seasons (Figure 4.2) except that the BCS values during the rainy season decreased from two months to one month precalving whereas the BWT increased during the same period. Higher BCS loss occurred during the rainy (0.21) than dry season (0.11) during the 2 months following parturition. The mean BCS and BCSC during the rainy season were significantly ($P<0.001$) and ($P<0.05$), respectively higher than during the dry season (Table 4.8).

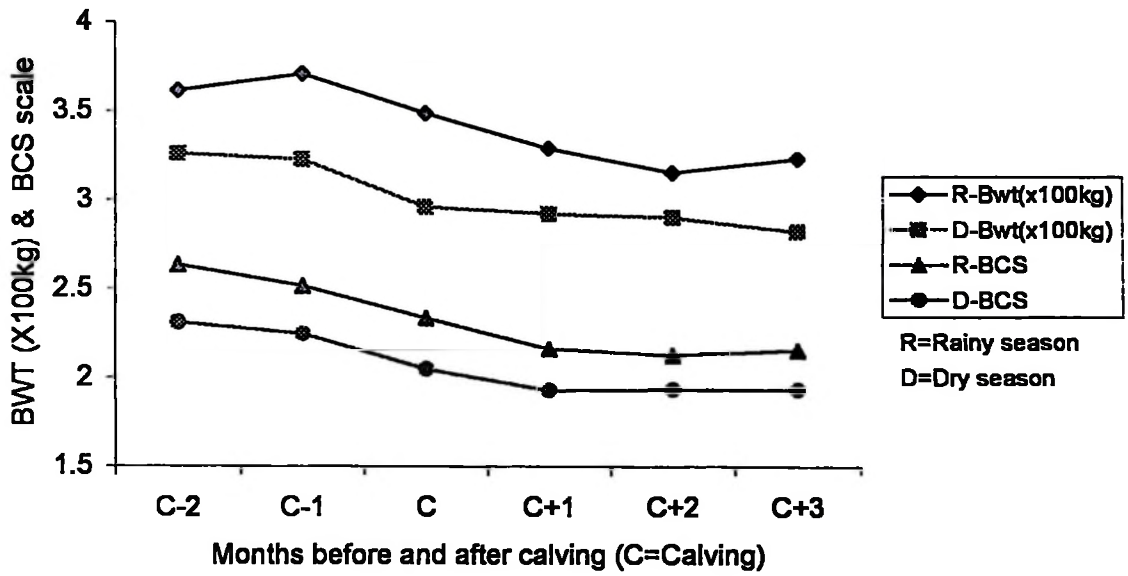


Figure 4.2: Trends of body weight (BWT) and body condition score (BCS) between 2 months prepartum (C-2) and 3 months postpartum (C+3) during rainy and dry seasons

Table 4.8: Means (± SEM) for BWT, BCS, BCSC, MY and concentrations of Ca, P, Cu and PUN in blood during rainy and dry seasons

Variable	Season						P-value
	N	Overall	N	Rainy season	N	Dry season	
BWT (kg)	322	320.8 ± 3.9	160	342.3 ± 5.5	162	302.2 ± 6.1	***
BCS	322	2.2 ± 0.0	160	2.33 ± 0.03	162	2.07 ± 0.04	***
BCSC	51	2.2 ± 0.1	27	2.4 ± 0.1	24	2.0 ± 0.1	*
PUN (mg/dl)	272	8.4 ± 0.2	150	8.9 ± 0.3	122	7.7 ± 0.3	**
Plasma Ca (mg/dl)	321	7.7 ± 0.1	160	6.9 ± 0.1	161	8.6 ± 0.1	***
Plasma P (mg/dl)	321	4.3 ± 0.1	160	4.9 ± 0.1	161	3.9 ± 0.2	***
Plasma Cu (µg/ml)	319	0.44 ± 0.01	160	0.44 ± 0.02	159	0.44 ± 0.02	ns
MY (L/day)	4140	8.4 ± 0.4	2070	9.4 ± 0.1	2070	7.3 ± 0.1	*

*** = P<0.001; * = P<0.05;** = P<0.01; ns = Not significantly different (P>0.05)

4.2.6 Effect of season on plasma urea nitrogen

Plasma urea nitrogen (PUN) concentrations decreased for two months before calving to calving during the rainy season (Figure 4.3). The PUN increased for two months following calving, then declined up to three months postcalving. More fluctuations and significantly (P<0.01) lower PUN concentrations were observed during the dry than the rainy season (Table 4.8). The difference in mean PUN values between the seasons was highest two months before and after calving.

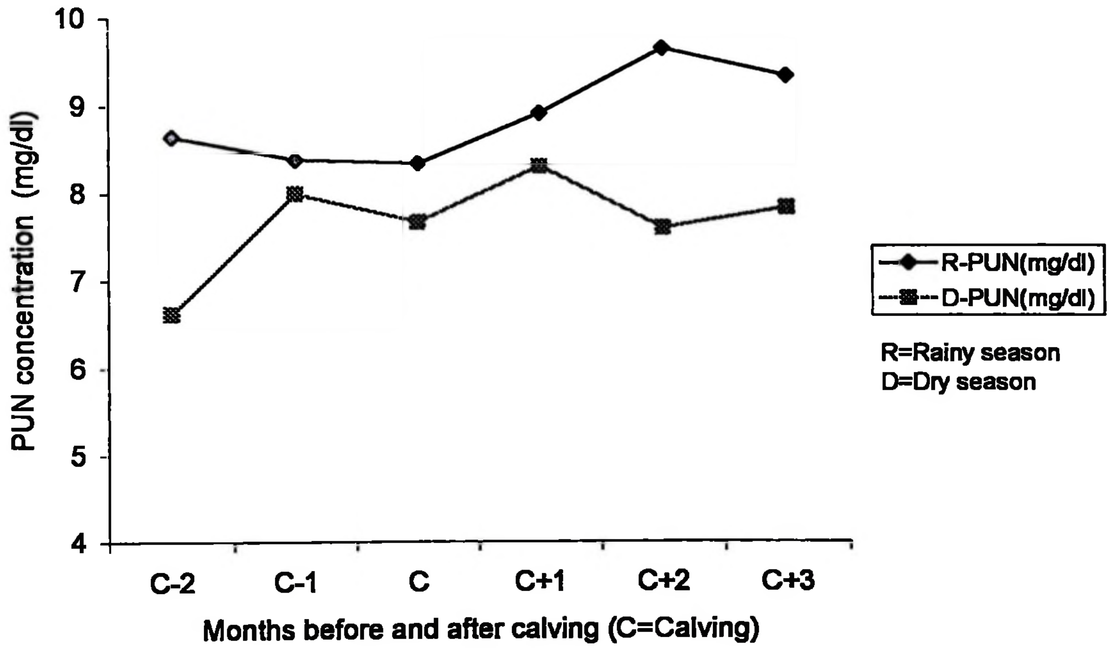


Figure 4.3: Trends of plasma urea nitrogen concentration between 2 months prepartum (C-2) and 3 months postpartum (C+3) during rainy and dry seasons

4.2.7 Effect of season on plasma calcium, phosphorus and copper concentration

Trends of plasma Ca, P and Cu concentrations between two months precalving and three months postcalving during rainy and dry seasons are shown in Figure 4.4. Calcium concentration in plasma was significantly ($P<0.001$) higher during the dry than the rainy season (Table 4.8) while plasma P concentration values during the rainy season were significantly ($P<0.001$) higher than in dry season during most of the study period. Variations in mean plasma Cu concentrations between the seasons were not significant ($P>0.05$) (Table 4.8).

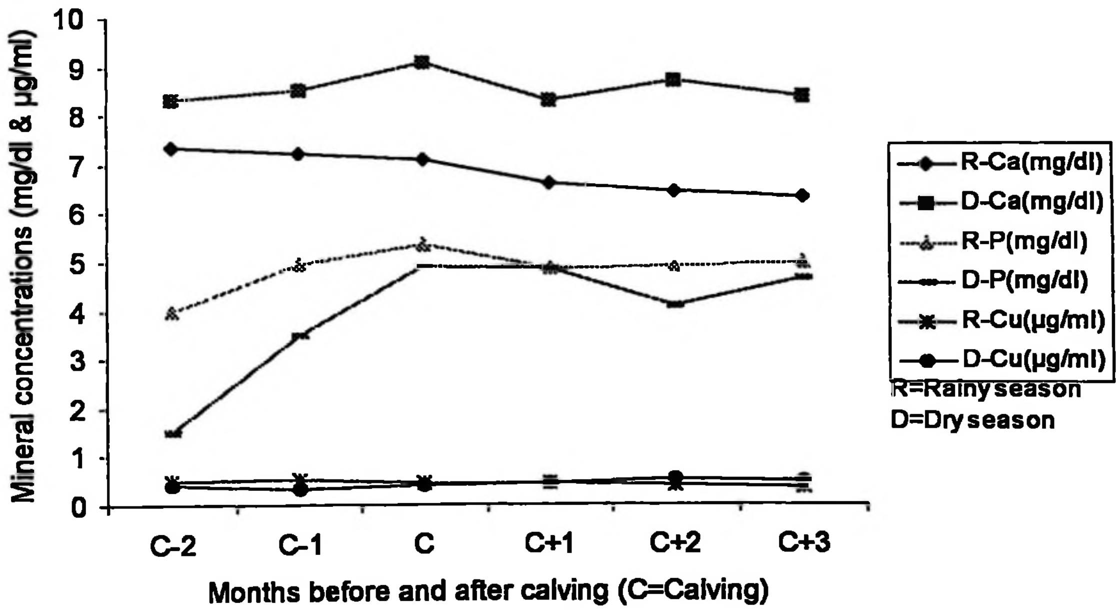


Figure 4.4: Trends of plasma Ca, P and Cu concentration between 2 months prepartum (C-2) and 3 months postpartum (C+3) during rainy and dry seasons

4.2.8 Effect of season on milk yield

Mean milk yield (MY) during the dry season increased following parturition with a peak observed in two weeks following calving (Figure 4.5). The MY then progressively dropped for the rest of the experimental period. The trend was similar during the rainy season, but with significantly (P<0.05) higher MY than in dry season (Table 4.8).

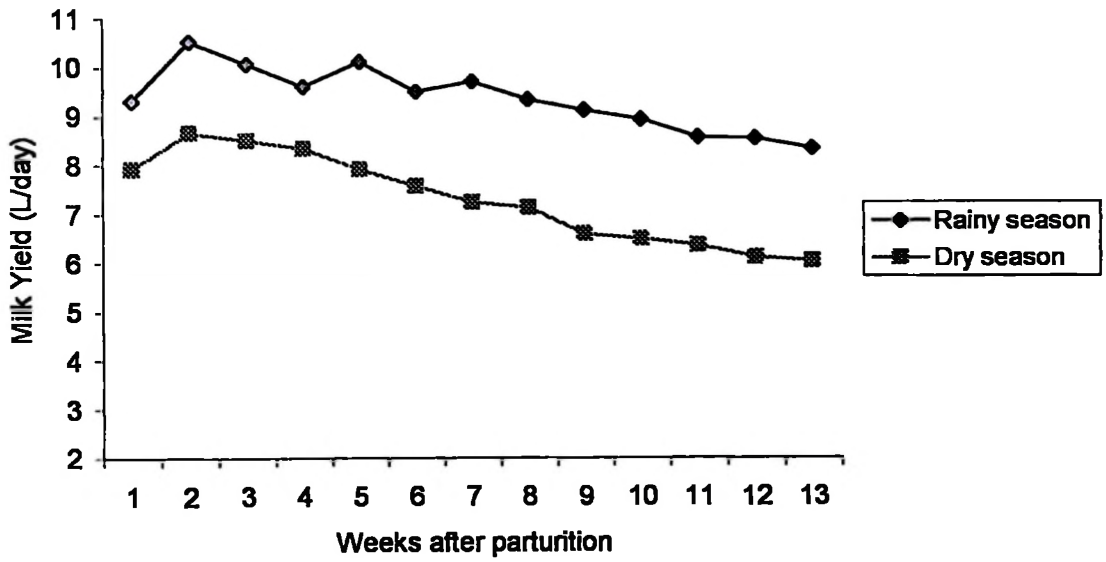


Figure 4.5: Trends of milk yield for 13 weeks post calving during the rainy and dry seasons

4.2.9 Effect of season on days to postpartum resumption of cyclicity, days to postpartum first visual oestrus, services per conception and calving interval

Oestrus detection rate was 66%. A higher proportion of cows that calved during the rainy season resumed postpartum ovarian cyclicity before 90 days than cows that calved in the dry season (Table 4.9). However, the association between season and days from parturition to resumption of ovarian cyclic activity (DPOA) (before or after 90 days) was not significant ($P>0.05$). The association between season and DPO was also not significant ($P>0.05$) although higher percentage of cows that calved during the rainy season showed postpartum first visual oestrus earlier than those that calved during the dry season. The mean DPO for animals calving in rainy season was significantly ($P<0.05$) lower than for those calving during the dry season (Table 4.10). The animals calving during the rainy season had fewer services per conception (SC) and shorter CIs although the differences were not statistically significant ($P>0.05$).

Table 4.9: Proportions of cows in relation to days from parturition to resumption of ovarian cyclic activity (DPOA) and days from parturition to first visual oestrus (DPO) during rainy and dry seasons

Parameter/ Category	N	Overall (%)	Groups: N	Rainy season (% cows)	N	Dry season (% cows)	χ-square p-value
DPOA							
≤ 90 days PP	15	29.4	9	34.6	6	24.0	
> 90 days PP	36	70.6	17	65.4	19	76.0	
Total	**51**	**100.0**	**26**	**100.0**	**25**	**100.0**	ns
DPO							
< 90 days PP	11	22.9	6	24.0	5	21.7	
90-150 days PP	13	27.1	8	32.0	5	21.7	
> 150 days PP	24	50.0	11	44.0	13	56.5	
Total	**48**	**100.0**	**25**	**100.0**	**23**	**100.0**	ns

Table 4.10: Means (±SEM) for reproductive performance variables in cows during rainy and dry seasons

RP variables	N	Overall	N	Rainy season	N	Dry season	P-value
DPO (days)	44	178.7 ± 19.6	25	136.7 ± 25.2	19	220.8 ± 30.1	*
SC	37	1.5 ± 1.2	22	1.37 ± 0.21	15	1.42 ± 0.31	ns
CI (days)	34	485.7 ± 20.1	20	454.8 ± 25.8	14	516.6 ± 30.8	ns

* = P<0.05; ns = Not significantly different (P>0.05)

4.2.10 Associations between some of the measured variables in cows

Correlation coefficients between reproductive performance indices and some measured variables are shown in Table 4.11. The DPO was negatively correlated at various levels of significance to all measured variables except plasma Ca while SC was negatively correlated to all parameters except BCS and BCSC. Calving interval was negatively correlated at various levels of significance to all variables except plasma Ca. Results in Table 4.12 show that BCS was positively correlated at various levels of significance with BWT, PUN and plasma P.

Table 4.11: Pearson correlations between reproductive performance parameters and BWT, BCS, BCSC, plasma Ca, P, Cu, PUN, MY and parity in cows

Variables	Reproductive performance parameters								
	DPO			SC			CI		
	N	r	P-value	N	r	P-value	N	r	P-value
BWT	40	-0.315	0.047(*)	32	-0.295	0.102	33	-0.339	0.053
BCS	44	-0.424	0.004(**)	36	0.035	0.839	37	-0.394	0.016(*)
BCSC	40	-0.348	0.028(*)	32	0.006	0.974	33	-0.238	0.183
Plasma Ca	44	0.194	0.206	36	-0.006	0.971	37	0.174	0.303
Plasma P	44	-0.551	0.000(***)	36	-0.071	0.679	37	-0.506	0.001(**)
Plasma Cu	44	-0.188	0.221	36	-0.123	0.476	37	-0.161	0.341
PUN	44	-0.459	0.002(**)	36	-0.343	0.041(*)	37	-0.574	0.000(***)
MY	38	-0.175	0.294	33	-0.189	0.293	33	-0.094	0.601
Parity	44	-0.134	0.385	36	-0.126	0.462	37	-0.236	0.159

*** Correlation is significant at 0.001 level (2-tailed).
** Correlation is significant at 0.01 level (2-tailed).
* Correlation is significant at 0.05 level (2-tailed).

Table 4.12: **Pearson correlations between BWT, BCS, BCSC and plasma minerals, PUN, MY and parity in cows.**

Variables	BWT			BCS			BCSC		
	N	r	P-value	N	r	P-value	N	r	P-value
Plasma Ca	48	-0.368	0.008(**)	54	-0.291	0.028(*)	48	-0.363	0.009(**)
Plasma P	48	0.280	0.047(*)	54	0.367	0.005(**)	48	0.179	0.209
Plasma Cu	48	-0.011	0.941	54	0.006	0.964	48	-0.113	0.429
PUN	48	0.434	0.001(**)	54	0.411	0.001(**)	48	0.211	0.137
MY	38	0.617	0.000(***)	43	0.257	0.084	38	0.112	0.484
Parity	48	0.377	0.006(**)	54	0.089	0.512	48	0.012	0.931
BWT				48	0.286	0.042(*)	48	0.236	0.095

*** Correlation is significant at 0.001 level (2-tailed).
** Correlation is significant at 0.01 level (2-tailed).
* Correlation is significant at 0.05 level (2-tailed).

4.2.11 Incidence of reproductive diseases and disorders

Dystocia was the most frequently observed disorder overall, followed by mastitis, retained foetal membranes and milk fever (Table 4.13). Most of the dystocia cases occurred in females that had male calves (Table 4.14). There was a significant association between an overall occurrence of reproductive diseases and disorders between the two seasons ($P<0.05$) (Cramer's $V < 0.05$) with more diseases and disorders occurring during the rainy season.

Table 4.13: Cumulative incidence of reproductive diseases and disorders during the rainy and dry seasons

Disease/ disorder	Total		Season				χ-square p-value
			Dry season		Rainy season		
	Count	%	Count	% within season	Count	% within season	
Abortion	1	1.8	0	0.0	1	3.6	
Dystocia	6	10.5	3	10.3	3	10.7	
Clinical mastitis	4	7.0	0	0.0	4	14.3	
Milk fever	2	3.5	0	0.0	2	7.1	
Pyrexia of unknown origin	2	3.5	0	0.0	2	7.1	
Retained foetal membranes	3	5.3	1	3.4	2	7.1	
Sudden Death	1	1.8	0	0.0	1	3.6	
Vulval rupture at calving	1	1.8	0	0.0	1	3.6	
Total N	57		29		28		*

* = P<0.05

Table 4.14: Cumulative incidence of reproductive diseases and disorders by sex of calf

Reproductive diseases and disorders	Total		Calf sex			
			Female		Male	
	Count	%	Count	% within sex of calf	Count	% within sex of calf
Abortion	1	1.8	0	0.0	1	3.3
Dystocia	6	10.5	1	3.7	5	16.7
Clinical mastitis	4	7.0	1	3.7	3	10.0
Milk-fever	2	3.5	1	3.7	1	3.3
Pyrexia of unknown origin	2	3.5	1	3.7	1	3.3
Retained foetal membranes	3	5.3	2	7.4	1	3.3
Sudden Death	1	1.8	0	0.0	1	3.3
Vulval rupture	1	1.8	0	0.0	1	3.3
Total N	57		27		30	

4.3 Results from supplementation experiment (Experiment 3)

4.3.1 Monthly rainfall pattern for year 2003

Monthly rainfall pattern recorded at Tukuyu meteorological station during the year 2003 is shown in Figure 4.6. The highest amount of rainfall was recorded in April and the lowest during the months of August and September when there was no rain at all.

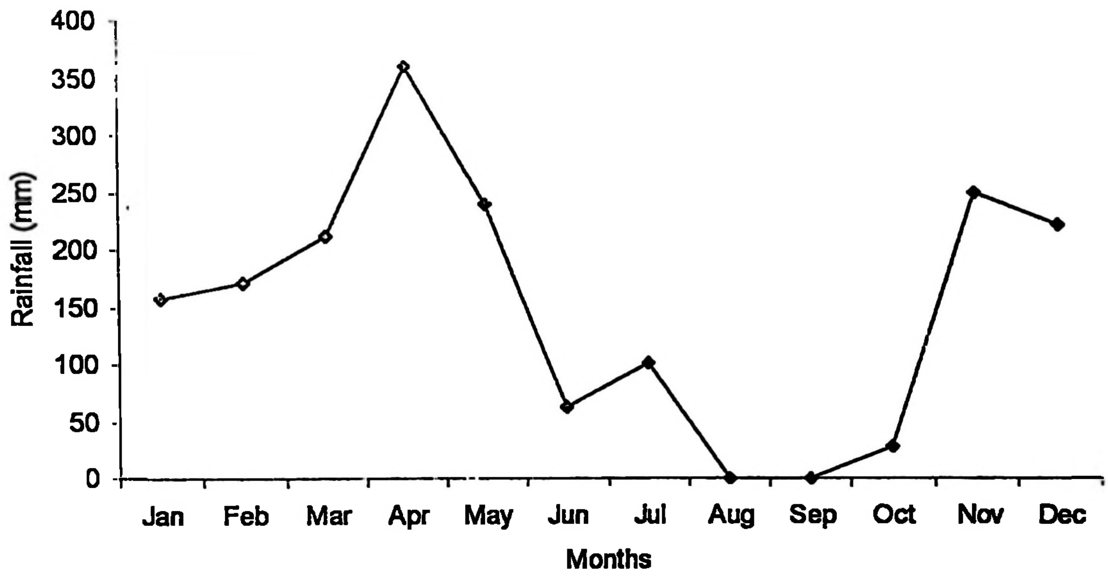


Figure 4.6: Monthly rainfall pattern recorded at Tukuyu meteorological station in year 2003

4.3.2 Dry matter, metabolisable energy and crude protein in natural pastures

Mean values for DM, ME and CP in native pastures are shown in Table 4.15. Dry matter in pastures increased from the months of March and April and reached a peak during the months of June and July (Figure 4.7). A decrease in DM was observed from around June and July to November and December values. The mean CP in pastures showed a decrease from the months of March and April towards June and July. After June and July there was an increase with highest values recorded during the months of November and December. Metabolisable energy showed a similar pattern to that of CP with maximum values occurring in November and December.

Table 4.15: Mean chemical composition of natural pastures fed to dairy cattle in Rungwe district

Component %	Mean ± SEM	Minimum	Maximum
DM	29.4 ± 2.2	14.9	42.7
ME (MJ/kgDM)	5.7 ± 0.2	3.3	8.1
CP	9.3 ± 0.5	6.4	14.0
CF	31.4 ± 1.2	22.5	46.8
EE	1.0 ± 0.1	0.5	1.7
Ash	13.6 ± 1.0	8.9	27.5
Ca	0.6 ± 0.1	0.1	1.3
P	0.2 ± 0.02	0.1	0.4
Cu (mgCu/kgDM)	0.27 ± 0.35	0.10	0.53

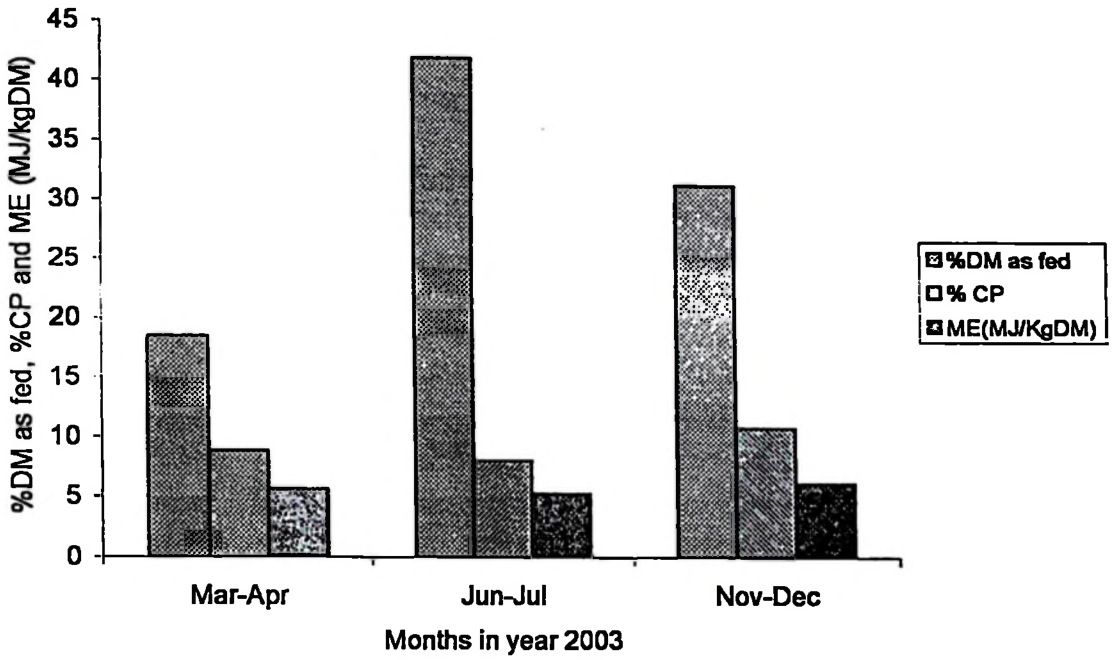


Figure 4.7: Trends of DM, %CP and ME (MJ/kgDM) in pastures during the year 2003

4.3.3 Calcium, phosphorus and copper in natural pastures

Mean values for Ca, P and Cu in natural pastures are shown in Table 4.15. Calcium in pastures increased from the months of March and April towards June and July and a lesser increase from June and July to November and December (Figure 4.8). A similar trend to that of Ca was observed for Cu but an opposite trend was the case for P with values decreasing from March and April through June and July to November and December.

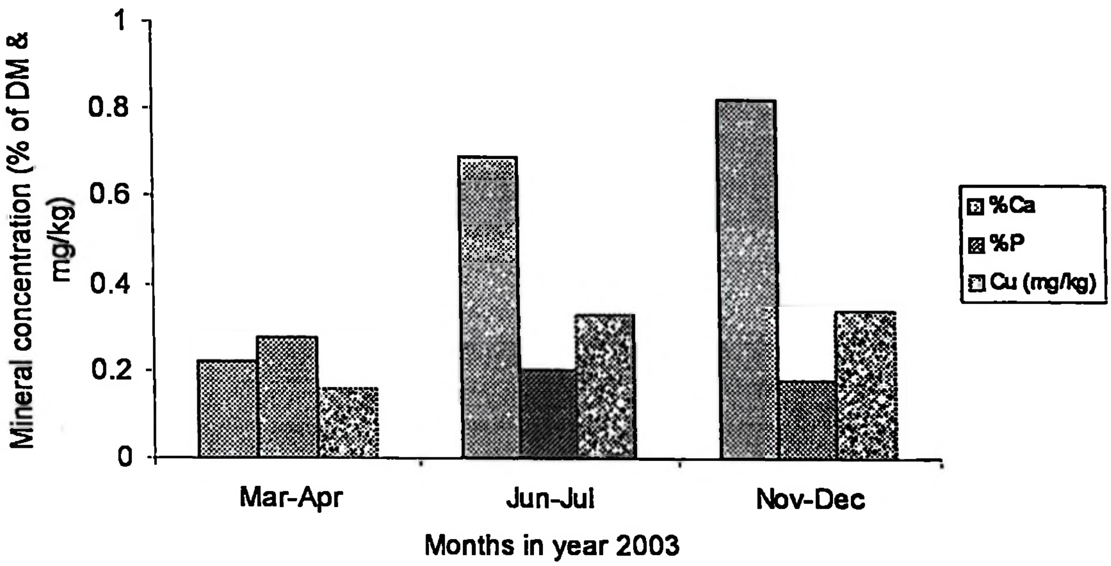


Figure 4.8: **Mineral content of natural pastures in the year 2003**

4.3.4. Daily dietary nutrient balance for supplemented animals

Mean daily dietary nutrients' balances before and after calving are shown in Table 4.16. ME and CP balances were positive for two months precalving and negative for two months postcalving. Calcium balance was negative from two months to one month before calving after which it turned positive up to two months postcalving. Negative balance was observed for P and Cu throughout the duration of experimental period.

Table 4.16: Mean daily dietary nutrient balance for two months before and after calving for supplemented animals

Source	DMI (kg)	ME (MJ)	CP (g)	Ca (g)	P (g)	Cu (mg)
Two months to one month before calving						
Pasture	3.4	19.1	316.2	20.4	6.8	0.9
Supplement	2.4	32.2	331.4	5.5	3.1	45.6
Total	5.8	51.3	647.6	25.9	9.9	46.5
Requirements		49.0	339	33.2	19.5	58.0
Balance		+2.3	+308.6	-7.3	-9.6	-11.5
One month before calving to calving						
Pasture	6.3	36.0	585.9	37.8	12.6	1.7
Supplement	2.4	32.2	331.4	5.5	3.1	45.6
Total	8.7	68.2	917.3	43.3	15.7	47.3
Requirements		58.2	393.5	37.7	22.6	87
Balance		+10.0	+523.8	+5.6	-6.9	-39.7
Overall nutrient balance precalving (two months before calving to calving)						
Pasture	4.9	27.9	455.7	29.4	9.8	1.3
Supplement	2.4	32.2	331.4	5.5	3.1	45.6
Total	7.3	60.1	787.1	34.9	12.9	46.9
Requirements		53.6	366.3	35.5	21.1	72.5
Balance		+6.5	+420.8	-0.6	-8.2	-25.6
Calving to one month after calving						
Pasture	9.3	52.9	864.9	55.8	18.6	2.5
Supplement	2.7	36.2	372.9	6.2	3.5	51.3
Total	12.0	89.1	1237.8	62.0	22.1	53.8
Requirements		110.0	1355.6	42.8	33.0	120.0
Balance		-20.9	-117.8	+19.2	-10.9	-66.2
One month to two months after calving						
Pasture	9.1	51.9	846.3	54.6	18.2	2.5
Supplement	2.7	36.2	372.9	6.2	3.5	51.3
Total	11.8	88.1	1219.2	60.8	21.7	53.8
Requirements		109.0	1346.0	42.5	32.7	118.0
Balance		-20.9	-126.8	+18.3	-11.0	-64.2
Overall nutrient balance postcalving (calving to two months after calving)						
Pasture	9.2	52.4	855.6	55.2	18.4	2.5
Supplement	2.7	36.2	372.9	6.2	3.5	51.3
Total	11.9	88.6	1228.5	61.4	21.9	53.8
Requirements		109.5	1350.8	42.7	32.9	119
Balance		-20.9	-122.3	+18.7	-11	-65.2

4.3.5 Effect of supplementation on body weight and body condition score

The mean BWT for the control group decreased for three months before calving, after which it further decreased for two months following calving then stabilized from two to three months postcalving (Figure 4.9). The mean BWT for the supplemented group increased for three months before calving, then decreased for two months after calving and showed a slight increase from two to three months postcalving. The BCS for both the control and supplemented groups increased from three months precalving to two months before calving when they started decreasing up to two months postcalving. After two months following calving the BCS in supplemented animals started to increase while that of the control group was still decreasing. The mean values of BWT and BCS for the supplemented group were significantly ($P<0.001$) higher than the control group (Table 4.17). Furthermore, the supplemented group had significantly ($P<0.01$) higher body condition score at calving (BCSC) than the control group.

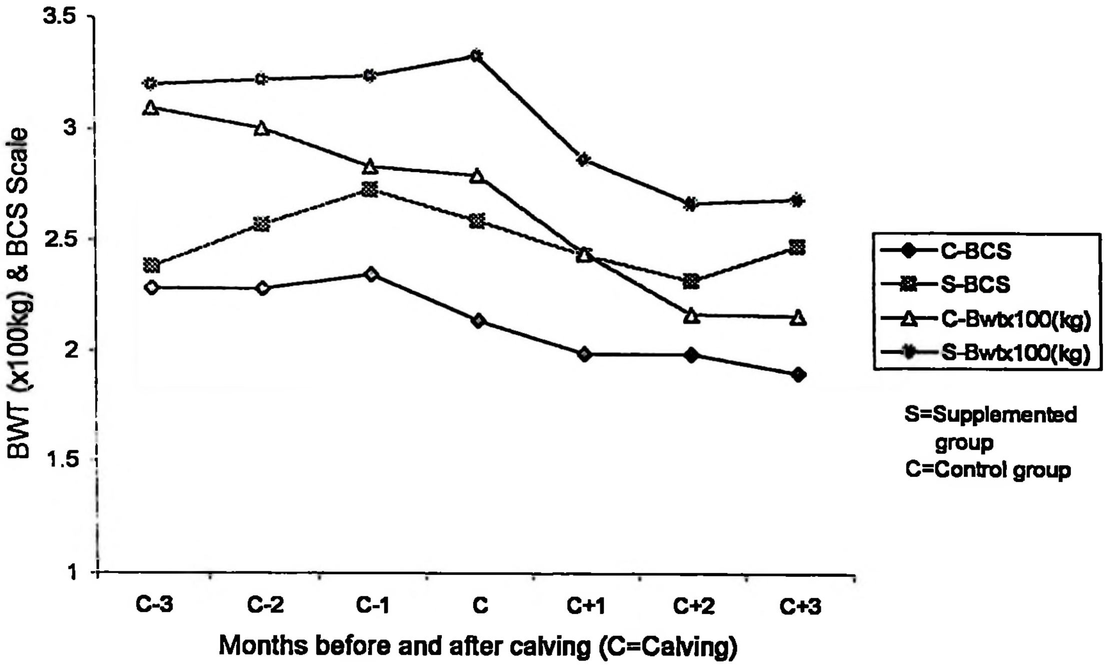


Figure 4.9: Trends of body weight and body condition score between 3 months prepartum (C-3) and 3 months postpartum (C+3) for control and supplemented groups

Table 4.17: Means (± SEM) for BWT, BCS, BCSC, PUN, plasma minerals and production parameters in control and supplemented groups

Parameter	Group						P-value
	N	Overall	N	Control	N	Supplemented	
BWT (kg)	431	287.1 ± 3.7	200	268.2 ± 5.6	231	306.1 ± 5.0	***
BCS	431	2.3 ± 0.03	200	2.2 ± 0.04	231	2.5 ± 0.03	***
BCSC	60	2.4 ± 0.1	30	2.2 ± 0.1	30	2.6 ± 0.1	**
PUN (mg/dl)	428	10.4 ± 0.1	213	9.3 ± 0.2	215	11.5 ±0.2	***
Plasma Ca (mg/dl)	427	10.7 ± 0.1	214	10.7 ± 0.1	213	10.6 ± 0.1	ns
Plasma P (mg/dl)	427	4.9 ± 0.1	214	4.6 ± 0.1	213	5.2 ± 0.1	**
Plasma Cu (μg/ml)	426	0.43 ± 0.01	214	0.39 ± 0.02	212	0.46 ± 0.02	**
MY (L/day)	5125	10.4 ± 0.5	2519	9.1 ± 0.7	2606	11.6 ± 0.7	***
CBwt (kg)	63	24.7 ± 0.5	31	23.4 ± 0.7	32	26.0 ± 0.7	**

*** = $P<0.001$; ** = $P<0.01$; ns = Not significantly different ($P>0.05$)

4.3.6 Effect of supplementation on plasma urea nitrogen

The mean PUN for both the control and supplemented groups increased from three to two months before calving after which they diverged whereby that of supplemented animals continued to increase while that of the control group decreased up to calving (Figure 4.10). The mean PUN concentration of the supplemented group was significantly ($P<0.001$) higher than the control group (Table 4.17).

