REPRODUCTIVE PERFORMANCE OF CROSSBRED CATTLE DEVELOPED FOR MILK PRODUCTION IN THE SEMI ARID TROPICS AND THE EFFECT OF FEED SUPPLEMENTATION

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ABSTRACT

Three on-station experiments, one survey and two on-farm studies were undertaken in Matebeleland South Province, Zimbabwe. The objective of these series of studies was to assess the effect of feed supplementation and breed on reproductive performance and milk yield in cows bred for use in the smallholder dairy sector.

In the first on-station experiment, freshly calved Tuli x Jersey and Nkone x Jersey (crossbred) and Tuli and Nkone (indigenous) cows were offered two diets starting at five days post calving. The diets were; grazing of natural pasture at a stocking rate of 1LU:15ha alone or supplemented with 2kg/cow/d of a maize/soyabean-based commercial dairy meal. Ovarian activity was monitored using milk progesterone profiles. The estimated cumulative probability of ovulation occurring by 200d postpartum for supplemented cows was 0.9 and higher (P < 0.5) than the probability of 0.63 obtained for unsupplemented cows. Supplementary feeding also reduced (P < 0.5) the mean intervals from calving to ovulation in indigenous and crossbred cows. There was an interaction (P < 0.05) between breed and diet on the oestrus detection rates. Indigenous supplemented cows had the highest increase in oestrus detection rate. The pregnancy and calving rates were higher (P < 0.05) in crossbred cows than in indigenous cows. The interaction between breed and diet on pregnancy and calving rates was significant (P < 0.05). Supplemented indigenous cows had the highest assumed pregnancy rate and supplemented crossbred cows had the highest actual pregnancy rate and calving rate. In indigenous cows, the pregnancy loss rate was increased (P < 0.05) by supplementary feeding. However, supplementary feeding reduced pregnancy loss rate (P < 0.05) in crossbred cows. All the supplemented indigenous cows that lost pregnancies were in their first parity and all crossbreds that lost pregnancies were multiparous and were not supplemented. The mean daily milk yield was significantly higher in crossbred than in indigenous cows (P < 0.05). Supplemented cows in both breeds had higher (P < 0.05) bodyweights than control cows. There was an interaction (P < 0.05) between breed and diet on body condition scores. Supplemented indigenous cows had the highest body condition scores.

The experimental treatments and methodology in the second on-station experiment were similar to Experiment 1 except for milking management. Crossbred cows were superior to indigenous cows in terms of reproductive performance and milk yield (P < 0.5). The interval from calving to first ovulation was 76 ± 41 d for crossbred and 106 ± 38 d for indigenous cows. Supplementary feeding reduced (P < 0.05) the interval from calving to first ovulation in both breeds. There was an interaction (P < 0.05) between breed and diet on the oestrus detection rates. Supplemented indigenous cows had the highest increase in oestrus detection rate. Indigenous cows had higher (P < 0.05) bodyweights and body condition scores than crossbreds irrespective of diet. There was an interaction (P < 0.05) between breed and diets on (P < 0.05)

bodyweights. Supplemented crossbred cows had the highest increase in bodyweights.

In the third on-station experiment, cows were supplemented prepartum using *Sorghum bicolor-Lablab purpureus* mixed silage. The cows were offered a control diet consisting of grazing natural pasture at a stocking rate of 1LU:15ha and three supplementary diets supplying 0.16, 0.32 and 2 times maintenance (M) energy requirements. Ovarian activity was monitored using milk progesterone profiles. Supplementation at the level of 0.32 M and 2 M improved body condition at calving and reduced the interval from calving to first ovulation in the indigenous cows ($P < 0.05$). Interaction between breed and supplementation level on the interval from calving to ovulation was significant ($P < 0.05$). Crossbred cows had higher pregnancy rates than indigenous cows across all supplementary feeding levels. The crossbred cows produced higher ($P < 0.001$) mean daily milk yields than indigenous cows

A survey to assess the reproductive performance and milk yield of cows in smallholder farming areas was conducted in Gulathi and Irisvale. The farmers claimed that calving intervals were two to three years long and milk yields were 1.5 kg/cow/day. However, there was no information on calving to ovulation intervals, calving rates and lactation lengths. Based on these findings, an observational study was conducted to measure the reproductive performance and milk yield of the cows. Milk yield, bodyweight and body condition scores were measured starting from calving. Milk progesterone was used to assess reproductive performance. The study showed that out of 36 cows monitored only three crossbred cows had ovulated by 200 days postpartum. A mean interval from calving to ovulation of 63 ± 29 d and a calving rate of 3% were obtained. Average daily milk yield was 1.2 ± 0.9 kg and lactation length was 174 ± 47 d.

A second on-farm study was carried out to determine the effect of feed supplementation on reproductive performance and milk yield. Cows on the control diet were allowed to graze on natural pasture at a stocking rate of 1LU:20ha. In addition to grazing of natural pastures, supplemented cows were offered 2kg/cow/day of a maize/soyabean-based dairy meal starting from calving until conception. Supplementary feeding reduced ($P < 0.05$) the interval from calving to ovulation from 132 ± 63 d to 102 ± 69 d. Oestrus detection rate was increased ($P < 0.05$) by supplementary feeding from 10% to 41%. Supplementary feeding increased conception rate from 35% to 80% and calving rate from 18% to 65% over two seasons. Daily milk yield increased from 1.26 ± 0.5 kg to 3.3 ± 1.3 kg.

The studies demonstrated that feed supplementation was beneficial in improving reproductive performance and milk yield of cows in smallholder farming sectors. In addition, crossbred cows were superior to indigenous cows in terms of their reproductive performance and milk yield.

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ABBREVIATIONS

d	Day
DM	Dry matter
g	Gramme
GFA	Geselleschaft Fur Agrar projekte in ubersee MBH
h	Hour
ha	Hectare
IAEA	International Atomic Energy Agency
kg	Kilogramme
LU	Livestock unit
m	Metres
ME	Metabolisable energy
MJ	Mega-joule
ml	Milliliter
mm	Millimeters
SD	Standard deviation
^{0}C	Degrees Celcius
^{0}E	Degrees east
^{0}S	Degrees south
<	Less than
>	Greater than
%	Per cent
$	Dollar
±	Plus or minus
=	Equal to

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CHAPTER 1

1. INTRODUCTION

The current chapter describes the justification, problem statement and the objectives of the study.

1.1 Justification

Smallholder dairy production is gaining popularity in most developing countries (Kaluba, 1992; Mupunga and Dube, 1992; Swai, Minja and Zylstra, 1992) due to the increasing demand for milk by the ever-expanding human population. Many countries recognise milk production as a catalyst for promoting a variety of developmental activities in the smallholder farming communities (Henson, 1987). The advantages of smallholder dairy farming include the production of milk for consumption, for income generation and the development of livestock and infrastructure in the participating communities. Smallholder farmers participating in collective dairy production also gain experience in making decisions, managing grazing schemes and marketing milk and its products as a cooperative.

The success of smallholder dairying is evident in Kenya and in India. In Kenya about 85% of the 2 billion litres per year milk industry is in the hands of 40 000 smallholder farmers (Mwenya, 1992) and in India, the success of the dairy project, Operation Flood, has included millions of smallholder farmers (Aneya, 1993). However, in Zimbabwe the smallholder sector supplies 2% to the marketed milk compared to the commercial dairy sector, which produces 98% of the milk on the market (Hamudikuwanda, Munyoro, Mutisi, Ball and Moyo, 2000). The commercial dairy sector however experienced a steady reduction in the number of producers involved from 581 in 1980 to 328 in 1999 due to viability problems (Nyoni, 2000). Consequently, the total amount of milk produced in Zimbabwe, at 180 million litres in 1999, was less than the 350 million litres required for domestic and export markets (Hamudikuwanda *et al.,* 2000). As a result, the Ministry of Agriculture (1995) has been promoting the expansion of smallholder dairy production in order to meet the domestic requirements for milk.

Dairy production in the smallholder sector is characterised by low milk production and poor reproductive performance of the cows kept by the farmers. Research has shown that milk production levels vary between 244 and 779 kg per cow per lactation for breeds indigenous to Zimbabwe (Richardson, Oliver and Clarke, 1979; Tawonezvi, Dube, and Khombe, 1987). In general, these cows produce one calf every two years (Mukasa-Mugerwa, 1989; Honhold, Hill, Knottenbelt, Perry and Morton, 1992). Ideally, it should be possible to achieve a mean calving interval of 365 days (Titterton, 1987). The reasons for this low productivity include the shortage of appropriate dairy breeds and poor nutrition (Machaya, 1994).

Several studies have consistently shown that breeds indigenous to semi-arid tropics produce low milk yields per lactation and that imported exotic dairy breeds have not achieved the levels of production recorded in temperate environments (Kurtu, Tawah, Rege, Nega-Alemayehu and Mesfin-Shibre, 1999). Because of this, smallholder dairy producers have been advised to use crossbred cows because they are hardy and they have good milk production characteristics (Syrstad, 1990).

1.2 The Problem Statement

Smallholder dairy farmers in the semi-arid areas of Zimbabwe adopted the recommendation to use crossbred cows for milk production. This recommendation was based on the higher milk production characteristics of the crossbreds when compared to the indigenous cows. However, the milk production levels and the reproductive performance of these crossbreds under the semi-arid conditions remains unknown. In Kenya, Muinga (1992) reported calving intervals of 480 days in crossbred dairy cows and recommended feed supplementation as a way of improving fertility. However, the data generated were insufficient to underpin the actual causes of the long calving intervals and to show the exact benefits of feed supplementation. There is therefore a need to carry out research to identify the factors that cause the long calving intervals.

1.3 Objectives

The main objective of this study was therefore to evaluate the reproductive performance and milk yield of crossbred (Nkone/Tuli x Jersey) and indigenous (Nkone/Tuli) cows used for milk production in semi-arid areas of Zimbabwe, and to assess the effects of supplementary feeding on reproductive performance and milk yield.

The specific objectives of the study were:

1. to establish the interval from calving to first ovulation in crossbred and indigenous cows.
2. to determine the oestrus detection rates in crossbred and indigenous cows.
3. to evaluate the pregnancy rates in crossbred and indigenous cows.
4. to measure the milk yield of crossbred and indigenous cows.
5. to study the effect of supplementary feeding on reproductive performance and milk yield in crossbred and indigenous cows.

1.4 Hypotheses

1 Crossbred cows have better reproductive performance than indigenous cows. They have shorter intervals from calving to first ovulation and they have higher observed oestrus and higher pregnancy rates than indigenous cows.

2 Milk yield is higher in crossbred cows compared to indigenous cows.

3 Supplementary feeding improves reproductive performance and milk yield in both the crossbred and indigenous cows.

CHAPTER 2

2 LITERATURE REVIEW

2.1 Introduction

Chiduza (1994) reported that 75% of the national population in Zimbabwe resided in smallholder farming areas. The people in these areas depended on agriculture as their major means of livelihood (Food and Agricultural Organisation (FAO), 1994). These people were referred to as smallholder farmers because they had limited land holdings and experienced shortages of labour and capital (Ortiz and Meneses, 1990). From the beginning of the 1980s, there was a general consensus that national food security depended on improving smallholder agricultural production since the majority of people resided in the smallholder farming sector (FAO, 1994). This realisation led the government of Zimbabwe to introduce various programmes for improving agricultural production in the smallholder sector. These programmes included the improvement of milk production.

In 1983, the government of Zimbabwe established the Dairy Development Program (DDP) with the aim of improving milk production in smallholder farming areas. As a result, ten pilot projects were established in the high rainfall areas (Natural Regions II and III). By 1996, 2 046 smallholder farmers had registered with DDP and 656 of these were producing milk (Dube, 1996). In 1998, milk production in the smallholder sector was extended to Matebeleland

(Hamudikuwanda *et al.,* 2000), a semi-arid area originally described as unsuitable for dairying (Boitumelo, 1992). However milk production in the semi-arid areas was limited by the seasonal fluctuations in animal feed supply (Topps, 1985), nature of the farming systems (Berry, 1985) and the available breeds of cattle (Mupunga and Dube, 1992).

2.2 Seasonal Fluctuations in Animal Feed Supply

Topps and Oliver (1993) described the nutritional characteristics of natural pastures in semi-arid areas of Zimbabwe and reported that natural pasture was the major source of nutrients for cattle in smallholder farming areas. The nutritional quality and biomass production of the natural herbage available to livestock depended on the season of the year (Topps and Oliver, 1993). Topps (1985) reported that the semi-arid areas were characterised by a distinct pattern of wet and dry seasons. Generally, the wet season was four to five months long and was followed by a dry season that persisted for seven to eight months. During the wet season, the vegetation grew rapidly and abundantly. The Small Scale Dairy Handbook (1993) reported that the grassland herbage had a digestibility value of 65% and contained energy levels ranging from 9.2 to 12.5 MJ of ME per kg DM. Crude protein levels varied from 100 g/kg DM to 200 g/kg DM. The phosphorus levels were 27g/kg DM depending on the grass species, amount of leaf and the presence of legumes. However, the crude protein and phosphorus contents (Ndikum-Moffor, Yonkeu, Tawa, Mbah and Pano, 1994) in these pastures were only able to support milk production levels of 6 to 7 kg/cow/d and could not support the nutrient requirements of high producing dairy cattle (Mbwile, Mwakilembe, and Madata, 1992). From the end of the rainy season into the dry season, natural grasses became highly fibrous and were of low digestibility (< 40%). In addition, the biomass was low and the grasses were deficient in crude protein (< 70 g/kg DM). Such poor quality grasses led to a decline in bodyweight and body condition (Topps, 1985). This decline stressed pregnant cows to such an extent that the energy demands of the subsequent lactation severely depleted body reserves (Ward, 1968). Such cows experienced a rapid loss in body mass during lactation and their reproductive performance and milk yield could only be improved by postpartum supplementation (Buck, Light, Rutherford, Miller, Rennie, Pratchett, Capper, and Trail, 1976).

2.3 Nature of the Farming Systems

Berry (1985) reported that the traditional systems of milk production in the semi-arid areas were part of a mixed farming system and they relied on crop residues and natural herbage as animal feeds. The interrelationships between land, crops grown, animals reared and human beings are illustrated in Figure 2.1. The figure shows that the human diet comprised of food crops, milk and meat. It also shows that natural herbage, forage crops and crop residues provided the bulk of cattle feed in the smallholder sector and that crop production relied heavily on animal draught power and manure. In addition, cattle were used for social functions such as payment of *lobola* (bride price), maintenance of social prestige and wealth status (Frisch and Vercoe, 1987). Bulls were often used as representatives of ancestral spirits and such animals were called *mudzimu* bulls (GFA, 1987).

MECHANICAL ENERGY

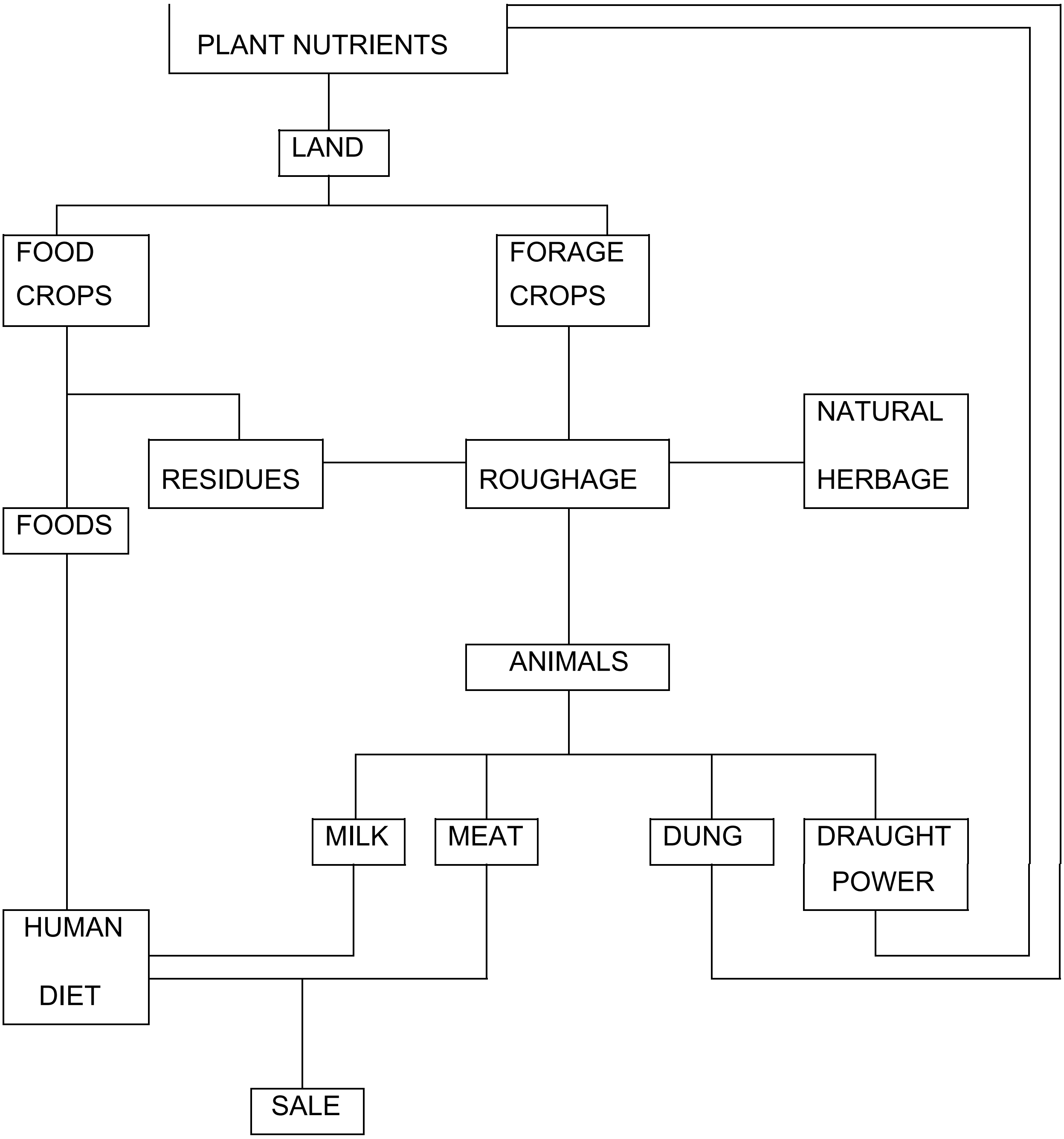


Figure 2.1 A diagrammatic representation the interelationships between land, crops grown, animals reared and human beings in smallholder farming systems (Adapted from Berry, 1985).

Shumba and Whingwiri (1988) reported that the use of cattle for milk production was relatively more important than their use for meat production or for cash income in traditional smallholder farming systems. In addition, the use of cattle for milk production was relatively more important in the drier Natural Regions (IV and V) of Zimbabwe where the cropping potential is low (see Table 2.1). However, most of the milk produced was only sufficient for household consumption because of the low yields. The traditional production systems were characterised by low milk production, short lactation periods, low calving rates, and long calving intervals (Chigaru, 1997).