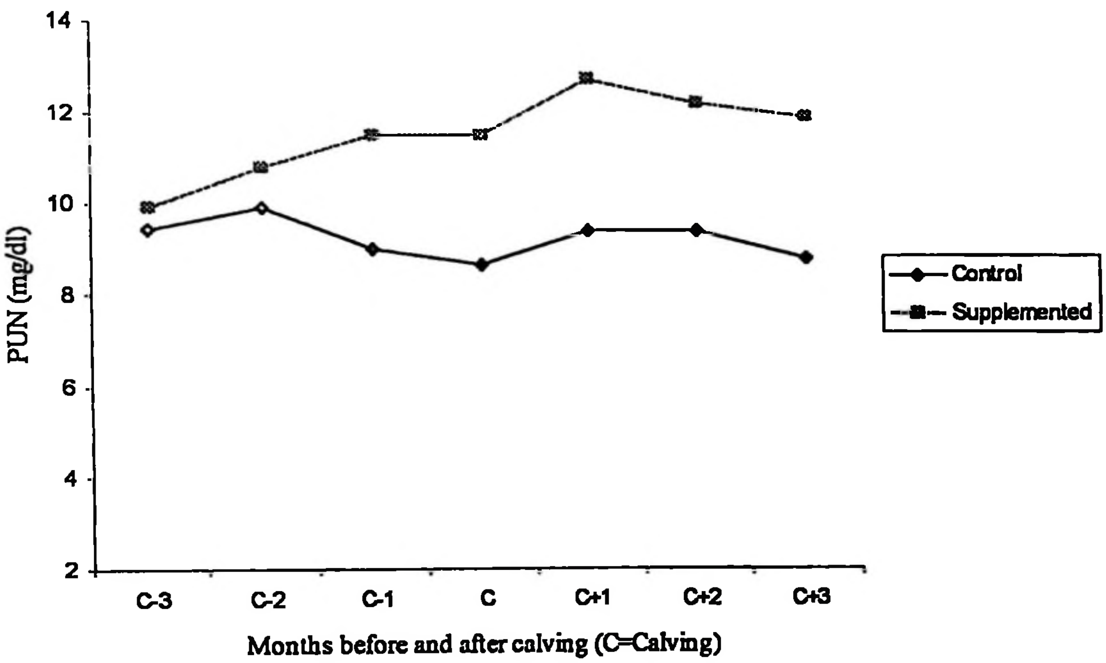


Figure 4.10: Trends of plasma urea nitrogen concentration between 3 months prepartum (C-3) and 3 months postpartum (C+3) for control and supplemented groups

4.3.7 Effect of supplementation on plasma calcium, phosphorus and copper concentration

The mean plasma Ca concentration did not differ much between the control and supplemented group throughout the experimental period (Figure 4.11). The mean plasma P concentration for the control group fluctuated below the plasma P levels for the supplemented group during most of the experimental period (Figure 4.11). Mean P concentration for the supplemented group increased throughout the last trimester and for a month postcalving after which it declined up to three months postcalving. The mean plasma P as well as Cu concentrations for the supplemented group were significantly ($P<0.05$) higher than the values for the control group (Table 4.17).

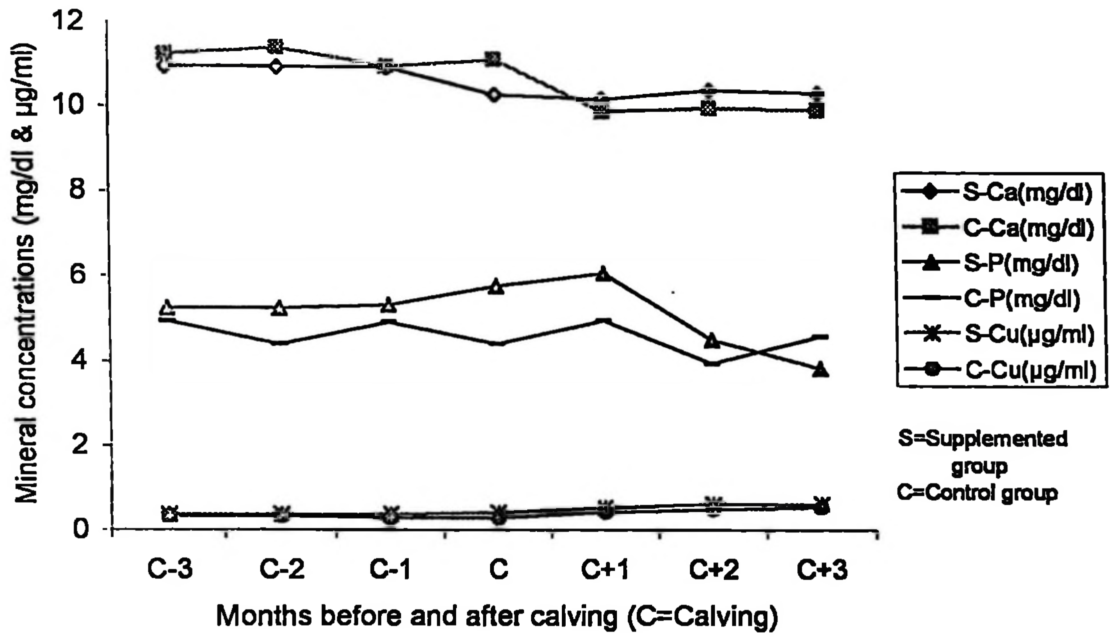


Figure 4.11: Trends of plasma Ca, P and Cu concentration between 3 months prepartum (C-3) and 3 months postpartum (C+3) for supplemented and control groups

4.3.8 Effect of supplementation on milk yield and calf birth weight

Mean MY trend for control group showed an increase reaching its peak at three weeks after parturition (Figure 4.12). The highest rate of increase in MY was observed during the first two weeks after parturition. Progressive decline in MY occurred from three to thirteen weeks postcalving. The MY at thirteen weeks after calving was lower than the MY during the first week postcalving. The MY trend for the supplemented group was similar to that of the control group except that there was better milk production persistency in this group than the control group. The mean MY for the supplemented group remained significantly ($P<0.001$) higher than the MY for the control group for the entire experimental period (Table 4.17).

The supplemented group had significantly ($P<0.01$) higher calf birth weights (CBwt) than the control group (Table 4.17).

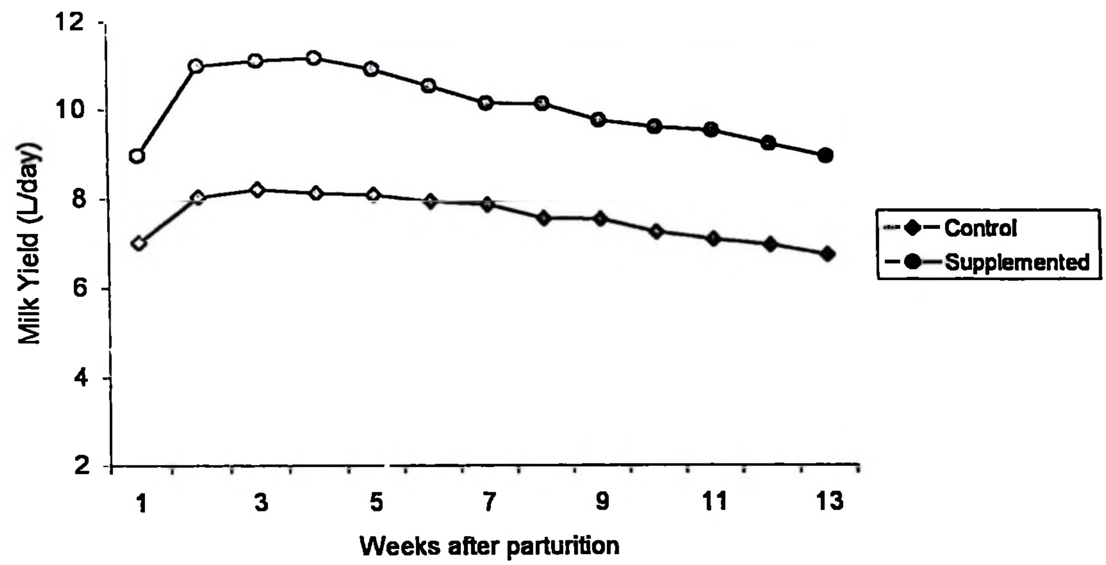


Figure 4.12: Trends of milk yield for 13 weeks post calving in supplemented and control groups

4.3.9 Effect of supplementation on days to postpartum resumption of cyclicity and days to postpartum first visual oestrus

Oestrus detection rate was 68%. The percentages of cows showing postpartum resumption of ovarian cyclicity before and after 90 days for supplemented and control groups are shown in Table 4.18. Postpartum ovarian cyclicity resumed before 90 days in a greater proportion of animals that were supplemented than those in control group although the association between the groups (supplemented and control) and days to initiation of cyclicity (before or after 90 days postpartum) was not significant ($P>0.05$). Postpartum first visual oestrus was observed earlier in a larger proportion of supplemented animals compared to animals in the control group (Table 4.18) and the association between the groups (supplemented and control) and days to postpartum first visual oestrus was significant ($P<0.001$) with significant strength of association (Cramer's V <0.001). The overall mean DPO (± SD) was 125.0 ± 9.7 days while the supplemented group had significantly ($P<0.05$) lower DPO of 103.2 ± 11.9 days than the control group (146.8 ± 15.3 days).

Table 4.18: Proportions of cows in different categories of days from parturition to resumption of ovarian cyclic activity (DPOA) and days from parturition to first visual oestrus (DPO) for supplemented and control groups

Parameter/ Category			Groups				χ-square p-value
	N	Overall (%)	N	Supplemented (% cows)	N	Control (% cows)	
DPOA							
≤ 90 days PP[1]	27	56.5	16	50.0	11	36.7	
> 90 days PP	35	43.5	16	50.0	19	63.3	
Total	62	100.0	32	100.0	30	100.0	ns
DPO							
< 90 days PP	17	28.8	10	34.5	7	23.3	
90-150 days PP	22	37.3	17	58.6	5	16.7	
> 150 days PP	20	33.9	2	6.9	18	60.0	
Total	59	100.0	29	100.0	30	100.0	***

[1]PP = postpartum; ns = Not significantly different ($P>0.05$); *** = $P<0.001$

4.3.10 Effect of parity on body weight and body condition score

Bodyweights progressively increased from primiparous and peaked at parity six (Figure 4.13 and Table 4.19). Primiparous cows were significantly (P<0.001) lighter while those in sixth parity or more were significantly heavier than the rest. However, the differences observed among the different parities for mean BCS as well as BCSC were not significant (P<0.05) (Figure 4.14 and Table 4.19).

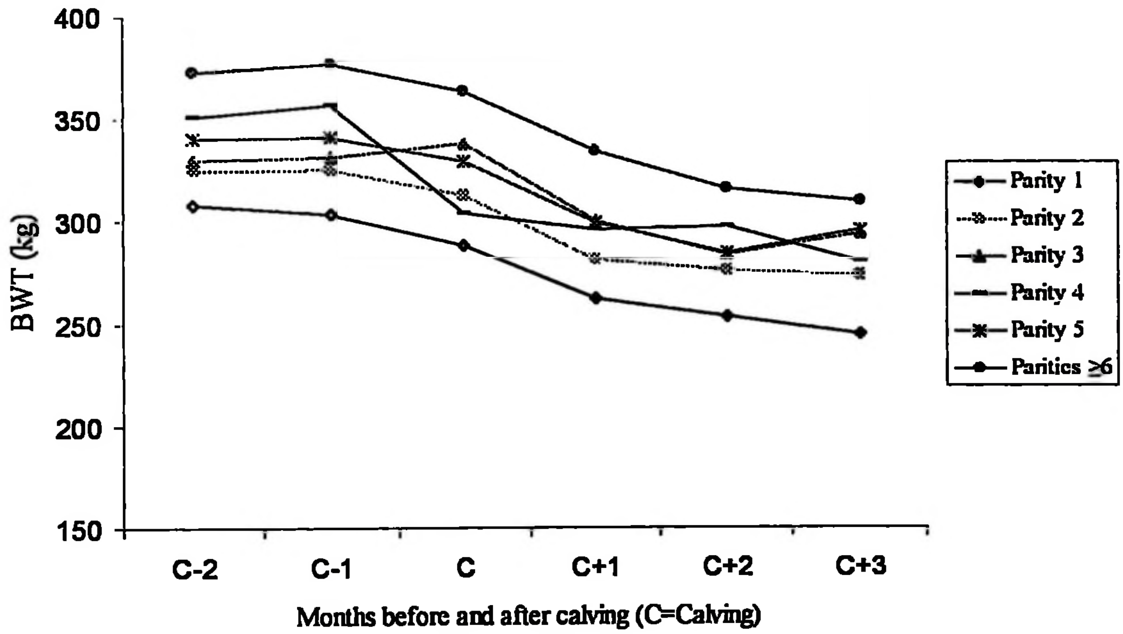


Figure 4.13: Trends of body weight for cows of different parities

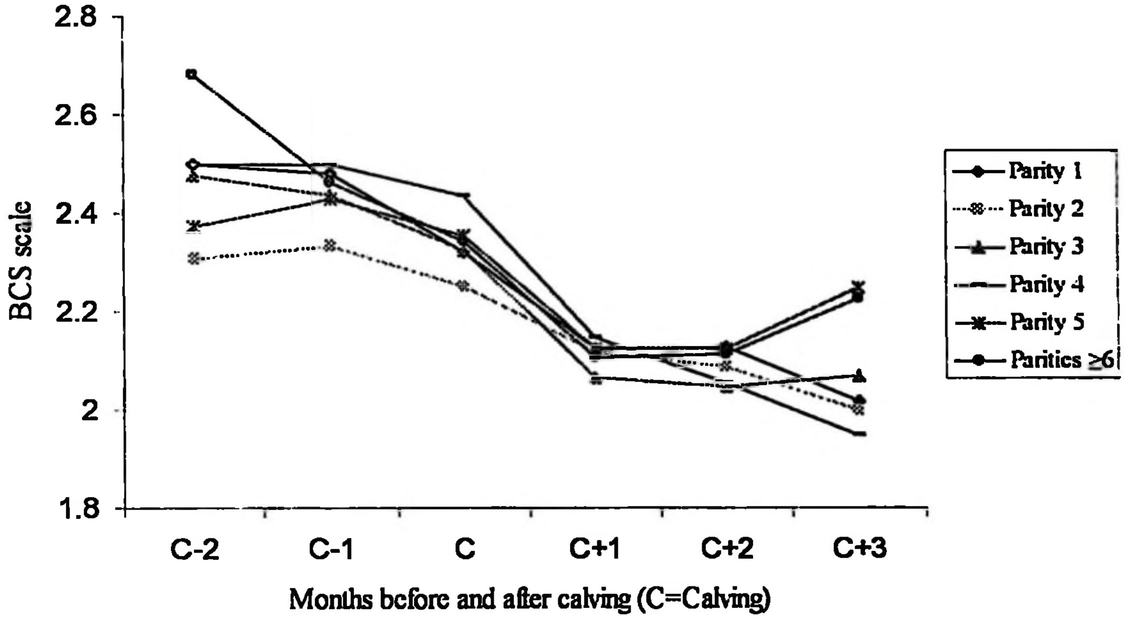


Figure 4.14: Trends of body condition score for cows of different parities

Table 4.19: Means (± SEM) for BWT, BCS, BCSC, PUN, plasma minerals and production parameters among cows of different parities

Variable	Parity of cows											
	1		2		3		4		5		≥6	
	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
BWT (kg)	163	277.2 ± 5.0^{a}	195	299.6 ± 4.6^{b}	104	313.6 ± 5.6^{b}	56	314.8 ± 8.6^{bc}	44	315.8 ± 9.7^{bc}	78	346.2 ± 7.3^{c}
BCS	163	2.3±0.04	195	2.2±0.03	104	2.2±0.04	56	2.3±0.06	44	2.3±0.07	78	2.3±0.05
BCSC	30	2.5±0.1	32	2.3±0.1	26	2.4±0.1	11	2.8±0.3	8	2.3 ±0.2	14	2.5±0.3
PUN	161	9.4 ± 0.3^{a}	194	10.1 ± 0.2^{b}	102	10.2 ± 0.3^{b}	54	11.8 ± 0.6^{b}	43	10.8 ± 0.5^{b}	77	11.0 ± 0.5^{b}
Ca (mg/dl)	162	11.2 ± 0.2^{b}	195	10.4 ± 0.1^{a}	103	11.0 ± 0.2^{ab}	55	10.8 ± 0.3^{ab}	43	10.3 ± 0.3^{a}	77	10.7 ± 0.3^{ab}
P (mg/dl)	162	5.4±0.2	195	5.0±0.1	102	4.6±0.2	54	4.6±0.4	42	5.1±0.3	77	5.3±0.3
Cu (µg/ml)	162	0.41 ± 0.03^{a}	194	0.42 ± 0.02^{a}	102	0.49 ± 0.03^{ab}	53	0.57 ± 0.04^{b}	42	0.52 ± 0.04^{ab}	76	0.38 ± 0.04^{a}
MY (L/day)	990	6.6 ± 0.8^{a}	1620	8.7 ± 0.6^{ab}	995	8.5 ± 0.8^{ab}	360	13.1 ± 1.5^{ab}	368	11.0 ± 1.3^{ab}	540	14.3 ± 1.5^{b}
CBwt (kg)	30	23.6±1.2	32	24.7±0.9	25	26.0±1.1	11	25.1±2.2	8	24.3±1.9	13	25.4±2.1

Means with different superscripts within each row are significantly different; *$P<0.05$; ** = $P<0.01$; *** = $P<0.001$; ns = Not significantly different ($P>0.05$)

4.3.11 Effect of parity on blood plasma urea nitrogen

Primiparous cows had relatively low mean PUN before calving, lowest value after calving and significantly (P<0.01) lowest overall value of all parities (Figure 4.15 and Table 4.19). Cows in parity four showed the highest mean PUN values for most of experimental period.

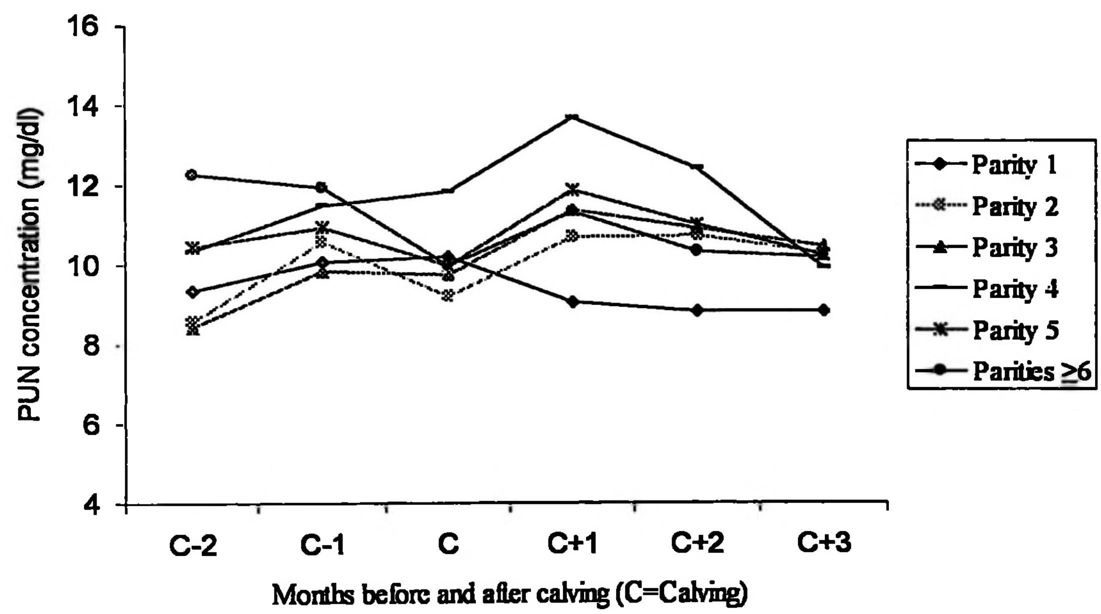


Figure 4.15: Trends of plasma urea nitrogen concentration between 2 months prepartum (C-2) and 3 months postpartum (C+3) for cows of different parities

4.3.12 Effect of parity on plasma calcium, phosphorus and copper concentration

Trends for mean plasma Ca for cows in different parities are shown in Figure 4.16. Primiparous cows had a significantly (P<0.01) higher mean plasma Ca concentration than pluriparous (Table 4.19) while cows in fifth and second parities had significantly lower plasma Ca concentration than cows in all other parities. During most part of the experimental period, the highest mean plasma P concentration was observed in cows in first parity while the lowest mean plasma P concentrations were observed in cows in third and fourth parities (Figure 4.17) but the differences were not significant ($P>0.05$) (Table 4.19).

Figure 4.18 shows trends for mean plasma Cu for cows in different parities. The differences among parities for plasma Cu concentrations were significant ($P<0.001$) with cows in parity four showing the highest Cu concentrations while the group of cows in parities one, two and higher than five showing the lowest plasma Cu concentrations (Table 4.19). There was a trend of increasing plasma Cu from primiparous to the fourth parity then a progressive decrease as parity increased.

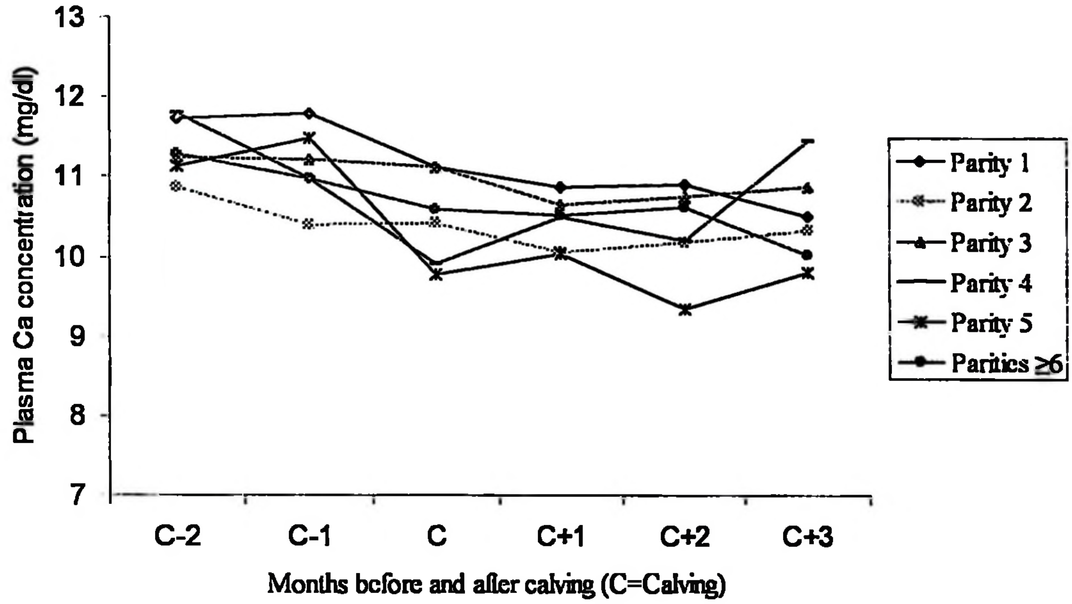


Figure 4.16: Trends of plasma Ca concentrations for cows of different parities

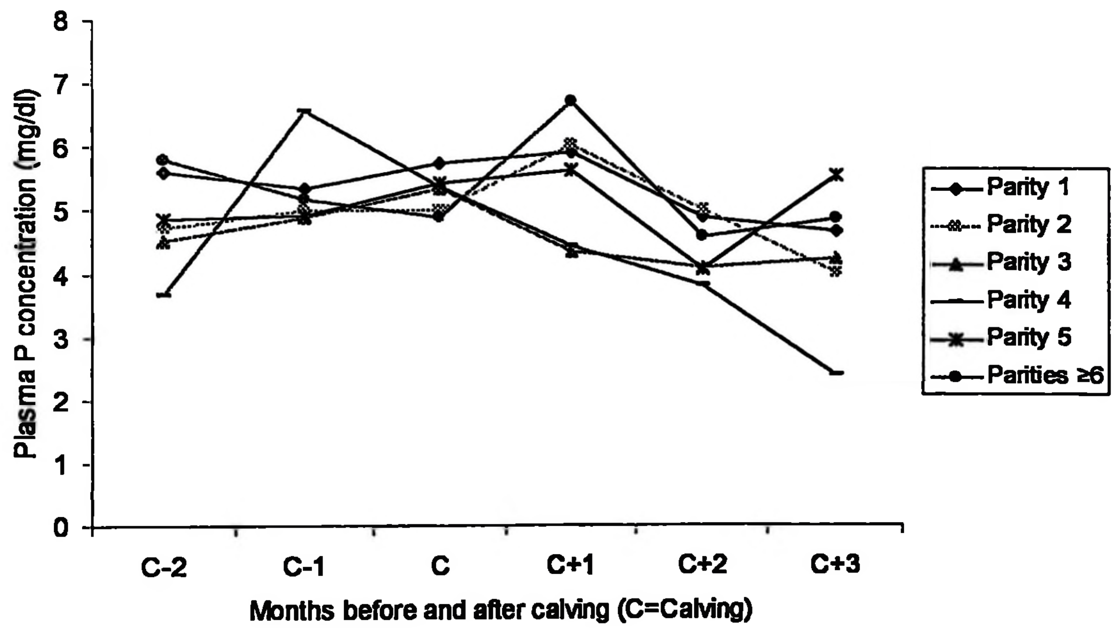


Figure 4.17: Trends of plasma P concentrations for cows of different parities

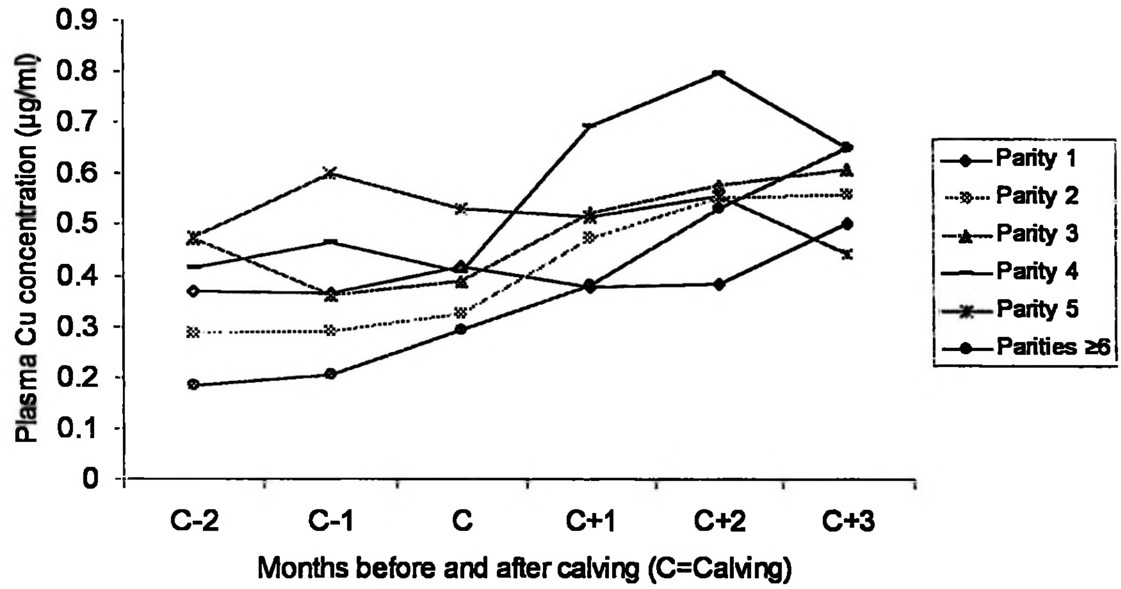


Figure 4.18: Trends of plasma Cu concentrations for cows of different parities

4.3.13 Effect of parity on milk yield and calf birth weight

Figure 4.19 shows MY trends for cows in different parities. Highest level of MY and highest rise in MY during the first month postpartum were observed in cows in parity six while the lowest level of MY and lowest rise in MY during the first month were observed in primiparous cows. Cows in parities two and three produced more milk than the primiparous cows but less milk than the rest of cows. The observed variations in MY among parities were significant ($P<0.001$) with lowest and highest mean MY in primiparous cows and cows in parities higher than five, respectively (Table 4.19).

Although a trend of increasing CBwt with increasing parity from first to third was noted, there was no significant ($P>0.05$) effect of parity on CBwt (Table 4.19).

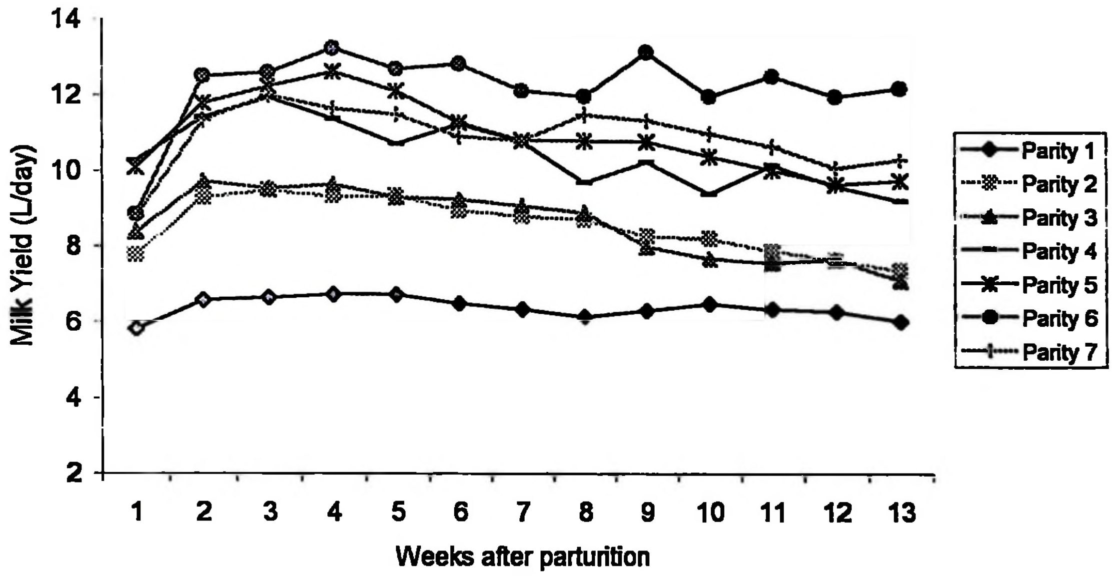


Figure 4.19: Milk yield trends for 13 weeks post calving for cows in different parities

4.3.14 Effect of parity on days to postpartum resumption of cyclicity and days to postpartum first visual oestrus

The percentages of cows showing postpartum resumption of ovarian cyclicity and days to first postpartum visual oestrus for different parities are shown in Table 4.20. The lowest percentage of cows resuming postpartum ovarian cyclicity before 90 days was observed in primiparous cows while the highest proportion was observed in cows of fifth parity. In addition, the lowest percentage of cows showing early first postpartum oestrus was observed in parity one while the highest percentage was observed in parity three.

Table 4.20: **Proportions of cows in relation to days from parturition to resumption of ovarian cyclic activity (DPOA) and days from parturition to first visual oestrus (DPO) for cows in different parities**

Category	Parity											
	1		2		3		4		5		≥6	
	N	%	N	%	N	%	N	%	N	%	N	%
DPOA												
≤ 90 days *PP	6	22	15	47	7	35	3	27	4	50	5	42
> 90 days *PP	21	78	17	53	13	65	8	73	4	50	7	58
Total	27	100	32	100	20	100	11	100	8	100	12	100
DPO												
< 90 days *PP	5	19	9	28	6	30	2	20	2	29	4	25
90-150 days *PP	8	31	14	44	3	15	4	40	3	43	5	31
> 150 days *PP	13	50	9	28	11	55	4	40	2	29	7	44
Total	26	100	32	100	20	100	10	100	7	100	16	100

*PP = postpartum

4.3.15 Incidence of reproductive diseases and disorders

Retained foetal membranes were the most frequently encountered disorders, followed by mastitis and sudden deaths (Table 4.21). Higher incidence of mastitis was observed in the supplemented group than the control group. However, the association between overall occurrence of diseases and disorders and supplementation was not significant (P>0.05).

Table 4.21: Cumulative incidence of reproductive diseases and disorders for control and supplemented groups

Disease/ disorder	Total		Group				χ-square p-value
			Control		Supplemented		
	Count	%	Count	% within group	Count	% within group	
Abortion	1	1.6	0	0	1	3.1	
Dystocia	1	1.6	1	3.1	0	0.0	
Mastitis	5	7.8	0	0.0	5	15.6	
Milk fever	2	3.1	1	3.1	1	3.1	
Pyrexia of unknown origin	1	1.6	1	3.1	0	0.0	
Retained foetal membranes	6	9.4	3	9.4	3	9.4	
Stillbirth	1	1.6	1	3.1	0	0.0	
Sudden death	3	4.7	2	6.3	1	3.1	
Total	64		32		32		ns

ns = Not significantly different (P>0.05)

4.3.16 Economic analysis of concentrate supplementation

The economic analysis of supplementation of dairy cattle for two months pre- and postcalving taking into account the milk produced for three months after calving revealed a marginal profit of 18,730.81TSh per cow, which was equivalent to 208.12 TSh per cow per day (Table 4.22).

Table 4.22: Quantity and supplement costs, amount and revenue of MY, and marginal values for cows under experimental and farmers' supplementation regimes

Item	Supplementation regime		Marginal values
	Experimental	Farmer	
Supplementation costs			
Amount (kg) supplemented per cow (60 days pre- and post-calving)	310.2	145.9	164.3
Total cost (TSh) of supplement	29,292.19	13,772.96	15,519.23
Total supplementation costs (TSh)	45,292.19	25,772.96	19,519.19
MY and MY revenue			
Total MY (litres)	1044	819	225
Milk fed to calf (litres)	270	270	0
Milk available for sale (litres)	774	549	225
Revenue from milk sold (TSh)	131,580.00	93,330.00	38,250.00
Marginal profit (TSh)/cow/90days	86,287.81	67,557.04	18,730.81
Marginal profit (TSh)/cow/day	958.75	750.63	208.12

CHAPTER 5

DISCUSSION

5.1 Findings from the baseline survey (Experiment 1)

5.1.1 Household structure and land ownership

The observation that men with an average age of 56.7 years headed most households among the respondents in the current survey was similar to survey findings reported by Urassa and Raphael (2001) where male-headed households were predominant and age modal class of smallholder farmers was 51-60 years of age in Morogoro municipality. Survey reports by Mollel *et al.* (1999) and Mulangila (1997) also reported more male-headed households than female-headed households in Turiani and Tanga, respectively. Similarly, Mugo *et al.* (2001) observed that 92 % of the households were male headed and mean age of household heads was 53.9 (with a wide range of 26-104 years) in smallholder farms of Nduuri, Embu, Kenya while in a study by Adesehinwa *et al.* (2004), 70% of smallholder farmers were males and 50% were between 51 and 60 years old in some parts of South-western Nigeria. The sex of the head of the household may affect reproductive performance in some aspects, such as driving a cow on heat to the bull which is likely to be an easier task for a male than a female. The age of head of households can affect the productivity of dairy cattle because the ability to carry out the daily management activities especially cutting and carrying fodder to feed cattle would be expected to diminish with age. However, the age of head of household would have less influence on dairy productivity when the head of household is not directly involved in the day-to-day cattle managemement activities. In the current survey, the number of children in a household (6.9) was in agreement with a mean of 7.6 members of household reported by Mugo *et al.* (2001) in Kenya.

The observation that a large proportion (59.7%) of farmers had formal primary education and only few (5.6%) lacked formal education in the present survey was similar to findings by Safari *et al.* (2000) where farmers who completed primary education made up between 60% and 75% of the respondents number among smallholder farmers in Turiani district. A review by Mugo *et al.* (2001) revealed similar findings where about 85% of the household heads had attained primary education while 15% had no formal education in Embu, Kenya. In contrast to the current study the majority of smallholder farmers in Morogoro municipality had acquired at least secondary school education (Urassa and Raphael, 2001). The difference in level of education between the studies is because the present study was carried out mainly in rural areas where most residents are likely to be less educated compared to urban residents. Most urban smallholder farmers interviewed by Urassa and Raphael (2001) were employed and kept cattle to supplement their income, whereas respondents in the current study considered cattle as their most important source of income.

The importance of education is related to ability of farmers to keep production and reproduction records, so that they can be able to measure their performance, compare the performance to achievements by others and set goals for improvement. However, some previous findings suggested that level of education, age and gender of head of household have little influence on performance of livestock in smallholder dairy cattle system in Tanzania. Rutamu and Udén (1999) found no influence of age, gender and level of formal education of farmer to the performance of crossbred heifers in coastal areas of Tanzania. Despite of the variations in level of education, Urassa and Raphael (2001) found no significant effect of educational level on milk production of the dairy cattle. The lack of influence of level of farmers' education on dairy cattle performance (Rutamu and Udén, 1999; Urassa and Raphael, 2001) is somewhat surprising and intriguing, as one would expect that educated farmers are in a better position to make informed decisions. Furthermore, even if the management of dairy cattle is done by hired labour, the educated farmers are expected to have a better ability to follow up the operations more closely than non-educated farmers.

In the current survey the farmers owned 5.0 acres of land on the average, which was similar to 4.9 acres, reported by Lerenius and Skarback (1987) from a previous survey carried out in Rungwe district. Under such land limitation, intensification remains the only choice to pursue for improvement of smallholder dairy cattle productivity and reproduction.

5.1.2 Sources of income and number of dairy cattle per household

Dairy cattle production is the most important source of income and food for the households with crop production being second for majority of smallholder dairy farmers across the divisions in Rungwe district. An equivalent importance of dairy cattle has been reported elsewhere in smallholder dairy farmers from Iringa region in the southern highlands zone (Leslie *et al.*, 1999). The relative importance placed on dairy or crop production activities dictates the distribution of resources between the two. When more importance is placed on crop production, allocation of resources would likely favour activities related to crop production. In a survey carried out in smallholder farmers in Ethiopia (ILCA, 1981) it was revealed that when forage crops were grown, labour was allocated first to subsistence and cash crop production and only secondly to forage production. On mixed farms in Kenya, fertiliser and manure application to fodder crops was uncommon due to competition for the resources for coffee, maize and vegetables (Chudleigh, 1974). Laborious and time-consuming work involved in tea and coffee production was reported as a potential constraint to dairy production in Rungwe (Lerenius and Skarback, 1987).

In the present survey, farmers in Pakati division considered crop production as more important than dairy farming. This could partly be attributed to its geographic location that is far from the urban centres, which serve as milk markets and dairy input supply centres. Most respondents in Pakati had no access to better milk markets in urban areas, such as Tukuyu and Ukukwe due to distance and poor roads. As a result most of them depended to a large extent on tea, bananas and to a lesser extent on coffee production as sources of income. In contrast to milk, which the farmers had to transport a long way to customers, buyers collected tea, bananas and coffee from the villages.

The observation that the smallholder farmers on average reared 2.2 animals per household in the present survey was similar to findings in Tanga where smallholder farmers on average owned between 1-2 dairy cows (Urassa, 1999) and falls within the range of 2-3 heads of cattle per household reported for smallholder dairy farms in Tanzania (Kurwijila and Boki, 2003). The number of dairy cattle reared could partly be a result of land limitations often reported in areas with good potential for dairy cattle production (Lerenius and Skarback, 1987).

5.1.3 Dairy cattle feeding and milk production

Dependence on indigenous natural pastures as the source of basal diet to dairy cattle farmers in Rungwe is related to the small plots of land owned and hence small plots allocated for growing pastures. Fodder production was estimated to occupy only about 16% of cultivated area in Rungwe district (Lerenius and Skarback, 1987). Similarly, shortage of land was found to be one of the key factors limiting establishment of pasture plots in Turiani (Makauki *et al.*, 1999; Safari *et al.*, 2000).

The large proportion of respondents (94.4%) that had adopted a cut and carry feeding system in Rungwe is similar to findings from elsewhere in Tanzania where proportions reported varied between 89.2% and 100% (Lekule *et al.*, 1998; Safari *et al.*, 2000; Urassa and Raphael, 2001). Similar to other areas where zero grazing is practised (Aminah and Chen, 1989) cattle were not offered food during the night in Rungwe district, which means the animals were likely to be underfed. Another shortfall of the system is when there is failure to recycle the nutrients leading to decreased pasture production. The situation in Rungwe is one where the manure is not returned to soil in areas where the natural pastures grow, instead it is used in farms for crop production. With increasing cattle population and concurrent relative diminishing land, the system could gradually lead to suppressed production of natural pastures since more nutrients will be permanently withdrawn from the soil. Exhausted soil resulting in poor pastures could further confound any existing dietary nutritional deficiencies (Massawe, 1999). Another shortfall of zero grazing system is due to lower quality of pasture and low productivity observed when cut pasture is offered compared to grazed pasture (Vincente-Chandler *et al.*, 1964; Soetrisno *et al.*, 1985; Wong *et al.*, 1987). In a study to evaluate the performance at pasture and zero grazed crosses between East African Zebu with Frieasian and Jersey cattle in Tanga, Msangi *et al.* (2001) observed days to first oestrus (120 vs. 162), days to conception (198 vs. 234) and shorter CI (480 vs. 509) in pasture and zero grazed cattle, respectively.

Changes in quality and quantity of natural pastures due to seasonal variation in rainfall are common throughout the tropics (Aminah and Chen, 1989). Similar effects of seasonal decline in amount and quality of pastures on MY and RP could be affecting the smallholder dairy cattle in Rungwe just as reported in smallholder crossbred dairy cattle elsewhere (Msanga *et al.*, 1999; Kanuya and Greve, 2000; Bareeba and Samaanya, 2002).

The observed milk yield (MY) of 7.9 L with a range of 5.0 to 18.5 L/day in the current survey was more than 6.3 L/day reported by Urassa and Raphael (2001) for smallholder farmers in Morogoro, and 5.7 L/day reported by Lyimo *et al*, (2004) for smallholder farms in sub-humid coastal Tanzania, but similar to 7.5 L/day for 100 days in milk reported for smallholder farms in Iringa and Mbeya regions in SHZ (Balikowa, 1997). The variations in mean MY among the studies, could largely be due to differences in feeding management, especially concentrate feeding, because milk production is strongly influenced by the amount of concentrate fed (Van Schaik *et al.*, 1996). Weather elements especially temperature could also influence MY, because heat stress reduces feed intake and MY. Hence temperature differences can partly explain the lower MY reported in hot areas such as Morogoro and the sub-humid coastal Tanzania than cooler areas in southern highland zone such as Iringa and Mbeya regions. Other reasons for differences in MY among the studies could be genetic as well as the differences in stages of lactations and whether or not non-lactating cows were included in calculations of MY.

The large range between the lowest and highest values for milk production in the present survey suggests that there is a room for improvement in milk production of dairy cattle in Rungwe district.

5.1.4 Dairy cattle breeding and reproductive performance

Breeding using bulls was the only method observed in the present survey. This was because AI service was not available in the district and efforts to introduce it failed because farmers could not afford the cost and consistently opted for cheaper bull service. Lack of facilities for AI contributed to the failure of AI service since all the equipment were to be hired from Mbeya about 80 km away, which further increased the cost and confounded the heat detection and service timing (DALDO-Rungwe, personal communication, 2001). Smallholder dairy farmers in Turiani have been reported to suffer from similar problems (Safari *et al.*, 2000).

Since all the dairy farmers in the area used natural mating (hand mating) of their cows, heat detection could be an important factor in relation to cattle reproduction because few farmers kept their own bulls. Inefficient heat detection could lead to late heat detection and late service, which reduces chances of conception. The fact that most farmers could theoretically explain quite satisfactorily how they observe and detect heat, may suggest that some other factors might be involved, which interferes with heat detection. Crop production, being almost as important a source of income as dairy cattle production, could pose a considerable competition for labour, especially during the peak period of labour demand when less time is presumably spared for heat observation.

The small number of farmers keeping bulls among the respondents gave an impression that availability of bulls might be a factor adversely affecting the RP. However, the average distance of 1.4 km to bulls suggested otherwise.

The best and worst performance in Tukuyu and Pakati divisions, respectively in terms of age at puberty, age at first mating, age at first calving, and CI signified differences in dairy management between the divisions. The differences in dairy management between the divisions reflected differences in access to inputs, proximity to markets and infrastructure, and in resource endowments. The observed differences in cattle RP parameters between the divisions were consistent with ranking of sources of income where dairy cattle production was ranked second to crop production and highest percentage of respondents failing to offer concentrates to cattle in Pakati. Tukuyu division consists of the urban and suburbs of Tukuyu town while Pakati consists of predominantly rural settlements. Areas close to urban markets and those connected to transport infrastructure gain most from products they produce (Lugalla, 1993) and are within easy reach of farm inputs, hence they are likely to perform better than their rural counterparts away from markets and inputs.

The observed age at puberty (20.5 months) in the current survey was higher than 7 to 18 months expected in cattle (Roberts, 1971; Jainudeen and Hafez, 1987). The age at first mating (21.5 months ranging from 17.5 to 26.2 months) observed in the current survey was similar to observations made in Turiani where age at first mating was 18-25 (Safari *et al.*, 2000) but higher than the recommended range of 15 to 18 months

(Roberst, 1971). In the current survey, age at first calving (AFC) (30.8 months) was lower than the average of 34.5 months reported for smallholder dairy farms in Tanzania (Kishinhi, 1999) but higher than the recommended AFC which is 24 months (Quigley *et al.*, 1996). The AFC of 30.8 months observed in the current survey was within the range of 28.0 to 35.5 months that has been reported from various parts of tropics for improved dairy cattle (Kiwuwa *et al.*, 1983; Chopra, 1990; Dalal *et al.*, 1990).

The CI (526 days) observed in the present survey was comparable to CIs observed in Turiani, where 92% of dairy cows had CIs longer than 420 and 50% CIs ranged from 420 to 540 days (Safari *et al.*, 2000). However, the CI recorded in the current survey was higher than the average for smallholder dairy farms in Tanzania, which is 466.8 days (Kinshinhi, 1999) and the expected range of 375-390 days in well-managed cattle (Wattiaux, 2004). Factors that possibly contribute to the suboptimal RP in terms of age at puberty, age at mating, AFC and CI in the current survey include nutritional, managemental and reproductive diseases and disorders.

A number of characteristics of smallholder dairy cattle system in Rungwe district like other smallholder dairy systems elsewhere, suggest that nutritional factors, especially energy and minerals deficiencies could be making a significant contribution to the poor RP of dairy cattle in the area. The zero grazing system may contribute to poor RP of dairy cattle in Rungwe in the same way as in smallscale farms of peri-urban Dar es Salaam and Morogoro (Nkya and Swai, 1999) where the mean heifer age at first observed oestrus and cow CI of zero grazed animals was longer than animals under grazing management. In addition to the shortfalls of cut and carry system, high cost and unavailability of concentrate ingredients could be taking its toll. Previous survey by Lerenius and Skarback (1987) in Rungwe district identified high cost and unavailability of concentrates and minerals as the main problems with milk production. Similar observations have been made in smallholder farming areas by Safari *et al.* (2000) who reported unaffordable prices and short supply of maize at certain periods (January-June) as the main constraints to smallscale dairy production in Turiani and Urassa and Raphael (2001) who revealed high cost of concentrates among the major constraints to smallholder dairy farming in Morogoro municipality. Furthermore, it has previously been shown that farmers in Rungwe provide improper forage combinations, inadequate labour for stall fed cows and offer feeds at low DMI below the recommended rate of 3% of live weight (Mussa, 1998). Provision of feeds at low DMI and inadequate labour in Rungwe district could be related to heavy labour involved in collecting fodder for cattle as reported by Lerenius and Skarback, (1987). The large range between the lowest and highest values for CI in the current survey implies that there is a considerable potential for improvement in reproductive performance of dairy cattle in Rungwe district.

Heat detection is of utmost importance among managemental factors in areas where natural mating by hand-mating and zero grazing system is practiced as in Rungwe district. This is because confinement and isolation of animals contributes to decrease in oestrus expression in animals that have to be accurately identified to be in heat for timely and successful breeding (Lucy, 2003). Diseases and reproductive disorders of dairy cattle that were recorded in Rungwe, such as retained foetal membranes, mastitis, abortion, uterine prolapse, anoestrus, dystocia, stillbirth and parturient paresis have variable adverse effects on production and reproduction of animals. Mujuni and Mgongo (1994) reported complete failure of lactation, short lactation lengths and reduced MY in cows that experienced abortions, stillbirths and premature calvings while Nkya and Swai (1999) reported reduced reproductive efficiency due to abortion in association with retained placenta in cows in Morogoro. In the current survey, the observed diseases that were not directly related to reproductive system, such as pyrexia of unknown origin (PUO) and East coast fever (ECF) could affect reproduction indirectly through loss of appetite, decreased energy intake, loss of body condition and negative energy balance.

5.2 Findings from field monitoring study and concentrate supplementation for improvement of reproductive performance of dairy heifers and cows (Experiments 2 and 3)

5.2.1 Nutritional values of natural pastures

The mean ME in pasture (5.7 MJ/kgDM) in the present study (Table 4.15) was below 7.95 MJ/kgDM observed by Mussa (1998) in the same area and less than the expected range (7.0 to 11.0 MJ/kgDM) for tropical native or improved grasses when cut between 2-8 weeks regrowth (Wan Hassan *et al.*, 1981; Doto *et al.*, 2004). The probable reasons for the variations among the reported ME values are differences in species of grasses, stage of maturity, seasons, and years when the pastures were cut and analysed. Values of ME as low as 7 MJ/kgDM are observed for mature pasture or unfertilised grass with low leaf content but well fertilised actively growing tropical grass pasture can provide 9 MJ ME/kgDM (Moss, 2004). The variations in ME content of the pastures in the present experiment (Figure 4.7) were expected due to the effect of season on quality of pasture and were consistent with the observed pattern of rainfall (Figure 4.6). The observed mean (9.3%) CP content of pasture in the current experiment (Table 4.15) was lower than 10.46% CP reported by Mussa, (1998) in the same area and was within the range of values for most tropical pastures containing mainly grasses which is 7-12% CP (Aminah and Chen, 1989). This is in contrast to a well fertilised actively growing tropical grass pasture containing 30-40% green leaf which can provide 14-19% CP (Moss, 2004). The observed pasture protein content variations in the present experiment (Figure 4.7) were mainly due to the effect of season on pasture CP that was linked to the rainfall trends (Figure 4.6). Mwakatundu (1977) reported similar seasonal variations in CP content of pasture from a number of locations in Kenya and Tanzania where the CP ranged from 2.4% at Iwambi (Tanzania) in dry season to 20.6% at Kabete (Kenya) in rainy season. Urassa (1999) observed similar seasonal variations in three districts where CP values during the rainy season were better than dry season in Tanga (10.8% vs. 10.3%), Muheza (11.5% vs. 9.0%) and Lushoto (10.4 vs. 10.1).

The observed low mean ME with high CP in pastures (Table 4.15) in the present study could partly be due to the *in vitro* digestibility method used. The method always underestimates digestibility values of forages when compared to *in vivo* data (Tilley and Terry, 1963). In addition, lower digestibility values obtained at the DASP laboratory of Sokoine University of Agiculture have been suspected to be partly due to poor nutritional status of rumen liquor donor animals, which leads to low numbers of microbes in the liquor and hence low digestibility (Yona, 2004). Underestimation of the *in vitro* digestibility will lead to lower ME content.

Pasture Ca content (0.6%) in the current experiment (Table 4.15) was higher than 0.33% reported by Mussa (1998) for the same area but the pasture P contents (0.2%) were similar in the two studies. The probable reasons for the difference in pasture Ca levels between the current and Mussa's report could be differences in stage of maturity, seasons and years of observation where pattern and amount of rainfall play a role through their effects on plant growth, maturity as well as leaching of Ca in soil.

The rise in pasture Ca and decrease in P during dry season in the current experiment were expected since Ca content of pastures does not vary much or may rise (McDowell, 1992) while P decreases with maturity (Underwood and Suttle, 1999). Increase in pasture Ca and decrease in P during dry season has been reported by numerous previous studies (Mwakatundu, 1977; Mussa, 1998; Phiri, 2001). The pasture Cu concentration in the current experiment (0.27mgCu/kg) was far less than the critical dietary levels of 5mgCu/kg (Cunnigham, 1992).

5.2.2 Influence of stage of reproductive cycle, season, supplementation and parity on body weight and body condition scores

5.2.2.1 Effect of stage of reproductive cycle on body weight and body condition score

The observed increase in BWT with decreasing BCS two months before calving to one month before calving (Table 4.7) in the present experiment indicates an increase in BWT due to growth of the foetus partially at the expense of dam's mobilised body tissue reserves. The decrease in BWT and BCS for a month towards calving indicates that the diet provided failed to meet the nutrient requirements and body reserves and tissues were being mobilised to meet the requirements. The decrease in BWT and BCS a month before calving was consistent with the reported decline in DMI that begins around three weeks before calving in cattle carrying single foetuses (Bertics *et al.*, 1992). In addition, there is a large increase in gestational nutrient demands and nutrients are partitioned in favour of the foetus, placenta and possibly mammary gland development during the same period (Van Saun, 1991; Bell, 1995; Chandler, 1995). Meikle *et al.* (2004) made similar observations where BCS decreased from one month before parturition. Further decrease in BWT and BCS observed up to two months after calving in the present experiment, reflects the loss of BWT due to expulsion of the conceptus as well as insufficient dietary nutrient supply in relation to demands during this period which was possibly exacerbated by low DMI. It has been shown that the total intake of energy by cows after calving is usually less than energy requirements until 70 to 85 days even in healthy cows because of their slow response to increasing DMI in early lactation (Larry and Joe, 1994; Bell, 1995). In the present experiment, the observed similarity in BWT and BCS trends was expected due to previous (Meikle *et al.*, 2004) as well as the currently observed (Table 4.12) positive correlation of the two variables in cattle.

Improvement in BWT and BCS observed from two months postcalving indicates that the animals were in positive energy balance. More rapid recovery of BWT than that observed in the current experiment was reported by Iwama, *et al.* (2004) where BWT was observed to decrease for only 21 days postcalving after which it stabilised. The faster energy balance recovery in Iwama's study than in the present experiment was likely due to a nutrient richer diet provided, which included more ME (11.1 vs. 5.7 MJ/kgDM) and CP (16 vs. 9.3%) than the feeds consumed by cattle in the current experiment.

5.2.2.2 Effect of season and supplementation on body weight and body condition score

In experiment 2 of the current study, the higher mean BWT and BCS for cows calving during the rainy season than dry season were expected due to increased amount and quality of energy, CP, and minerals intake that were consistent with higher PUN and plasma P in the same group of animals. These observations were in agreement with the other findings that changes in live weight and body condition are related to nutritional status of cattle (Kunkle and Sand, 1990). Similar observations were made in crossbred grazed cattle where cows calving during the rainy season lost less weight (11.3 kg) from calving to weaning than cows calving during dry season (19.4 kg) although the difference was not statistically significant (Msangi *et al.*, 2001). In contrast to the current experiment, calving season did not appear to be an important factor on live weight changes for zero-grazed animals (Msangi *et al.*, 2001). Higher daily supplementation of the zero-grazed cows with 3.5 kg/d concentrate made from maize bran, copra cake and bone meal is likely to be the reason for the contrasting observations. Msangi *et al.* (2001) reported findings similar to current observations on BCS where cows calving in dry season lost 0.5 points more than those calving in rainy season.

The improved BWT and BCS during the rainy season can be linked to the increased energy and protein intake as a result of enhanced quality and quantity of pasture, which is related to pattern of rainfall. During experiments 2 and 3 rainfall began around October when fresh pasture started growing. This was consistent with highest CP (10.9%) and ME (6.1MJ/kgDM) observed in November and December (Figure 4.7). The rainfall peaked in April but the pasture CP (8.9%) and ME (5.6MU/kgDM) were lower than in November and December due to advanced stage of maturity of the pasture. In the current experiment, the lowest values for pasture CP (8.1%) and ME (5.3MJ/kgDM) during the months of June and July were expected since this period was towards the end of rainy season when the pasture was mature with high quantities of fibre and low digestibility.

The higher plasma P in cows during the rainy season (Table 4.8) was consistent with variations recorded for pasture P content (Figure 4.8) where the P content of pasture declined as plants matured (Underwood and Suttle, 1999). The increased P intake during the rainy season as indicated by higher plasma P concentration (Tables 4.8) was also beneficial in terms of improved BWT and BCS because low dietary P levels adversely affect feed intake and utilisation efficiency (Durand and Kawashima, 1980; Call *et al.*, 1987).

The higher mean BWT and BCS for supplemented than unsupplemented animals in experiments 3 of the current study were expected as a result of an increase in quantity and quality of energy, CP, and minerals intake, which were consistent with higher PUN, plasma P and Cu in the same group of animals. The improvement in BWT and BCS observed in the current supplementation experiment were similar to those observed in cattle (Grigsby *et al.*, 1991; Vanzant and Cochran, 1994; Horn *et al.*,

1995) resulting from energy supplementation. In addition, supplemental energy (Caton and Dhuyvetter, 1997) and UDP (Anderson *et al.*, 1988; Kerley and Williams, 1995) improved weight gain in stocker cattle grazing summer pasture.

Under the feeding conditions of the current experiment where pasture ME was low (5.7MJ/kgDM) and in the absence of steaming up of animals, energy was likely to be among the limiting nutrients and improvement in BWT and BCS of the supplemented group can therefore be associated with increased energy intake. Part of the effect of supplementation to BWT and BCS could be attributed to increased protein intake that resulted in increase up to normal values of PUN in the supplemented group (Table 4.17). Favourable effect of protein on BWT and BCS could also be through improvement of fibre degradability and feed intake (Call *et al.*, 1987). In the current experiment, the observed CP content in pasture (9.3%) was higher than the critical level of CP required in the pasture before intake is reduced by protein deficiency, which has been estimated to be between 6.0 and 8.5% (Milford and Minson, 1966; Minson, 1967; Sprinkle, 1996) but was less than 12% recommended by NRC (2001) for dry cows. Feeding less than 11% CP to prefresh transition cows may limit ruminal fibre degradation (Dorshorst and Grummer, 2002). The supplemented cows in the present experiment were therefore likely to have better ruminal fibre degradation due to higher CP in their diet and hence higher BWT and BCS.

The increased P intake for the supplemented animals as indicated by higher plasma P (Table 4.17) can also be linked to improvement in BWT and BCS since P intake levels of less than approximately 0.25% negatively affect feed intake and can reduce rumen microbial growth resulting in less microbial protein, lowered digestibility and decreased energy supply (Durand and Kawashima, 1980; Call *et al.*, 1987).

In addition, the higher plasma Cu in the supplemented group than the control group (Table 4.17) could have played a role in improving BWT and BCS for the supplemented animals. Findings from previous studies have reported improvements in feed intake, average daily gain (ADG), and gain:feed ratio when cattle were supplemented with Cu (Maro *et al.*, 1980; Arthington *et al.*, 2003; Spears *et al.*, 2004). In contrast, other studies have reported no favourable effects or even adverse effects as a result of Cu supplementation (Rabiansky *et al.*, 1999; Engle and Spears, 2000a and 2000b; Yost *et al.*, 2002). The reasons for conflicting results in reported cases are unclear but findings from the present and other studies signify the complex nature of interactions of Cu with other dietary minerals especially molybdenum, sulphur and iron (Underwood and Suttle, 1999).

The earlier postpartum BCS recovery observed in the supplemented animals than the control animals in the current experiment suggests that the improved nutrition as a result of supplementation led to earlier offset of the negative energy balance.

5.2.2.3 Effect of parity on body weight and body condition score

In the present study, the observation that the primiparous cows were lighter than pluriparous cows was expected since most if not all primiparous would likely be younger, still growing and have lower DMI (Rémond *et al.*, 1991) than pluriparous cows. Likewise, Iwama *et al.* (2004) observed lower DMI and BWT in primiparous cows than pluriparous cows.

The trend of progressive increase of BWT from primiparous to cows of parity six and above in the present experiment suggests that the cows had not reached their mature BWTs and were still growing. Considering the age at first calving (30.8 months) in the current study (Table 4.6) and calving interval of 485.7 days (Table 4.10), the dairy cattle in Rungwe district would be in their fourth parity at 6.5 years of age. However, the BWT for cows of parity four and above was increasing (Table 4.19) which means that the cows failed to attain mature BWT even at 6.5 years of age, which is beyond the 6 years of age when cattle attain their mature body weight (Field, 1990). Failure to attain expected adult weight is largely due to poor feeding throughout animal's life. Underfeeding of a calf during the first 4 months of life following birth is however more dangerous because there is little possibility of compensatory growth (Johnson, 1988; Troccon and Petit, 1989).

Live weight gain can only occur after the cow's maintenance and lactation requirements are met (Sprinkle, 1996). Studies on crossbred heifers in Tanzania showed that up to 22% of all female young stock get permanently stunted, resulting in a high age at first calving and poor milk production (Rutamu, 1994; Rutamu, 1996; De Wolf, 1997). Similarly, inadequate nutrition and delayed maturity were reported to contribute to reduced reproductive efficiency in smallholder dairy farmers in

Morogoro (Nkya and Swai, 1999). Similar observation was made in cows in Northern Thailand where cows attained only 90% of the mature size and 70% of mature BWT due to insufficient feeding (Chongkasikit *et al.*, 2003). Failure to attain mature BWT up to parity six in the current experiment underlines the need for improvement of nutritional management throughout the cow's life in Rungwe district.

Lack of significant variation in BCS among the parities in the present study was in contrast to a study by Meikle *et al.* (2004) where primiparous cows had lower BCS consistent with higher NEFA and β-hydroxybutyrate (BHB) concentrations during the early postpartum period compared to pluriparous cows. This was attributed to increased needs for growth in primiparous cows occurring simultaneously with the demands of lactation and their lower feed intake capacity (Rémond *et al.*, 1991).

5.2.3 Influence of stages of reproductive cycle, season, supplementation and parity on plasma urea nitrogen

5.2.3.1 Effect of stage of reproductive cycle on plasma urea nitrogen

The observed increase in PUN from two months before calving to one month before calving although not significant (Table 4.7) in the current experiment could be associated with improvement in dietary CP intake. Concentration of urea nitrogen in blood is directly related to ruminal ammonia absorption and PUN levels reflect the intake of effective rumen degradable protein (RDP), including ammonia and NPN (Huyler *et al.*, 1999) as well as the function of the liver and kidneys (Oltner and

Wiktorsson, 1983). The increase in PUN could also be due to imbalanced energy:protein supply due to an energy deficiency (Bell, 1995). A decrease observed from a month precalving to calving could be associated with the general decrease in DMI that occurs around this time.

The observed increase in PUN for one month after calving followed by more or less stable values in the present study could be due to enhanced tissue protein breakdown associated with low protein intake and high levels of glucocorticoid, catecholamine and GH whose peak releases occur at parturition (Bell, 1995). Similar increase in PUN after calving has been reported by Reist *et al.* (2003) while Spicer *et al.* (2000) made comparable observations where milk urea nitrogen concentrations increased during early lactation then remained more or less constant after 3 weeks postcalving.

5.2.3.2. Effect of season and supplementation on plasma urea nitrogen

The higher mean PUN observed during the rainy season than the dry season (Table 4.8) in experiment 2 and for the supplemented than control group in experiment 3 (Table 4.17) of the current study could be attributed to increased CP intake from pastures during the rainy season and from the supplement, respectively. This finding was in agreement with observation of higher CP of pastures during the rainy season in experiment 3 of the current study (Figure 4.7). Although the mean PUN observed during the rainy season (8.9 mg/dl) in experiment 2 of the current study was significantly higher than during the dry season (7.7 mg/dl), both values were below the reference value 10.1 mg/dl (Alejandrino *et al.*, 1999) indicating that protein intake

The lack of significant variations in plasma PUN among the parities (except the primiparous when compared to the rest of the parities) in the current study (Table 4.19) was in agreement with suggestions from previous studies that although concentration of PUN is a useful measure of changes in protein status or protein nutrition of ruminants (Hammond, 1983), it is not as sensitive as desired to factors such as parity (Huntington and Archibeque, 1999). Similarly, Eicher *et al.* (1999) observed no influence of parity on diurnal pattern of milk urea nitrogen (MUN), which is highly correlated to PUN.

5.2.4 Influence of stages of reproductive cycle, season, supplementation and parity on plasma mineral concentration

5.2.4.1 Effect of stage of reproductive cycle on plasma mineral concentration

The observed slight increase in plasma Ca concentrations for two months towards calving in experiment 2 of the current study (Table 4.7), was likely a result of increased activity of endocrine system as a response to low plasma Ca due to increased foetal growth demand in late gestation rather than improving dietary Ca intake. This is because throughout experiment 2, plasma Ca concentrations were below the normal range, which is 9.6-12.3 mg/dl (Kaneko, 1989) and the critical value of 10 mg/dl (McDonald *et al.*, 1997) in adult cattle. During hypocalcaemia, conservation of Ca facilitated by the endocrine system at the kidney, mobilisation of Ca from bone, and increased absorption from the digestive tract have high physiological priority (Horst, 1986). Bone resorption might have also been partially taking place resulting from an effect of protein deficiency because protein depletion during late pregnancy can lead to bone resorption (Sykes and Field, 1972). The observed decline in plasma Ca for a month following calving was expected due to high demand for Ca among other minerals during this period. Most cows are in negative Ca and P balance during early lactation (Beede, 1995; Risco, 1995; Knowlton and Herbein, 2002) since most of the minerals during this period are secreted in colostrum and milk. In a study with Holstein cows Kume and Tanabe (1993) showed that among other minerals, Ca, P and Cu secretions in colostrums for 24 h after parturition were largest although the amounts of minerals in colostrums varied. It has been reported that an influx of 23 g of Ca from blood to colostrums occurs during the first 24 hours after calving, which is 9 times the available Ca pool in plasma (Van Saun, 1991; Risco, 1995).

In experiment 2 of the present study, the mean plasma P concentration was below the reference value throughout the experimental period (Table 4.7). Blood plasma P concentrations are normally 6-8 mg/dl in growing cattle and 4-6 mg/dl in adult animals (Beede and Davidson, 1999) and normal range in cows is 4 mg/dl to 8 mg/dl (Forar *et al.*, 1982) while concentrations of < 6 mg/dl indicate deficiency of the mineral (McDonald *et al.*, 1997). In the current experiment plasma P concentrations increased for two months before calving from a markedly low concentration of 2.7 mg/dl. Such a value (2.7 mg/dl) could be a result of low dietary P intake. Phosphorus deficiency may occur when cows are fed marginally low dietary P and challenged by extra demand for P in late pregnancy with accelerated foetal growth. In the last trimester of gestation, the conceptus requires between 2 and 5 g/day of P from maternal pools (House and Bell, 1993). Consequently, plasma P and salivary P declines with duration of feeding marginal diets and faecal excretion gradually decreases (Ternouth, 1989; AFRC, 1991; Coates and Ternouth, 1992). The observed prepartum increase in plasma P in current experiment could be a direct result of stimulation of physiological correction by low plasma P and/or an indirect result of correction of the hypocalcaemia, facilitated by parathyroid hormone and vitamin D. During the mobilisation of 10 ions of Ca from bone, 6 phosphate ions are also released into the blood pool (Horst, 1986). Normally low blood P rapidly stimulates physiological correction, as P absorption is responsive to renal production of 1,25-DIHYDROXYVITAMIN D.

The decrease in plasma P observed following parturition in experiment 2 of the present study (Table 4.7) can be explained by high demands of P for colostrum and milk formation in early lactation. Similar physiological correction mechanisms would be involved in the postpartum as described for the prepartum period. However, the observed decline indicates that the physiological correction of hypophosphatemia was not sufficient to raise the plasma P concentrations to normal. Such a condition could be further complicated because of Ca deficiency since parathyroid hormone is secreted, which increases the renal loss of phosphate and increases salivary secretion of phosphate (Wright *et al.*, 1982). The salivary loss of phosphorus may be 30 to 90 g/d, which is more significant than the 1 to 10 g/d phosphorus typically excreted by the kidney (Reinhardt *et al.*, 1988). However, Goff *et al.* (2002) showed that eliminating hypocalcaemia and milk production failed to allow the cows to maintain normal plasma P concentrations. This finding indicates that milk production and hypocalcaemia are not the only factors responsible for the periparturient decline in blood P concentration. Other authors (Horst and Jorgensen, 1982; Beede, 1995) suggested that increased cortisol concentrations at calving might cause a redistribution of P from extracellular to intracellular stores resulting in the low plasma P concentrations observed in periparturient cows.

Although not statistically significant, the decrease in plasma Cu for two months precalving up to calving (Table 4.7) in experiment 2 of the current study might be a sign of an increased requirement of Cu during this period. Studies have shown that stress associated with foetal development and calving may increase the copper requirement. Waterman *et al.* (1991) showed that dairy cows had significantly lower liver copper stores at calving than at later stages of lactation and Hemken *et al.* (1993) reported that at least 15 ppm Cu in the diet is required to replenish the mothers' liver stores because the foetal liver was taking up the Cu more rapidly than the mother. The author suggested that the 10 ppm copper requirement might not be adequate during late gestation when there is rapid foetal development.

5.2.4.2 Effect of season and supplementation on plasma calcium, phosphorus and copper concentration

The effect of season on blood plasma mineral concentration is exerted through its effect on availability of the minerals from soil to pastures and the ultimate mineral concentration in pastures. Higher mean plasma Ca observed during dry season than rainy season in experiment 2 of the present study suggested higher quantities of Ca in forages during the dry season than the rainy season. This suggestion was consistent with higher levels of Ca in pastures during the dry season than the rainy season observed in experiment 3 of the current study (Figure 4.8). Calcium content of forage does not vary much or it may rise with maturity (McDowell, 1992). A number of studies (Rodgers, 1975; Mwakatundu, 1977; Mussa, 1998; Phiri, 2001) reported higher Ca in pastures during the dry season than the rainy season. However, despite the higher Ca content in pastures during the dry season, Mwakatundu (1977) observed mixed results on blood plasma Ca concentrations. Cattle from some of sampled stations showed expected results of higher Ca in plasma during the dry season than the rainy season, while other stations showed higher plasma Ca during rainy season than dry season. This suggests that the relationship between pasture Ca and plasma Ca is not a simple linear one.

The mean plasma Ca for both the control (10.7mg/dl) and supplemented (10.6mg/dl) groups in the present supplementation experiment were within the normal range of reference values. Findings in the present supplementation experiment suggest that the observed mean Ca in pasture (0.6%) was adequate for the current level of production and farmers supplementation. Calcium deficiency has occasionally occurred in grazing, high-producing dairy cows on acid, sandy or peaty soils in humid areas, where the available grazing was composed mainly of quick-growing grasses which contained < 0.2%, as reported from parts of India, the Philippines and Guyana (Underwood and Suttle, 1999). The lack of difference in mean Ca values between the supplemented and control groups and the observed higher mean P values in supplemented than control group in the current supplementation experiment (Table 4.17), could be due to the fact that Ca in serum is less responsive to dietary changes in intakes of the mineral than is inorganic P. This is due to regulatory actions of parathyroid hormone, calcitonin and vitamin D, which in most species maintain the plasma Ca concentration close to 10 mg/dl (Underwood and Suttle, 1999).

In experiments 2 and 3 of the current study, the higher mean plasma P concentration during the rainy season than dry season and in supplemented than control animals was expected due to increased P intake during the rainy season and in supplemented animals. The concentration of P in blood plasma reflects the intake of P in ruminants (Ternouth, 1989) and higher P intake was likely during the rainy season than the dry season due to higher content of P in pasture during the rainy than dry season (Figure 4.8). Similarly, Mwakatundu (1977) and Rodgers (1975) reported higher P content in pasture and blood plasma during the rainy than dry season in cattle and wild animals, respectively. In the present experiment, P deficiency was observed during the rainy season (4.9 mg/dl) and more marked deficiency (3.9 mg/dl) in the dry season. The normal range of plasma P in cows is 4 mg/dl to 8 mg/dl (Forar *et al.*, 1982) and concentrations of < 6 mg/dl indicate deficiency of the mineral (McDonald *et al.*, 1997) while values within a band of 3.1-4.7 mg/dl indicate possibility of future losses if P supplies are not improved (Underwood and Suttle, 1999). Plasma Ca concentration has been shown to increase during P deficiency (Breves *et al.*, 1985). But such an increase in plasma Ca as a result of P deficiency was not observed in the current experiment, presumably due to concurrent Ca deficiency. The P deficiency in the present experiment occurred concurrently with protein deficiency because protein content of herbage falls with P (Figures 4.7 and 4.8). Protein deficiency, and frequently also energy deficiency, are exacerbating factors in the malnutrition of livestock in P deficient areas (Underwood, 1981).

In the current supplementation experiment, the observed lower mean plasma P for the control than the supplemented group was in agreement with previous experiments where plasma P was lower for cows receiving low P diets than those receiving high P diets (Kincaid *et al.*, 1981; Dhiman *et al.*, 1995; Wu and Satter, 2000). The observed mean plasma P concentration (4.6mg/dl) for the control group in the current supplementation experiment (experiment 3) was within a band of values (3.1-4.7 mg/dl), which indicate marginal deficiency and possibility of future production losses if P supplies are not improved (Underwood and Suttle, 1999). The mean P concentration for supplemented group (5.2 mg/dl) although better than the control group was still below the critical value of 6 mg/dl (McDonald *et al.*, 1997). The observed low plasma P concentrations were consistent with low pasture P (0.2%) that was below the critical level of (0.25%) (McDowell *et al.*, 1983) suggesting a need for higher P supplementation level than the level used in the current experiment.

The lack of significant difference in plasma Cu concentration between the rainy and dry seasons in experiment 2 of the current study could be a result of effects of Cu stores in the liver that can be released in cases of dietary deficits (Underwood and Suttle, 1999). The current results however differ from those reported by Mwakatundu (1977) where plasma Cu was higher in the rainy than the dry season. Throughout experiment 2 of the present study, plasma Cu concentrations were below the reference values, and hence indicative of nutritional deficiencies for the mineral in both seasons. Blood and Radostits (1989) regard plasma Cu concentrations < 1 μg/ml to be indicative of Cu deficiency in cattle while others consider concentrations <0.6 μg/ml as indicative of Cu deficiency (Minatel and Carfagnini, 2002).