Richardson, Oliver and Clarke (1979) reported that milk yield values ranged from 527 to 779 kg over a lactation period of 98 days in Nkone cows in smallholder farming areas of Zimbabwe and in studies by Tawonezvi, Dube, and Khombe (1987) using Mashona cows, milk yield ranged from 244 to 481 kg over a lactation period of 80 days. Annual calving rates were estimated to range from 33% to 52% (Gubbins and Frankherd, 1983). Sibanda (1993) reported calving intervals of up to four years in smallholder farming areas.

2.4 Available Breeds

The Small Scale Dairy Handbook (1993) reported that the predominant cattle reared in the smallholder farming areas of Zimbabwe were of the Sanga type. The Sanga cattle were classified as *Bos taurus* and included the Mashona, Nkone and Tuli breeds (Frisch, 1997).

Table 2.1 Relative value (%) of cattle functions in different agroecological regions (GFA, 1987)

	Natural Region II	Natural Region IV-V
Traction	38.6	25.6
Manure	11.3	4.9
Milk	29.9	42.7
Meat	18.8	Nil
Herd growth	7.1	26.4
Total	100	100

Galina and Navarro-Fierro (1991) reported that natural selection over hundreds of generations provided Sanga cattle with the following characteristics:

- they had a high level of heat tolerance that was derived partly from low heat production and partly from the ability to dissipate heat. The latter characteristic was due to a high density of efficient sweat glands that increased the loss of heat through evaporation, and the relatively thin, sleek coat, which facilitated loss of heat by convection to the surrounding air.
- the cattle had a partial resistance to ticks, and therefore to many tickborne diseases occurring in Zimbabwe.
- they were able to survive on inadequate levels of nutrition because of their small body size, high metabolic rate and efficient digestion at low levels of feeding.

However, besides the advantages mentioned above, the Sanga cattle had several disadvantages. They had a low milk yield potential and their lactation length was short when compared to European breeds (Mupunga and Dube, 1992). In addition, they did not let-down milk during milking unless they were stimulated by the presence of a calf (Syrstad, 1988; Mupunga and Dube, 1992). These disadvantages made the Sanga cows unsuitable for dairying.

Because of these problems, many tropical countries attempted to replace the indigenous cattle with exotic dairy types (Mbah, Mbanya and Messine, 1987; Thorpe, Kang'ethe, Rege, Mosi, Mwandotto and Njuguna, 1993) in order to meet the growing demand for milk and milk products. However, purebred exotic dairy cattle were expensive to acquire and maintain and they were not adapted to the harsh conditions of the smallholder farming environment (Mupunga and Dube, 1992). In addition, the lack of proper dairy cattle management in the smallholder farming sector was not ideal for the exotic breeds. Therefore, the use of exotic purebred dairy cattle in this sector was generally not recommended in the semi-arid tropics, except where production was carried out in an improved environment and under good management.

Some countries resorted to upgrading the dairy potential of indigenous cows through breeding using imported semen (Mbah *et al.,* 1987). This approach improved milk production by combining the adaptive traits of the indigenous breeds and the high milk yield potential and good temperament of the exotic *Bos taurus* breeds (Syrstad, 1990). Mupunga and Dube (1992) reported milk production levels of 1-3 kg/d over a lactation period of 150 days for indigenous breeds compared to 4-10 kg/d over a lactation period of 240 days in crossbred cows.

A study by Francis, Sibanda, Østergaard, and Sithole (1996) in Nharira-Lancashire, and Jingura (2000) in Gokwe smallholder dairy areas, revealed that indigenous cows and beef breeds such as Brahman and Afrikaner were used for milk production indicating a shortage of suitable dairy breeds. The lack of ideal and proven crossbreeds in Zimbabwe has forced the smallholder farmers to rely strongly on the indigenous cattle for milk production. It is, therefore, essential to carry out research work on ways of improving milk production in indigenous cows and developing crossbred cows that are high yielding and suitable for the harsh smallholder farming environment.

2.5 The Effect of Feed Supplementation on Milk Yield

Peters and Ball (1995) reported that the main objective of dairy farming was to produce milk as economically as possible. Robinson (1990) indicated that adequate nutrition was required for high milk production. When fed alone, tropical forages supported milk yields of up to 7 kg/d in smallholder farming systems (Humphreys, 1991). Supplementary feeding was, therefore, required for optimum milk production (Preston, 1989). The supplements required by the dairy cattle should contain adequate levels of energy and protein and minerals such as phosphorus, manganese, copper, iodine and zinc (Chakoma, 1995).

Research has shown that supplementing the diets of indigenous and crossbred cattle significantly increased the milk production and lactation length. Mutsvangwa, Hamudikuwanda and Makoni (1989) supplemented indigenous cows with poultry litter, which is relatively cheap and readily available in the smallholder farming sector. They reported daily milk offtakes of 1.5 kg and 1.8 kg for the non-supplemented and the poultry litter groups, respectively. Cows receiving poultry litter exhibited longer and more persistent lactations than the non-supplemented cows highlighting the beneficial effects of supplementation. Studies performed by McSweeney, Fitzpatrick, D'-Occhio, Reid and Entwistle (1993) showed an increase in milk yield in crossbred heifers supplemented daily with 0.5 kg formaldehyde treated sunflower seed meal and 1 kg cracked maize for 60 days postpartum as compared to cows receiving hay *ad libitum*. Muinga

(1992) found that daily supplementation of crossbred dairy cows (Aryshire/Brown Swiss x Sahiwals) with 1kg of maize bran and 2kg of leucaena on dry matter basis increased milk yield from 3.7 kg/d to 8.6 kg/d. Supplementation also had an effect on the rate at which milk yield declined over the 13 weeks of the trial. In unsupplemented cows, milk yield fell by over 40% between the first three weeks and the last four weeks of the trial, whereas in supplemented cows the decline was less than 10%.

However, other workers have found insignificant milk yield responses to feed supplementation. Ducker, Morant, Fisher and Haggert (1985) supplemented Friesland dairy heifers with diets containing four different feeding levels. The diets were based on maize silage and concentrates. They found no significant effects of the feeding treatments on milk yield at any stage of lactation. Kurtu *et al.* (1999) found insignificant improvements in milk yield in response to postpartum concentrate supplementation in indigenous Arsi cows but reported significant increases in the milk yield of crossbred cows subjected to the same treatment. Several researchers attributed the poor milk production of breeds indigenous to semi-arid areas to their tendency to lay down body fat instead of producing more milk when they were offered supplementary feeding (Mbah *et al.,* 1987), and others ascribed the poor milk production to low food intake by the indigenous cows (Jennings and Holmes, 1985).

2.6 Reproductive Performance

The ultimate goal of the dairy industry is to operate an economically efficient production system and this depended upon high reproductive efficiency of the cows (Royal, Darwash, Flint, Webb, Woolliams and Lamming, 2000). Darwash, Lamming and Wolliams (1997) defined reproductive efficiency as a measure of the ability of a cow to conceive and maintain pregnancy when it is served at the appropriate time in relation to ovulation. Poor fertility decreased the profit margin due to loss in milk yield, cost of replacing culled cows and decreased calf sales per cow (Stoat, Veerkamp and Wassell, 1999). Peters (1991) classified poor fertility of cows into four categories, which were; failure to undergo ovarian cycles (anoestrus), failure to exhibit oestrus at the appropriate time (behavioural anoestrus), failure to conceive when mated or inseminated and embryonic or fetal losses. These forms of poor fertility are discussed in the following sections.

2.7 The Measurement of Reproductive Performance

Hamudikuwanda (1999) highlighted the importance of measuring reproductive performance in cows. It was of economic benefit to the farmer for a cow to produce a calf every year (Cattle Producers Association, 1989). This means that since the gestation period is 285 days (Rhaka, Igboeli and King, 1971), cows must be managed in such a way that the reproductive performance measures should not exceed the values stated in Table 2.2. The most common indices of reproductive performance are calving interval, interval from calving to first observed oestrus, interval from calving to first ovulation, and calving rate.

Table 2.2 Ideal values for measures of reproductive performance (Adapted from Hutchinson, 1984).

Measure	Goal
Calving interval	365-380 d
Interval from calving to first observed oestrus	Less than 50 d
Interval between oestri	20-23 d
Interval from calving to first ovulation	Less than 40 d
Interval from calving to conception	85-100 d
Services/conception	1.5-1.7
Conception rate to first service	50% or greater
Average conception rate	80-85%
Calving rate	75-80%
Fetal loss rate	Less than 5%

2.7.1 Calving interval

Calving interval was reported to indicate the period between two successive calvings (Peters and Ball, 1995). The calving interval was subdivided into two major periods, which were the calving to conception and the gestation periods. The later was fixed in length while the former varied depending on the type of breed and the nutritional status of the cow. A calving interval of 12-13 months was considered optimal and was achieved when the calving to conception interval was less than 85 to 105 days (Keeling, Rajamahendran and Ravindran, 1992). However, Sibanda (1993) reported calving intervals of up to four years in smallholder farming areas.

2.7.2 Interval from calving to first observed oestrus

Senger (1994) reported that the interval from calving to first observed oestrus is calculated as the number of days from calving until the first overt oestrus. Darwash, Lamming and Wooliams (1999) reported that during pro-oestrus, the dominant follicle secreted oestradiol, which in the absence of progesterone acted on the hypothalamus to induce the behavioural symptoms of oestrus. Broers (1993) reported that cows that were in oestrus stood when they were mounted by the bull or by other cows. During this period, copious amounts of mucus flowed to the exterior from the vulva causing the vulva to swell and redden. The cows became restless and mounted other animals. Some cows ate less feed and produced less milk when they were in oestrus. Oestrus signs were often misinterpreted since most of these signs were also exhibited by animals that were either about to go into oestrus, in oestrus or had just gone through oestrus. Of all these signs, the standing reflex (standing firmly when mounted) was the most reliable indication of oestrus and this was referred to as standing heat (Meredith, 1995).