The observed improvement in plasma Cu concentration in supplemented animals in the current supplementation experiment (Table 4.17) was similar to findings by Maro *et al.* (1980), Ward *et al.* (1996), and Spears *et al.* (2004) where Cu supplemented Friesian female calves, Simmental x Angus x Hereford calves, heifers and steers, respectively had higher plasma Cu than the unsupplemented animals. Although the mean plasma Cu concentration of the supplemented group (0.46μg/ml) was higher than the control group (0.39μg/ml) in the current experiment, both groups showed mean values within a marginal deficiency band of values, which is 0.2-0.6 µg/ml. (Underwood and Suttle, 1999). Serum Cu concentration below the band of values indicates high probability of current or future dysfunction and impairment of health or production, while values above the band indicate minimal likelihood of Cu supplementation being beneficial (Underwood and Suttle, 1999).

The low plasma Cu concentrations in the current experiment could be related to the observed very low pasture Cu (0.27mgCu/kg), which was lower than the critical value of 5mgCu/kg (Cunnigham, 1992). These findings therefore suggest that the level of supplementation was not enough to raise the plasma Cu concentration to the recommended level or bioavailability of Cu was low. However, determination of adequate levels of Cu in the diet requires further investigation since Cu requirements of animals are powerfully influenced by interactions between Cu and other dietary components, particularly molybdenum, sulphur and iron (Ward *et al.*, 1997; Underwood and Suttle, 1999; Spears *et al.*, 2004).

Supplemented animals showed inadequacy in terms of P and Cu although the supplement ingredients were calculated to cover for deficits. The explanation for the unsatisfactory response might partly be due to the fact that the nutritional requirements used for calculation assumed a positive balance of nutrients in animals at the beginning of the dry period, while the experimental animals in the current experiment might have been in negative nutrients balance, hence their actual requirements were higher than the tabulated values. Another reason for the poor response of P and Cu supplementation might be due to lower mineral content in the mineral premix than the content indicated in the manufacturer's manual. Since the mineral content of the mineral premix was not analysed, it is not easy to make a clear recommendation. It is advisable to analyse the mineral premix available in the market in Tanzania to be able to advise farmers on proper supplementation.

5.2.4.3. Effect of parity on plasma calcium, phosphorus and copper concentration

The higher mean plasma Ca and P observed in primiparous than pluriparous cows in the present experiment (Table 4.19) are in agreement with studies by Romo *et al.* (1991) and Kume *et al.* (2003). However, Iwama *et al.* 2004 found no significant difference in plasma Ca and P concentrations between primiparous and pluriparous cows. The differences among the experiments could be due to variations in planes of Ca and P nutrition before and during the different experiments. The higher plasma Ca and P in primiparous than pluriparous cows during the peripartum period in the current experiment can be explained by their better ability for intestinal Ca and P absorption and bone resorption. It has been reported that intestinal and bone $1,25(OH)_2D_3$ receptor activity is age dependent and the younger cows have greater ability to mobilise Ca and P from increased intestinal absorption and bone store than older cows (Horst *et al.*, 1978, 1990, 1997; Iwama *et al.*, (2004).

The observed trend of increasing plasma Cu from primiparous to fourth parity after which it decreased was attributed to higher Cu demands for growth and pregnancy in younger cattle than older ones up to fourth parity while on Cu deficient diet. It has been observed that such age effect on plasma Cu may only manifest itself when the cattle are on a Cu deficient ration (Smart and Christensen, 1985). Similarly, Alonso *et al.* (2000) observed significantly higher blood levels of Cu in female calves than cows.

5.2.5 Influence of season, supplementation and parity on milk production

5.2.5.1 Effect of season and supplementation on milk yield

The higher milk yield (MY) during the rainy season (Figure 4.5 and Table 4.8) in experiment 2 and for supplemented animals (Figure 4.12 and Table 4.17) in experiment 3 of the current study was expected due to higher levels of energy, protein and minerals available to the animals during the rainy season and supplementation, respectively. The higher MY was consistent with higher BWT, BCS, BCSC, PUN and plasma P in the same animals (Tables 4.8 and 4.17). In addition, the higher MY in supplemented animals was in agreement with higher plasma Cu in the same group of animals. Similar improvement in MY (1.5 L/day) was observed when crossbred cows were supplemented with 4 kg of maize bran, 2 kg of cotton seed cake and 100g of Bayslick® minerals per day for 17 days in various districts of Tanga region (Urassa, 1999). In agreement to the current study, Bareeba and Samaanya (2002) reported higher MY during the rainy season than the dry season (10.4 vs. 8.2 L/day and 12.4 vs. 9.3 L/day) in crossbred primiparous and cows in second lactation, respectively.

The positive response to supplementation in the current study implies that pastures alone were not adequate for optimum MY. Positive response in milk production to concentrate supplementation has been observed even for cows on properly managed pastures (Bernard and Carlisle, 1999; Polan *et al.*, 1986) indicating that pasture alone was not sufficient to support milk production in high yielding cows. Following parturition, cows have high nutritional demands to facilitate milk production. In most cases the demands are too high to be met from the dietary source hence cows mobilise body reserves to maintain their MY. Underfed lean cows still mobilise body reserves but not sufficiently to maintain their yield of milk, fat and proteins.

Increased energy intake during the rainy season and for the supplemented animals in the current study contributed to higher MY during the rainy season and in the supplemented cows. When high quality pasture is available in adequate quantities, ME is the most limiting factor for milk production in Holstein cows (Kolver and Muller, 1998; Kolver *et al.*, 1998). Low energy intake during late pregnancy can result in slightly lowered CBwt and lower milk production among other things (Cornelia and Barry, 2000).

Improved protein intake, as indicated by higher PUN values during the rainy than dry season (Table 4.8) and in the supplemented than unsupplemented animals (Table 4.17) enhanced MY during the rainy season and in supplemented animals. The fact that cows secrete protein in milk, along with the fact that they have a very limited ability to store protein, makes protein feeding a critical factor. Protein must be consumed daily in order to maintain uniform high production (Lane and Larry, 1995).

The enhanced P intake as indicated by higher plasma P during the rainy season (Table 4.8) and for the supplemented animals (Table 4.17) could have favoured milk production during the rainy season and in the supplemented group of animals. This is because lactating animals respond to dietary deficiency of Ca or P by reducing MY without affecting the concentrations of the minerals in the milk produced (Underwood and Suttle, 1999). In experiment 3 of the current study, the lower MY in the control group consuming pastures of 0.2% P was in agreement with findings by Call *et al.* (1987) where dietary P level of 0.24% decreased feed intake and MY.

The negative correlations between MY and DPO, SC and CI although not significant in the current study were in agreement with observation by Mujuni *et al.* (1990b) where negative correlations between milk produced in the first 30 days of lactation and days to first service ($r = -0.23$) and conception ($r = -0.22$) as well as SC ($r = -0.15$) were observed. The increased MY during the rainy season and supplementation without concurrent decrease in RP in the present study suggests that the level of MY was not above the level that would upset the RP. Similarly, Mujuni *et al.* (1990b) observed shorter intervals from calving to service and conception as well as better SC and CI in cows that produced 18.8 than those that produced 8.2 L/day during the first 30 days postpartum.

Body condition score and BCSC, though not significant were positively related to MY in the current study (Table 4.12) thus potentially useful indicators to ensure optimal MY from cows. Lack of significant association between BCS and MY as well as BCSC and MY in the current study was in contrast to a study by Msangi *et al.* (2002), where body condition was found to be among important determinants of MY in crossbred dairy cattle and cows with better BCSC had higher MY and longer lactations than those with lower BCS. Milk yield responses due to increased condition score were also recorded from a number of other studies in cows (Domecq *et al.*, 1997; Chagas *et al.*, 2000; Carson *et al.*, 2001).

Practically, the effects of supplementation on MY can be monitored using BCS since the two are positively correlated (Table 4.12). Increasing BCSC from 2.0 to 2.4 and 2.2 to 2.6 resulted in increase in mean MY from 7.3 to 9.4 L/day and 9.1 to 11.6 L/day during the first 13 weeks postcalving in experiment 2 and 3 of the current study, respectively. In the same way, McNamara *et al.* (2001) observed daily yields of 24.1, 26.2 and 28.2 kg/day during the first 8 weeks of lactation, from cows with BCSC of 2.60, 2.76 and 2.88, respectively. Similarly, increasing body condition score pre-calving from 2.73 to 3.00 resulted in significantly higher daily MY (24.2 vs. 25.5 kg) during the first 4 weeks of lactation (Ryan *et al.*, 2003). The current and previous results suggest that increasing BCSC up to at least 3 can increase MY in early lactation.

An additional benefit of improved BCSC is from increased fat content of milk because of the general tendency for cows with a higher BCSC to produce milk with higher fat content but similar protein content as cows with lower BCSC (Stockdale, 2000). Ferguson and Otto (1989) concluded that cows whose BCSC falls below 2.5 have decreased milk production and reproductive problems while cows scoring 3 at calving would produce amounts of milk similar to cows scoring 4 at calving, but only if postpartum rations are of high quality and intake is truly *ad libitum*. If mean BCSC of 2.5 is taken as a cut off point, the lower MY in the control group with BCSC 2.2 was in agreement with Ferguson and Otto's (1989) conclusion although it is hard to conclude from the current experiment whether milk production in the supplemented group with BCSC of 2.6 was optimum.

Mean MY increase due to supplementation in the present experiment was 2.5 L/day, which represented a mean increase of 27.5%. The mean amount of supplement consumed by an average weight cow (287.1 kg) across the seasons for 2 months before and after calving was 2.6 kg/d. Assuming 1 L of milk weighs 1 kg the milk response (MR) to supplementation expressed as kg of milk/kg supplement was 0.96. The MR in the present experiment was higher than 0.7 observed by O'Brien *et al.* (1999) during a similar stage of lactation. The difference in MR between the studies could be due to differences in quality and amount of basal diet as well as supplements and the genetic makeup of the animals. Marginal MR to increasing amounts of concentrate has been described as curvilinear (Kellaway and Porta, 1993; Polan, 2000; Reis and Combs, 2000) therefore maximum supplementation levels may or may not result in maximum profitability. Marginal MR decreased above 3 to 4 kg DM/d of concentrate in some studies, but this is not consistent and occurred primarily when pasture quality and quantity were not limiting and with cows of moderate genetic merit (Peyraud and Delaby, 2001). Similarly, Ariaga-Jordán *et al.* (2001) observed no response in MY when two groups of cows were fed 3 and 5 kg/cow/day of commercial concentrate in smallholder set up in Mexico.

Stage of lactation has been shown to influence lactational responses to concentrate supplements (Dixon and Stockdale, 1999). In early lactation, cows partition more nutrients toward milk production, thus MR to supplementation may be higher than in late lactation, when more nutrients are directed to body weight gain (Kellaway and Porta, 1993). The average MY response to concentrate supplementation of grazing cows supplemented with 3 kg DM/d concentrate was 0.7, 0.4, 0.5, and 0 kg milk/kg concentrate when they were between 86 to 114, 115 to 133, 134 to 187, and 188 to 243 days in milk, respectively (O'Brien *et al.*, 1999).

5.2.5.2 Effect of parity on milk yield

The observations that primiparous cows and cows over parity five produced the lowest and highest MY while the rest of parities' productions were in between and not significantly different (Table 4.19), was very similar to observations made in a group of zero grazed crossbred cows where MY from calving to weaning was significantly affected by parity and cows in first lactation had less daily MY (6.1 L) in comparison to cows between second to fifth lactation (8.6 L) and cows in over sixth lactation (8.9 L) (Msangi *et al.*, 2001). Similar findings have been repeatedly observed in other studies (Kume *et al.*, 2003; Meikle *et al.*, 2004; Iwama *et al.*, 2004) where primiparous cows produced less milk than pluriparous cows. The low MY for the primiparous cows in the present experiment was consistent with their low PUN and BWT (Table 4.19) when compared to cows in other parities. Both BWT and age have influence on MY but BWT has been shown to have more significant effect during the first 240 days postpartum than the age (Fisher *et al.*, 1984). In addition primiparous cows have lower DMI than mature cows (Rémond *et al.*, 1991; Iwama *et al.*, 2004). The relatively lower DMI and the needs for growth occurring simultaneously with demands of lactation could add to reasons for lower milk production observed in the primiparous cattle (Rémond *et al.*, 1991). Age effects on MY have previously been reported to be greater for younger than older cattle (Keown and Everett, 1985; Morales *et al.*, 1989; Duraes and Keown, 1991). Also, age effects were more important for earlier lactations. Advancing age was associated with higher MY within all lactations, but this effect diminished as lactation advanced (Khan and Shook, 1996).

5.2.6 Effect of supplementation and parity on calf birth weight

The observation that the supplemented dams in experiment 3 gave birth to significantly heavier calves than the unsupplemented counterparts (Table 4.17) could be attributed to influence of improved nutrition of the dam, which increased nutrient supply to the developing foetus. Improved nutrition in the supplemented group of dams was indicated by higher BWT, BCS, BCSC, PUN as well as plasma P and Cu. Bellows *et al.* (1971) reported a positive correlation between birth weight and size and maternal BCS at the end of mating season, the second trimester and parturition. Influence of dams' prepartum nutrition on CBwts has been observed in cattle (Laster, 1974; Corah *et al.*, 1975) with energy intake showing more influence than protein intake in both short and long-term nutritional studies (Wiltbank *et al.*, 1965; Holland and Odde, 1992). In agreement with present study, cows with higher level of supplementation, higher BCSC and higher BWT gains postpartum had heavier calves at birth (Spitzer *et al.*, 1995).

However, in other studies nutrient intake of cows during gestation did not significantly alter weight of calves at birth (Goehring *et al.*, 1989; Rasby *et al.*, 1990; Wiley *et al.*, 1991). This can partly be explained by levels of feed intake and body energy stores at the beginning and during the studies. Body energy stores of the dam at the start of supplementation have an influence in ultimate CBwt, since maternal metabolic and physiological adaptations during pregnancy allow acute nutrient intake variations to only minimally affect CBwt by mobilisation of nutrients from maternal tissue stores to maintain conceptus development. Additionally, foetal metabolism is also responsive and adaptive to periods of limited nutrient availability (Fowden, 1989). Eckles (1976) stated that CBwt is not ordinarily influenced by the ration received by the dam during gestation unless severe nutritional deficiencies exist.

Chronic malnutrition, however, may dramatically affect birth weight (Wiltbank *et al.*, 1965). The observed differences in CBwts between the supplemented and control groups in the current experiment therefore suggest that animals in Rungwe were chronically malnourished. Furthermore, the observed low level of supplementation (Table 4.4), delayed puberty (Table 4.6), low ME, marginal P and low Cu content in pastures (Table 4.15), delayed mature BWT (Table 4.19) and suboptimal DPO and CI (Table 4.10) in the current study imply that the animals in Rungwe district were undernourished.

Lack of significant variation in CBwt among parities (Table 4.19) although primiparous cows and cows in third parity had the lightest and heaviest calves, respectively in the present experiment, is comparable to findings by Tudor (1972) and Guedon *et al.* (1999) who observed no significant influence of parity on CBwt and Holland and Odde (1992) who observed lowest birth weights in two-year-old heifers. Relative competition for nutrients between the still-growing dam and the developing fetus has been cited as the reason for low calf birth weight in younger cows (Joubert and Hammond, 1958).

5.2.7 Effect of season, supplementation and parity on days to postpartum resumption of cyclicity, days to postpartum first visual oestrus, services per conception and calving interval

The observed oestrus detection rates of 66% and 67% in experiments 2 and 3, respectively in the current study were higher than the critical value of 65%. Values below 65% are considered as indicative of heat detection problem (Laing *et al.*, 1988).

Both the effects of season and supplementation are exerted through increased intake of energy, protein and minerals to improve the reproductive process. In experiments 2 and 3 of the current study, greater proportion of animals that calved in rainy season (Table 4.9) and those supplemented (Table 4.18) showed shorter DPOA and DPO than animals that calved in dry season and unsupplemented animals, respectively. This could be due to better nutrition in the rainy season and supplemented animals than the dry season and unsupplemented animals. In the same way, the shorter mean DPO, CI and less SC for animals calving during the rainy season than during the dry season would be due to better nutrition during rainy than dry season. Similarly, the shorter mean DPO observed in supplemented group of animals than the control group in experiment 3 was a result of better nutrition in the supplemented than the control group. Kanuya and Greve (2000) made similar observations in SHZ where cows that calved at the beginning of rainy season exhibited shortest CI, while those that calved in dry season had longest average CI. Bareeba and Samaanya (2002) observed improved SC during the rainy season in zero grazed crossbred cows. Furthermore, in agreement with the current study, Negussie *et al.* (1999) and Msanga *et al.* (1999) observed improved SC and CI, respectively on crossbreds during the rainy season although the improvement was not significant. Reduction of DPO in the current supplementation experiment was similar to findings by Nkya *et al.* (1999a) where supplementation of concentrate comprising of maize bran (70%), cottonseed cake (28%) and minerals (2%), resulted in reduction of post-partum anoestrus period from 86.3 to 71.2 days and calving to conception from 102.4 to 80.4 days.

The better RP during the rainy season was due to the effect of season, which favours the availability from pasture of energy, protein and some minerals (Figures 4.7 and 4.8). In the present study the improved RP for cows that calved during the rainy season and the supplemented animals was consistent with higher BWT, BCS, BCSC, PUN, and plasma P in those groups of animals (Tables 4.8 and 4.17). Furthermore, the improved RP for supplemented animals corresponded with higher plasma Cu in that group of animals.

The observed small proportions of primiparous cows that showed postpartum ovarian cyclicity and first observed visual oestrus before 90 days compared to pluriparous cattle in the present study (Table 4.20) was consistent with lower BWT, and PUN observed in the same parity (Table 4.19). The inferior RP in primiparous than pluriparous cattle in the current study was in agreement with previous studies where primiparous cows had longer intervals from calving to first postpartum ovulation, calving to AI, calving to conception, more services per conception, longer days open and longer CI than pluriparous cows (Dachir *et al.*, 1984; Reksen *et al.*, 1999; Negussie *et al.*, 1999).

The observed RP inferiority in primiparous cows while being similar in BCS and BCSC to the rest of parities was similar to observations by Jonsson *et al.* (1999) where the probability of pregnancy was affected by parity, being lowest in first-lactation cows but with no evidence of more negative energy balance in these cows than in cows of higher parities. Relatively low BWT of primipara cows was suspected to be a contributing factor (Jonsson *et al.*, 1999). The relatively poor RP in primiparous cows in the current experiment was probably due to negative energy balance related to the increased needs for growth occurring simultaneously with demands of lactation and their lower feed intake capacity (Rémond *et al.*, 1991). Primiparous cows tend to have higher negative energy balance postpartum than do pluriparous cows (Lucy *et al.*, 1992). However, the assumed higher negative energy balance in primiparous than pluriparous cows in the current experiment was not reflected in BCS. This means that the difference in negative energy balance between the primiparous and pluriparous cows was enough to affect the RP but too low to influence BCS significantly between the primiparous and pluriparous.

Energy balance, protein and minerals influence BWT and BCS, which are both related to RP in cattle. It has been observed that during dry season, nutritional deficiencies cause cows to lose weight resulting in post-partum anoestrus and delayed re-conception (Rennie *et al.*, 1977) as a result of negative energy balance, which is known to play a major role in initiation of ovulatory ovarian cycles in postpartum dairy cattle (Canfield and Butler, 1991). Butler & Smith (1989) observed anestrous duration that was associated with BCS loss in cattle. These authors and others (Huszenicza *et al.*, 1987, 1988) demonstrated that the sooner the cows restore the energy balance, the sooner they will start cycling and become pregnant.

Higher body weight gain before calving during the rainy season (Figure 4.2) and in the supplemented group (Figure 4.9), earlier body weight recovery (2 months postcalving) during the rainy season, higher weight gains postcalving in the supplemented group when compared to their counterparts in the current study can be related to the higher nutrition and better RP in the same group of animals. Patil and Deshpande (1981) made similar observations where Gir cows that gained weight in the first three months after parturition showed heat during that period, while those that lost weight remained anoestrus.

The observed higher levels of dietary protein as indicated by PUN during the rainy season (Table 4.8), for the supplemented animals (Table 4.17) and pluriparous cows (Table 4.19) could have contributed to improving the DPOA, DPO and though not significantly improving the SC and CI in the same animals. In addition to stimulation of DMI (Butler, 1998) dietary protein may decrease the incidence of silent heats and increase conception rates in lactating cows (Van Saun *et al.*, 1993; Donna *et al.*, 1997).

The improved RP during the rainy season and in the supplemented animals could partly have been a result of the increase in dietary and plasma P in the same animals

(Tables 4.8 and 4.17). Dramatic increase in fertility levels and growth in cattle after P supplementation has been reported in many parts of the world (McDowell, 1976; Engels, 1981; Bauer *et al.*, 1982). Low P content in pasture (0.2%) observed in current study in Rungwe signifies a risk of infertility in unsupplemented dairy cattle. This is because reproduction is likely to be impaired when dietary P concentrations are extremely low (<0.25%) (Wu *et al.*, 2000), where rumen microbes may have inadequate amounts of P for maximum growth, resulting in less microbial protein (Durand and Kawashima, 1980; Petri *et al.*, 1988) and possibly lowered ration digestibility (Durand and Kawashima, 1980). Under these extreme conditions, low dietary P could conceivably have an indirect effect on RP through impact on the cow's energy balance (De Vries *et al.*, 1999). Furthermore, since cell growth, division and differentiation are essential for gamete formation and embryo development, fertility may be affected by P deficiency because P is a component of deoxy- and ribonucleic acids and plays a vital role in energy utilization and transfer, which are essential functions in cell growth, division and differentiation (Hafez, 1980; Underwood and Suttle, 1999).

The improved DPOA and DPO for supplemented animals in the current study could partially be attributed to higher plasma Cu in this group than the unsupplemented animals since the rate of conception in ruminants is directly related to rate of uptake of Cu (Grace and Clark, 1991) and suppressed oestrus has been observed in cows grazing on Cu deficient pastures (Underwood, 1977). Furthermore, supplemented cows showed more standing heats, improved conception on first service (Kropp, 1992) and reduced calving to conception interval and matings per conception (Manickam and Balagopal, 1993).

The significant negative correlation between BCS and BCSC to DPO, as well as between BCS to CI, and between BCSC to CI though not significant strongly suggest that BCS can be used meaningfully for predicting RP. Similar relationship between BCS and RP has been reported previously but recommended values of BCSC and BCS loss that could be allowed following parturition in order to avoid negative effects on RP vary among studies. However, all studies seem to agree on the BCSC not to exceed 4, necessity to maintain body condition score at or above 2.75 during the breeding season and to minimise BCS loss to less than 0.5 units between calving and breeding (Grainger *et al.*, 1982; Morton, 2000; Pryce *et al.*, 2001; McNamara *et al.*, 2001). Wildman *et al.* (1982) and McDowell (1994) recommended BCSC of 3.5 to 4.0 with acceptable BCS loss after calving not to exceed 1 score five to seven weeks postpartum.

In light of previous studies, the higher BCS loss for 2 months postpartum observed during the rainy season (0.21) than during the dry season (0.11) would be consistent with better RP during the dry season than the rainy season, which was however not the case in the current experiment. This finding suggests that the effect of BCS losses postcalving is outweighed by the effect of BCSC on RP. Although the mean BCSC during the rainy season (2.4) was significantly higher than during the dry season

(2.0), it was still below a range of values 2.5-3.5 recommended (Wildman *et al.* 1982; Ferguson and Otto, 1989; McDowell, 1994) for optimum RP in dairy cattle.

The BCSC in experiment 2 of the current study agreed well with the RP findings because although shorter mean DPO (136.7 days) and CI (454.8 days) were observed for the cows that calved during the rainy season than the DPO (220.8 days) and CI (516.6 days) for cows which calved during the dry season, both values were higher than what would be expected in a well-managed dairy herd, where cows must be pregnant within 60 - 115 days after calving and attain a CI of between 360 and 390 days (Roberts, 1971). The SC during the rainy season (1.37) and dry season (1.42) in the present experiment were within the normal average of 1.3 to 1.7 in a good managed herd (Roberts, 1971).

Results of the current study (Experiment 3) indicated that the supplement was sufficient to improve the BCSC of the animals from 2.2 to 2.6, a value that was within the recommended range of 2.5 to 4 (Wildman *et al.*, 1982; Ferguson and Otto, 1989; McDowell, 1994) consistent with improvement of proportions of animals with shorter DPOA and DPO. Supplementation also reduced the mean DPO from 146.8 to 103.2 days, which was within the range (60-115 days) that is expected in a well-managed herd (Roberts, 1971). Mean values for SC and CI were not obtained for supplementation experiment because very few pregnancies had been confirmed and no cow had subsequently calved by the end of the study.

Although the optimum range of BCSC for optimum RP remains unsettled, body condition scoring is a useful tool for predicting RP, because of the positive relationship between body condition and RP.

5.2.8 Incidence of reproductive diseases and disorders

The incidence (10.5%) of dystocia observed in experiment 2 of the current study (Table 4.13) was higher than 1.6% observed in experiment 3 (Table 4.21) of the same study. The incidence of dystocia in experiment 2 was also higher than 1.7% reported for dairy cattle in smallholder herds kept under zero-grazing management systems in rural highland area of Tanzania (Kanuya *et al.*, 2000), and just over the range of expected incidence of dystocia in cattle that is 2-10% (Senger, 2003).

The observation of higher incidence of dystocia in cows that had male calves than female calves in experiment 2 of the current study (Table 4.14) can be related to calf sizes. Calf's birth weight and sex are among the important factors believed to influence frequency of dystocia (Ritchie and Anderson, 1994). Male calves tend to be larger than females and much of the influence of sex of calf on dystocia is believed to be indirect, through its effect on increased calf size. However, differences in dystocia between calf sexes remained even after correcting for birth weight (Ritchie and Anderson, 1994), suggesting that factors other than foetal size may be involved. High incidence of dystocia in experiment 2 could also be a result of crossbreeding between Short Horn Zebu cattle and exotic dairy breeds due to increased sizes and weights of calves. In addition, a weak cow and/or calf may lead to failure of the cow and/or calf to adequately achieve normal delivery.

A slightly higher frequency of dystocia during the rainy season in experiment 2 of the current study (Table 4.13) could also be a result of heavier calves born during this period. In addition, lower plasma Ca observed during the rainy season than dry season could have contributed to the higher incidence of dystocia and retained foetal membranes during the season since low Ca has been associated with occurrence of dystocia and retained foetal membranes. Farms that had a policy of administering low Ca prepartum diets to dry cows had more dystocia and retained foetal membranes (Correa, *et al.*, 1990).

The incidence of clinical mastitis observed in experiment 2 (7.0%) and 3 (7.8%) were higher than 5.0% reported in smallholder herds under zero-grazing systems in rural highlands of northern Tanzania (Kanuya *et al.*, 2000) and crossbred cows under extensive management in Morogoro (Shem *et al.*, 2002). Low incidence (2.4% to 4.0%) of mastitis have been reported in smallholder and large scale dairy farms in Morogoro urban and peri-urban areas (Shekimweri *et al.*, 1998; Shem *et al.*, 2001) and high incidences of 21%, 10-14%, 22.4%, 25% and 19.6% in Iringa, Tanga, Kibaha, Morogoro, and Kenya, respectively (Swai *et al.*, 2000; Swai *et al.*, 2002; Mdegela *et al.*, 2004; Shitandi *et al.*, 2004). The variation in incidence of mastitis among the studies is a reflection of different levels of production, hygiene and control measures used by farmers. The lower incidence of mastitis reported in some of the previous studies imply achievable levels that could be used as targets to improve on mastitis control in Rungwe district.

In the present study, the higher incidence of mastitis observed during the rainy season (Table 4.13) and for supplemented animals (Table 4.21) than dry season and unsupplemented animals, respectively could be caused by a number of factors such as the increase in MY that would predispose the cows to mastitis if total milk removal from the udder was not achieved. Similarly, Mujuni *et al.* (1990b) reported higher incidence of mastitis in higher than lower yielding cows. Relatively unhygienic conditions in barns and lower plasma Ca (Table 4.8) during the rainy season than the dry season could also affect the incidence of mastitis. Calcium is an essential nutrient that influences resistance to diseases (McDowell, 1992; Hogan *et al.*, 1996). It is involved in antioxidant systems that maintain the integrity of phagocytic cells and lymphoid tissues (Hogan *et al.*, 1996). Impairments of the antioxidant system can result in a higher incidence and more severe clinical signs of disease (Miller *et al.*, 1996). The higher incidence of mastitis during the rainy season than dry season in the current experiment was also consistent with the observed higher incidences of parturient paresis and retained foetal membranes during the same period in the current experiment. Parturient paresis and retained foetal mebranes have been reported to increase the odds of mastitis (Correa *et al.*, 1990).

On the other hand, the higher plasma Cu in the supplemented than the unsupplemented animals (Table 4.17) would be expected to enhance immunological protection in the supplemented animals. Copper is an important element for normal immune function (Underwood and Suttle, 1999). Harmon and Torre (1994) observed fewer infected quarters at calving in heifers fed supplemental copper than unsupplemented animals and Scaletti *et al.* (2001) reported reduced severity of mastitis following experimental challenge with *E. coli* in copper supplemented heifers. Therefore lower Cu status would be expected to contribute to increased susceptibility to infections such as mastitis. However, although higher in the supplemented animals plasma Cu was still marginally deficient and probably insufficient for its role in the immune system in the current supplementation experiment and other factors such as hygiene and level of milk production might have been more important factors in the pathogenesis of mastitis in this case.

In the current study, the observed incidence for retained foetal membranes of 5.3% in experiment 2 and 9.4% in experiment 3 were higher than 4.2% reported in smallholder dairy cattle herds under zero-grazing systems in rural northern highlands of Tanzania (Kanuya *et al.*, 2000) but were within the expected range of incidence for retained foetal membranes, which is 4-12% (Senger, 2003). Incidences of retained foetal membranes of more than 12 to 15% are considered excessive (Studer, 1998). In contrast to observations in UK where little seasonal change in the number of cases of retained foetal membranes occurs (Laven, 2003), higher incidence of retained foetal membranes was observed in rainy season than dry season in the present experiment. The higher incidence of retained foetal membranes during the rainy season than the dry season could be related to the higher incidences of dystocia, parturient paresis and abortion during the same season. Retention of foetal membranes has been associated with a range of different factors including dystocia, abortion, milk fever, low protein diets prepartum, and selenium deficiency or toxicity, vitamin E, and/or A (Roberts, 1986). Nkya and Swai, (1999) observed similar relationship between retained foetal membranes and abortion where animals that aborted were more associated with foetal membrane retention than those that never aborted. Lower plasma Ca during the rainy season than the dry season in experiment 2 of the present study suggests that hypocalcaemia was a contributing factor since it leads to increased secretion of cortisol, which is believed to be a factor in increased incidence of retained foetal membranes (Goff, 1999).

The incidences of postparturient paresis in experiment 2 (3.5%) and 3 (3.1%) of the current study were higher than 1.7% and 1.4% observed in rural northern highlands and peri-urban Dar es Salaam and Morogoro areas in Tanzania, respectively (Kanuya *et al.*, 2000; Nkya and Swai, 1999) but within the expected normal range of 3 to 8% (Littledike *et al.*, 1981; Riond, 2001) and below the critical range, which is 6 to 8% (Studer, 1998). The higher incidence of parturient paresis during the rainy than the dry season in the current experiment was consistent with higher MY and lower plasma Ca observed during the same period since hypocalcaemia is the underlying cause for parturient paresis (Oetzel and Barmore, 1992).

The observed 1.8% and 1.6% incidence of abortion in experiments 2 and 3 of the current study, respectively were below the critical level of 2.0% (Ferguson, 1989). The incidences were also lower than 9.9% and 16.0% reported in smallholder dairy cattle of peri-urban Dar es Salaam and Morogoro (Nkya and Swai, 1999) and northern highlands (Kanuya *et al.*, 1998), respectively.

Stillbirths were not observed during experiment 2 while the incidence in experiment 3 (1.6%) was below the acceptable critical range of 5-15% (Ferguson, 1989).

The causes of all sudden deaths in the current study were not determined due to lack of veterinary post-mortem services, willingness and ability of the farmers to pay for them and no attempt was made to make any speculation on causes of the deaths which were 1.8 and 4.7% in experiments 2 and 3, respectively.

The lack of association between overall occurrence of diseases and disorders to supplementation (Table 4.21) suggests that at the current level of nutrition, factors other than nutritional were more important in the course of development of diseases and disorders. The fact that a number of reproductive diseases and disorders are interrelated could account for the general observation of higher incidence of diseases and disorders in the same season with a significant association between an overall occurrence of the diseases and disorders between the two seasons (Table 4.13). The overall effect of reproductive diseases and disorders on RP in the current experiment was outweighed by nutritional factors, since despite the higher occurrence of the disorders during the rainy season, cattle calving during the rainy season had better RP than during the dry season due to improved nutrition through the season. The low impact of diseases and disorders was consistent with the general observation that all diseases and disorders occurred within the expected incidence levels except for dystocia, which was just above the normal incidence value. This implied that intervention by supplementation would be more rational than disease control measures to improve the RP in Rungwe district.

5.2.9 Daily dietary nutrient balance in supplemented animals

The observed positive ME and CP balances from two months precalving to one month precalving (Table 4.16) were consistent with increasing BWT, BCS, (Figure 4.9) and PUN (Figure 4.10) during the same period. Further positive ME and CP balances observed for a month before calving were in agreement with the increase in BWT and stable PUN values during the same period. However, the decline in BCS that occurred a month before calving when BWT was increasing and PUN was stable, suggests that nutrients were being preferentially utilised in favour of the foetus resulting in BWT increase as a result of increase in weight of the foetus rather than deposition as adipose tissue of the dam. The last month of gestation is characterised by increased demand for nutrients that are partitioned in favour of the rapidly growing foetus in cattle (Van Saun, 1991; Bell, 1995; Chandler, 1995). The negative ME and CP balances observed for two months after calving were consistent with the drop in BWT and BCS during the same period. However the PUN increased for a month after calving when CP balance was negative. The rise in PUN concentration a month following calving is likely to be a result of tissue protein breakdown as a response to low protein intake, negative CP balance and increased protein demand for milk production. Comparable increase in PUN and milk urea nitrogen concentrations after calving were reported by Reist *et al.* (2003) and Spicer *et al.* (2000), respectively.

The negative Ca balance observed from two to one month precalving (Table 4.16) was not reflected in the trends for plasma Ca during the same period (Figure 4.11). This could partly be due to bone resorption occurring as a response to dietary Ca deficiency. There is strong homeostasis of Ca that is achieved by hormonal regulation of intestinal absorption, bone resorption and kidney excretion of Ca that maintains the plasma Ca concentrations close to 10 mg/dl (Table 4.17) in mammals (Underwood and Suttle, 1999). The observed negative balances in dietary P and Cu during the entire experimental period were consistent with deficiencies observed in mean plasma P and Cu concentrations (Figure 4.11 and Table 4.17).

The low level of pasture ME (5.7MJ/kgDM) in the current study (Table 4.15) compared to the value of 7.95 MJ/kgDM (Mussa, 1998) used during formulation of the experimental ration may partially explain the observed negative balance for ME after calving. In addition, the higher milk yield during the supplementation study (10.4 L/day) than the 8.4 L/day used during formulation of the test diet contributed to the observed negative balance for all the nutrients following calving. Furthermore, the levels of mineral elements in the commercial mineral mix used could have been lower than the levels indicated in manufactures manual.

The dietary nutrient balances observed in the current experiment call for further improvement in levels of energy and protein intake following calving and P and Cu for two months before and after calving. Assuming similar conditions of management and production as under the current supplementation experiment a diet that would cover the observed deficits for a 287 kg crossbred cow producing 11.6 L of milk per day could be formulated to contain 12.9 ME (MJ/kg), 130.8 g/kg CP, 9.3 g/kg Ca, 5.5 g/kg P and 80 mg/kg Cu from HM (75%), SSC (20%), and SM (5%) and fed at 3.0 kg/day for 2 months precalving and 4.4 kg/day for 2 months after calving

5.2.10 Economic analysis of concentrate supplementation in Rungwe

The marginal profit from increased MY revealed positive returns. However the true profit should also consider other benefits resulting from supplementation which include improved RP, higher MY beyond the period of 90 days postcalving as well as improved immunity, BWT, BCS and CBwt. All these traits are of economic importance and should make concentrate supplementation an even more attractive proposition.

The economic analysis findings in the current study were consistent with results of analysis of strengths, weaknesses, opportunities and threats to Tanzania dairy industry, which revealed that milk production has attractive profit margins in most farming areas where appropriate technology such as strategic supplementation is applied (Kurwijila and Boki, 2003).

Urassa (1999) reported similar findings from a supplementation trial in smallholder crossbred dairy cattle in Tanga where supplementation of a concentrate (4 kg of maize bran, 2 kg of cotton seed cake and 100 g of Bayslick® minerals per animal per day) was profitable with 60 and 43.8% of cows being above the break even point in the rainy and dry seasons, respectively. The marginal profit (184 TSh/cow/day) reported by Urassa (1999) was comparable to 208 Tsh/cow/day obtained in the current study. Similarly, Mlay *et al.* (2005) revealed positive returns when smallholder dairy cattle supplemented with 4 kg per/cow/day of maize bran and minerals (99% maize bran and 1% Super Macklick ®) were compared to those that were supplemented with maize bran mixed with sunflower meal (68% maize bran, 31% sunflower mean plus 1% Super Macklick ®). The marginal profit of 354 Tsh/cow/day (Mlay *et al.*, 2005) was higher than 208 Ths/cow/day realised in the current experiment. The differences in marginal profit between the studies could be due to a range of factors that affect the amount of milk produced and hence affect the revenue from sale of milk such as the nutritional status of animals at the start of experiment and level of supplementation used. Other factors include the cows' genotype and parity since milk production is influenced by genotype (Msanga *et al.*, 2000) and primiparous cows produce less milk than pluriparous ones (Msangi *et al.*, 2001; Meikle *et al.*, 2004). In addition, stage of lactation when milk production was recorded will influence the amount recorded because more milk is produced in early lactation than later (Little, 2004). In addition, differences in prices of milk and concentrate ingredients used will lead to differences in marginal profits between studies.

When the economic analysis in the current study is viewed against levels of productive and reproductive performance in cows and heifers in Rungwe district, it would seem that profits from dairying somehow end up in non-dairy activities. This occurs because dairy farming is part of a complex farming system with numerous income and cost variables affected by dynamic priorities. In addition, farmers in Rungwe like in other poor rural areas might be facing capital constraints that limit the ability to finance the variable costs associated with concentrate supplementation (Rey *et al.*, 1993). Economic theory suggests that farmers facing capital constraints would tend to use lower levels and combinations of inputs than those whose production activities are not limited by capital constraints. Lack of adequate credit facilities is among the constraints to dairy development in Kagera, Iringa and Mbeya regions (Kinsey, 1994; Mwakalile *et al.*, 2002). Access to credit can facilitate levels of input use closer to their potential levels. Production loans from financial institutions can, therefore, lead to higher levels of output per farm and yield given fixed resources such as land (Freeman *et al.*, 1998).

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Main conclusions from the three experiments conducted during the study

Experiment 1 clearly showed that reproductive performance of smallholder dairy cows and heifers was suboptimal as measured by age at puberty, age at first mating and calving interval. It was concluded that poor nutrition, poor heat detection and reproductive diseases and disorders could be the main causes of the suboptimal reproductive performance.

In the monitoring study (Experiment 2) it was found that the reproductive performance was not affected significantly by heat detection and/or reproductive diseases and disorders although there were incidences of dystocia. Levels of calcium, phosphorus, copper and urea nitrogen in blood plasma were lower than expected critical values for the animals, which led to a conclusion that nutritional deficiencies particularly after calving and during the dry season could to a large extent account for the suboptimal reproductive performance of animals. This was further confirmed by the low body condition scores observed during the dry season and after calving in this study. Body condition score at calving proved to be a good predictor of reproductive performance. Body condition score was negatively correlated with number of days from calving to first observed visual oestrus and calving interval.

It was concluded from ME, P, and Cu analyses of pastures that there was a need for concentrate and mineral supplementation of cows and heifers. In addition, concentrate supplementation (Experiment 3) improved plasma urea nitrogen, body condition scores, live body weights, milk production, calf birth weights and reproductive performance of the animals. Simple marginal analysis showed that concentrate supplementation was profitable. However, the level of supplementation in this study was not sufficient to improve the plasma P and Cu concentrations to levels normally recommended for dairy cattle under these conditions.

6.2 Recommendations drawn from the study

i. Since only one level of supplementation was studied it would have been of interest to include more levels in order to come up with clear conclusion in relation to plasma P and Cu concentrations, reproductive performance and profitability.

ii. There were large variations on milk production and calving interval parameters in the present study and this was probably brought about by differences in levels of exotic blood, apart from nutrition and parity of the animals. It is therefore recommended that in future studies the level of exotic blood and its interaction with the other factors be taken into consideration although it is very difficult under farm conditions.

iii. There were no clear reasons for the rather high incidences of dystocia in dairy cattle in Rungwe district and therefore there is a need to identify causative factors to this problem.

iv. Body condition scoring should be introduced to the smallholder farmers in Rungwe district as a simple and practical tool for nutritional management of dairy cattle. An indicative figure of not less than 2.5 body condition score at calving could be used. However, further research is required to establish the optimum body condition score at calving for optimum reproductive performance and milk production in crossbred cattle in Rungwe district

REFERENCES

Adashi, E. Y., Resnick, C. E., D' Ercole, A. J., Svoboda, M. E. and van Wyk, J. J. (1985). Insulin-like growth factors as intraovarian regulators of granulosa cell growth and function. *Endocrine Reviews*. 6, 400-420.

Adesehinwa, A. O. K., Okunola, J. O. and Adewumi, M. K. (2004). Socio-economic characteristics of ruminant livestock farmers and their production constraints in some parts of South-western Nigeria. *Livestock Research for Rural Development*. 16, 8.

AFRC (Agricultural and Food Research Council) (1991). A reappraisal of the calcium and phosphorus requirements of sheep and cattle. Technical Committee on Responses to Nutrients, Report number 6. *Nutrition Abstracts and Reviews* (Series B). 61, 573-612.

AFRC (Agricultural and Food Research Council) (1993). *Energy and protein requirements of ruminants*. An advisory manual prepared by the AFRC Technical Committee on responses to nutrients. (CAB International: Wallingford, UK). pp. 24.

Alejandrino, A. L., Asaad, C. O., Malabayabas, B., De Vera, A. C., Herrera, M. S., Deocaris, C. C., Ignacio, L. M. and Palo, L. P. (1999). Constraints on dairy cattle productivity at the smallholder level in the Philippines. *Preventive Veterinary Medicine*. 38, 167-178.

Allrich, R. D. (1994). Endocrine and neural control of estrus in dairy cows. *Journal of Dairy Science*. 77, 2738-2744.

Alonso, M. L., Benedito, J. L., Miranda, M, Castillo, C., Hernández, J. and Shore, R. F. (2000). Arsenic, cadmium, lead, copper and zinc in cattle from Galicia, NW Spain. *The Science of the Total Environment*. 246, 237-248.

Aminah, A. and Chen, C. P. (1989). Future prospects for fodder and pasture production. Feeding dairy cows in the tropics. FAO animal production and health paper 86. *Proceedings of the FAO expert consultation held in Bangkok*, Thailand 7-8 July, 1989.

Anderson, S. J., J. K. Merrill, and T. J. Klopfenstein. (1988). Soybean hulls as an energy supplement for the grazing ruminant. *Journal of Animal Science*. 66, 2959.

AOAC (Association of Official Analytical Chemists). (1990). *Official Methods of Analysis*. 15th Ed., Arlington, VA. pp. 42

ARC, (Agricultural Research Council), (1990). *Nutrient requirements of ruminant livestock*. 4th Ed. CAB International, Wallingford, UK. pp. 82.

Ariaga-Jordán, C. M., Flores-Gallegos, F. J., Peña-Carmona, G., Albarrán-Portillo, B., García-Martínez, A., Espinoza-Ortega, A., González-Esquivel, C. E. and

Castelán-Ortega, O. A. (2001). Participatory on-farm evaluation of the response to concentrate supplementation by cows in early lactation in smallholder peasant (*campesino*) dairy production systems in the highlands of central Mexico. *Journal of Agricultural Science, Cambridge*. 137, 97-103.

Arije, G. R., Wiltbank, J. N. and Hopwood, M. J. (1974). Hormone levels in pre- and postparturient beef cows. *Journal of Animal Science*. 39, 338-347.

Armstrong, D. V. (1994). Heat stress interactions with shade and cooling. *Journal of Dairy Science*. 77, 2044-2050.

Armstrong, D. G. and Hansel, W. (1959). Alteration of the bovine estrous cycle with oxytocin. *Journal of Dairy Science*. 42, 533-542.

Arthington, J. D., Pate, F. M. and Spears, J. W. (2003). Effect of copper source and level on performance and copper status of cattle consuming molasses-based supplements. *Journal of Animal Science*. 81, 1357-1362.

Arthur, G. H., Noakes, D. E. and Pearson, H. (1989). *Veterinary Reproduction and Obstetrics (Theriogenology)*. 6th Ed., London, United Kingdom, Bailliere Tindall. pp. 641.

Assey, R. J., Kessy, B. M., Matovelo, J. A. and Minga U. (1998). Incidence of gross reproductive abnormalities in small east African zebu cattle. *Tropical Animal Health and Production*. 30, 361-368.

Babbie, E. R. (1990). *Survey Research Methods*. Wadsworth Publishing Co. Belmont California. pp. 395.

Balikowa, D. (1997). Reproductive and lactation performance of dairy cattle on smallholder farms in Iringa and Mbeya regions. Unpublished Dissertation for Award of Msc degree at Sokoine University of Agriculture, Morogoro, Tanzania.

Barr, H. L. (1975). Influence of estrus detection on days open in dairy herds. *Journal of Dairy Science*. 58, 246-247.

Bareeba, F. B. and Samaanya, J. P. (2002). Effect of seasonality of feed resources on milk production under zero grazing system in Uganda. *Proceedings of the joint 17th Scientific Conference of the Tanzania Society for Animal Production and the 20th Scientific Conference of the Tanzania Veterinary Association, AICC-Arusha, December 3rd –5th*. pp. 183-189.

Bauer, B., Galdo, E., McDowell, L. R., Koger, M., Loosli, J. K. and Conrad, J. H. (1982) Mineral status of cattle in tropical lowlands of Bolivia. In: *Trace Element Metabolism in Man and Animals*. Gawthorne, J M., Jowell, J. M. and White, C. L. (Eds). Berlin, Springer. pp. 50-53

Beam, S. W., and Butler, W. R. (1997). Energy balance and ovarian follicle development prior to the first ovulation postpartum in dairy cows receiving three levels of dietary fat. *Biology of Reproduction.* 56, 133-142.

Beam, S. W. and Butler, W. R. (1999). Effects of energy balance on follicular development and first ovulation in postpartum dairy cows. *Journal of Reproduction and Fertility. Supplement.* 54, 411-424.

Bebe, B. O., Udo, H. M. J., Rowlands, G. J. and Thorpe, W. (2003). Smallholder dairy systems in the Kenyan highlands: breed preferences and breeding practices. *Livestock Production Science.* 82, 117-127.

Beede, D. K. (1995). Macromineral element nutrition for the transition cow: practical implications and strategies. *Proceedings of Tri-State Nutrition Conference.* Eastridge, M. L. (Ed). The Ohio state university. Columbus. pp. 175.

Beede, D. K. and Davidson, J. A. (1999). Phosphorus: Nutritional management for Y2K and beyond. *Proceedings of Tri-State Nutrition Conference. April 20-21, 1999* Eastridge, M. L. (Ed). The Ohio state university. Columbus. pp. 51.

Bell, A. W. (1995). Regulation of organic nutrient metabolism during transition from late pregnancy to early lactation. *Journal of Animal Science.* 73, 2804-2819.

Bellows, R. A., Short, R. E., Anderson, D. C., Knapp, B. W. and Pahnish, O. F. (1971). Cause and effect relationships associated with calving difficulty and calf birth weight. *Journal of Animal Science.* 33, 407-415.

Bellows, R. A., Short, R. E. and Richardson, G. V. (1982). Effects of sire, age of dam and gestation feed level on dystocia and postpartum reproduction. *Journal of Animal Science.* 55, 18-27.

Bereskin, B. and Touchberry, R. W. (1967). Some effects of pregnancy on body weight and paunch girth. *Journal of Dairy Science.* 50, 220-224.

Bernard, J. and Carlisle, R. J. (1999). Effect of concentrate feeding level on production of Holstein cows grazing winter annuals. *The Professional Animal Scientist.* 15, 164-168.

Bertics, S. J., Grummer, R. R., Cadorniga-Valino, C. and Stoddard, E. E. (1992). Effect of prepartum dry matter intake on liver triglyceride concentration and early lactation *Journal of Dairy Science.* 75, 1914-1922.

Bierschwal, C. J., Gaverick, H. A., Martin, C. E., Youngquist, R. S., Cantley, T. C. and Brown, M, D. (1975). Clinical response of dairy cows with ovarian cysts to GnRH. *Journal of Animal Science.* 41, 1660-1665.

Block, S. S., Butler, W. R., Ehrhardt, R. A., Bell, A. W., Van Amburgh, M. E. and Boisclair, Y. R. (2001). Decreased concentration of plasma leptin in periparturient dairy cows is caused by negative energy balance. *Journal of Endocrinology*. 171, 339-348.

Blood, D. C. and Radostits, O. M. (1989). *Veterinary Medicine*. A textbook of diseases of cattle, sheep, pigs and horses. 7th Ed., Bailliere Tindal, London. pp. 1172.

Boodoo, A. A., Boodhoo, K., Toolsee, P., Saraye, G. and Rangasamy, M. (1999). Improving the productivity of dairy cows on smallholder farms in Mauritius through studies on nutrition and reproduction. *Proceedings of the final Research Co-ordination Meeting of a Co-ordinated Research Project organised by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna, Austria, 7-11 September*. IAEA-TECDOC-1102. pp. 45-55.

Borle, A. B. (1974). Calcium and phosphate metabolism. *Annual Review of Physiology*. 36, 361-390.

Braun, W. F. (1980). A review of prostaglanding therapeutics in reproduction. *Veterinary Medicine Small Animal Clinics*. 75 (4), 649-656.

Breves, G., Ross, R. and Holler, H. (1985). Dietary phosphorus depletion in sheep: effects on plasma inorganic phosphorus, calcium, 1,25-$(OH)_2$-Vit. D and alkaline phosphatase and on gastrointestinal P and Ca balances. *Journal of Agricultural Science, Cambridge*. 105, 623-629.

Britt, J. H. (1992). Impacts of early postpartum metabolism on follicular development and fertility. *The Bovine Practitioner*. 24, 39-43.

Britt, J. H., Scott, R. G., Armstrong, J. D. and Whitacre, M. D. (1986). Determinants of estrous behavior in lactating Holstein cows. *Journal of Dairy Science*. 69, 2195-2202.

Brown, E. M. (1991). Extracellular Ca^{2+} sensing, regulation of parathyroid cell function and role of Ca^{2+} and other ions as extracellular (first messengers). *Physiological Reviews*. 71, 371-411.

Brumby, P. J. and Sholtens, R. G., (1986). *Management and health constraints of small-scale dairy production in Africa*. ILCA Bulletin No. 25, International Livestock Centre for Africa, Addis Ababa, Ethiopia, pp. 9-12.

Buvanendran, V., Olayiwole, M. B. and Piotrowska, K. I. (1981). A comparison of milk production traits in Friesian x White Fulani crossbred cattle. *Animal Production*. 32, 165-170.

Buskirk, D. D., Lemenager, R. P. and Horstman, L. A. (1992). Estimation of net energy requirements (NE_m and NE) of lactating beef cows. *Journal Animal Science*. 70, 3867.

Butcher, J. E., Call, J. W., Blake, J. T. and Shupe, J. L. (1979). Dietary phosphorus levels can cause problems in beef cows. *Journal of Animal Science*. 49 (Supplement 1), 359.

Butler, W. R. (1998). Review: effect of protein nutrition on ovarian and uterine physiology in dairy cattle. *Journal of Dairy Science*. 81, 2533-2539.

Butler, W. R. (2000). Nutritional interactions with reproductive performance in dairy cattle. *Animal Reproduction Science*. 60-61, 449-457.

Butler, W. R. and Smith, R. D. (1989). Interrelationships between energy balance and postpartum reproductive function in dairy cattle. *Journal of Dairy Science*. 72, 767-783.

Butler, W. R., Calaman, J. J. and Beam, S. W. (1996). Plasma and milk urea nitrogen in relation to pregnancy rate in lactating dairy cattle. *Journal of Animal Science*. 74, 858-865.

Butler, W. R., Cherney, D. J. R. and Elrod, C. C. (1995). Milk urea nitrogen (MUN) analysis: Field trial results on conception rates and dietary inputs. *Proceedings of Cornell Nutrition Conference for Feed Manufacturers*. Cornell University, Ithaca, NY. pp. 89.

Butler, W. R., Everett, R. W. and Coppock, C. E. (1981). The relationships between energy balance, milk production and ovulation in postpartum Holstein cows. *Journal of Animal Science*. 53, 742-748.

Bwire, J. M. N. and Wiktorsson, H. (1996). Pre-weaning nutritional management and dry season nutritional supplementation on intake, growth and onset of puberty of improved Zebu heifers. *Livestock Production Science*. 46, 229-238.

Call, J. W., Butcher, J. E., Blake, J. T., Smart, R. A. and Shupe, R. L. (1978). Phosphorus influence on growth and reproduction of beef cattle. *Journal of Animal Science*. 47, 216-225.

Call, J. W., Butcher, J. E., Shupe, J. L., Blake, J. T.and Olson, A. E. (1986). Dietary phosphorus for beef cows. *American Journal of Veterinary Research*. 47, 475-481.

Call, J. W., Butcher, J. E., Shupe, J. L., Lamb, R. C., Boman, R. L. and Olson. A. E. (1987). Clinical effects of low dietary phosphorous concentrations in feed given to lactating dairy cows. *American Journal of Veterinary Research*. 48, 133-136.

Canfield, R. W. and Butler, W. R. (1991). Energy balance, first ovulation and the effects of naloxone on LH secretion in early postpartum dairy cows. *Journal of Animal Science*. 69, 740-746.

Canfield, R. W., Sniffen, C. J. and Butler, W. R. (1990). Effects of excess degradable protein on postpartum reproduction and energy balance in dairy cattle. *Journal of Dairy Science*. 73, 2342-2349.

Carruthers, T. D. and Hafs, H. D. (1980). Suckling and four-times daily milking: influence on ovulation, estrus and serum luteinizing hormone, glucocorticoids and prolactin in postpartum Holsteins. *Journal of Animal Science*. 50, 919-925.

Carson, A. F., Dawson, L. E. R., McCoy, M. A., Kilpatrick, D. J. and Gordon, F. J. (2001). Effects of rearing regime on body size, reproductive performance and milk production during the first lactation in high genetic merit dairy herd replacements. *Animal Science*. 74, 553-565.

Caton, J. S. and Dhuyvetter, D. V. (1997). Influence of Energy Supplementation on Grazing Ruminants:Requirements and Responses. *Journal of Animal Science*. 75, 533-542.

Cecava, M. J. (1995). Rumen physiology and energy requirements. In: *Beef Cattle Feeding and Nutrition*. 2nd Ed. Perry, T. W. and Cecava, M. J. (Eds.), Academic Press, San Diego, CA. pp. 3-24.

Chagas, L. M., Morgan, S. R., Gore, P. J. S., Clark, B. A. and Verkerk, G. A. (2000). Postpartum anoestrous interval and metabolic changes in heifers supplemented with pasture pre-partum. *Proceedings of the New Zealand Society of Animal Production*. 61, 188-191.

Chalya, J. N. (1998). Dairy feeding systems, feed and manure management. Research review no. 6. In: *The Tanzanian dairy sub-sector, Reviews of potential dairy research thrusts and sites following a rapid appraisal*. pp. 18.

Chandler, P. (1995).Transition period of cows presents unique challenges to nutritionists. *Feedstuffs*. 67, 11.

Chongkasikit, N., Aussawin, S., Vearasilp, T. and Langholz, H-J. (2003). Body condition and body weight in Northern Thai dairy cattle. Deutscher Tropentag, October 8-10, 2003. Göttingen.

Chopra, C. S. (1990). Comparative performance of half-breds of Holstein, Friesian, Brown Swiss and Jersey with Hariana in Semi-arid tropics. *Indian Journal of Animal Sciences*. 60, 93-96.

Chudleigh, P. (1974). *Description of smallholder ruminant production systems in the high potential areas of Kenya*. Project Report no. 4. National Agricultural Research Station, Kitale, Kenya.

Coates, D. B. and Ternouth, J. H. (1992). Phosphorus kinetics of cattle grazing tropical pastures and implications for the estimation of their phosphorus requirements. *Journal of Agricultural Sciences, Cambridge*. 119, 401-409.

Cohen, R. D. H. (1980). Phosphorus in rangeland ruminant nutrition: a review. *Livestock Production Science*.7, 25-37.

Coleman, D. A., Thane, W. V. and Dailey, R. A. (1985). Factors affecting reproductive performance of dairy cows. *Journal of Dairy Science*. 68, 1793-1803.

Corah, L. R., Dunn, T. G. and Kaltenbach, C. C. (1975). Influence of prepartum nutrition on the reproductive performance of beef females and the performance of their progeny. *Journal of Animal Science*. 41, 819.

Cornelia, K. and Barry, Y. (2000). *Effects of Nutrition on Beef Cow Reproduction*. Alberta Agriculture. Agdex 420/51-1.

Correa, M. T., Curtis, C. R., Erb, H. N., Scarlett, J. M. and Smith, R. D. (1990). An ecological analysis of risk factors for postpartum disorders of Holstein-Friesian cows from thirty-two New York farms. *Journal of Dairy Science*. 73, 1515-1524.

Cunnigham, J. G. (Ed) (1992). *A text book of Veterinary Physiology*. W. R. Saunders company, United States of America. pp. 350-400.

Dachir, S., R. W. Blake, and P. G. Harms. (1984). Ovarian activity of Holstein and Jersey cows of diverse transmitting abilities for milk. *Journal of Dairy Science*. 67, 1776-1782.

Dalal, D. S., Arora, K. C. and Rathi, S. S. (1990). Factors affecting herd life production and first lactation traits in crossbreed dairy cattle. *International Journal of Tropical Agriculture*. 8, 89-92.

Das, S. M., Forsberg, M. and Wiktorsson, H. (1999). Influence of restricted suckling and level of feed supplementation on postpartum reproductive performance of zebu and crossbred cattle in the semi-arid tropics. *Acta Veterinaria Scandinavica*. 40, 57-67.

De Kruif, A. and Brand, A. (1978). Factors influencing the reproductive capacity of a dairy herd. *New Zealand Veterinary Journal*. 178, 183-189.

De Vries, M. J., Van der Beek, S., Kaal-Lansbergen, L. M. T. E., Ouweltjes, W. and Wilmink. J. B. M. (1999). Modeling of energy balance in early lactation and the effect of energy deficits in early lactation on first detected estrus postpartum in dairy cows. *Journal of Dairy Science*. 82, 1927-1934.

De Vries, M. J. and Veerkamp R. F (2000). Energy balance of dairy cattle in relation to milk production. *Journal of Dairy Science*. 83, 62-69.

De Wit, A. A., Cesar, M. L. and Kruip, T. A. (2001). Effect of urea during in vitro maturation on nuclear maturation and embryo development of bovine cumulus-oocyte-complexes. *Journal of Dairy Science*. 84, 1800-1804.

De Wit, J. N. (1990). Interactions of milk components with other ingredients in food systems. *Proceedings of the XXIII international Dairy congress. October 8-12, 1990*, Montreal Canada. Dairying in changing World. pp.1437-1447.

De Wolf, J. T. (1997). Heifer in Trust Schemes. In: *Proceedings of the 24th Scientific Conference of the Tanzania Society of Animal Production, LITI-Tengeru, Arusha*, August 5th - 7th. 24, 105-114.

Dhiman, T. R., Satter, L. D. and Shaver, R. D. (1995). Milk production and blood phosphorus concentrations of cows fed low and high dietary phosphorus. *Research Summaries*, U.S. Dairy Forage Research Center, Madison, WI. pp. 105.

Dickey, J. F., Henrick, D. M. and Bierly, S. (1975). Hormonal relationship in postpartum Holstein cows. *Journal of Animal Science*. 41, 348-352.

Diehl, J. R. and Day, B. N. (1974). Effect of prostaglanding F2 alpha on luteal function in swine. *Journal of Animal Science*. 39 (2), 392-396.

Dillon, J. and Hardaker, J. B. (1980). *Farm management research for small farmer development*. FAO Agricultural Services Bulletin, no 41, Rome. 20pp.

Dixon, R. M., and Stockdale, C. R. (1999). Associative effects between forages and grains: consequences for feed utilization. *Australian Journal of Agricultural Research*. 50, 757-773.

Domecq, J. J., Skidmore, A. L., Lloyd, J. W. and Kaneene, J. B. (1997). Relationship between body condition scores and milk yield in a large dairy herd of high yielding Holstein cows. *Journal of Dairy Science*. 80, 101-112.

Donna, M., Phillips, A. and Jr. Heersche, G. (1997). Role of nutrition on reproductive performance. Cooperative extension service, University of Kentucky. ASC-138. http://www.ca.uky.edu/agc/pubs/asc/asc138/asc138.pdf (Accessed in December, 2004)

Dorshorst, M. E. and Grummer, R. R. (2002). Effects of day relative to parturition and dietary crude protein on rumen fermentation in prepartum transition cows. *Journal of Dairy Science*. 85, 2290-2298.

Doto, S. P., Kimambo, A. E., Mgheni, D. M., Mtenga, L. A., Laswai, G. H., Kurwijila, L. R., Pereka, A. E., Kombe, R. A., Weisbjerg, M. R., Hvelplund, T., Madsen, J. and Petersen, P, H. (2004). Tanzania Feedstuff Table for Ruminants. ENRECA (SUA-MU/RVAU-DIAS) and ASLIP Projects.

Duby, R. T. and Prange, R. W. (2003). Physiology and endocrinology of the estrous cycle. Dairy Integrated Reproductive Management. IRM-2. West Virgina University Extension service. http://www.wvu.edu/~exten/infores/pubs/livepoul/dirm2.pdf (Accessed in June, 2004).

Duraes, M. C. and Keown, J. F. (1991). Age-month factors-mature equivalent factors for three yield traits for non-registered and registered cattle. *Revista Brasileira de Genetica.* 14:713.

Durand, M. and Kawashima, R. (1980). Influence of minerals in rumen microbial digestion. In: Digestive Physiology and Metabolism in Ruminants. Ruckebusch, Y. and Thivend, P. (Eds.). MTP press Ltd., Lancaster, England. pp. 375-408.

Eckles, C. H. (1976). The nutrients required to develop the bovine fetus. University of Missouri Agriculture Experimental Station. Research Bulletin. pp. 26.

Eicher, R., Bouchard, E. and Tremblay, A. (1999). Cow level sampling factors affecting analysis and interpretation of milk urea concentrations in 2 dairy herds. *Canadian Veterinary Journal.* 40, 487-492.

Emery, R. S., Liesman, J. S. and Herdt, T. H. (1992). Metabolism of long chain fatty acids by ruminant liver. *Journal of Nutrition.* 122, 832-837.

Engels, E. A. N. (1981). Mineral status and profiles (blood, bone and milk) of the grazing ruminant with special reference to calcium, phosphorus and magnesium. *South African Journal of Animal Science.* 11, 171.

Engle, T. E. and Spears, J. W. (2000a). Effects of dietary copper concentration and source on performance and copper status of growing and finishing steers. *Journal of Animal Science.* 78, 2446-2451.

Engle, T. E. and Spears, J. W. (2000b). Dietary copper effects on lipid metabolism, performance, and ruminal fermentation in finishing steers. *Journal of Animal Science.* 78, 2452-2458.

Ensminger, M. E. and Perry, R. C. (1998). *Beef Cattle Science* (7th Ed.) Interstate Publishers, Inc., Danville, IL. pp. 45-50.

Esslemont, R. J. (1979). Management with special reference to fertility. In: *Feeding strategy for the high yielding dairy cow.* Broster and Swan, Crosby Lockwood. pp. 258-294.

Esslemont, R. J. (1992). Measuring dairy herd fertility. *Veterinary Record.* 131, 209-212.

Faye, B., Grillet, C., Tessema, A. and Kamil, M. (1991). Copper deficiency in ruminants in the rift valley of East Africa. *Tropical Animal Health and Production.* 23, 172-180.

Ferguson, J. D. (1989). Meeting the Challenges of New Technology. *Monsanto Technical Symposium preceding the Cornell Nutrition Conference.* Monsanto Agricultural Co., St. Louis, MO. pp. 39.

Ferguson, J. D., Blanchard, T., Hoshall, D., Galligan, D. T. and Chalupa, W. (1988). High rumen degradable protein as a possible cause of infertility in a dairy herd. *Journal of American Veterinary Medical Association*. 192, 659-662.

Ferguson, J. D. and Chalupa, W. (1989). Impact of protein nutrition on reproduction in dairy cows. *Jornal of Dairy Science*. 72, 746-766.

Ferguson, J. D., and Otto, K. A. (1989). Managing body condition in dairy cows. *Proceedings of Cornell Nutrition Conference*. Syracuse, NY. Cornell University, Ithaca, NY. pp. 75-87.

Fisher, L. J., Hall, J. W. and Jones, S. E. (1984). Weight and age at calving and weight change related to first lactation milk yield. *Journal of Dairy Science*. 66, 2167-72.

Field, T. G. (1990). Genetic prediction of mature weight in Hereford females. Unpublished Thesis for Award of PhD degree at Colorado State University, Fort Collins, USA.

Fonseca, F. A., Britt, J. H., McDaniel, B. T., Wilk, J. C. and Rakes, A. H. (1983). Reproductive traits of Holstein and Jersey: Effects of age, milk yield, and clinical abnormalities on involution of cervix and uterus, ovulation, estrous cycles, detection of estrus, conception rate and days open. *Journal of Dairy Science*. 66, 1128-1147.

Forar, F. L., Kincaid, R. L. Preston, R. L. and Hillers, J. K. (1982). Variation of inorganic phosphorus in blood plasma and milk of lactating cows. *Journal of Dairy Science*. 65, 760-763.

Fouricho, C., Seegers, H. and Malher, X. (2000). Effect of disease on reproduction in the dairy cow: A meta-analysis. *Theriogenology*. 53, 1729-1759.

Fowden, A. L. (1989). The endocrine regulation of fetal metabolism and growth. In: *Research in Perinatal Medicine*. Gluckman, P. D., Johnston, B. M. and Nathanielsz, P. W. (Eds.), Advances in Fetal Physiology, Perinatology Press, Ithaca, NY. 8, 229-243.

Francis, J. and Sibanda, S. (2001). Participatory action research experiences in smallholder dairy farming in Zimbabwe. *Livestock Research for Rural Development*. 13, 3.

Francos, G. and Meyer, E. (1988). Analysis of indices of cows with extended postpartum anoestrus and other reproductive disorders compared to normal cows. *Theriogenology*. 29, 399-412.

Freeman, H. A., Simeon, K. E. and Mohammad, A. J. (1998). Credit constraints and smallholder dairy production in the East African highlands: application of a switching regression model. *Agricultural Economics*. 19, 33-44.

Gangwar, P. C., Branton, C., and Evans, D. L. (1965). Reproductive and physiological responses of Holstein heifers to controlled and natural climatic conditions. *Journal of Dairy Science*. 48, 222.

Garcia-Bojalil, C. M., Staples, C. R., Risco, C. A., Savio, J. D. and Thatcher, W. W. (1998). Protein degradability and calcium salts of long-chain fatty acids in the diets of lactating dairy cows: reproductive responses. *Journal of Dairy Science*.81, 1385-1395.

Gengelbach, G. P., Ward, J. D., Spears, J. W. and Jr. Brown, T. T. (1997). Effects of copper deficiency and copper deficiency coupled with high dietary iron or molybdenum on phagocytic cell function and response of calves to a respiratory disease challenge. *Journal of Animal Science*. 75, 1112-1118.

Ginther, O. J., Wiltbank, M. C., Fricke, P. M., Gibbons, J. R. and Kot, K. (1996). Selection of the dominant follicle in cattle. *Biology of Reproduction*. 55, 1187-1194.

Glauber, C. E. Lagger, J. and Recoulat, A. (1993). Effect of supplementation with injectable phosphorus on the reproductive performance in dairy cows. Phosphataemia evaluation. *Veterinaria-Argentina*. 10, 462-465.

Goehring, T. B., Corah, L. R. and Higgins, J. J. (1989). Effect of energy and lasalocid on productivity of first calf beef heifers. *Journal of Animal Science*. 67, 1879-1888.

Goff, J. P. (1992). Cation-anion difference of diets and its influence on milk fever and subsequent lactation: the good and the bad news. *Proceedings of Cornell Nutrition conference*. pp. 148.

Goff, J. P. (1999). Mastitis and retained placenta-relationship to bovine immunology and nutrition. In: *Advances in Dairy Technolonogy*. Kennelly, J. (Ed). University of Alberta, Edmonton. 11, 185-192.

Goff, J. P., Kimura, K. and Horst, L. R. (2002). Effect of mastectomy on milk fever, energy, and vitamins A, E, and ß-carotene status at parturition. *Journal of Dairy Science*. 85, 1427-1436.

Gonzalez-Padilla, E., Wiltbank, J. N. and Niswender, G. D. (1975). Puberty in beef heifers. I. The interrelationship between pituitary, hypothalamic and ovarian hormones. *Journal of Animal Science*. 40, 1091.

Grace, N. D. and Clark, R. G. (1991). Trace element requirements, diagnosis and prevention of deficiencies in sheep and cattle. In: Physiological Aspects of Digestion and Metabolism in Ruminants. Tsuda, T., Sasaki, Y. and Kawashima, R. (Eds) *Proceedings of the Seventh International Symposium on Ruminant Physiology*, Academic Press, Tokyo. pp. 321-346.

Grainger, C., Wilhelms, G. D. and McGowan, A. A. (1982). Effect of body condition at calving and level of feeding in early lactation on milk production of dairy cows. *Australian Journal of Experimental Agriculture and Animal Husbandry*. 22, 9-17.

Grigsby, K. N., Rouquette, Jr. F. M., Ellis, W. C. and Hutcheson, D. P. (1991). Use of self-limiting fishmeal and corn supplements for calves grazing rye-ryegrass pastures. *Journal of Production Agriculture*. 4, 476.

Grummer, R. R., (1997). Transition feeding: impact on fertility, milk production and post-calving disorders. In: "Future feeding today". *Proceedings of a dairy seminar by Ridley Agriproducts*. pp. 77-88.

Guedon, L., Saumande, J. and Desbals, B. (1999). Relationships between calf birth weight, prepartum concentrations of plasma energy metabolites and resumption of ovulation postpartum in Limousine suckled beef cows. *Theriogenology*. 52, 779-789.

Guerouali, A. (1999). Improving the productivity of imported dairy cattle on small-holder farms in Morocco through supplementation with fish silate blocks. *Proceedings of the final Research Co-ordination Meeting of a Co-ordinated Research Project organised by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna, Austria, 7-11 September*. IAEA-TECDOC-1102. pp. 67-77.

Gunn, K. J. and Ternouth, J. H. (1994). The effect of phosphorus deficiency upon ruminal microbial activity and nitrogen lambs. *Proceedings of Australian Society of Animal Production*. 20, 445.

Gustafsson, A. H. and Palmquist, D. L. (1993). Diurnal variation of rumen ammonia, serum urea, and milk urea in dairy cows at high and low yields. *Journal of Dairy Science*. 76, 475.

Hafez, E. S. (Ed.) (1980). *Reproduction in farm animals*. 4th Ed., Balliere Tindal, London. 627pp.

Hammond, A. C. (1983). The use of blood urea nitrogen concentration as an indicator of protein status in cattle. *The Bovine Practictioner*. 18, 114-118.

Hardie, A. R. and Ax, R. L. (1981). A 40-year survey fo cystic ovaries in dairy cows. *Journal of Dairy Science*. 64 suppliment I. pp. 149.

Harmon, R. J. and Torre, R. M. (1994). Copper and zinc: Do they influence mastitis? In: *Proceedings of the 33rd annual meeting of the National Mastitis Council, Orlando, Florida*. National Mastitis Council, Inc., Arlington, VA, USA. pp. 54.

Heap, R. B., Gwyn, M., Laing, J. A. and Walters, D. E. (1973). Pregnancy diagnosis in cows. Changes in milk progesterone concentration during the oestrous cycle and pregnancy measured by a rapid radioimmunoassay. *Journal of Agricultural Sciences*. 81, 151-157.