Allrich (1994) reported that the duration of oestrus ranged from 3 to 28 hours and in some cows ovulation was not accompanied by oestrus. Factors such as breed and level of feeding determined the duration of oestrus. Accurate oestrus detection in cows and heifers influenced the reproductive performance and profitability of dairy herds and was very important where artificial insemination was used or in smallholder dairies where communal bulls were used and the farmers had to bring cows observed in oestrus to the bull. Senger (1994) calculated that the failure to detect oestrus led to delayed insemination, low conception rates and extended calving intervals resulting in an estimated annual loss of over US$300 million to the dairy industry in the USA. Similar losses were reported in Zimbabwe (Mutsvangwa and Hamudikuwanda, 1994).

Holmann, Black and Shumway (1987) found that the traditional method of heat detection used by herdsmen was observation of oestrus. He reported that this method often resulted in incorrect diagnosis depending on the duration of oestrus, frequency of observation and skill of the observer. However, the use of milk or blood progesterone concentrations improved the accuracy of oestrus detection (McLeod, Foulkes, William, and Weller*,* 1991). Milk or blood samples for progesterone analysis were collected at least twice a week until the cows conceived. Oestrus was assumed to have occurred when progesterone concentrations fell to levels below 3 ng/ml and 1 ng/ml in milk and blood samples, respectively (Darwash *et al*., 1999). Oestrus observed by the stockman was then confirmed by reference to progesterone profiles.

2.7.3 Interval to postpartum ovulation

Broers (1993) reported that parturition in cows was followed by a period of anoestrus or anovulation during which no cyclical ovarian activity occurs. The purpose of postpartum anoestrus was to allow the reproductive system to recover before the next pregnancy occurred. Postpartum anoestrus was therefore a necessary and normal sequel to parturition in cows and it was only a problem when it was prolonged since this delayed conception and increased the calving intervals. Perreira (1999) found that factors such as breed, suckling and feeding levels influenced the length of the anoestrus. For example, the postpartum anoestrus period was generally shorter in dairy cattle than in suckled beef cows (Peters, 1991). Peters and Riley (1982) reported that 95 % of dairy cows and 40 % of beef cows under farming conditions in the United Kingdom had resumed ovarian cycles by day 50 postpartum. This was because the suckling stimulus delays the release of GnRH from the hypothalamus by stimulating the release of β-endophin, which is known to suppress cyclic activity (Lamming, Wathes and Peters, 1981)

The effects of energy on ovarian activity are discussed in section 2.8.1.1. McClure (1994) recommended that protein levels that were compatible with requirements for maintenance and growth were enough to support normal oestrus activity. Deficiencies in minerals such as phosphorus, copper, iodine and manganese resulted in long postpartum anoestrus periods in beef cows (Smith and Somade, 1994). Ovulation disorders (section 2.7.3.1) also prolonged the postpartum anoestrous.

Prolonged postpartum anoestrus was the major cause of infertility in beef and dairy cows (Burke, Macmillan and Verkerk, 1996). The principal cause of postpartum acyclicity was the suppression of the pulsatile release of luteinizing hormone (LH) from the anterior pituitary (Schillo, 1992). Luteinizing hormone was requisite for cyclical ovulation activity as delivery of this gonadotropin to the ovary stimulated follicle maturation and oestradiol secretion, which initiated events that led to ovulation (Mitchell, King, Gebbie, Ranilla and Robinson, 1998). Milk progesterone levels were used to compare the intervals from calving to first ovulation between cows and between lactations (Darwash *et al.,* 1997). As depicted in Figure 2.2, measurements of milk progesterone were effective in estimating the interval from parturition to first ovulation and in characterizing ovarian activity as a series of luteal and inter-luteal intervals. The interval between heats, interval from calving to conception and number of services per conception were determined from progesterone profiles.

2.7.3.1 Ovulation disorders

Studies by Caraty, Evans, Fabre-Nys and Karsh (1995) revealed that the dominant ovarian follicle secreted oestradiol-17β, which initiated the ovulatory LH surge. Oestradiol induced a neuroendocrine signal, which in turn caused a surge in the gonadotropin-releasing hormone (GnRH) secretion. Failure to

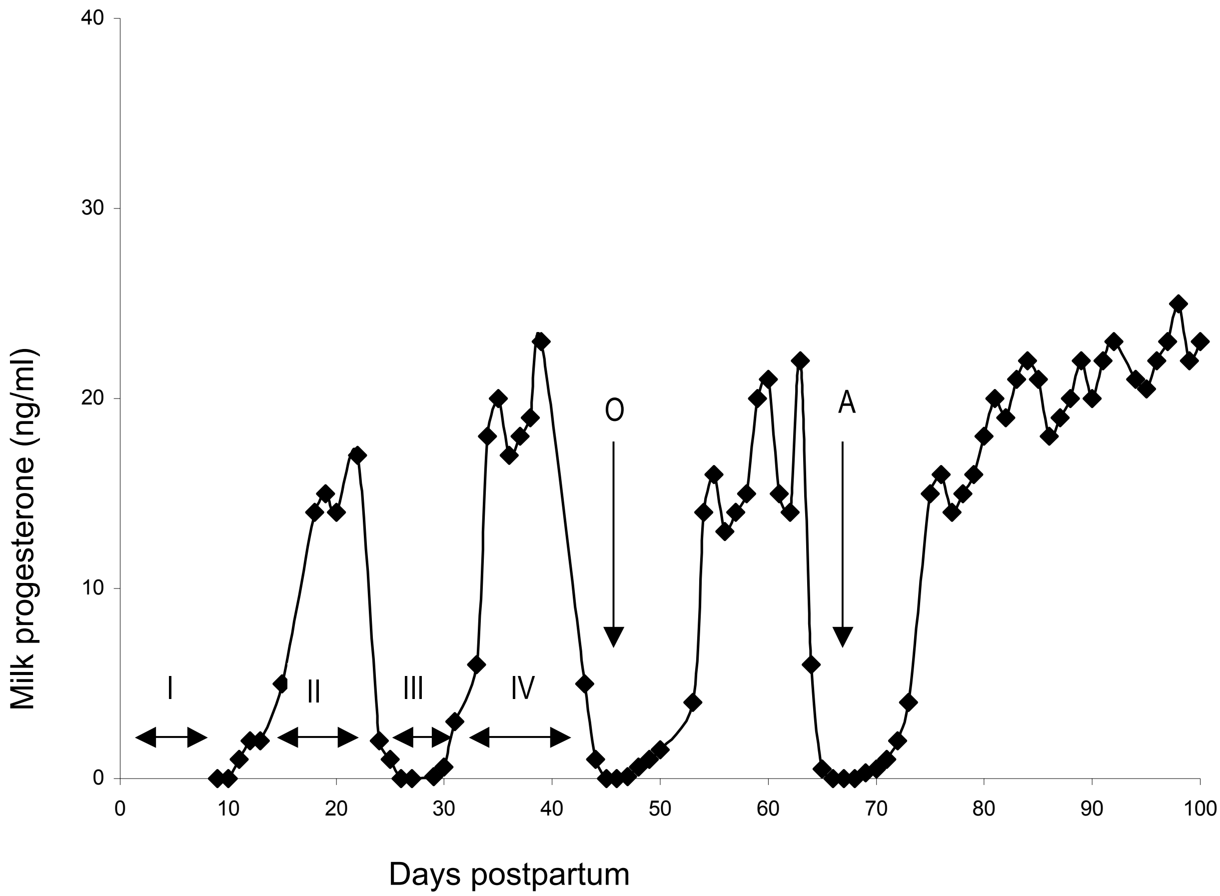


Figure 2.2 The use of milk progesterone concentrations in characterizing the reproductive activity in postpartum cows: I = interval from parturition to commencement of ovulation; II = first luteal phase; III = inter-luteal interval; IV = second luteal phase; O = oestrus; A = artificial insemination resulting in pregnancy. (Adapted from Darwash *et al.*, 1999).

release adequate and timely LH levels led to the formation of either follicular or luteal cysts (Darwash *et al.,* 1999).

Garverick (1997) described follicular cysts as follicle-like structures, which were more than 25 mm in diameter and persisted on the surface of the ovary for more than 10 days in the absence of a corpus luteum. They grew in a disorderly manner and failed to either regress or to undergo atresia but instead they accumulated fluid. Cows with follicular cysts were infertile and only conceived when normal cycles resumed.

When ovaries were undergoing cystic degeneration, the walls of the growing follicle degenerated. Oocyte development was therefore terminated and about a third of the cysts luteinised (Mukasa-Mugerwa, 1989). Luteal cysts were less frequent than follicular cysts. The luteal cysts had a large antrum surrounded by several layers of luteal cells, which continuously produced progesterone, rendering the cow anoestrus.

According to Darwash *et al.* (1999), luteolysis was delayed in some cows leading to a condition referred to as a persistent corpus luteum. The persistent corpus luteum continued to produce enough progesterone to prevent further follicular development, ovulation and oestrus. Consequently, affected cows had low conception rates (Lamming and Darwash, 1998).

2.7.4 Calving rate

Calving rate was defined as the number of calves born per 100 services (Peters and Ball, 1995). From a biological point of view, calving rate was the most appropriate measure of fertility (Peters and Ball, 1995). However, even under ideal conditions, with 100% 'normal' cows and 100% efficiency of oestrus detection, a 100% calving rate was not achievable. This was mainly due to embryonic or foetal deaths that occurred in the cows.