Helmer, S. D., and. Britt, J. H. (1985). Mounting behavior as affected by stage of estrous cycle in Holstein heifers. *Journal of Dairy Science*. 68, 1290-1296.

Hemken, R.W., Clark, T. W. and Du, Z. (1993). Copper: Its Role in Animal Nutrition. In: *Biotechnology in the Feed Industry*. Lyons, T. (Ed.), Altech Technical Publications, Nicholasville, KY. pp. 35-39.

Herd, D. B. (1994). Identifying copper deficiencies under field conditions. *Procceedings of Florida Ruminant Nutrition Symposyum*. pp. 76.

Hernandez, J., Risco, C. A., Elliott, J. B. (1999). Effect of oral administration of a calcium chloride gel on blood mineral concentrations, parturient disorders, reproductive performance, and milk production of dairy cows with retained fetal membranes. *Journal of American Veterinary Medical Association*. 215, 72-76.

Higginbotham, G. E., Torabi, M. and Huber, J. T. (1989). Influence of dietary protein concentration and degradability on performance of lactating cows during hot environmental temperatures. *Journal of Dairy Science*. 72, 2554-2564.

Hof, G., Vervoorn, M. D., Lenaers, P. J. and Tamminga, S. (1997). Milk urea nitrogen as a tool to monitor the protein nutrition of dairy cows. *Journal of Dairy Science*. 80, 3333-3340.

Hogan, J. S., Weiss, W. P. and Smith, K. L. (1996). Nutrition and mammary host defences against diseases in dairy cattle. In: *Progress in Dairy Science*. Phillips, C. J. C. (Ed.) CAB Int., Wallingford, UK. pp. 45-57.

Holland, M. D. and Odde, K. G. (1992). Factors affecting calf birth weight: A review. *Theriogenology*. 38, 769-798.

Horn, G. W., Cravey, M. D., McCollum, F. T., Strasia, C. A., Krenzer, E. G. and Claypool, P. L. (1995). Influence of high-starch vs high-fiber energy supplements on performance of stocker cattle grazing wheat pasture and subsequent feedlot performance. *Journal of Animal Science*. 73, 45-54.

Horst, R. L. (1986). Regulation of calcium and phosphorus homeostasis in the dairy cow. *Journal of Dairy Science*. 69, 604-616.

Horst, R. L. and Jorgensen, N. A. (1982). Elevated plasma cortisol during induced and spontaneous hypocalcemia in ruminants. *Journal of Dairy Science*. 65, 2332-2337.

Horst, R. L., DeLuca, H. F. and Jorgensen, N. A. (1978). The effect of age on calcium absorption and accumulation of 1,25-dihydroxyvitamine D3 in intestinal mucosa of rats. *Metabolic Bone Disease and Related Research*. 1, 29-33.

Horst, R. L., Goff, J. P. and Reinhardt, T. A. (1990). Advancing age results in reduction of intestinal and bone 1,25-dihydroxyvitamine D receptor. *Endocrinology*. 126, 1053-1057.

Horst, R. L., Goff, J. P., Reinhardt, T. A. and Buxton, D. R. (1997). Strategies for preventing milk fever in dairy cattle. *Journal of Dairy Science*. 80, 1269-1280.

Houe, H., Ostergaard, S., Thilsing-Hansen, T., Jorgensen, R. J., Larsen, T., Sorensen, J. T., Agger, J. F., Blom, J. Y., (2001). Milk fever and subclinical hypocalcaemia. An evaluation of parameters on diagnosis, risk factors and biological effects as input for a decision support system for disease control. *Acta Veterinaria Scandinavia*. 42, 1-29.

House, W. A. and Bell, A, W. (1993). Mineral Accretion in the Fetus and Adnexa During Late Gestation in Holstein Cows. *Journal of Dairy Science*. 76, 2999-3010.

Houterman, J. F., Dummer, R. M., Lutalala, E. M. and de Wolf, J. T. (1993). Quantitative aspects of heifer-in-trust credit schemes: The Kagera experience. *Proceedings of the 20th Scientific Conference of the Tanzania Society of Animal Production, AICC-Arusha, August 16th -18th*. 20, 168-188.

Huntington, G. B. and Archibeque, S. L. (1999). Practical aspects of urea and ammonia metabolism in ruminants. Proceedings of the American Society of Animal Science, 1999. http://www.asas.org/jas/symposia/proceedings/0939.pdf. Accessed in Jan. 2005.

Hurnik, J. F., King, G. J. and Robertson, H. A. (1975). Estrous and related behaviour in postpartum Holstein cows. *Applied Animal Ethology*. 2, 55-68.

Hurwitz, S. (1996). Homeostatic control of plasma calcium concentration. *Critical Reviews in Biochemistry and Molecular Biology*. 31, 41-100.

Huszenicza, G., Haraszti, J., Molnár, L., Solti, L., Fekete, S., Ekés, K. and Yaro. A. C. (1988). Some metabolic characteristics of dairy cows with different postpartum ovarian function. *Journal of Veterinary Medicine*. 35, 506-515.

Huszenicza, G., Molnar, L., Solti, L. and Haraszti, J. (1987). Postpartal ovarian function in Holstein and crossbred cows on large scale farms in Hungary. *Journal of Veterinary Medicine*. 34, 249-263.

Huyler, M. T., Kincaid, R. L. and Dostal, D. F. (1999). Metabolic and Yield Responses of Multiparous Holstein Cows to Prepartum Rumen-Undegradable Protein. *Journal of Dairy Science*. 82, 527–536.

ILCA, (1981). Dairy development. *ILCA bulletin no 11*. Report on a workshop on smallholder development in the East African highlands. Addis Ababa, 25th –29th August, 1980.

Ingco, M. D., Mitchell, D. O. and McCalla, A. F. (1996). Global food supply prospects: A background paper prepared for the world food summit, Rome. November, 1996. World bank technical paper no. 353. Washington DC.

Iwama, Y., Kamiya, M., Tanaka, M. and Shioya, S. (2004). The change of dry matter intake, milk yield and bone turnover in primiparous cows compared to multiparous cows during early lactation. *Animal Science Journal*.75, 213.

Izaike, Y. (1990). Effects of suckling stimulation and milk yield on postpartum ovarian activity and uterine involution n grazing beef cows. *Japan Agricultural Research Quarterly*. 24, 209-215.

Jainudeen, M. R. and Hafez, E. S. E. (1987). Cattle and water buffalo In: *Reproduction in farm animals*. Hafez, E. S. E. (Ed.), Lea and Febiger, Philadelphia (1987). pp. 297-314.

Janowski, T., Raŕ, A., Chmiel, J. and Zduńczyk, S. (1986). Influence of suction on the activity of ovaries in cows after parturition determined on the basis of the level of progesterone in the blood (Translated title). *Medizinische Welt*. 6, 365-367.

Jenkins, T.G., and Ferrell, C. L. (1983). Nutrient requirements to maintain weight of mature, nonlactating, nonpregnant cows of four diverse breed types. *Journal of Animal Science*. 56, 761.

Johnson, I.D. (1988). The effect of prepubertal nutrition on lactation performance by dairy cows. In: Nutrition and lactation in the dairy cow. Garnsworthy, P. C. (Ed.). *Proceedings of the 46th University of Nottingham Easter School in Agricultural Science*. pp. 171-192.

Jonsson, N. N., Pepper, P. M., Daniel, R. C. W., McGowan, M. R. and Fulkerson. W. (1999). Associations between non-parturient postpartum hypocalcemia and the interval from calving to first ovulation in Holstein-Friesian cows. *Animal Science*. 68, 377-383.

Jordan, E. R., Chapman, T. E., Holtan, P. E. and Swanson, L. V. (1983). Relationships of dietary crude protein to composition of uterine secretions and blood in high-producing postpartum dairy cows. *Journal of Dairy Science*. 66, 1854-1862.

Joubert, D. M. and Hammond, J. A (1958). Crossbreeding experiment with cattle, with special reference to the maternal effect in South Devon-Dexter crosses. *Journal of Agricultural Science*. 51, 325-341.

Kaneko, J. J. (Ed.) (1989). Clinical Biochemistry of Domestic Animals. 4th Ed. Academic Press Inclusion, United States of America, 750-800.

Kanuya, N. L.and Greve, T. (2000). Effect of parity, season and FSH treatment on the calving interval of Ayrshire cows in the tropics. *Tropical Animal Health and Production*. 32, 197-204.

Kanuya, N. L., Kessy, B. M., Bittegeko, S. B. P., Mdoe, N. S. Y. and Aboud, A. A. O. (1998). Suboptimal reproductive performance of dairy cattle in zero-grazed smallholder herds in Arumeru district. Tanzania Veterinary Journal. 18, Supplementary 4. In: *Proceedings of Tanzania Veterinary Association Scientific Conference, Arusha, Tanzania, 1st - 3rd December, 1998.* 15, 160-169.

Kanuya, N. L., Kessy, B. M., Bittegeko, S. B., Mdoe N. S. and Aboud, A. A. (2000). Suboptimal reproductive performance of dairy cattle kept in smallholder herds in a rural highland area of northern Tanzania. *Preventive Veterinary Medicine*. 45, 183-192.

Karg, H. and Schallenberger, (1982). *Factors Influencing Fertility in Postpartum cow*. Martinus Nijhoff Publishers. The Hague. Boston. London. pp. 585.

Kappel, L.C., Ingraham, R.H. and Morgan, E.B. (1984). Selenium concentrations in feed and effects of treating Holstein cows with selenium and vitamin E on blood selenium values and reproductive performance. *American Journal of Veterinary Research*. 45, 691.

Kellaway, R. and Porta, S. (1993). Feeding concentrates supplements for dairy cows. Dairy Research and Development Corporation. Australia.

Keller, H. F., Chew, B. P., Erb, R. E. and Malven, P. V. (1977). Mammary transfer of hormones and constituents into secretions when cows were milked or secretions were sampled pre-partum. *Journal of Dairy Science*. 60, 546-556.

Keown, J. F., and R. W. Everett, R. W. (1985). Age-month adjustment factors for milk, fat, and protein yields in Holstein cattle. *Journal of Dairy Science*. 68, 2664.

Kerley, M. S. and J. E. Williams. (1995). Proc. 2nd National Alternative Feeds Symposium. St. Louis, MO. 14-17.

Kessler, G and Wolfman, M. (1964). An automated procedure for the determination of calcium and phosphorus. *Clinical Chemistry*. 10, 521-531.

Khan, M. S. and Shook, G. E. (1996). Effects of age on milk yield:Time trends and method of adjustment. *Journal of Dairy Science*. 79,1057-1064.

Kifaro, G. C. (1995). Performance of exotic dairy cattle in Southern Highlands of Tanzania and prospects for genetic improvement. PhD thesis. Sokoine University of Agriculture, Morogoro.

Kincaid, R. L., Hillers, J. K. and Cronrath, J. D. (1981). Calcium and phosphorus supplementation of rations for lactating cows. *Journal of Dairy Science*. 64, 754-758.

Kindahl, H., Lindell, J. O. and Edqvist, L. E. (1981). Release of prostaglandin F2α during the oestrous cycle. *Acta Veterinaria Scandinavica*. 77, 143-158.

King, G. J. (1993). Reproductive performance and problems. Pages 531–565 *in* Reproduction in Domesticated Animals. Vol. B 9. Elsevier Sci. Publ. B.V., Amsterdam, The Netherlands.

Kinsey, E. (1994). Aspects of credit in dairy development. The HPI Tanzania experience. *Proceedings of the 21st Scientific Conference of the Tanzania Society of Animal Production, AICC-Arusha, August 16th -18th*. 21, 58-68.

Kishinhi, S. S. (1999). Comparative performance of dairy cattle under large scale and smallholder dairy farms in Tanzania: A review. *Proceedings of the 26th Scientific Conference of the Tanzania Society of Animal Production, LITI-Tengeru, Arusha*, August 3rd -5th. 26, 212-219.

Kitalyi, A. and Massawe, N. F. (2000). Livestock feeding management systems and impact on environment: The case of Eastern Africa. *Proceedings of the 27th Scientific Conference of the Tanzania Society of Animal Production, UCLA-Dar es Salaam*, August 3rd -5th. 27, 105-114.

Kivaria, F. M., Noordhuizen, J. P. T. M. and Kapaga, A. M. (2004). Risk indicators associated with subclinical mastitis in smallholder dairy cows in Tanzania. *Tropical Animal Health and Producion*. 36, 581-592.

Kiwuwa, G. H. (1968). Reproduction efficiency and milk production of dairy cattle. *East African Agricultural Journal*. 33, 335-343.

Kiwuwa, G. H., Trail, J. C. M., Kurtu, M. Y., Worku, G., Anderson, F .M. and Durkin, J. (1983). Crossbreed dairy cattle productivity in Arsi region, Ethiopia. International Livestock Centre for Africa, ILCA Research Report No. 11. Addis Ababa, Ethiopia. pp. 29.

Knowlton, K. F. and Herbein, J. H. (2002). Phosphorus partitioning during early lactation in dairy cows fed diets varying in phosphorus content. *Journal of Dairy Science*. 85, 1227-1236.

Kodagali, S. B. (1974). Report on study of infertility in cattle 1965-69. *Veterinary Bulletin*. 45, 1285 (*Animal Breeding Abstracts* 43:3369).

Kolver, E. S., and Muller, L. D. (1998). Performance and nutrient intake of high producing Holstein cows consuming pasture or a total mixed ration. *Journal of Dairy Science*. 81, 1403–1411.

Kolver, E. S., Muller, L. D., Barry, M. C. and Penno, J. W. (1998). Evaluation and application of the Cornell net carbohydrate and protein system for dairy cows fed diets based on pasture. *Journal of Dairy Science*. 81, 2029-2039.

Kotwica, J., Skarzynski, D., Bogacki, M., Melin, P. And Starostka, B. (1997). The use of an oxytocin antagonist to study the function of ovarian oxytocin during luteolysis in cattle. *Theriogenology*. 48, 1287-1299.

Kotwica, J., Skarzynski, D., Miszkiel, G. and Okuda, K. (1999). Oxytocin modulates the pulsatile secretion of PGF2α in initiated luteolysis in cattle. *Research in Veterinary Science*. 66, 1-5.

Kristensen, E., Larsen, C. E. S., Kyvsgaard, N. C., Madsen, J. and Henriksen, J. (2004). Livestock Production – The twenty first century's food revolution. *Livestock Research for Rural Development*. 16, 1.

Kropp, J. R. (1992). The role of copper in beef cattle fertility. In: *The roles of amino acid chelates in animal nutrition*. Ashmead, H. D. and Park Ridge, N. J. (Eds.) Noyes publications. pp. 154-169.

Kume, S., Nonaka, K. and Tanabe, S. (2003). Relationship between parity and mineral status in dairy cows during the periparturient period. *Animal Science Journal*. 74, 211-215.

Kume, S. and Tanabe, S. (1993). Effect of parity on colostral mineral concentrations of Holstein cows and value of colostrum as a mineral source for newborn calves. *Journal of Dairy Science*. 76, 1654-1660

Kumwenda, M. S. L. (1999). Improveing the productivity of dairy cattle on smallholder farms in Mzuzu milkshed area in Malawi: Constraints and possible interventions. *Proceedings of the final Research Co-ordination Meeting of a Co-ordinated Research Project organised by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna, Austria, 7-11 September*. IAEA-TECDOC-1102. pp. 35-44.

Kunkle, W. E. and Sand, R. S. (1990). The effect of body condition on rebreeding. In: *International conference on livestock in the tropics and subtropics*. University of Florida, Gainesville. pp. B44-B54.

Kurwijila, L. R. and Boki, K. J. (2003). A review of the small scale dairy sector – Tanzania. Milk and dairy products, post-harvest losses and food safety in Sub-Saharan Africa and the Near East. FAO Prevention of Food Losses Programme. pp. 38.

Kurwijila, L. R., Rwehumbiza, H. M. and Mchau, W. K. (1996). Challenges and coping strategies for the Tanzania dairy industry to satisfy the future demand for milk and milk products by the growing human population. *Proceedings of the 23rd Scientific Conference of the Tanzania Society of Animal Production, LITI-Tengeru, Arusha, August 20th - 22nd*. 23, 1-22.

Labhsetwar, A. T., Collins, W. E., Tayler, W. J. and Casida, L. E. (1964). Some pituitary ovarian relationships in peri-parturient cow. *Journal of Reproductive Fertility*. 8, 85-88.

Laing, J. A., Brinley-Morgan, W. J. and Wagner, W. C. (1988). *Fertility and Infertility in Veterinary Practice*. 4th Ed. Baillière Tindalll Ltd. London NW1 7DX.

Lane, O. E. and Larry, D. G. (1995). Feeding the dairy herd. Georgia extension publications, Bulletin 816/November, 1995.

Langlands, J. P. (1987) *Assessing the nutrient status of herbivores.* In: *The Nutrition of Herbivores.* Hacker and Ternouth, J. H. (Eds.) Academic Press, London. pp. 363-390.

Larry, D. G. and Joe, W. W. (1994). Nutrition and reproduction interactions in dairy cattle. Georgia extension publications, Bulletin 1111/September, 1994.

Laster, D. B. (1974). Factors affecting pelvic size and dystocia in beef cattle. *Journal of Animal Science.* 38, 496.

Lauderdale, J. W. (1972). Effects of prostaglanding F2 on pregnancy and oestrous cycle of cattle. *Journal of Animal Science.* 35, 246.

Laven, R. (2003). Retained foetal membranes. National Animal Disease information Service. http://www.mdc.org.uk/mdc-technical/documents/RetainedFoetalMembranes.pdf. (Accessed in Dec. 2004).

Lekule, F. P; Sarwatt, S. V and Petersen, P. H. (1998). The SURUDE Heifer-In-Trust scheme a preliminary assessment. Proc. TSAP Conf. Vol. 25: 13-19.

Leng, R. A. (1990). Factors affecting the utilization of 'poor quality' forages by ruminants particularly under tropical conditions. *Nutrition Research Reviews.* 3, 277-303.

Leonard, F. C., O'Connell, J. and O'Farrell, K. (1994). Effect of different housing conditions on behaviour and foot lesions in Friesian heifers. *Veterinary Record.* 134, 490-494.

Lerenius, C. and Skarback, G. (1987). Milk - the new cash crop? A survey of small dairy farms in Rungwe District, Tanzania, 1986. A report from two minor field studies. Arbetsrapport, -U-Landsavdelningen,-Sveriges-Lantbruksuniversitet. pp. 53, 67.

Leslie, J., Swai, E., Karimuribo, E. and Bell, C. (1999). Tanga and Southern Highlands Dairy Development Programmes: Socio-economic aspects and farmer perceptions of dairy cattle keeping and animal disease. DFID/NRRD Animal health research programme report. University of Reading. UK.

Lishman, A. W., Allison, S. M. J., Fogwell, R. L., Butcher, R. L. and Inskeep, E. K. (1979). Follicular development and function of induced corpora lutea in underfed postpartum anoestrus beef cows. *Journal of Animal Science.* 48, 867.

Little, D. A. (1980). Observations on the phosphorus requirement of cattle for growth. *Research in Veterinary Science.* 28, 258.

Little, S. (2004). Incalf adviser training course workbook. Dairy research and development corporation, Melbourne. pp. 2.

Littledike, E. T., Young, J. W. and Beitz, D. C. (1981). Common metabolic diseases in cattle: Ketosis, milk fever and downer cow complex. *Journal of Dairy Science*. 64, 1465-1482.

Lotthammer, K-H. (1989). Influence of nutrition on reproductive performance of the milking/gestating cow in the tropics. Feeding dairy cows in the tropics. FAO animal production and health paper 86. Proceedings of the FAO expert consultation held in Bankok, Thailand 7-8 July, 1989.

Lourens, D. C. (1995). A comparative observational study on the reproductive performance of dairy cows with metritis and normal cows. *South African Journal of Animal Science*. 25, 21-25.

Lowman, B. G., Scott, N. and Sommerille, S. (1973). Condition scoring of cattle. East of Scotland college of Agriculture, Bulletin no. 6.

Lucey, S., Rowlands, G. J. and Russell, A. M. (1986). Short-term associations between disease and milk yield of dairy cows. *Journal of Dairy Research*. 53, 7–15.

Lucy, M. C. (2000). Regulation of ovarian follicular growth by somatotropin and insulin-like growth factors in cattle. *Journal of Dairy Science*. 83, 1635-1647.

Lucy, M. C. (2001). Reproductive loss in high-producing dairy cattle: Where will it end?. *Journal of Dairy Science*. 84, 1277-1293.

Lucy, M. C. (2003). Physiological Mechanisms Leading to Reproductive Decline in Dairy Cattle. *Proceedings of the 2nd bi-annual W. E. Petersen symposium*. April 8, 2003. University of Minnesota-St. Paul campus.

Lucy, M. C., Savio, J. D., De Badinga, L., La Sota, R.L. and Thatcher, W. W. (1992). Factors that affect ovarian follicular dynamics in cattle. *Journal of Animal Science*. 70, 3615-3620.

Lugalla, L. (1993). Poverty and adjustment in Tanzania: Grappling with poverty issues during adjustment period. URT, Planning Commission.

Lyimo, C. E. (1994). Constraints to the productivity of smallholder dairy cattle. *Proceedings of the 21st Scientific Conference of the Tanzania Society of Animal Production, AICC-Arusha, August 16th –18th*. 21, 127-136.

Lyimo, Z. C., Nkya, R., Schoonman, L. and van Eerdenburg, F. J. (2004). Post-partum reproductive performance of crossbred dairy cattle on smallholder farms in sub-humid coastal Tanzania. *Tropical Animal Health and Production*. 36, 269-279.

Macmillan, K. L., Lean, I. J. and Westwood, C. T. (1996). The effects of lactation on the fertility of dairy cows. *Australian Veterinary Journal*. 73, 141-147.

Madsen, O. and Vinther, K. (1975). Performance of purebred and crossbred dairy cattle in Thailand. *Animal Production*. 21, 209-216.

MAFF (1975). Ministry of Agriculture, Fisheries and Food, Manual of Parasitological Laboratory Techniques. Reference book no. 418, 3rd Ed.

Maizon, D. O., Oltenacu, P. A., Gröhn, Y. T., Strawderman, R. L. and Emanuelson, U. (2004). Effects of diseases on reproductive performance in Swedish Red and White dairy cattle. *Preventive Veterinary Medicine*. 66, 113-126.

Manickam, R. and Balagopal, R. (1993). Influence of copper and vitamin A in the reproductive performance of dairy cows. *Journal of Dairying, Foods and Home Sciences*. 12, 153-155

Makauki, A. F., Lekule, F. P. and Kawa, I. H. (1999) Awareness of farmers in multipurpose tree planting in Turiani division, Morogoro (R) district. A Case study of Kidudwe, Kunkhe and Lungo villages. *Proceedings of the 26th Scientific Conference of the Tanzania Society of Animal Production, LITI-Tengeru, Arusha, August 3rd - 5th*. 26, 142-152.

Mario, G. (1982). Reproduction functions during the postpartum period in the cow. *Nordic Veterinary Medicine*. 34, 264-275.

Maro, J. K., Kategile, J. A. and Hvidsten, H. (1980). Studies on copper and cobalt in dairy calves. *British Journal of Nutrition*. 44, 25-31.

Massawe, N. F. (1999). Strategies based on participatory rural appraisal for improving the utilization of forages to increase profitable milk production on smallholder farms in Tanzania. Ph D Thesis, Univ. Reading, UK. pp. 293.

McDonald, P., Edwards, R. A. and Greenhalgh, J. F. D. (1997). *Animal Nutrition*. 4th Ed. Longman Scientific and Technical. 92-96.

McDowell, L. R. (1976). Mineral deficiencies and toxicities and their effect on beef production in developing countries. In: *Beef Cattle Production in Developing Countries*. Smith, A. J. (Ed.) University of Edinburgh, Centre for Tropical Veterinary Medicine. pp. 216-241.

McDowell, L. R. (1985). Calcium, phosphorus, and fluorine. In: *Nutrition of Grazing Ruminants in Warm Climates*. McDowell, L. R. (Ed.) Academic Press, Orlando, Florida. pp. 189-212.

McDowell, L. R. (1992). *Minerals in Animal and Human Nutrition*. Academic Press Inc. New York. pp. 324-325.

McDowell, L. R. Conrad, J. H., Ellis, G. L. and Loosli, J. K. (1983). Minerals for grazing ruminants in tropical regions. University of Florida, Department of Animal Science Extension Bulletin. pp. 86.

McDowell, R. E. (1994). *Dairying with Improved Breeds in Warm Climates*, (KinnicKinnic Agri-sultants, Raleigh, NC, USA). pp. 23-54.

Mchau, K. W. (1980). Dairy Cattle at Village Level in Rungwe District, Res. Report No. 30 Mbeya Tanzania Uyole Agricultural Centre.

Mchau, K. W. (1991). The impact of upgrading the Tanzania shorthorn Zebu on small holder dairy production in Mbeya region. PhD thesis. Sokoine University of Agriculture, Morogoro.

Mchau, K. W. and Mwakatumbula, I. D. A. (1981). Dairy recording on small scale farms in Rungwe district, Tanzania. UAC Research report No. 40.

McLeod, B. J. and Williams, M. E. (1991). Incidence of ovarian dysfunction in post partum dairy cows and the effectiveness of its clinical diagnosis and treatment. *Veterinary Record*. 128, 6, 121-124.

McNamara, S., Murphy, J. J., O'Mara, F. P. and Rath, M. (2001). Effect of diet type pre-calving and concentrate level post calving on dry matter intake pre and post calving, and on cow performance in early lactation. *Proceedings of the Agricultural Research Forum, 14th and 15th March* 2000. pp. 251.

Mdegela, R. H., Kusiluka, L. J. M., Kapaga, A. M., Karimuribo, E. D., Turuka, F. M., Bundala, A., Kivaria, F., Kabula, B., Manjurano, A., Loken, T. and Kambarage, D. M. (2004). Prevalence and determinants of mastitis and milk-borne zoonoses in smallholder dairy farming sector in Kibaha and Morogoro districts in Eastern Tanzania. *Journal of Veterinary Medicine*. 51, 123-128.

Mdoe, N. and Wiggins, S. (1996). Dairy products demand and marketing in Kilimanjaro region, Tanzania. *Food Policy*. 21, 319-336.

Mdoe, N. S. Y., Mnenwa, Y. K. R. and Nyange, D. (2000). Economic liberalization and the livestock sub sector in Tanzania. *Proceedings of the 27th Scientific Conference of the Tanzania Society of Animal Production, UCLAS,-Dar es Salaam. August 3rd - 5th*. 27, 97-106.

Meikle, A., Kulcsar, M., Chilliard, Y., Febel, H., Delavaud, C., Cavestany, D. and Chilibroste, P. (2004). Effects of parity and body condition at parturition on endocrine and reproductive parameters of the cow. *Reproduction*. 127, 727-737.

Mihm, M. and Austin, E. J. (2002). The final stages of dominant follicle selection in cattle. *Domestic Animal Endocrinology*. 23, 155-166.

Milford, R. and Minson, D. J. (1966). Intake of tropical pasture species. Proc. 9th Int. Grassld. Congr. Sao Paulo. pp. 815-822.

Minatel, L. and Carfagnini, J. C. (2002). Evaluation of the diagnostic value of plasma copper levels in cattle. *Preventive Veterinary Medicine*. 53, 1-5.

Minson, D. J. (1967). The voluntary intake and digestibility in sheep, of chopped and pelleted *Digitaria decumbens* (Pangola grass) following a late application of fertilizer nitrogen. *British Journal of Nutrition*. 21, 587-597.

Miller, J. K., Madsen, F. C., Holwerda, R. A. and Campbell, M. H. (1996). Zinc may protect periparturient dairy cattle against excessive dietary iron. *Feedstuff*. 96.

Miyamoto, Y., Skarzynski, D. J. and Okuda, K. (2000). Is tumour necrosis factor □a trigger for the initiation of endometrial prostaglandin $F2\alpha$ release at luteolysis in cattle? *Biology of Reproduction*. 62, 1109-1115.

Mlay, P. S., Pereka, A. E., Balthazary, S. T., Phiri, E. C. J., Hvelplund, T., Weisbjerg, M. R. and Madsen, J. (2005). The effect of maize bran or maize bran mixed with sunflower cake on the performance of smallholder dairy cows in urban and peri-urban area in Morogo, Tanzania. *Livestock Research for Rural Development*. 17, 1.

Mollel, E. L., Lekule, F. P., Kurwijilia, R. L., Turuka, F. M. and Peterrsen, P. H. (1999). A socio-economic study on the role of gender in smallscale crop-livestock farming in Turiani division, Morogoro. *Proceedings of the 26^{th} Scientific Conference of the Tanzania Society of Animal Production, LITI-Tengeru, Arusha, August 3^{rd} –5^{th}*. 26, 121-127.

Monget, P., Fabre, S., Mulsant, P., Lecerf, F., Elsen, J. M., Mazerbourg, S., Pisselet, C. and Monniaux, D. (2002). Regulation of ovarian folliculogenesis by IGF and BMP system in domestic animals. *Domestic Animal Endocrinololgy*. 23, 139-154.

Moore, J. E., Kunkle, W. E. and Brown, W. F. (1991). Forage quality and the need for protein and energy supplements. In: *1991 Beef Cattle Short Course Proceedings*. University of Florida, Gainesville, FL.

Moore, R. B. Fuquay, J. W. and Drapala, W J. (1992). Effects of late gestation heat stress on postpartum milk production and reproduction in dairy cattle. *Journal of Dairy Science*. 75, 1877-1882.

Morales, F., Blake, R. W., Stanton, T. L. and Hahan, M. V. (1989). Effects of age, parity, season of calving, and sire on milk yield of Carora cows in Venezuela. *Journal of Dairy Science*. 72, 2161.

Morton, J. (2000) Section 5: Very important factors. In: *The In-calf Project*. Progress report No. 2, Melbourne, Dairy Research and Development Corporation. pp. 24-43.

Moss, R. (2004). Dairy replacement heifers: Feed requirements and forage quality. Mutdapilly Research Station. DPI. The state of Queensland, department of primary industries and fisheries. http://www.dpi.qld.gov.au/dairy/3065.html#Introduction. (Accessed in Jan. 2005).

Msanga, Y. N., Bryant, M. J. and Katule, A. M. (1999). Effect of environmental factors and proportion of holstein blood on days to first insemination and calving interval of crossbred dairy cattle on smallholder farms in northeast Tanzania. *Proceedings of the 26th Scientific Conference of the Tanzania Society of Animal Production, LITI-Tengeru, Arusha, August 3rd - 5th*. 26, 161-167.

Msanga, Y. N., Bryant, M. J., Rutam, I. B., Minja, F. N. and Zylstra, L. (2000). Effect of environmental factors and of the proportion of Holstein blood on the milk yield and lactation length of crossbred dairy cattle on smallholder farms in North-east Tanzania. *Tropical Animal Health and Production*. 32, 23-31.

Msanga, J. F., Tungaraza, R., Olumu, L. M. U. and Muhairwa, A. (1989). Bovine mastitis bacterial isolates from sub-clinical and clinical mastitis in the Lake zone of Tanzania. *Tanzania Veterinary Bulletin*. 9, 13-17.

Msangi, B. S. J., Brayant, M. J., Kavana, P. Y., Msanga, Y. N. and Kizima, J. B. (1999). Body measurements as a management tool for crossbred dairy cattle at a smallholder farm condition. . *Proceedings of the 26th Scientific Conference of the Tanzania Society of Animal Production, LITI-Tengeru, Arusha, August 3rd - 5th*. 26, 168-175.

Msangi, B. S. J., Brayant, M. J., Nkya, R. and Thorpe, P. J. (2004). The effects of a short-term increase in supplementation on reproduction performance in lactating crossbred dairy cows. *Tropical Animal Health and Production*. 36, 775-787.

Msangi, B. S. J., Bryant, M. J., Thorne, P. J. and Dijkman, J. (2002). Condition of the cow at calving as a determinant of milk yield in crossbred dairy cows on smallholder farms in North East coastal Tanzania. *British Society of Animal Science annual meeting. 12-15 November 2002*, UADY, Mexico. pp. 198-199.

Msangi, B. S. J., Msanga, Y. N., Brayant, M. J. and Nkya, R. (2001). Performance at pasture and zero grazed crossbred dairy cows in the sub-humid coast of Tanzania. *Proceedings of the 28th Scientific Conference of the Tanzania Society of Animal Production, AICC-Arusha, December 3rd - 5th*. 28, 148-154.

Msechu, J. K. K. (1988). Contribution of milk from the traditional livestock sector in Tanzania In: *Proceedings of Tanzania Society of Animal Production*. 15, 199 - 213.

Mtumwa A. and Mwasha P. S. (1995). The strategy for sustainable dairy development in Tanzania. *Proceedings of the 22nd Scientific Conference of the Tanzania Society of Animal Production, AICC-Arusha, August 15th - 17th*. 22, 1-13.

Mugo, C. R., Okoba, B. O., Ngoroi, E. H. and Kang'ara, J. N. (2001). Household diversity in the smallholder farms of Nduuri, Embu, Kenya. East African PLEC General Meeting, Arusha, Tanzania, 26-28, November.

Mujuni, P. F. and Mgongo, F. O. K. (1994). Abnormally terminated pregnancies in a Tanzanian dairy herd: consequences and clinical management. *Preventive Veterinary Medicine.* 18, 287-291.

Mujuni, P. F., Mgongo, F. O. K. and Kanuya, N. L. (1990a). Age at first calving and its effects on subsequent reproductive performance in dairy cows in Tanzania. *Proceedings of the 17th Scientific Conference of the Tanzania Society of Animal Production, AICC-Arusha, Septembert 25th - 27th.* 17, 121-126.

Mujuni, P. F., Mgongo, F. O. K., Batamuzi, E. K. and Kanuya, N. L. (1990b). Influence of milk production on health and reproductive performance of dairy cattle in a selected herd of Tanzania. *Proceedings of the 17th Scientific Conference of the Tanzania Society of Animal Production, AICC-Arusha, Septembert 25th - 27th.* 17, 149-155.

Mujuni, P. F., Mgongo, F. O. K and Kanuya, N. L. (1996). The incidence rates and relationships between endometritis and ovarian inactivity of postpartum dairy cows in a tropical area. *Tanzania Veterinary Journal.* 16, 23-31.

Mulangila, R. C. T. (1997). A study on dairy cattle productivity in Tanga region. Msc dissertation. Sokoine University of Agriculture. pp. 132.

Munro, C. D., Watson, E. D., McBride, B., Martin, B., Booth, J. M. and Holdsworth, R. (1982). Monitoring preservice reproductive status in dairy cows. *Veterinary Record.* 110, 77-81.

Mukasa-Mugerwa, E. (1989). *A review of reproductive performance of female* Bos Indicus *(Zebu) cattle.* ILCA Monograph No. 6. ILCA, Addis Ababa, Ethiopia.

Mussa, H. M. (1998). Smallholder dairy production feed budgeting strategy in the Southern highlands of Tanzania. A case study of Rungwe and Mbozi districts. Msc. Dissertation. Sokoine University of Agriculture, Tanzania.

Mwaanga, E. S. and Janowski, T. (2000). Anoestrus in dairy cows: Causes, prevalence and clinical forms. Review Article. *Reproduction in Domestic Animals.* 35, 193-200.

Mwakalile, I. N. F., Bachmann, F., Mshana, Y. and Mugittu, V. K. (2002). Improved livestock management and rural livelihood: Twenty years of experiences of Southern Highlands Dairy Development Project in Mbeya and Iringa regions, Tanzania. *Proceedings of the joint 17th Scientific Conference of the Tanzania Society for Animal Production and the 20th Scientific Conference of the Tanzania Veterinary Association, AICC-Arusha, December 3rd - 5th.* pp. 35-52.

Mwakatundu, A. G. K. (1977). A study of the nutritive value of East African pastures for ruminants with special reference to mineral nutrition in grazing dairy cattle. PhD thesis. University of Nairobi, Kenya. pp. 20-154.

Mwakyembe, (1996a). Economics of small scale dairy farming: Iringa and Mbeya regions, Tanzania. Report 1 submitted to Chief Technical Advisor, SHDDP, Iringa.

Mwakyembe, (1996b). Economics of small scale dairy farming: Iringa and Mbeya regions, Tanzania. Report 2 submitted to Chief Technical Advisor, SHDDP, Iringa.

Mwatawala, H. W., Kifaro, G. C. and Petersen, P. H. (2003). Phenotypic and genetic parameters for reproduction and lactation traits of Friesian x Boran crosses in Tanzania. *Proceedings of the 30th Scientific Conference of the Tanzania Society of Animal Production, 4H Centre-Tanga, October 28th -30th*. pp. 108-119.

Nebel, R. L. and McGillard, M. L. (1993). Interactions of high milk yield and reproductive performance in dairy cows. *Journal of Dairy Science*. 76, 3257-3268.