2.7.4.1 Embryo and fetal loss

Ball (1997) reported that the development of the bovine conceptus was divided into the embryonic and the foetal stages. The embryonic stage was the period from conception to the complete formation of the primitive organs at 45 days post breeding. The foetal stage was the period ranging from 46 days postpartum up to the end of pregnancy.

Pregnancy could be terminated at any of these two stages. When the conceptus died before 17 days after fertilisation, the cow often returned to oestrus after a normal cycle without showing any clinical evidence that a pregnancy had existed. Embryonic mortality at a later stage was associated with a delayed return to oestrus, often without any other clinical evidence of reproductive disorders (Meredith, 1995).

Embryonic mortality represented a major component of reproductive wastage in all domestic animals, and in cattle up to 40% of fertilised zygotes were lost before calving (Diskin and Sreenan, 1986; Peters, 1996). The magnitude of embryonic mortality in cattle differed among studies. It ranged from 8% to 42% when measured before day 42 of pregnancy and most of the embryonic losses occurred between days 8 and 18 after conception (Zavy, 1994). Studies based on either ovum, embryo or fetal recoveries at various stages after breeding indicated that early embryonic deaths between days 8 and 18 of pregnancy accounted for 75 to 80% of all embryonic and fetal mortalities (Roche, Boland and McGeady, 1981; Diskin and Sreenan, 1986). Since these embryonic losses occurred within the normal period of the oestrous cycle there was an opportunity for rebreeding and successful conception although a substantial loss in production had already occurred. After implantation, only 5 to 8% of fetuses were lost prior to calving (Sreenan and Diskin, 1986). These fetal losses, although accounting for a smaller proportion of reproductive wastage, were critical because they occurred during advanced pregnancy and as a result, the re-establishment of normal cycles and conception were delayed (Ball, 1997). The main features of the extent and timing of embryo mortality are summarised in Table 2.3.

The exact causes of the high rate of embryo and fetal losses are poorly understood. Shelton, Gayerie de Abreu, Hunter, Parkinson and Lamming (1990) found that early embryonic losses were related to premature regression of the corpus luteum, a condition referred to as luteal inadequacy.

When the corpus luteum of a pregnant cow regressed prematurely, progesterone secretion ceased resulting in pregnancy failure. Premature

Table 2.3 Approximate pregnancy rates and cumulative embryo/fetal loss in artificially inseminated cattle (Peters, 1996).

Days after conception	Pregnancy rate (%)	Cumulative loss (%)
0	90	10
13	81	19
19	66	34
42	60	40
280 (calving rate)	55	45

regression of the corpus luteum was caused by the presence of a strong or early signal from the dam or a weak or delayed signal from the embryo to prevent loss of the corpus luteum (Darwash *et al.,* 1997).

Studies carried out using refined genetic techniques and chromosome analysis have revealed that part of the embryo loss during the first twenty-one days of pregnancy was due to 'non-viable embryos' (Blowey, 1990; Thatcher*,* Staples, Danet-Desnoyers, Oldick and Schimitt, 1994). If the non-viable embryos were allowed to develop to full term, the resultant calf was deformed to the extent that it did not live a normal life. Early embryonic mortality was therefore suggested to be a method of eliminating potentially deformed calves in the early stages of pregnancy and this was an advantage to the survival of the species (Blowey, 1990). However, cytogenic studies showed that gross chromosomal defects accounted for only 3-7.5% of embryo losses (Wilmut, Sales and Ashworth*,* 1986). Other factors were therefore responsible for embryonic losses.

Environmental factors such as heat stress were shown to markedly increase early embryonic losses (Putney, Mullins, Thatcher, Drost and Gross, 1989). For example it was reported that a 10-hour period of hyperthermia, beginning at the onset of oestrus and before insemination in superovulated heifers resulted in severe retardation of embryonic development and increased embryonic death when the embryos were evaluated at day 7 after fertilisation (Putney *et al.,* 1989).

One possible cause of this high rate of embryonic death was the thermal induction of chromosomal abnormalities during the resumption of meiosis while the oocyte was still in the intraovarian follicular environment following the preovulatory surge of LH (Thatcher *et al.,* 1994).

2.8 Factors Affecting Reproductive Performance

A variety of environmental (season of the year), physiological (age and parity), genetic (breed) and husbandry (level of feeding) factors were reported to influence fertility in the pregnant and postpartum cow (Peters, 1991).

A study on cattle reproduction in the tropics showed that Holstein cows conceived more in the cool months of the year than during the hot season (Galina and Arthur, 1990). This was because reproduction in the Holstein breed was affected by high temperature and high humidity. Zebu and crossbred cows tended to be in peak reproductive activity during the rain season when grazing conditions and therefore nutrient availability were optimal (Mukasa-Mugerwa, 1989). Hunter (1980) measured cow fertility using the length of the calving interval. He found that cow fertility increased up to four years of age and then declined after seven years in dairy cows and after ten years in beef cows.

2.8.1 Influence of nutrition on reproductive performance

The importance of nutrition as a factor limiting reproductive performance in ruminant livestock is well recognised (Robinson, 1990). In smallholder farming systems, fluctuations in feed supply were reported to be the major causes of poor reproductive performance (Chimonyo, 1998). This limitation was due to low levels of feeding (Ducker *et al.*, 1985) and/or deficiencies of nutrients such as energy, protein, minerals and vitamins in the feed (Manspeaker, Robl and Edwards, 1988). Dietary regimes should support milk production at an economic level whilst maintaining animal health and reproductive performance (Peters, 1996).

2.8.1.1 Energy

Most of the research carried out in the nutrition and fertility of the cow has concentrated on dietary energy requirements, since energy was found to be the major limiting nutrient in dairy cows. Low energy levels in the diet and the resultant loss in bodyweight negatively affected fertility and the efficiency of production (Teleni and Hogan, 1989). Cows were reported to stop ovarian cycling when they lost 17% of their bodyweight (Topps, 1977). Under smallscale commercial farming conditions, Zerbini, Gemeda, Wold and Tegegne (1994) reported that bodyweight losses during the first 60 to 90 days postpartum delayed the exhibition of oestrus. Underfed cows had a large proportion of small follicles (3-10 mm in diameter) and a small proportion of large (> 10 mm) follicles and presumably a very small proportion of potential ovulatory follicles (Lucy, Savio, Badinga, De La Sota and Thatcher, 1992). Zerbini, Wold and Gemeda (1996) added that underfed Zebu cows did not ovulate for more than two years and when they were adequately fed, they resumed normal oestrous cycles within 46 days of the improved feeding and were able to conceive by day 75 after the feeding started. These observations indicated that undernutrition interrupted normal ovarian functioning.

Loucks, Laughlin, Mortoa, Girton, Nelson and Yen (1992) found that the oestrogen positive feedback on LH was more sensitive in underfed animals. The increased sensitivity in turn limited gonadotrophic stimulation of the ovary, and this in turn delayed or even prevented ovulation. Nutritional inadequacies also reduced the growth of follicles by decreasing the number of GnRH receptors on the anterior pituitary gland (Imakawa, Kittock and Kinder, 1983). Although energy restriction did not reduce the magnitude of the release of LH, it delayed the response time to GnRH stimulation (Robinson, 1990). In addittion, Day, Imakawa, Zalesky, Kittok and Kinder (1986) and Loucks *et al.* (1992) reported that nutritional stress reduced the frequency of LH episodic release. Imakawa *et al.* (1983) also found that energy restriction reduced the release of progesterone and inhibin through the interruption of the neuro-hypophyseal-pituitary-ovarian-axis.

The nutritional status of cows on range was estimated by determining the levels of non-esterified fatty acids (NEFA) (Winugroho and Situmorang, 1989) and systemic urea levels (Ndlovu and Mupeta, 1996) in blood plasma. Schillo (1992) reported that NEFA were precursors of milk fat and also influenced the neuro-endocrine activities that regulated the synthesis and release of reproductive hormones, such as Prostaglandin $F_{2\alpha}$. Plasma concentration of NEFA was negatively correlated to glucose (Teleni and Hogan, 1989).

Because blood composition measurements were not practical under field conditions, body condition scoring was suggested as the best indicator of nutritional status of animals (Topps, 1977). Body condition was measured as a score on an arbitrary scale, which estimated the amount of fat reserves and flesh in specific anatomical regions on the live animal (Gearhart, Curtis, Erb, Smith, Sniffen and Cooper, 1990). The technique involved estimation of body fatness by palpating the amount of subcutaneous fat in the tailhead and loin area and giving a score ranging from 1 (emaciated) to 5 (obese) (Mulvany, 1981). The body condition score was a better index of the nutritional status of an animal than bodyweight, especially in cows. Bodyweight was not a good indicator of body reserves because cows with similar mass were either small and fat or large and thin. Bodyweight was also affected by gut fill and pregnancy (Mulvany, 1981). The fat reserves were mobilised to sustain productive functions such as work, lactation and reproduction when there was limited feed availability or feed intake, such as during early lactation (Mulvany, 1981).

2.8.1.2 Protein

Although it is generally accepted that energy is more important than protein in influencing fertility in cows (Peters and Ball, 1995), adequate amounts of dietary protein are required for normal fertility in cows. Bolanos, Meneses and Forsberg (1996) demonstrated that inadequate protein intake led to low incidences of oestrus in cows. Kaur and Arora (1995) reported low conception rates in cows fed on diets deficient in protein. Cattle in smallholder farming areas of Zimbabwe depend mainly on pastures and crop residues for their feed requirements. The crude protein content of these feedstuffs during the dry season is less than 70 g/kg DM (Topps, 1977). Inadequate amounts of protein in the diet of cows in early lactation were reported to reduce milk production and reproductive performance in cows (Hamudikuwanda, 1999). On the other hand, Elrod, Van Amburgh and Butler (1993) reported that excess protein in the diet was costly and had a negative effect on reproduction. They found that high levels of dietary protein were associated with low pregnancy rates in cows. Hamudikuwanda (1999) added that the effect of dietary protein on reproduction was complicated since there was a possible utilization of the protein as an energy source.