Negussie, E, Brännäng, E. and Rottamann, O. J. (1999). Reproductive performance and herd life of dairy cattle at Asella livestock farm, Arsi, Ethiopia. II: Crossbreds with 50, 75 and 87.5% European inheritance. *Journal of Animal Genetics*. 116, 225-234.

Newcomb, R., Booth, W. D. and Rowson, L. E. (1977). The effect of oxytocin treatment on the levels of prostaglandin F in the blood of heifers. *Journal of Reproduction and Fertility*. 49, 17-24.

Nkya, R., Aboud, A. A. and Kessy, B. M. (1999a). Improving the productivity of smallholder dairy cattle in peri-urban Morogoro, United Republic of Tanzania. *Proceedings of the final Research Co-ordination Meeting of a Co-ordinated Research Project organised by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna, Austria, 7-11 September*. IAEA-TECDOC-1102. pp. 79-85.

Nkya, R., Shem, M. N. and Urio, N. A. (1999b). Dry season supplementation of dairy cows with urea molasses mineral blocks and molasses-urea mix in the Morogoro region in Tanzania. *Proceedings of the final Research Co-ordination Meeting of a Co-ordinated Research Project organised by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna, Austria, 7-11 September*. IAEA-TECDOC-1102. pp. 57-65.

Nkya, R. and Swai, E. M. (1999). Some factors associated with reduced dairy cattle reproductive performance in small scale farms of peri-urban Dar es Salaam and Morogoro. *Tanzania Veterinary Association Proceedings*. 19, 113-122.

Norman, A. W. and Hurwitz, S. (1993). The role of Vitamin D endocrine system in avian bone biology. *Journal of Nutrition*. 123, 310-316.

NRC. (1984). Nutrient Requirements of Beef Cattle. National Academy Press. Washington, D.C.

NRC. (1996). Nutrient Requirements of Dairy Cattle. National Academy Press. Washington, D.C.

NRC. (2001). Nutrient Requirements of Dairy Cattle. National Academy Press. Washington, D.C.

Obese, F. Y., Okantah, S. A., Oddoye, E. O. and Gyawu, P. (1999). Post-partum reproductive performance of Sanga cattle in smallholder peri-urban dairy herds in the Accra plains of Ghana. *Tropical Animal Health and Production*. 31, 181-190.

O'Brien, B., Dillon, P., Murphy, J. J., Mehra, R. K., Guinee, T. P., Connolly, J. F., Kelly, A. and Joyce, P. (1999). Effects of stocking density and concentrate supplementation of grazing dairy cows on milk production, composition and processing characteristics. *Journal of Dairy Research*. 66, 165-176.

Ocon, O. M. and Hansen, P. J. (2003). Disruption of Bovine Oocytes and Preimplantation Embryos by Urea and Acidic pH. *Journal of Dairy Science*. 86, 1194 - 1200.

O'Connor, M. and Dechow, C. (2002). Minimize the adverse effect of 'the dog days of summer' on reproduction. *SW Pennsylvania Dairy Newsletter*. 2, 1.

Oetzel, G. R. and Barmore, J. A. (1992). Palatability of anionic salts fed in a concentrate mix. *Journal of Dairy Science*. 75, 297.

Ogaa, J. S., Llewelyn, C. A., Odiawo, G. O. Nyathi, C. B., Obwolo, M. J., Hill, F. W. G., Vickers, D. B., Majok, A. A. and Moyo, P. (1992). Studies on indigenous cattle under traditional management in Zimbabwe: 3. Reproductive performance. *Zimbabwe Veterinary Journal*. 23, (3), 121-133.

Ojango, J. M. K. (2000). Performance of Holstein-Friesian cattle in Kenya and the potential for genetic improvement using international breeding values. PhD thesis. Wye College, University of London. UK.

Okuda, K., Miyamoto, Y. and Skarzynski, D. J. (2002). Regulation of endometrial prostaglandin F2□synthesis during luteolysis and early pregnancy in cattle. Domestic Animal Endocrinology. 23, 255-264.

Olive, S. P., Schrick, F. N., Hockett, M. E. and Dowlen, H. H. (2000). Clinical and subclinical mastitis during early lactation impairs reproductive performance of dairy cows. National Mastitis Council 2000 regional meeting, Cleveland, Ohio, August, 24. pp. 34.

Oltner, R., and Wiktorsson. H. (1983). Urea concentrations in milk and blood as influenced by feeding varying amounts of protein and energy to dairy cows. *Livestock Production Science*. 10, 457-467.

Omore, A., Muriuki, H., Kenyanjui, M., Owango, M. and Staal, S. (1999). The Kenyan dairy subsector, A rapid appraisal. KARI/MoA/ILRI Collaborative Research Project Report.

Ouweltjes, W. Smolders, E. A. A., Elving, L., Van Eldik, P. and Schukken, Y. H. (1996). Fertility disorders and subsequent fertility in dairy cattle. *Livestock Production Science*. 46, 213-220.

Paris, T. R. (2000). Crop–animal systems in Asia: socio-economic benefits and impacts on rural livelihoods, *Agricultural Systems*. 71, 147-168.

Parkinson, T. J., Wathes, D. C., Jenner, L. J. and Lamming, G. E. (1992). Plasma and luteal concentrations of oxytocin in cyclic and early-pregnant cattle. *Journal of Reproduction and Fertility*. 94, 161-167.

Patil, J. S. and Deshpande, B. R. (1981). Study of bodyweight changes during antepartum, parturition and postpartum periods in Gir cows with special reference to exhibition of postpartum actions. *Indian Veterinary Journal*. 58, 376-379.

Patton, R. A., Bucholtz, H. F., Schmidt, M. K. and Hall, F. M. (1988). Body condition scoring - A management tool. Department of Animal science, Michigan State University, East Lansin, Michigan.

Paynter, D. I. (1987). The diagnosis of copper deficiency. In: *Copper in Animals and Man*, Vol. 1. Howell, J. C. and Gawthorne, J. M. (Eds.). CRC Press Inc., Boca Raton, Florida. pp. 101-119.

Pereka, A. E. and Phiri, E. C. J. H. (1998). Mineral content in soils and pasture grasses at ASAS farm, Iringa, Tanzania. *Tanzania Veterinary Journal*. 18, 101-109.

Peters, A. R. (1984). Reproductive activity of the cow in the postpartum period. Factors affecting the length of the postpartum acyclic period. *British Veterinary Journal*. 140, 76-84.

Peters, A. R. and Ball, P. J. H. (1995). *Reproduction in cattle*. 2nd Ed. Butterworth & Co. London, England.

Petri, A., Müschen, H., Breves, G., Richter, O. and Pfeffer, E. (1988). Response of lactating goats to low phosphorus intake 2. Nitrogen transfer from the rumen ammonia to rumen microbes and proportion of milk protein derived from microbial amino acids. *Journal of Agricultural Science, Cambridge*. 111, 265-271.

Peyraud, J. L., and Delaby, L. (2001). Ideal concentrate feeds for grazing dairy cows responses to supplementation in interaction with grazing management and grass quality. In: *Recent Advances in Animal Nutrition*. Garnsworthy, P. C. and Wiseman, J. (Eds.), Notthingham University Press, UK. pp. 203.

Phiri, E. C. J. H. (2001). Performance of grazing crossbred cattle supplemented with minerals: Calcium, phosphorus and zinc. PhD thesis. Sokoine University of Agriculture, Tanzania.

Phiri, E. C. J. H. and Pereka (1998). The effect of mineral glass boluses (COSECURE®) supplementation on plasma copper, ceruloplasmin, glutathione peroxidase and other parameters in grazing heifers. *Tanzania Veterinary Journal.* 18, 136-145.

Phiri, E. C. J. H., Pereka, A. E., Mgasa, M. N. and Larsen, T. (1997). Plasma calcium and inorganic phosphorus in grazing cattle at ASAS farm, Iringa, Tanzania. *Tanzania Veterinary Journal.* 17, 44-49.

Phiri, E. C. J. H., Pereka, A. E., Mgasa, M. N. and Larsen, T. (2000). The effect of calcium, phosphorus and zinc supplementation on health performance of grazing dairy cattle. *Proceedings of the 27th Scientific Conference of the Tanzania Society of Animal Production, UCLAS-Dar es Salaam, August 3rd –5th*. 27, 35-50.

Polan, C. E. (2000). Supplementation of lactating cows on pasture. *Proceedings of Mid-Atlantic Dairy Grazing Conference*. Abington, VA. pp. 23-42.

Polan, C. E., Blaser, R. E., Miller, C. N. and Wolf, D. D. (1986). Utilization of pasture by lactating cows. *Journal of Dairy Science*. 69, 1604-1612.

Pott, E. B., Tulio, R. R., De Almeida, I. L., De Brum, P. A. L. and De Sousa, J. L. (1987). Desempenho reprodutivo de bovinos na sub-regiao dos Paiaguas do Pantanal Mato-grossense: II Efeito da suplementacao mineral sobre indices reprodutivos de novilhas. Pesquisa Agropecuaria Brasileira, Brasilia, Brasil 22, 1265

Pryce, J. E., Coffey, M. P. and Slmm, G. (2001). The relationship between body condition score and reproductive performance. *Journal of Dairy Science*. 84, 1508-1515.

Quigley, J. D., Nyabadza, C. S. T., Benedictus, G., Brand, A. (1996). Monitoring replacement rearing: objectives and materials and methods. In: *Herd health and production management in dairy practice*. Brand A., Nordhuizen J. P. and Schukken Y. H. (Eds.), Wageningen Pers., Wageningen. pp. 75-102

Qureshi, M. S., Siddiqui, M. M., Khattak, S. G., Habib, G., Samad, H. A. and Haque, I. (2000). Reproduction-nutrition interaction in dairy buffaloes. IV. Effect of macro-minerals intake. *Egyptian Journal of Dairy Science*. 28, 121-127.

Rabiansky, P. A., McDowell, L. R., Velasquez-Pereira, J., Wilkinson, N. S., Percival, S. S., Martin, F. G., Bates, D. B. Johnson, A. B., Batra, T. R. and Salgado-Madriz, F. G. (1999). Evaluating copper lysine and copper sulfate sources for heifers. *Journal of Dairy Science*. 82, 2642-2650.

Radcliff, R. P., VandeHaar, M. J., Chapin, L. T., Pilbeam, T. E., Ashley, R. W., Puffenbarger, S. M., Stanisiewski, E. P., Beede, D. K. and Tucker, H. A. (1998). Effects of diet and exogenous bST on reproductive performance on dairy heifers. *Journal of Dairy Science*. 81, (1), 884. (Abstract)

Radcliff, R. P., VandeHaar, M. J., Skidmore, A. L., Chapin, L. T., Radke, B. R., Lloyd, J. W., Stanisiewski, E. P. and Tucker, H. A. (1997). Effects of diet and bovine somatotropin on heifer growth and mammary development. *Journal of Dairy Science*. 80, 1996-2003.

Rajala-Schultz, P. J., Saville, W. J. A., Frazer, G. S. and Wittum, T. E. (2001). Association between milk urea nitrogen and fertility in Ohio dairy cows. *Journal of Dairy Science*. 84, 482-489.

Randel, R. D. (1990). Nutrition and postpartum rebreeding in cattle. *Journal of Animal Science*. 68, 853-862

Rasby, R. J., Wetteman, R. P., Geisert, R. D., Rice, L. E. and Wallace, C. R. (1990). Nutrition, body condition, and reproduction in beef cows: fetal and placental development and estrogen and progesterone in plasma. *Journal of Animal Science*. 68, 4276-4287.

Rege, J. E. O. (1991). Genetic analysis of reproductive and productive performance of Friesian cattle in Kenya. 1. Genetic and phenotypic parameters. *Journal of Animal Breeding and Genetics*. 108, 412-423.

Reinhardt, T. A., Horst, R. L. and Goff, J. P. (1988). Calcium, phosphorus, and magnesium homeostasis in ruminants. *Veterinary Clinics of North America-Food Animal Practice*. 4, 331-350.

Reis, R. B. and Combs, D. K. (2000). Effects of increasing levels of grain supplementation on rumen environment and lactation performance of dairy cows grazing grass-legume pasture. *Journal of Dairy Science*. 83, 2888-2898.

Reist, M., Erdin, D., von Euw, D., Tschuemperlin, K., Leuenberger, H., Delavaud, C., Chilliard, Y., Hammon, H. M., Kuenzi, N. and Blum, J. W. (2003). Concentrate Feeding Strategy in Lactating Dairy Cows: Metabolic and Endocrine Changes with Emphasis on Leptin. *Journal of Dairy Science*. 86, 1690-1706.

Reksen, O., Tverdal, A. and Ropstad, E. (1999). A comparative study of reproductive performance in organic and conventional dairy husbandry. *Journal of Dairy Science*. 82, 2605-2610.

Rémond, B., Cisse, M., Ollier, A. and Chilliard, Y. (1991). Slow release somatotropin in dairy heifers and cows fed two levels of energy concentrate. *Journal of Dairy Science*. 74, 1370-1381.

Rennie, R., Light, D., Rutherford, A., Miller, M., Fisher, I., Pratchtt, D., Capper, B., Buck, N. and Trail, J. C. M. (1977). Beef cattle productivity under traditional and improved management in Botswana. *Tropical Animal Health and Production*. 9, 1-6.

Rey, B., Thorpe, W., Shapiro, B., Smith, J., Osuji, P., Mullins, G. and Agyemang, K. (1993). Improvement of dairy production to satisfy the growing consumer demand in SSA – A conceptual framework for research, ILCA Market-oriented smallholder dairying research, working document no. 1. Addis Ababa, Ethiopia.

Riond, J-L. (2001). Animal nutrition and acid base balance. *European Journal of Nutrition*. 40, 245-254.

Risco, C. A. (1992). Calving related disorders. *Proceedings of Large Dairy Herd Symposium*. Van Horn, H. H. and Wilcox, C. J. (Eds.). American Dairy Science Association., Savoy, IL. pp. 192.

Risco, C. A. (1995). Nutritional management of dry cows and calving related disorders. Proc. Acad. Dairy Vet. Consult. p. 1.

Ritchie, H. D. and Anderson, P. T. (1994). Calving difficulty in beef cattle. Michigan State University extension beef bulletins – E1611921. http://www.msue.msu.edu/msue/imp/modaa/e1611921.html. Accessed in Nov. 2004.

Roberts, S. J. (1971). *Veterinary obstetrics and genital diseases (Theriogenology)*. 2nd Ed., Edward Brothers, Inc. Ann Arbor, Michigan. pp. 376.

Roberts, S. J. (1986). *Veterinary Obstetrics and Genital Disease (theriogenology)*. 3rd Ed. David & Charles, Inc.: North Pomfert, Vermont. pp. 981.

Roche, J. F., Mackey, D. and Diskin, M. D. (2000). Reproductive management of postpartum cows. *Animal Reproduction Science*. 60-61, 703-712.

Rodgers, W. A. (1975). Mineral content of some soils, range grasses and wild animals from Southern Tanzania. *East Africa Agriculture Forest Journal*. 41, 32-35.

Roman-Ponce, H., Thatcher, W. W., Caton, D., Barron, D. H. and Wilcox, C. J. (1978). Thermal stress effects on uterine blood flow in dairy cows. *Journal of Animal Science*. 46, 175-180.

Romo, G. A., Kellems, R. O., Powell, K. and Wallentine, M. V. (1991). Some blood minerals and hormones in cows fed variable mineral levels and ionic balance. *Journal of Dairy Science*. 74, 3068.

Royal, M. D., Darwash, A. O., Flint, A. P. F., Webb, R., Woolliams, J. A. and Lamming, G. E. (2000). Declining fertility in dairy cattle: Changes in traditional and endocrine parameters of fertility. *Animal Science*. 70, 487-502.

Rugambwa, V. K., Muttagwaba, T. J. and Houterman, J. F. (1994). Economic contribution and the economics os smallholder dairy production in Kagera region, Tanzania. *Proceedings of the 21st Scientific Conference of the Tanzania Society of Animal Production, AICC-Arusha, August 16th - 18th*. 21, 36-50.

Rutamu, I. (1994). The sustainability of heifer-in trust credit Scheme: The Tanga experience. *Proceedings of the 21st Scientific Conference of the Tanzania Society of Animal Production, AICC-Arusha, August 16th –18th*. 21, 96-113.

Rutamu, I. (1996). The Sector Approach towards Dairy Development in Tanzania. In: *Proceedings of the 23rd Scientific conference of the Tanzania Society of Animal Production Arusha*. pp. 34-38.

Rutamu, I. B. and Udén, P. (1999) Effect of farm location and management practices on growth performance of crossbred heifers in the coastal areas of Tanzania. *Proceedings of the 26th Scientific Conference of the Tanzania Society of Animal Production, LITI-Tengeru, Arusha, August 3rd - 5th*. 26, 38-55.

Ryan, G., Murphy, J. J., Crosse, S. and Rath, M. (2003). Effect of pre-calving diet on post-calving cow performance. *Livestock Production Science*. 79, 61-71.

Safari, J., Lekule, F. P., Sarwatt, S. V., Mollel, E. L. and Makauki, A. F. (2000). A study of some aspects of dairy management practices of farmers in Morogoro rural district: A case study of SURUDE and HPI beneficiaries in Turiani division. *Proceedings of the 27th Scientific Conference of the Tanzania Society of Animal Production, UCLAS-Dar es Salaam, August 3rd –5th*. 27, 18-27.

Saiddudin, S., Riesen, J. W., Tyler, W. J. and Casida, L. E. (1968). Relation of postpartum interval to pituitary gonadotropins, ovarian follicular development and fertility in dairy cows. *Wisconsin Agriculture Experimental Station Research Bulletin*. 270, 15.

Samuel, C. (1977). Physiological and pathological characteristics of bovine uterus postpartum. Areview. *Malaysian Veterinary Journal*. 6, 125-132.

Scaletti, R.W., Trammell, D. S. Smith, B. A. and Harmon, R. J. (2001). Role of dietary copper in altering response to intramammary E. coli challenge. Pages 29-33 in Proc. Int. Mastitis Symp., Natl. Mastitis Counc./Am. Assoc. Bovine Practitioners, Vancouver, BC, Canada.

Schelling, S. (Ed.) (1996). Australian dairy: The comprehensive reference to the Australian dairy industry. Morescope publishing Pty. Ltd. Camberwell, Victoria.

Schillo, K. K. (1993). Possible roles of endogenous opioids in control of luteinizing hormone secretion in female ruminants. In: *Opioids in Farm Animals*. Parvize, N. (Ed.), Landwirtschaftsverlag, Münster. pp. 1-14.

Sendalo, D. S., Mtenga, L. A. and Ekern, A. (1988). Mineral status of soils and forages and effects of mineral supplementation on performance of lambs. *Proceedings of the 15th Scientific Conference of the Tanzania Society of Animal Production, AICC, Arusha, September, 27th - 30th*. 15, 30-45.

Senger, P. L. (1994). The estrus detection problem: New concepts, technologies, and possibilities. *Journal of Dairy Science*. 77, 2745.

Senger, P. L. (2003). Fertility factors-Which ones are really important?. *Proceedings of the 6th Western Dairy Management Conference, March 12-14, 2003*, Reno, NV-89. http://www.wdmc.org/2003/Fertility%20Factors-%20Which%20Ones%20are%20Really%20Important.pdf. (Accessed in Oct. 2004).

Shekimweri, M. T., Kurwijila, L. R. and Mgongo, F. O. K. (1998). Incidence, causative agents and strategy of control of mastitis among smallholder dairy herds in Morogoro, Tanzania. *Tanzania Journal of Agricultural Sciences*. 1, 28-36.

Shem, M. N., Malole, J. M. L., Machangu, R., Kurwijila, L. R. and Fujihara. T. (2001). Incidence and causes of sub-clinical mastitis in dairy cows on smallholder and large scale farms in Tropical areas of Tanzania. *Asian-Australian Journal of Animal Science*. 14, 3.

Shem, M. N. and Mdoe, N. S. Y. (2002). Dairy production and poverty alleviation in Tanzania: A historical perspective. *Proceedings of the joint 17th Scientific Conference of the Tanzania Society for Animal Production and the 20th Scientific Conference of the Tanzania Veterinary Association, AICC-Arusha, December 3rd - 5th*. pp. 112-127.

Shem, M. N., Mosha, F. A., Machangu, R., Kambarage, D. and Fujihara, T. (2002). Bovine mastitis in Zebu and Crossbred cattle under extensive management system in Tanzania. *Asian-Australian Journal of Animal Science*. 15, 751-756.

Shiferaw, Y., Tenhagen, B. A., Bekana, M. and Kassa, T. (2003). Reproductive performance of crossbred dairy cows in different production systems in the central highlands of Ethiopia. *Tropical Animal Health and Production*. 35, 551-561.

Shitandi, A., Anakalo, G., Galgalo, T. and Mwangi, M. (2004). Prevalence of bovine mastitis amongst smallholder dairy herds in Kenya. *Israel Veterinary Medical Association*. 59, 1-2.

Short, R. E., Bellows, R. A., Staigmiller, R. B., Berardinelli, J. G. and Custer, E. E. (1990). Physiological mechanisms controlling anoestrus and infertility in postpartum beef cattle. *Journal of Animal Science*. 68, 799-816.

Silke, V., Diskin, M. G., Kenny, D. A., Boland, M. P., Dillon, P., Mee, J. F. and Sreenan, J. M. (2002). Extent, pattern and factors associated with late embryonic loss in dairy cows. *Animal Reproduction Science*. 71, 1-12.

Silvia, W. J., Hatler, T. B., Nugent, A. M. and Laranja da Fonseca, L. F. (2002). Ovarian follicular cysts in dairy cows: an abnormality in folliculogenesis. *Domestic Animal Endocrinology*. 23, 166-167.

Sinclair, K. D., Kuran, M., Gebbie, F. E., Webb, R. and McEvoy, T.G. (2000). Nitrogen metabolism and fertility in cattle. II. Development of oocytes recovered from heifers offered diets differing in their rate of nitrogen release in the rumen. *Journal of Animal Science*. 78, 2670-2680.

Singh, C. S. P., Singh, S. K. and Singh, B. (1981). Studies on the incidence of infertility in cows. *Indian Veterinary Journal*. 58, 909-912.

Smart, M. E. and Christensen, D. A. (1985). The effect of cow's dietary copper intake, sire breed, age, on her copper status and that of her fetus in the first ninety days of gestation. *Canadian Journal of Comparative Medicine*. 49, 156-158.

Smart, M. E., Gudmundson, J. and Christensen D. A. (1981). Trace mineral deficiencies in cattle: A review. *Canadian Veterinary Journal*. 22, 372.

Smith, R. D., Perkins, B. L., Sniffen, C. J. and Pearson, E. G. (1984). Body condition and fatty liver in dairy cows – is there a relationship with reproductive performance? *Proceedings of Cornell Nutrition Conference for Feed Manufacturers, November 1-3, 1983*, Syracuse, Sheraton Motor Inn. 1984. pp. 20-25.

Smith, G. M. and White, C. L. (1997). A molybdenum-sulfur-cadmium interaction in sheep. *Australian Journal of Agricultural Research*. 48, 147-154.

Smith, J. W., Gilson, W. D. and Ely, L. O. (2002). Dairy reproduction benchmarks. Cooperative extension service. The University of Georgia College of Agricultural and Environmental Sciences. Bulletin 1210. pp. 5.

Soetrisno, D., Mahyuddin, M., Vijchulata, P., Osman, A. and Tan, H. S. (1985). Performance of sahiwal-Friesian cows under grazing and stallfeeding management. *Proceedings of 9th Annual Conference of Malaysian Society of Animal Production*. pp. 65-71.

Spears, J. W., Kegley, E. B. and Mullis, L. A. (2004). Bioavailability of copper from tribasic copper chloride and copper sulfate in growing cattle. *Animal Feed Science and Technology*. 116, 1-3.

Spicer, L. J., Francisco, C. C., Jones, D. and Waldner, D. N. (2000). Changes in milk urea nitrogen during early lactation in holstein cows. 2000 Animal Science Research Report. Oklahoma Agricultural Experiment Station .Divison of Agricultural Science and Natural Resources .Oklahoma State University. pp. 169-171.

Spitzer, J. C., Morrison, D. G., Wettemann, R. P. and Faulkner, L. C. (1995). reproductive responses and calf birth and weaning weights as affected by body condition at parturition and postpartum weight gain in primiparous beef cows. *Journal of Animal Science*. 73, 1251-1257.

Sprecher, D. J., Nebel, R. L. and Whitman, S. S. (1989). The predictive value, sensitivity and specificity of palpation per rectum and transrectal ultrasonography for the determination of bovine luteal status. *Theriogenology*. 31, (6), 1165-1172.

Sprinkle, J. E. (1996). Matching forage resources with cow herd supplementation. Arizona cooperative extension. Publication number 195023. http://ag.arizona.edu/pubs/animal/az9523.pdf. (Accessed in Feb. 2005).

SPSS for windows, release 12.0.1, copyright© SPSS Inc., 1989-2003.

Stabenfeldt, G. H. (1974). Physiologic, pathologic and therapeutic roles of progesterone in domestic animals. *Journal of American Veterinary Medical Association*. 164, 311-317.

Stephen, J., Sokombi, E. and Bitanyi, S. (2002). Poverty alleviation through smallholder dairying: Experiences of Mogabiri Farm Extension Centre, Tanzania. *Proceedings of the joint 17th Scientific Conference of the Tanzania Society for Animal Production and the 20th Scientific Conference of the Tanzania Veterinary Association, AICC-Arusha, December 3rd –5th*. pp. 81-86.

Stevenson, J. S. (2003). Reproductive Program Aids–Beneficial or Band Aid? *Proceedings of the 2nd bi-annual W. E. Petersen symposium. April 8, 2003.* University of Minnesota-St. Paul campus.

Stockdale, C. R., (2000). Differences in body condition and body size affect the responses of grazing dairy cows to high-energy supplements in early lactation. *Australian Journal of Experimental Agriculture*. 40, 903-911.

Stotz, D. (1979). Smallholder dairy development in past, present and future in Kenya. PhD Dissertation: Hohenheim University, Germany.

Studer, E. (1998). A veterinary perspective of on-farm evaluation of nutrition and reproduction. *Journal of Dairy Science*. 81, 872-876.

Suttle, N. F. (1986). Problems in the diagnosis and anticipation of trace element deficiencies in grazing livestock. *Veterinary Record*. 119, 148-52.

Sykes, A. R. and Field, A. C. (1972). Effects of dietary deficiencies of energy, protein and calcium on the pregnant ewe. I. Body composition and mineral content of the ewes. *Journal of Agriculutural Science, Cambridge*. 78, 109-117.

Swai, E. S., French, E. P., Ogden, N. H., Fitzpatrick, J., Kambarage, D. and Bryant, M. (2002). Occurrence and spatial distribution of clinical mastitis in smallholder dairy farms in Tanga, *Tanzania. Bulletin of Animal Health and Production in Africa*. 50, 205-212.

Swai, E. S., Karimuribo, E., Kambarage, D. M., French, N. P., Fitzpatrick, J. L and Bryant, M. J. (2000). Mastitis in small holder dairy farms in Tanzania: a neglected animal health condition and its economic implications to the farmer and milk processor. *Proceedings of the 27th Scientific Conference of the Tanzania Society of Animal Production, UCLAS-Dar es Salaam, August 3rd –5th*. 27, 28-34.

Swai, E. S., Minja, F. N. and Zylstra, L. (1993). Dairy development in Tanga, Tanzania. Future of livestock industries in East and Southern Africa. *Proceedings of the workshop held at Kadoma Ranch Hotel, Zimbabwe. 20th –23rd July*. pp. 157-164.

Swenson, M. J. (Ed.) (1970). Dukes' physiology of domestic animals, 4th Ed., Comstock Publishing Associates, Cornell University Presss, Ithaca and London. pp. 1253.

Tegegne, A., Entwistle, K. W. and Mukasa-Mugerwa, E. (1992). Effects of supplementary feeding and suckling intensity on postpartum reproductive performance of Small East African Zebu cows. *Theriogenology*. 38, (1), 97-106.

Ternouth, J. H. (1989). Endogenous losses of phosphorus by sheep. *Journal of Agricultural Science, Cambridge*. 113, 291-297.

Ternouth, J. H. and Sevilla, C. C. (1990). Dietary calcium and phosphorus repletion in lambs. *Australian Journal of Agricultural Research*. 41, 415-420.

Terqui, M., Chupin, D., Gathier, D., Perez, N., Pelot, J. and Maule'on, P. (1982). Influence of management and nutrition on postpartum endocrine functions and ovarian activity in cows. In: *Factors Influencing Fertility in the postpartum cow*. Karg and Schallenberger (Eds.), Martinus Nijhoff Publishers, The Hague. pp. 384-408.

Thatcher, W. W. (1974). Effects of season, climate, and temperature on reproduction and lactation. *Journal of Dairy Science*.47, 360.

Tilley, J. M. and Terry, K. A. (1963). A two stage technique for invitro digestibility of forage crops. *Journal of British Grassland Society*. 18, 104-111.

Titterton, M. (1994). The interaction between energy balance, hepatic metabolism and return to cyclicity in dairy cows in early lactation: a review and report on recent studies. *Journal of the Zimbabwe Society for Animal Production*. 6, 3-14.

Troccon, J. L. and Petit, M. (1989.) Croissance des génisses de renouvellement et performances ultérieures. *INRA Production Animale*, 2, 55-64.

Tudor, G. D. (1972). The effect of pre- and post-natal nutrition on the growth of beef cattle. I. The effect on nutrition and parity of the dam on calf birth weight. *Australian Journal of Agricultural Research*. 23, 389-95.

Udo, H. and Cornelissen, T. (1998). Livestock in resource-poor farming systems. *Outlook Agriculture*. 27, 237-242.

Underwood, E. J. (Ed.) (1977). *Trace element in Human and Animal Nutrition*. 4th ed. Academic Press, New York. pp. 50-150.

Underwood, E. J. (Ed.) (1981). *The mineral nutrition of livestock*. 2nd ed. Commowealth Agriculture Bureaux, United Kingdom. pp. 97-167.

Underwood, E. J. and Suttle, N. F. (1999). The mineral nutrition of livestock. 3rd Ed., CAB International.

Upham, G. L. (1991). Measuring dairy herd reproductive performance. *The Bovine Practitioner*. 26, 49-56.

Urassa, J. K. (1999). Study of the factors influencing milk output of dairy cattle under smallhoder farms in Tanga region. Msc dissertation. Sokoine University of Agriculture, Morogoro, Tanzania.

Urassa, J. K. and Raphael, E. (2001) The contribution of small scale dairy farming to community welfare: a case study of morogoro municipality. Published on the Internet by the eSAP - Project at http://www.fiuc.org/iaup/sap/. Electronic Publications from Sokoine University of Agriculture, Morogoro, Tanzania. (Accessed 10 January, 2005).

Urio, N. A. and Sarwatt, S. V. (1986). Dry season feeding alternatives. *Proceedings of the 13th Scientific Conference of the Tanzania Society of Animal Production, AICC-Arusha, August 16th –18th*. 13, 96-113.

URT. (2002). The United Republic of Tanzania population and housing census report.

Van Houtert, M. F. J. (1993). The production and metabolism of volatile fatty acids by ruminants fed roughages: a review. *Animal Feed Science andTechnology*. 43, 189-225.

Van Saun, R. J. (1991). Dry cow nutrition. *Veterinary Clinics of North America-Food Animal Practice*. 7, 599.

Van Saun, R. J., Uleman, S. C. and Sniffen, C. J. (1993). Effect of undegradable protein amount fed pre-partum on post-partum production in first lactaction Holstein cows. *Journal of Dairy Science*. 76, 236-244.

Van Schaik, G., Perry, B. D., Mukhebi, A. W., Gitau, G. K. and Dijkhuizen, A. A. (1996). An economic study of smallholder dairy farms in Murang'a district, Kenya. *Preventive Veterinary Medicine*. 29, 21-36.

VandeHaar, M. J. (1998). Feeding heifers as a long-term investment. *Proceedings of Northwest Dairy Nutrition Short course. January. 30, 1998, Semiahmoo, WA*, Washington State University. pp. 1.

Vandeplassche, M. (1982). *Reproductive efficiency in cattle:A guideline for projects in developing countries*. FAO Animal Production and Health Paper No. 25. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy. pp. 118.

Vanzant, E. S., and Cochran, R. C. (1994). Performance and forage utilization by beef cattle receiving increasing amounts of alfalfa hay as a supplement to low-quality, tallgrassprairie forage. *Journal of Animal Science*. 72, 1059.

Villa-Godoy, A., Hughes, T. A., Emery, R. S., Chapin, L. T. and Fogwell, R. L. (1988). Association between energy balance and luteal function in lactating cows. *Journal of Dairy Science*. 71, 1063-1072.

Vincente-Chandler, J., Caro-Costas, R., Pearson, R. W., Abruna, F., Figarella, J. and Silva, S. (1964). Intensive management of tropical forage in Puerto Rico. Univ. Puerto Rico Agric. Expt. Sta. Bull. 187.

Wagner, W. C. (1968). Physiology of the post partum female. *Iowa State University Veterinary Journal*. 30, (91), 75-76.

Walshe, M. J., Grindle, J., Nell, A. and Bachmann, M., (1991). Dairy development in sub-Saharan Africa: A study of issues and options. Tech. Pap. No. 135, World Bank, Washington DC.

Wan Hassan, W. E., Abu Bakar, C. and Tan, K. L. (1981). The performance of imported Jersey cattle in Malaysia I: Milk production. *Proceedings of the 5th Annual Conference of Malaysian Society of Animal Production*. pp. 192-201.

Ward, J. D., Gengelbach, G. P. and Spears, J. W. (1997). The effects of copper deficiency with or without high dietary iron or molybdenum on immune function of cattle. *Journal of Animal Science*. 75, 1400-1408.

Ward, J. D., Spears, J. W. and Kegley, E. B. (1996). Bioavailability of copper proteinate and copper carbonate relative to copper sulfate in cattle. *Journal of Dairy Science*. 79, 127-132.

Washburn, S. P., Silvia, W. J., Brown, C. H., McDaniel, B. T. and McAllister, A. J. (2002). Trends in reproductive performance in Southeastern Holstein and Jersey DHI herds. *Journal of Dairy Science*. 85, 244-251.

Waterman, D. F., Xin, Z., Harmon, R. J. and Hemken, R. W. (1991). Relationship of trace mineral status between stages of production in dairy cattle. *Journal of Dairy Science*. 74, (1), 297. (Abstract).

Wattiaux, M. A. (2004). Managing reproductive efficiency. Babcock Institute for international Dairy Research and Development. University of Wisconsin-Madson. Dairy Essentials. http://babcock.cals.wisc.edu/downloads/de/13.en.pdf. (Accessed in September, 2004).

Whisnant, C. S., Thompson, F. N., Kiser, T. E. and Barb, C. R. (1986). Effect of naloxone on serum luteinizing hormone, cortisol and prolactin concentrations in anestrous beef cows. *Journal of Animal Science*. 62, 1340-1345.

Whitmore, H. L., Tyler, W. J. and Casida. L. E. (1974). Incidence of cystic ovaries in holstein friesian cows. *Journal of American Veterinary Medical Association*. 165, 693-694.

Wiesrma, F. and Stott, G. H. (1969). New concepts in the physiology of heat stress in dairy cattle of interest to engineers. *Transactions of American Society of Agricultural Engineering*. 12, 130.

Wildman, E. E., Jones, G. M., Wagner, P. E., Bowman, R. L., Trout, H. F. Jr., and . Lesch, T. N. (1982). A dairy cow body condition scoring system and its relationship to selected production characteristics. *Journal of Dairy Science*. 65, 495–501.

Wiley, J. S., Petersen, M. K., Ansotegui, R. P. and Bellows, R. A. (1991). Production from first calf beef heifers fed a high or low level of prepartum nutrition and ruminally undegradable or degradable protein postpartum. *Journal of Animal Science*. 69, 4279.

Williams, G. L., Amstalden, M., Garcia, M. R., Stanko, R. L., Nizielski, S. E., Morrison, C. D. and Keisler, D. H. (2002). Leptin and its role in the central regulation of reproduction in cattle. *Domestic Animal Endocrinology*. 23, 339-349.

Wiltbank, J. N., Bond, J., Warwick, E. J., Davis, R. E., Cook, A. C., Reynolds, W. L. and Hazen, M. W. (1965). Influence of total feed and protein intake on reproductive performance in the beef female through second calving. USDA Tech. Bull. 1314.

Wolfenson, D., Roth, Z. and Meidan, R. (2000). Impaired reproduction in heat-stressed cattle: basic and applied aspects. *Animal Reproduction Science*. 60-61, 535-547.

Wong, C. C., Wan Hassan, W. E. and Tan, K. L. (1987). Milk production of Sahiwal x Friesian cow grazing on leucaena-B. decumbens pasture with concentrate supplementation. *Proceedings of the 10th Annual Conference of Malaysian Society of Animal Production*. pp. 280-286.

Wright, R. D., Blair-West, J. R., Nelson, J. F. and Tregear, G. W. (1982). Local action of parathyroid hormone (1-34) and (1-84) at the parotid gland of sheep. *Journal of. Endocrinology*. 94, 37–41.

Wu, Z. and Satter, L. D. (2000). Milk production and reproductive performance of dairy cows fed two concentrations of phosphorus for two years. *Journal of Dairy Science*. 83, 1052-1062.

Wu, Z., Satter, L. D. and Sojo, R. (2000). Milk production, reproductive performance, and fecal excretion of phosphorus by dairy cows fed three amounts of phosphorus. *Journal of Dairy Science*.83, 1028-1041.

Xin, Z., Silvia, W. J., Waterman, D. F., Hemken, R. W. and Tucker, W. B. (1993). Effect of copper status on LH secretion in dairy steers. *Journal of Dairy Science*. 76, 437-444.

Xin, Z., Waterman, D. F., Hemken, R. W. and Harmon, R. J. (1991). Effects of copper status on neutrophil function, superoxide dismutase and copper distribution in steers, *Journal of Dairy Science*. 74, 3078.

Yona, G. K. (2004). Prediction of *in vivo* digestibility of selected tropical forages using *in vitro* technique. MSc dissertation. Sokoine University of Agriculture, Morogoro, Tanzania.

Yost, G. P., Arthington, J. D., McDowell, L. R., Martin, F. G., Wilkinson, N. S. and Swenson, C. K. (2002). Effect of copper source and level on the tare and extent of copper repletion in Holstein heifers. *Journal of Dairy Science*. 85, 3297-3303.

Young, A. J. (2002). Troubleshooting reproductive records to determine potential problems. Part I. The nuts and bolts. Utah State University Extension Newsletter. http://extension.usu.edu/files/agpubs/repro2.htm. (Accessed in Sept. 2004).

APPENDICES
APPENDIX I
Informal survey checklist

General observations:

- Type of animals kept and their health (healthy, emaciated etc.)
- How are the animals kept (grazed, stall fed, tethered etc.)
- Type of grazing land, type of dominant grass species, any signs of overgrazing?
- Size of feeding trough, presence or absence of feed and type of feed present during the visit.
- For cultivated fodder, what are the species grown, the cutting regime, where are they grown?
- Any unused land that could be used for more fodder?
- Ask for concentrate and mineral samples to be sure of the type, how much they cost?.
- Observe the type of crop residues, how fed and stored.
- Observe types of crops grown and how, (intercropped or sole)
- For roadside grass ask for the cost of purchase and transport.

Interview guide

Types of dairy cattle kept:

- What breeds, types are kept?. See whether numbers of certain breeds/types are high or low, why?

Objectives of keeping dairy cattle:

- List the objectives and rank them according to importance, discuss each importance based on animals product produced, see where milk fits and discuss why in relation to other products. How does feed affect mentioned product, why?

Animal Health

- What are major diseases in the area? What is the impact on production e.g. mortality, reduced milk production, delays in reproduction, treatment cost
- Do the farmers have cases of retained placenta, still births, dystocia, abortions. If so is there any seasonality in occurrence of the reproductive problems?
- Any seasonality in disease occurrence? What are the disease control strategies?
- In case of diseased what do they do. Is the veterinary service available?. Are the drugs available?. Can they afford them?.

Animal Reproduction

- How do they realize when a heifer has reached puberty? What is the average age at puberty? When (age/weight) do they breed the heifer?
- How do they identify a cow on heat? What is the frequency of observation?
- Do their animals conceive on the first service? If not, how many times on the average the cow returns to service before conception? Why do they think the animal returns to service?
- What method of breeding do they use?. Where do they get the bull/AI service from. Is it possible to get the bull/AI service whenever they need it?. If not, what are the problems?
- What do they do when an animal fails to conceive?
- For how long do they milk a pregnant cow? If they dry the animal, how long is the dry period? Is there any special treatment to the dry animal (feeding etc).

Livestock feed inventory

- What do farmers feed their dairy animals? (list). Which feeds are seasonal and which are not? Which feeds are more important and why? (score and rank).
- For crop residues, what crop residues are used? where from? how are they transported home? How are they stored? When are they fed? Are they treated prior to feeding?
- For cultivated fodder, what are the species, yields, management (manure/fertilizers), cutting regimes (cutting height or frequency), feeding strategies, processing, storage, and scope for improvement.
- Any feeds sold? What is the price? Why do they sell?.
- Any purchased feed? Which feeds? Where from? At what price?

Feed allocation to animals

- What are the basic feeds to dairy cattle?. How much of each type is given?.
- Any specific times for feeding the animals? Which times? Why these times? How much is fed at a time? Any preferential feeding practiced? Why/why not?. Which animals are favoured? Why these?
- Are there any supplement feeds given to dairy cattle. If yes, what types, what are the ingredients. Are the supplements available all the time? What is the cost?

Feed seasonality:

- Seasonality for seasonal feeds: Which are the periods of abundant availability? How do they handle the excess? (processing, storage). Which are the periods of scarcity. What are the coping strategies during periods of scarcity?.

- For the non seasonal feeds, when are they used most and when less.

Other seasonalities:

- Rain seasonality (months), milk production seasonality (months)
- Livestock production cycles (breeding, calving, sales , disease incidences). Are the cycles be planned/occur naturally? If planned what are the reasons?

Milk production and marketing

- What is the average milk production/cow/day (L)?, lactation length? Who decides on use of milk?. What are the uses (sale, consumption, calf feeding).
- How is the milk market ? where is the market and the price/L? Variations and reliability of the market.
- Who controls the use of income from milk sales. What is the income used for?
- How is milk fed to the calf (bucket fed or suckling)

Constraints and suggestions for improvement

- Farmers to mention and discuss the main problems facing the smallholder dairy cattle industry and possible solutions.

APPENDIX II

Survey questionnaire

District.......................Division.......................Ward......................Village
......

1 Household data

1.1 Name of farmer...................

1.2 Education level: Primary school........Secondary school........College.........University............Other (specify)...............

1.3 Sex: Male...........Female.........

1.4 Marital status:
Married....... ..Single...........Widow...........Widower...........

1.5 Family members

Family members (relationship)	Sex (M/F)	Age (yrs)	Stays on farm (Y/N)	Occupation*
1. Head of household				
2				
3				

*Works on farm = 1; Works outside the farm = 2; Student = 3

2 Daily dairy cattle management:

Husband................Wife...................Other (specify)

3 Resource endowment

3.3 Land ownership(acres): own............rented...........

3.4 Sources and availability of water:

	Distance to source (km)	*Reliability
Well		
Dam		
River		
Others (specify)		

*very reliable = 1; reliable = 2; not reliable = 3.

3.5 Periods of peak labour demand (rank 1, 2, or 3)

Ploughing.....................Weeding.......................Harvesting...............

3.5.1 Coping strategies:

3.5 Sources of income (rank according to importance)

livestock.......crops.........crafts..........wages/salaries...........gardening........remit tances..........others...........

4..Livestock enterprise

Type	Total numbers
Dairy cattle	
Indigenous cattle	
goats	
sheep	
pigs	
donkeys	
chicken	
Others (specify)	

4.1 Dairy herd particulars

For how long have you been keeping cattle?..........(1 = < 5 years, 2 = ≥ 5 years)

Do you keep records on dairy cattle?..........(1 = Yes; 2 = No).

If yes what kind of records?..........(1 = Milk production; 2= milk sales; 3 = diseases; 4 = calving dates; 5 = service dates; Others (specify).

Type	Breed	Total numbers
Cows		
bulls		
calves		
heifers		

4.2 Dairy cattle breeding and reproduction

4.2.1 Age at attainment of puberty..........

4.2.2 Age at first mating...........

4.2.3 Calving interval...........

4.2.4 System of mating: seasonal..........continuous............

4.2.5 Method of mating:

Natural..........Natural (handmating)................Artificial insemination................

4.2.5 Distance from bull....................

4.2.6 Heat detection methods: By observation.......Observation (frequency)...........Others (specify)............

4.3 Dairy cattle health:

4.3.1 Common diseases

Disease	Control measures

4.3.2 Dairy cattle reproductive problems

	Very common	Common	Rare
Abortions			
Stillbirths			
Dystocia			
Retained placenta			
Anoestrus			
Milk fever			

4.4 Number of dairy animals that died in the last 12 months

	Number	Cause of death
cows		
bulls		
calves		
heifers		

4.5 Number of dairy animals disposed in the last 12 months

	Number	reason
cows		
bulls		
calves		
heifers		

4.6 Feeding and management of dairy animals

4.6.1 Rearing system...........(grazing = 1; zero grazing = 2, mixed = 3)

4.6.2 If grazing, time spent in grazing.........

4.6.3 Control over grazing areas.........(communal = 1; private = 2; other (specify).

4.6.4 If zero grazing, what is the feeding regime? (1 = production related; 2 = season related.

	Wet season		Dry season	
	Feed	Quant./day (kg)	Feed	Quant./day (kg)
Lactating cows	Natural pasture			
	Improved pasture			
	Hay			
	Crop residues			
Dry cows	Natural pasture			
	Improved pasture			

	Hay			
	Crop residues			
Heifers	Natural pasture			
	Improved pasture			
	Hay			
	Crop residues			

4.6.5 Do you supply supplementary feeds? Yes..........No...........What are the basic ingredients..............How many days is the concentrate fed per month?

	Morning		Evening	
	Feed	Quantity (kg)	Feed	Quantity (kg)
Lactating cows	Hominy meal			
	Cotton sees cake			
	Sunflower seed cake			
	Minerals			
	Other			
Dry cows	Hominy meal			
	Cotton sees cake			
	Sunflower seed cake			
	Minerals			
	Other			
Heifers	Hominy meal			
	Cotton sees cake			
	Sunflower seed cake			
	Minerals			
	Other			

4.6.6 Watering frequency and quantity (L).......................distance to source...........

4.7 Milk production

Average milk yield/cow/day (L)		Amount sold (L)	Amount consumed (L)	Other uses (specify) (L)
Wet season				
Dry season				

4.8 Feeding and management of dairy calves

4.8.1 Days on colostrums.........

Bucket fed..........amount................frequency...

Suckled..............amount................frequency...
......

4.8.2 Milk feeding

Bucket fed...........Suckling..........Mixed

Age of calf	Morning (litres)	Evening (litres)

4.8.3 Dry feed type/(s)...

Age when introduced (months)......................

Age of calf	Morning amount (kg)	Evening amount (kg)

5. Crop enterprise

Type of crop	Area grown (acres)	Average yield (bags)	Major/Minor crop

Use of crop residues to dairy cattle

Type of residue	Treatment	Storage

APPENDIX III

System of body condition scoring

Score 1:

Gluteal muscle wasted and has concave appearance. The hip bones, tail head, ribs and spinous processed are projecting prominently or less obvious but feel sharp when touched. No fat around the tail head.

Score 2:

Gluteal muscle has a straight appearance. Individual ribs can still be felt with slight hand pressure. There is tissue cover around the tail head and over the hip bones. The spinous processes can be identified individually when touched.

Score 3:

Gluteal muscle has a straight appearance. The ribs can not be easily felt. The hip bones are less prominent and felt rounded. The spinous processes can not be felt even with pressure. The areas on either side of the tail head have a degree of fat cover which can be easily felt.

Score 4:

The gluteal muscle bulges and looks convex. The hip bones are covered with tissue and no longer feel hard. The spinous processes can not be felt even with firm pressure. Folds of fat are beginning to develop over the rib and thighs of the animal.

Score 5:

The gluteal muscle bulges and looks convex. Animal has a blocky appearance. The spinous processes are completely covered by fat and the animals mobility is impaired by the large amount of fat carried.

APPENDIX IV

Determination of milk progesterone

Reagents:

1. Monoclonal antibody 6H11/14; 0.25 ml/vial of 1:10 dilution, lyophilised.
2. Radioactive tracer: progesterone-11-α-hemisuccinate-2[^{125}I] iodohistamine (10 μCi/100μl; Amersham; #IM-138) in methanol:water (9:1).
3. Milk standards: Lyophilised skim-milk standards with progesterone concentrations of 0, 1.25,2.5, 5, 10, 20 and 40 Nm (nmol/L).
4. Carbonate/bicarbonate tablets (coating buffer; EC Diagnostics, Sweden; #LD 8922).
5. Phosphate buffered saline (PBS) tablets (diluent buffer; EC Diagnostics, Sweden; #LD 9402).
6. Bovine serum albumin (BSA), RIA grade (Sigma; #A-9647).
7. Tween 20 (Sigma; #P-1379).
8. Sterile filtered distilled water/glycerol (50:50) solution, for reconstituting antibody.
9. Nanopure water for reconstitution of standards.
10. Nunc 1 ml cryovials (Nunc; #3666656), for storage of antibody stock solution.

Preparation of reagents and samples was done a day before commencing a series of assays:

- Coating buffer: About 70ml distilled water was placed in a 100 ml volumetric flask and a bicarbonate tablet added. The flask was shaken until the tablet was completely dissolved. Distilled water was added to make up to 100 ml mark. (This is 0.05 M carbonate buffer with a Ph 9.6 ± 0.05). It was labelled and stored at 4 ^{0}C.
- Diluent buffer (PBS): About 500 ml distilled water were placed in a beaker and one PBS tablet added (0.14 M NaCl, 3 Mm KCL) and stirred until completely dissolved. The solution was transferred to a 1 L volumetric flask and distilled water added to make up to the mark. (This is 0.01 M phosphate buffered saline with a Ph 7.4 ± 0.2. It was labelled and stored at 4 ^{0}C.

- Antibody stock solution: One vial of the lyophilised monoclonal antibody was reconstituted with 0.25 ml of diluent to obtain the antibody stock solution (1:10 dilution). This was aliquoted into 25 µl volumes in Nunc 1 ml cryovials. They were stored upright in a rack at -20^0C.
- Milk standards: Lyophilised milk standards were reconstituted by adding 1 ml of distilled water to each vial. They were allowed to stand overnight in refrigerator then shaken gently until they were dissolved.
- Washing solution: One g of Tween 20 was added to 1 L distilled water to obtain a 0.1% washing solution. The solution was mixed well until completely dissolved.

Coating and assay procedures:

a. Day 1.

- Nunc 'star' tubes were labelled in duplicate for Total Counts (TC), B_{zero} (B_0), standards, QC and unknowns as shown in the assay protocol (FAO/IAEA Programme, 1999 Bench protocol, version – ScRIA 3.1)
- One aliquot (25µl) of the antibody stock solution was transferred into a 50 ml volumetric flask. Complete transfer of antibody was ensured by repeated rinsing of the aliquot tube with coating buffer (0.05 M carbonate buffer). The flask was filled to the mark with the same buffer. This gave an antibody coating solution of 1/20,000.
- 300 µl of antibody coating solution were dispensed into each tube, except the TC tubes. The tubes were covered with parafilm and incubated overnight at 4^0 in refrigerator.

b. Day 2.

- After incubation, the contents of the tubes were decanted and the mouth of the tubes taped vigorously on absorbent paper to remove the remaining liquid. 500 µl of washing solution were added to each tube and decanted as described above. The tubes were rinsed a second time with 500 µl of washing solution and decanted as described above.
- 33 mg BSA (Bovine serum albumin) were weighed and transferred into a glass beaker with 33 ml of diluent buffer (PBS) and completely dissolved using a clean glass rod.
- 20 µl of stock tracer solution (^{125}I-Progesterone) were added and mixed well to obtain the tracer working solution.

- Two aliquots of 200 µl each were taken from tracer working solution and counted in a gamma counter for one minute for total counts (TC).

Assay set up:

- All components were allowed to reach room temperature (15-20 minutes) before setting up assay. All samples were gently mixed before pipetting.
- 40 µl of standard, QC or unkown sample were added to the respective antibody coated tube. 200 µl of tracer working solution were added to each tube including TC using a repeater pipette. The tubes were then covered with parafilm and incubated overnight at 4^0C.

c. Day 3.

- After incubation, the TC tubes were removed from the rack and all the remaining tubes decanted into a radioactive waste disposal container and allowed to drain for 5 minutes on absorbent paper. 500 µl of washing solution were added to each tube (except TC) and decanted to remove liquid as described above. The rinsing and decanting was done twice.

Measuring of radioactivity and calculation of results:

The radioactivity of each tube including TC was counted in gamma counter for a fixed time (60 seconds).

Maximum percentage binding (B_{max}) in the assay was calculated by dividing the average counts per minute (cpm) of the two zero binding tubes (B_0) by the average cpm of the two TC tubes and multiplying by 100.

B_{max} = (Average cpm of B_0/Average cpm of TC) x 100

Percent binding values (%B/ B_0) were calculated for all standards, samples and quality control tubes by dividing the cpm of each of these tubes with that of the B_0 tubes and multiplying by 100.

B/ B_0 = (Average cpm of standard or sample or QC/Average cpm of B_0) x 100

The average percent bound (B/ B_0) was plotted on the y-axis and the concentration of progesterone standard on the x-axis and the best fit line and equation of the line were generated using the Microsoft excel computer program. Progesterone concentrations of samples and Quality controls were calculated from the equation.

APPENDIX V

Determination of urea in blood plasma

Method:

NED Dye method

Principle:

Urea condenses with O-Phthalaldehyde and Naphthyl ethylene diamine to form an orange coloured complex. The rate of formation of this complex is directly proportional to urea concentration, and is monitored on an initial rate (fixed time) mode at 505 nm.

Reagents:

1. O-Phthalaldehyde reagent (O-Phthalaldehyde, Diluent, Surfanctant)
2. Ned (Ned, Diluent, Surfactant)
3. Urea standard (Urea 50 mg/dl, stabiliser)

Procedure:

Materials pipetted into tubes marked	Blank	Standard	Test
Distilled water	1000μl	-	-
Reagent 1	-	1000μl	1000μl
Standard	-	50	-
Serum	-	-	50
Mixed properly			
Reagent 2	-	500μl	500μl

- Spectrophotometer was blanked with distilled water
- Standard curve was prepared.
- Sample reading was done

Calculations:

Urea concentration (mg/dl) = (T2-T1/S2-S1) x 50

APPENDIX VI

Determination of total calcium in blood plasma

Principle and procedure:

Plasma is added to acidic 'Calcium Reagent 1' and incubated for a period of four minutes to ensure the release of protein bound calcium. Addition of 'Calcium reagent 2' forms an alkaline medium wherein cresolphthalein complexone forms a coloured complex with calcium irons, which is measured at 574 nm. The 8-hydroxyquinoline in the reagent binds the magnesium ions, thus minimizing their interference in the calcium assay.

Chemicals needed:

- Potassium chloride, KCl, MW 74.56
- 8-hydroxyquinoline (e.g FLUKA 55070), MW 145.16
- 0-cresolphthaleine complexone (e.g. FLUKA 64000), MW 636.62
- 2-amino-2-methyl-1-propanole (e.g. FLUKA 08580), MW 89.14
- Tritisol™ (Merck art. 1.09943), 1.000g Ca in HCl solution

Reagents:

- 7.456 g KCl was dissolved in 950 ml distilled water and adjusted to pH 1.80 with 1.0 N HCl. The flask was filled to 1000 ml. (The buffer is stable for 2 weeks if kept closed and chilled).
- Calcium reagent 1: 0.820 g 8-hydroxyquinoline + 0.025 g 0-cresolphathaleine complexone was dissolved in 480 ml KCl-HCl buffer. The pH was adjusted to 1.80. The flask was filled to 500 ml mark. (The reagent is stable for only 1 day).
- Calcium reagent 2: 14.26 g 2-amino-2-methyl-1-propanole was dissolved in 180 ml distilled water and pH adjusted to 10.3 with 3 N HCl-solution. The flask was filled to 200 ml. (Stable for weeks in closed bottles).

Procedure:

90 µl plasma was pipettted into a test tube containing 3.0 ml of 'Calcium reagent 1' and mixed on a whirl-mixer. 1.0 ml 'Calcium reagent 2' was added to the solution 4 minutes later, and the content was mixed once more. The mixture was stored for 5 minutes before reading in the spectrophotometer (574 nm). The reading was finished within 30 seconds in the spectrophotometer since the absorbance declines fast hereafter). Readings were done within 1 hour from addition of 'Calcium reagent 2'. Only acid washed tubes were used.

Standard curve:

Standard solution was used to prepare the standard curve. The standard solution was made from Tritisol Ca-solution. 1.000 g Ca was mixed ad 1000 ml of redistilled water, to make a molarity of 24.95 mmol/l.

APPENDIX VII

Determination of inorganic phosphorus in blood plasma

Principle of the procedure:

Inorganic phosphorus is assayed by measurement of vanado-phospho-molybdate complex formed in acid. Absorbance of this complex is read at 420 nm. Absorbance data are converted into reportable concentration values via standard curve.

Chemicals needed:

- Ammonium hepta molybdate tetrahydrate (e.g. Merck 1.01182.1000), MW 1235.86
- Ammonium meta vanadate, (e.g FLUKA 10028), MW 116.98
- Dilute hydrochloric acid
- Potassium di-hydrogen phosphate (e.g. Merck 2579201) MW 136.09
- Trichloroacetic acid (TCA) (e.g. FLUKA 91228) MW, 163.39

Reagent:

0.110 g NH_4VO_3 was dissolved in approximately 80 ml of distilled water (magnetic stirring). 4.000 g $(NH_4)_6Mo_7O_{24}, 4H_2O$ was added and dissolved. 10 ml 6 N HCl was added and the flask refilled ad 100 ml.

Procedure:

- One volume of plasma was added to 4 volumes of 10% TCA solution, mixed on a whirl mixer and centrifuged for 5 minutes at 3000*G.
- Two hundred µl of supernatant were pipetted into 200 µl of reagent. One and half ml of water was added, the mixture mixed on a whirl mixer and allowed to stand for 2-6 hours (minimum and maximum) in the dark before reading at 420 nm on spectrophotometer. Analyses were performed in duplicate.

Precaution taken: All utensils used were acid washed to make sure they were free of phosphates (detergents).

Standard curve:

Standard curve was prepared using KH_2PO_4 as P source.

APPENDIX VIII

Composition of Super Maclick® (Coopers Kenya Ltd) as per manufactures manual

Mineral	Amount (%)
Nacl	27.00
Ca	18.51
P	11.00
Mg	3.00
Fe	0.50
Cu	0.16
Mn	0.40
Zn	0.50
S	0.40
Co	0.02
I	0.02
Se	0.0015
Mo	0.0002

APPENDIX IX

Summary of analysis of variance and correlation tables

a. ANOVA for effect of season and month of reproductive cycle on BWT, BCS, plasma Ca, P, Cu, and PUN

Source	Dependent Variables	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Season	BCS	4.296	1	4.296	25.195	0.000	0.088
	C-Bwt	106074.621	1	106074.621	23.812	0.000	0.084
	Ca(mg/dL)	194.931	1	194.931	178.438	0.000	0.407
	P4 (mg/dl)	55.363	1	55.363	21.124	0.000	0.075
	Cu(ug/ml)	.001	1	.001	0.021	0.885	0.000
	Urea(mg/dl)	96.947	1	96.947	8.856	0.003	0.033
Month	BCS	7.966	5	1.593	9.344	0.000	0.152
	C-Bwt	83581.157	5	16716.231	3.753	0.003	0.067
	Ca(mg/dL)	15.868	5	3.174	2.905	0.014	0.053
	P4 (mg/dl)	154.227	5	30.845	11.769	0.000	0.185
	Cu(ug/ml)	0.070	5	0.014	0.362	0.874	0.007
	Urea(mg/dl)	36.192	5	7.238	0.661	0.653	0.013

b. ANOVA for effect of season on BCSC

Source	Dependent variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Season	BCSC	1.222	1	1.222	11.164	0.002	0.186

c. ANOVA for effect of season on MY

Source	Dependent varible	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Season	MY	4456.841	1	4456.841	431.250	0.000	0.094

d. ANOVA for effect of season on DPO, SC and CI

Source	Dependent Variables	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Season	DPO	58296.152	1	58296.152	4.601	0.040	0.126
	SC	0.042	1	0.042	0.060	0.808	0.002
	CI	31423.489	1	31423.489	2.363	0.134	0.069

e. Chi-square test for relationship between season and cyclicity

	Value	df	Asymp. Sig. (2-sided)	Cramer's V value
Pearson Chi-Square	0.692	1	0.406	0.116

f. Chi-square test for relationship between season and DPO

	Value	df	Asymp. Sig. (2-sided)	Cramer's V value
Pearson Chi-Square	0.336	2	0.513	0.167

g. Pearson correlations between DPO, SC, CI, BWT, BCS, BCSC, plasma Ca, P, Cu, PUN, MY and parity

		PARITY	MY	BWT	BCS	BCSC	Ca
PARITY	Pearson Correlation	1	.425(**)	.377(**)	.089	.012	-.291(*)
	Sig. (2-tailed)	.	.003	.006	.512	.931	.028
	N	57	46	51	57	51	57
MY	Pearson Correlation	.425(**)	1	.617(**)	.257	.112	-.380(**)
	Sig. (2-tailed)	.003	.	.000	.084	.484	.009
	N	46	46	41	46	41	46
BWT	Pearson Correlation	.377(**)	.617(**)	1	.286(*)	.236	-.368(**)
	Sig. (2-tailed)	.006	.000	.	.042	.095	.008
	N	51	41	51	51	51	51
BCS	Pearson Correlation	.089	.257	.286(*)	1	.868(**)	-.291(*)
	Sig. (2-tailed)	.512	.084	.042	.	.000	.028
	N	57	46	51	57	51	57

BCSC	Pearson Correlation	.012	.112	.236	.868(**)	1	-.363(**)
	Sig. (2-tailed)	.931	.484	.095	.000	.	.009
	N	51	41	51	51	51	51
Ca	Pearson Correlation	-.291(*)	-.380(**)	-.368(**)	-.291(*)	-.363(**)	1
	Sig. (2-tailed)	.028	.009	.008	.028	.009	.
	N	57	46	51	57	51	57
P	Pearson Correlation	.124	.341(*)	.280(*)	.367(**)	.179	-.337(*)
	Sig. (2-tailed)	.360	.020	.047	.005	.209	.010
	N	57	46	51	57	51	57
Cu	Pearson Correlation	-.061	.171	-.011	.006	-.113	-.032
	Sig. (2-tailed)	.652	.255	.941	.964	.429	.811
	N	57	46	51	57	51	57
PUN	Pearson Correlation	.385(**)	.550(**)	.434(**)	.411(**)	.211	-.132
	Sig. (2-tailed)	.003	.000	.001	.001	.137	.326
	N	57	46	51	57	51	57
DPO	Pearson Correlation	-.134	-.175	-.315(*)	-.424(**)	-.348(*)	.194
	Sig. (2-tailed)	.385	.294	.047	.004	.028	.206
	N	44	38	40	44	40	44
SC	Pearson Correlation	-.126	-.189	-.295	.035	.006	-.006
	Sig. (2-tailed)	.462	.293	.102	.839	.974	.971
	N	36	33	32	36	32	36
CI	Pearson Correlation	-.236	-.094	-.339	-.394(*)	-.238	.174
	Sig. (2-tailed)	.159	.601	.053	.016	.183	.303
	N	37	33	33	37	33	37

g. Pearson correlations..........continued

		P	Cu	PUN	DPO	SC	CI
PARITY	Pearson Correlation	.124	-.061	.385(**)	-.134	-.126	-.236
	Sig. (2-tailed)	.360	.652	.003	.385	.462	.159
	N	57	57	57	44	36	37
MY	Pearson Correlation	.341(*)	.171	.550(**)	-.175	-.189	-.094
	Sig. (2-tailed)	.020	.255	.000	.294	.293	.601
	N	46	46	46	38	33	33
BWT	Pearson Correlation	.280(*)	-.011	.434(**)	-.315(*)	-.295	-.339
	Sig. (2-	.047	.941	.001	.047	.102	.053

	Sig. (2-tailed)						
	N	51	51	51	40	32	33
BCS	Pearson Correlation	.367(**)	.006	.411(**)	-.424(**)	.035	-.394(*)
	Sig. (2-tailed)	.005	.964	.001	.004	.839	.016
	N	57	57	57	44	36	37
BCSC	Pearson Correlation	.179	-.113	.211	-.348(*)	.006	-.238
	Sig. (2-tailed)	.209	.429	.137	.028	.974	.183
	N	51	51	51	40	32	33
Ca	Pearson Correlation	-.337(*)	-.032	-.132	.194	-.006	.174
	Sig. (2-tailed)	.010	.811	.326	.206	.971	.303
	N	57	57	57	44	36	37
P	Pearson Correlation	1	.081	.473(**)	-.551(**)	-.071	-.506(**)
	Sig. (2-tailed)	.	.548	.000	.000	.679	.001
	N	57	57	57	44	36	37
Cu	Pearson Correlation	.081	1	.080	-.188	-.123	-.161
	Sig. (2-tailed)	.548	.	.554	.221	.476	.341
	N	57	57	57	44	36	37
PUN	Pearson Correlation	.473(**)	.080	1	-.459(**)	-.343(*)	-.574(**)
	Sig. (2-tailed)	.000	.554	.	.002	.041	.000
	N	57	57	57	44	36	37
DPO	Pearson Correlation	-.551(**)	-.188	-.459(**)	1	.107	.893(**)
	Sig. (2-tailed)	.000	.221	.002	.	.540	.000
	N	44	44	44	44	35	35
SC	Pearson Correlation	-.071	-.123	-.343(*)	.107	1	.336(*)
	Sig. (2-tailed)	.679	.476	.041	.540	.	.049
	N	36	36	36	35	36	35
CI	Pearson Correlation	-.506(**)	-.161	-.574(**)	.893(**)	.336(*)	1
	Sig. (2-tailed)	.001	.341	.000	.000	.049	.
	N	37	37	37	35	35	37

h. Chi-square test for relationship between occurrence of reproductive diseases and disorders in rainy and dry seasons

	Value	df	Asymp. Sig. (2-sided)	Cramer's V value
Pearson Chi-Square	15.888	8	0.044	0.528

i. Chi-square test for relationship between sex of the calf and incidences of occurrence of diseases

	Value	df	Asymp. Sig. (2-sided)	Cramer's V value
Pearson Chi-Square	7.539	8	0.48	0.364

j. ANOVA for effect of treatment on BWT BCS, PUN, plasma Ca, P, Cu and their covariates

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Treatment	BCS	8.067	1	8.067	46.296	.000	.142
	I_BCS	.382	1	.382	3.684	.056	.013
	Body weight	99905.862	1	99905.862	25.738	.000	.084
	I_BWT	10499.185	1	10499.185	3.583	.059	.013
	Calcium	.618	1	.618	.342	.559	.001
	I_CA	5.908	1	5.908	3.764	.053	.013
	Phosphorus	23.891	1	23.891	10.252	.002	.035
	I_P	3.532	1	3.532	2.087	.150	.007
	Copper	.420	1	.420	9.044	.003	.031
	I_CU	.108	1	.108	2.616	.107	.009
	UREA	354.513	1	354.513	71.616	.000	.204
	I_UREA	14.987	1	14.987	3.093	.080	.011

k. ANOVA for effect of treatment on CBwt, BCSC and MY

Source	Dependent variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Treatment	CBWT	106.154	1	106.154	7.267	.009	.106
	BCSC	2.204	1	2.204	11.578	.001	.166
	MY	7927.111	1	7927.111	636.864	.000	.111

l. ANOVA for effect of treatment on DPO

Source	Dependent variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Treatment	DPO	20203.773	1	20203.773	5.107	.029	.106

m. ANOVA for effect of parity on BWT, BCS, PUN, plasma Ca, P and Cu

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Parity	BCS	1.364	5	.273	1.368	.235	.011
	BWT	282692.957	5	56538.591	13.827	.000	.098
	Ca	30.032	5	6.006	3.529	.004	.072
	P	22.921	5	4.584	2.132	.063	.045
	Cu	.768	5	.154	4.888	.000	.098
	PUN	100.919	5	20.184	4.213	.001	.085

n. ANOVA for effect of parity on CBwt, BCSC and MY

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Parity	CBwt	30.620	5	6.124	.429	.826	0.049
	MY	225.516	5	45.103	6.477	.000	0.435
	BCSC	1.794	5	.359	1.827	.128	0.179

o. Chi-square test for relationship between treatment and proportions showing resumption of cyclicity before and after 90 days postpartum

	Value	df	Asymp. Sig. (2-sided)	Cramer's V value
Pearson Chi-Square	1.120	1	0.290	0.134

p. Chi-square test for relationship between treatment and categories of DPO

	Value	df	Asymp. Sig. (2-sided)	Cramer's V value
Pearson Chi-Square	19.864	2	.000	0.58

q. Chi-square test for relationship between treatment and incidences of occurrence of reproductive diseases and disorders

	Value	df	Asymp. Sig. (2-sided)	Cramer's V value
Pearson Chi-Square	9.424	8	0.308	0.385

APPENDIX X

Calculations of marginal profit of supplementation

The costs of concentrate ingredients and the mixed concentrate per kilogram were as follows:

- Cost of HM (HM_C) = 76 kg x 76.07 TSh/kg
- Cost of SSC (SSC_C) = 23 kg x 92.31 TSh/kg
- Cost of SM (SM_C) = 1 kg x 1538.46 TSh/kg.
- Cost per kg concentrate (C_C) = [HM_C + SSC_C + SM_C]/100
- C_C = [(76kg x 76.07 TSh/kgHM) + (23kg x 92.31 TSh/kgSSC) + (1 x 1538.46 TSh/kgMSP)]/100 = 94.43 TSh/kg of concentrate.

Calculations of total supplementation costs (60 days pre- and post-calving) and total MY revenue for 3 months post-calving for a 287.1kg supplemented cow were as follows:

- Mean feeding rate for 60 days precalving (FR_B) = (7g/kgBWT + 8g/kgBWT)/2 = 7.5 g/kgBWT
- Mean feeding rate for 60 days postcalving (FR_A) = (10g/kgBWT + 11g/kgBWT)/2 = 10.5 g/kgBWT
- Mean quantity supplemented for 60 days before calving (Q_B) = 7.5g/kgBWT x 287.1kgBWT x 60d = 129195g = 129.2kg
- Mean quantity supplemented for 60 days after calving (Q_A) = 10.5 g/kgBWT x 287.1kgBWT x 60d = 180873g = 181.0kg
- Total amount supplemented per cow (Q_T) = 129.2kg + 181.0kg = 310.2kg
- Total cost of supplement (TS_C) = 310.2kg x 94.43TSh/kg = 29,292.19TSh
- Total supplementation costs (TSS_C) = 29,292.19TSh + (4,000.00TSh/month x 4 months) = 45,292.19TSh
- Total milk yield (MY_T) = 11.6 L/day x 90 d = 1044L
- Calf's milk (M_C) = (4L/d x 30d) + (3L/d x 30d) + (2L/d x 30d) = 270L

- MY available for sale (MY_S) = 1044L – 270L = 774L
- Milk yield revenue (MY_R) = 170Sh/L x 774L = 131,580.00TSh

Calculations of total supplementation costs (2 months pre- and post-calving) and total MY revenue for 3 months post-calving for a 287.1kg supplemented maintained under average farmers' supplementation level were as follows:

- Total amount supplemented per cow (Q_T) = 1.9kg/d x 19.2d/month x 4 months = 145.9kg
- Total cost of supplement (TS_C) = 145.9 kg x 94.43TSh/kg = 13,772.96TSh.
- Total supplementation costs (TSS_C) = 13,772.96TSh + (3,000.00TSh/month x 4months) = 25,772.96TSh
- Total milk yield (MY_T) = 9.1L/d x 90d = 819L
- MY available for sale (MY_S) = 819L – 270L = 549L
- Milk yield revenue (MY_R) = 549L x 170Sh/L = 93,330.00TSh

Marginal profit of supplementation for 2 months pre- and postcalving was calculated as follows:

- Marginal TSS_C = TSS_C (Experimental supplementation) - TSS_C (Farmer's supplementation) = 45,292.19TSh – 25,773.00TSh = 19,519.19TSh
- Marginal MY_R = MY_R (Experimental supplementation) - MY_R (Farmer's supplementation) = 131,580.00TSh - 93,330.00TSh = 38,250.00TSh
- Marginal Profit from supplementation = Marginal MY_R - Marginal TSS_C = 38,250.00TSh - 19,519.19TSh = 18,730.81TSh