2.8.1.3 Vitamins and minerals

A thorough review on the effect of vitamins and minerals on reproductive performance was provided by McClure (1994). He reported that all essential vitamins and minerals required for normal growth and maintenance of health in cattle were also needed for normal reproduction. However, the specific actions of many of the vitamins and minerals in reproduction remain unknown.

The primary vitamins required by animals are vitamin A, D and E. McClure (1994) stated that Vitamin A was necessary for proper reproduction in cows since it influenced the synthesis of reproductive hormones. The vitamin also prevented abnormalities in the uterus of pregnant animals. Cows deficient in Vitamin A were reported to have low conception rates and also aborted during the last quarter of pregnancy (Smith and Somade, 1994). Lack of Vitamin D resulted in low levels of blood calcium and phosphorus, which in turn led to reduced fertility (Smith and Somade, 1994). Vitamin E is a biological antioxidant and it is important for optimum reproductive performance. Lack of Vitamin E was reported to cause birth of either dead or weak calves and it increased the incidence of retained placentas (McClure, 1994).

The essential minerals for dairy cows are calcium, phosphorus, manganese, copper and iodine. McClure (1994) reported that calcium is necessary for skeletal growth and milk production in cows. Deficiency of calcium at calving was reported to cause milk fever and to increase the incidence of dystocia, retained placenta, metritis, prolapsed uterus and delays uterine involution (McClure, 1994). Excess calcium intake influenced the absorption of other minerals such as phosphorus, magnesium, zinc, copper and other minerals that may play a role in reproduction.

Smith and Somade (1994) reported that phosphorus is necessary for energy metabolism, skeletal growth, milk production and reproduction. Phosphorus deficiency led to prolonged postpartum anoestrus, low conception rates anoestrus and decreased fertility (Smith and Somade, 1994). Ward (1968) reported that phosphorus was deficient in Zimbabwean soils. The author found that supplementing phosphorus to lactating Mashona cows during summer resulted in increased fertility. This response was achieved with a daily intake of between 2.5 and 5 g of phosphorus per cow.

Hurley and Doanne (1989) found that the deficiency of manganese led to delayed ovulation and birth of deformed calves. The same authors reported that inadequate levels of copper were responsible for decreased conception rates and increased foetal mortality. Iodine deficiency was responsible for silent oestrus and early embryonic losses (McClure, 1994).

2.9 Conclusion

The foregoing literature review revealed that smallholder milk production in the semi-arid tropics was currently centred on the use of indigenous cattle. Crossing indigenous cows with exotic purebred dairy bulls brought about improvements in milk yield. However, there was lack of information on the reproductive performance of the resultant crossbreeds and nothing was known on how these animals compare with indigenous cows. The feed resource base in the smallholder sector was inadequate and led to poor reproductive performance and milk yield in cows. However, there was lack of knowledge on the exact benefit of supplementary feeding on the reproductive performance and milk yield.

The objective of this study was therefore to assess the effect of feed supplementation on the reproductive performance and milk yield of crossbred and indigenous cows. Information on the reproductive characteristics and milk yield of the crossbreds will be useful in determining whether the crossbreds are suitable for use in smallholder dairy farming areas. Information on the effect of feed supplementation on reproductive performance and milk yield will assist in formulating appropriate feeding strategies.

CHAPTER 3

3. EFFECTS OF BREED AND CONCENTRATE FEED SUPPLEMENTATION ON REPRODUCTIVE PERFORMANCE AND MILK YIELD OF INDIGENOUS AND CROSSBRED COWS

Two on-station experiments were conducted over two seasons from 1997-1999 to investigate the effect of breed and postpartum concentrate feed supplementation on reproductive performance and milk yield of cows.

3.1 Experiment 1

3.1.1 Introduction

Programmes for generating income through smallholder milk production have been undertaken in many developing countries as a way of improving the standard of living for the rural folk (Mupunga and Dube, 1992). In Zimbabwe, there is great interest in increasing milk production in the smallholder sector, especially in the semi-arid areas of the country where cattle production is the major source of livelihood for the farmers. However, research work (Machaya, 1994) has revealed that poor reproductive performance and poor nutrition were the major contributory factors to low productivity of the indigenous cattle used for smallholder milk production.

There are few studies that have assessed the reproductive performance of crossbred cattle used for smallholder dairy production in semi-arid regions. Muinga (1992) reported that the calving interval for crossbred dairy cows in Kenya was 480 days and concluded that the cows re-conceived during the mid to late lactation period. He recommended feed supplementation as a way of reducing the calving intervals and thus raising the lifetime productivity of the cows. However, the study did not establish the specific causes of the long calving intervals. The purpose of the present study was therefore to assess the reproductive performance of indigenous and crossbred cows and the effect of supplementation with concentrates on the reproductive performance of the animals under controlled conditions.

3.1.2 Materials and methods

3.1.2.1 Site description

The study was conducted at Matopos Research Station, Matopos, Zimbabwe. The research station is located at 20^0S and 28^0E. The station is located in Natural Region IV of Zimbabwe, an agro-ecological zone where farming is semi-extensive (Central Statistics Office, 1997). The site lies at an altitude of approximately 1340 m. The mean annual rainfall received in the area is 570 mm and falls between October and April. The area experiences periodic droughts. The mean annual minimum and maximum daily temperatures experienced at the site are 20^0C and 30^0C, respectively. The soils are broadly referred to as granitic sands. The vegetation is mainly tree bush Savanna with *Hyparrhenia* and *Acacia* as the predominant grass and tree species, respectively.

3.1.2.2 Animals

Forty-six indigenous (23 Tuli and 23 Nkone) and 46 crossbred (23 Tuli x Jersey and 23 Nkone x Jersey) cows bred at Matopos Research Station were used in this study. All the indigenous cows were three years old and were in their first parity. Among the crossbred cows, 22 were in their first parity, ten were in their second parity, eight were in their third parity and six cows were in their fourth parity. The ages of the crossbred cows ranged from two to six years. The mean bodyweight of the indigenous cows was 328 $\pm$ 37.6 kg and their mean body condition score was 3.0 $\pm$ 0.4. The crossbred cows had an average bodyweight of 319 $\pm$ 60.4 kg and mean body condition score of 2.8 $\pm$ 0.4.

3.1.2.3 Experimental design and treatments

The crossbred and indigenous cows were stratified according to parity and randomly allocated to two diets. The two diets were; a control diet comprising grazing of natural grass and browse and a treatment diet consisting of grazing of natural grass and browse, supplemented with 2 kg/d of a maize/soyabean-based commercial dairy meal (Urelac® 14% CP, National Foods, Bulawayo, Zimbabwe). The dairy meal had a dry matter content of 93%. The stocking rate on the grazing was 1LU:15ha. The cows receiving the supplementary feed were fed individually once a day from calving up to a maximum of 60 days post breeding.

3.1.2.4 Experimental procedure

The milking of cows commenced five days after calving. This five-day delay in milking allowed the calves to get enough colostrum from their dams. During milking, the cows were brought in from the paddocks at 0730 h every day. The cows receiving the supplementary feed were then given the 2 kg of dairy meal each prior to milking. Udder washing was carried out before application of the milking salve to the teats. The milking was carried out once a day by hand in the absence of calves. The daily milk yield for each cow was measured using a graduated container. The cows were milked until drying off point, which was the point when the daily milk yield for a cow fell below 0.2 kg for five consecutive days. After milking, calves suckled their dams but were separated from the dams overnight.

Milk samples for progesterone analysis were collected from each cow every Monday, Wednesday and Friday beginning at 10 days postpartum until they dried off or up to a maximum of 200 days post calving whichever occurred first. The milk collected on the sampling day from each cow was thoroughly mixed using a stirring rod before the samples were collected into 1.5 ml plastic vials containing 10 ng of potassium dichromate preservative. The samples were then refrigerated at 4^0C pending analysis.

The bodyweights and body condition scores of the cows were recorded fortnightly from calving until the cows were dried off. The cows were weighed using a cattle scale (Kattleway Scale, Marondera, Zimbabwe). Body condition was assessed by two trained technicians using the 1 (very thin) to 5 (obese) scale described by Mulvany (1981). The average score for each animal was recorded.

Observations for oestrus were made by trained herdsmen three times per day between 05.00 and 18.00 h commencing from 10 days after calving up to 200 days post calving. The cows were presented to a bull for mating at the first observed oestrus occurring on or after 60 days postpartum. Bulls were introduced to run with the herd at 60 days after the last cow had calved to ensure that no cow was mated before 60 days postpartum. The bulls were allowed to run with the herd for a period of three months. Pregnancy diagnosis by rectal palpation was carried out by a veterinarian four months after the withdrawal of bulls.

3.1.2.5 Laboratory analysis

Progesterone concentration was measured in an un-extracted aliquot of whole milk samples by solid phase radioimmunoassay (RIA) using a commercial kit (Coat-A-Count, Diagnostic Products Corporation, Los Angeles, CA, USA). Seventy-two assays, each comprising of seven standards, two quality control (QC) samples and 80 milk samples were carried out. Based on QC values of 2 and 10 ng/ml, the intra-assay and inter-assay coefficients of variation were 8.1% and 10.2%, respectively.

3.1.3 Statistical analysis

Out of the 46 indigenous and 46 crossbreds cows that were used in the experiment, eight indigenous cows (four cows from the control group and four cows from the supplemented group) were dropped from the experiment because they produced unusually low milk yields (< 0.2 kg/d) and one crossbred cow died in an accident. Therefore, data from 38 indigenous and 45 crossbred cows were used for the laboratory and statistical analyses.

A progesterone profile was plotted for every cow under observation. The date of first ovulation was determined from the progesterone profiles as the day with the lowest concentration of progesterone occurring immediately before the first increase in progesterone concentration of equal to or greater than 3 ng/ml for more than two consecutive dates (Darwash *et al*., 1999). The interval from parturition to first ovulation was determined by calculating the number of days from calving to the first ovulation.

Survival analysis models (Everitt, 1994) for assessing the effect of breed and diet on the interval from calving to first ovulation of cows were fitted using the Statistical Package for Social Scientists (SPSS) (1988). Details of the survival analysis models are explained in Appendix 1. The Kaplan-Meier empirical estimate of the survivor function was computed and comparison between treatment groups was performed using the log-rank test. In the model, if a cow did not ovulate she was considered to be censored. If a cow ovulated she was considered to be uncensored. A censored observation meant that ovulation had not occurred during the time that the cow was in the study.

The oestrus detection rate was calculated by expressing the number of oestruses observed by the stockmen as a percentage of the total number of possible ovulations detected by progesterone analysis. Assumed pregnancy rates were determined from the progesterone profiles by expressing the number of cows assumed to be pregnant as a percentage of the total number of cows. Pregnancy was assumed to have occurred when progesterone concentration remained high at day 21 through to day 30 and beyond after the last ovulation. The estimate of the rate of pregnancy loss was based on a sustained production of progesterone during the first 30 days after breeding, that was followed by a sudden decline in progesterone levels, with or without a return to cyclic progesterone patterns during the 30 to 90-day postpartum interval. The rate of pregnancy loss was then calculated by expressing the number of cows losing pregnancy as a percentage of all cows assumed to be pregnant. Actual pregnancy rates were determined by expressing the number of cows confirmed to be pregnant by rectal palpation at 7 months as a percentage of all cows exposed to the bull. The calving rates were obtained by expressing the number of cows that calved as a percentage of all mated cows.

The association between pregnancy status and dietary and breed treatment combinations were determined by the Chi-square test using the PROC FREQ procedure (SAS, 1995). The effects of breed and diet on milk yield, interval from calving to first ovulation, square root transformed body condition scores (Gomez and Gomez 1984) and cow bodyweight were tested by analysis of variance using the General Linear Models (GLM) procedure (SAS, 1995). The model used was:

$$Y_{ijkl} = \mu + B_i + D_j + A_k + P_l + (BD)_{ij} + (BDAP)_{ijkl} + e_{ijkl}$$

Where:

Y_{ijkl} = dependent variable (average daily milk yield, interval from calving to first ovulation, body condition score and bodyweight)

μ = overall mean common to all observations

B_i = effect of the i^{th} breed (i = 1,2)

D_j = effect of the j^{th} diet (j = 1,2)

A_k = effect of the k^{th} age (k = 1,2..5)

P_l = effect of the l^{th} parity (l = 1,2..4)

$(BD)_{ij}$ = effect of interaction between the i^{th} breed and the j^{th} diet

$(BDAP)_{ijkl}$ = breed x diet x age x parity interaction

e_{ijkl} = random residual error associated with the ijklth observation

Differences between pairs of means for the treatment combinations were determined using the PDiff statistic (SAS, 1995).

3.1.4 Results

The progesterone profiles in the cows that resumed cycling after calving and in those that did not cycle were similar across treatments. The typical progesterone profiles for the cows that resumed cycling after calving and for those that did not cycle are shown in Figures 3.1 and 3.2.

There was a strong negative correlation ($r = -0.9$, $P < 0.01$) between the period from calving to first ovulation and time of calving relative to the 1st of January. The cows that calved at the beginning of the season had the longest postpartum anoestrus periods (Figure 3.3). Indigenous cows calved significantly earlier ($P < 0.01$) than crossbred cows. Figure 3.4 shows that the estimated cumulative probability of ovulation occurring by 200 days postpartum in supplemented cows was 0.9 and was higher than the probability of 0.63 obtained in unsupplemented cows (Log rank statistic 3.76, $P < 0.05$).

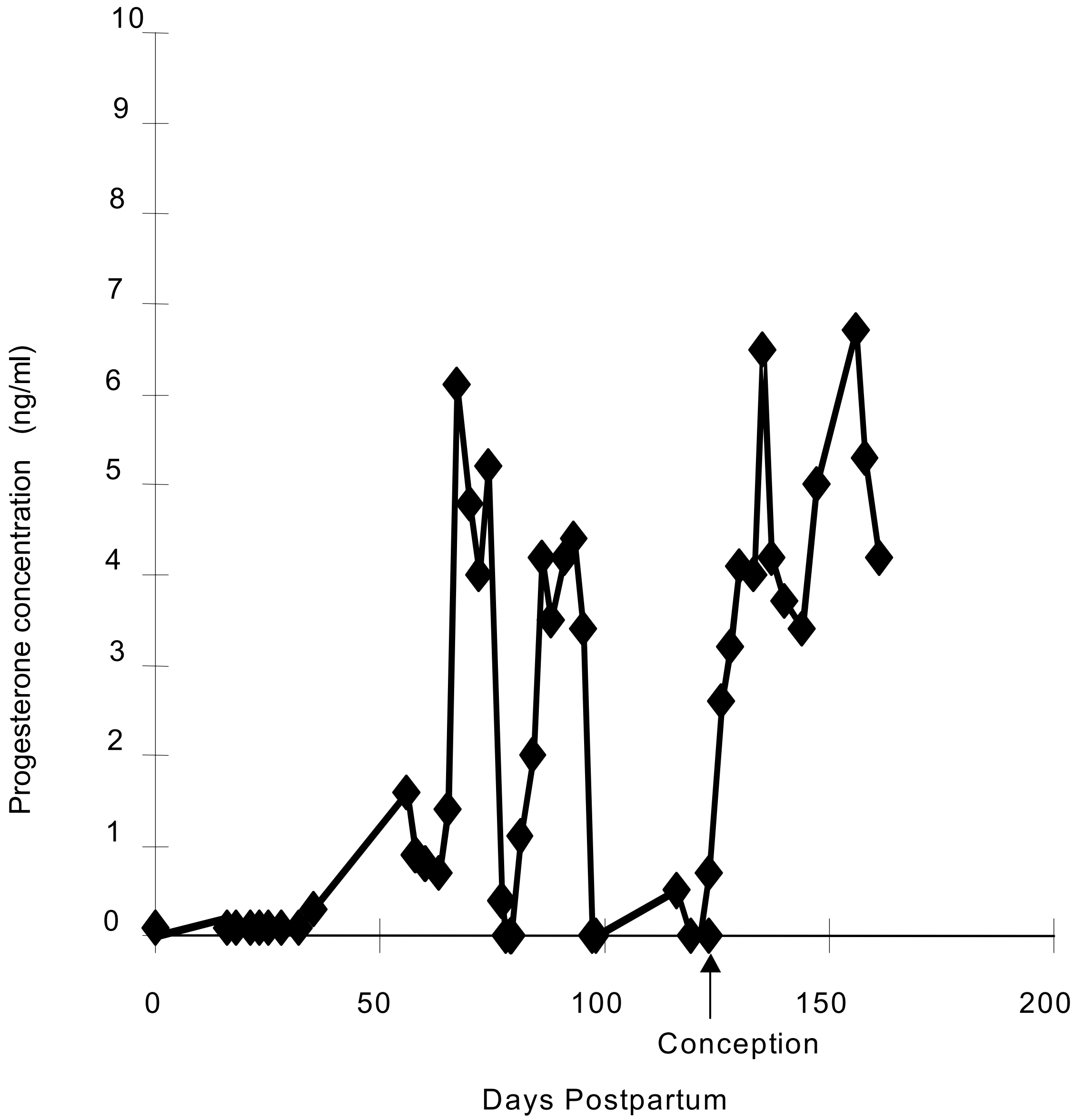


Figure 3.1 Crossbred cow in the control (non-supplemented) group that had exhibited ovarian activity by 55 days postpartum and commenced normal ovarian cycles and conceived at 120 days postpartum.

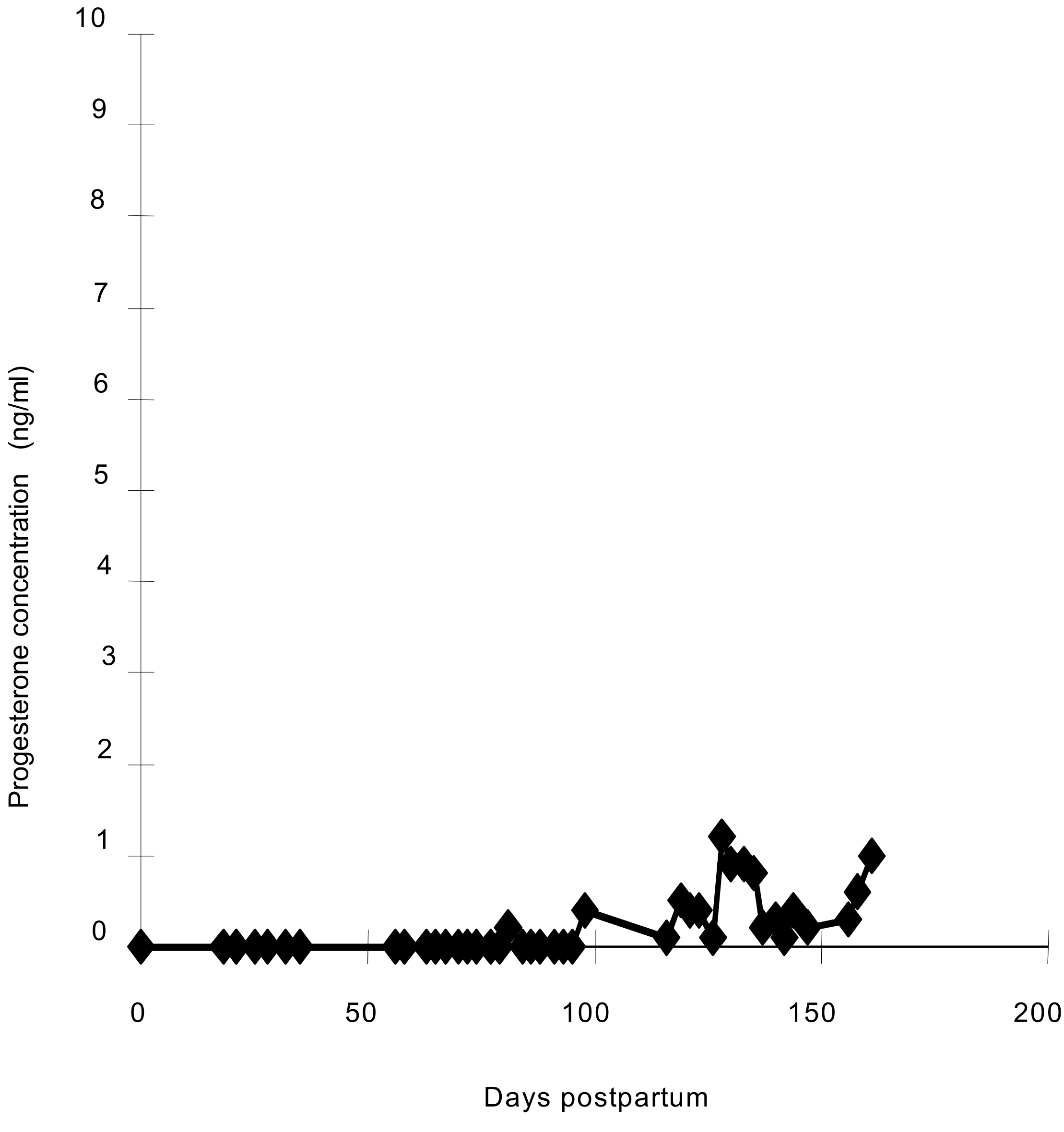
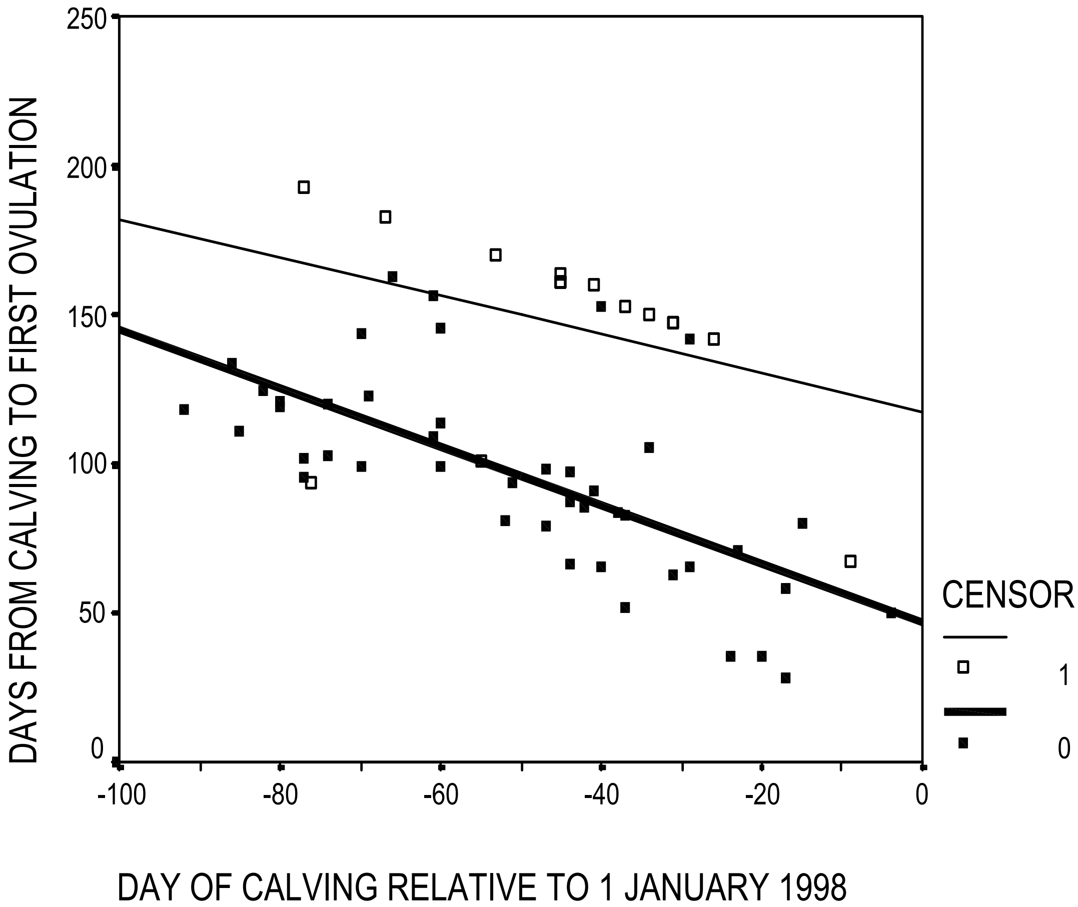


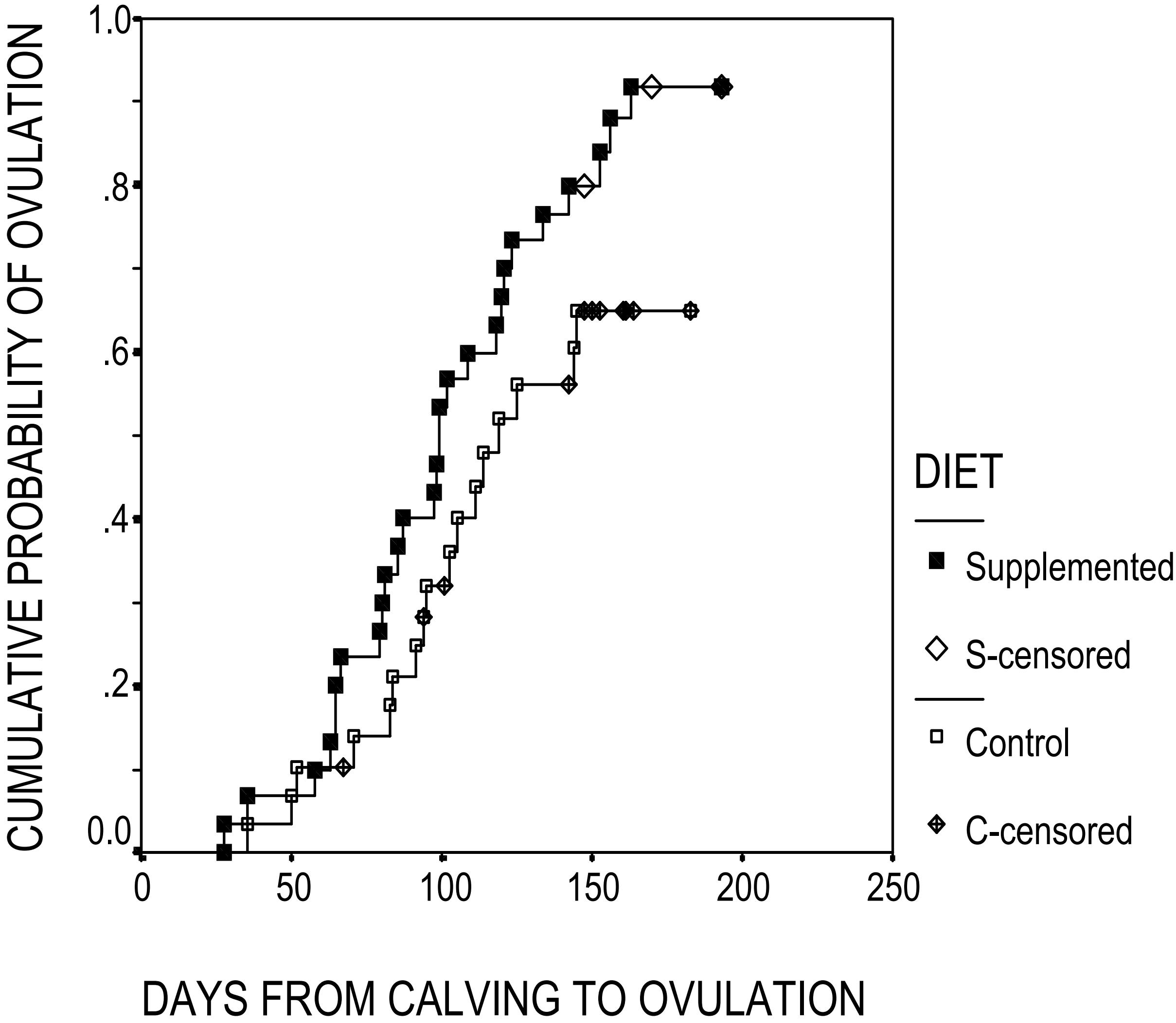
Figure 3.2 Indigenous cow in the control group that displayed no ovarian activity until at least 155 days postpartum.



Key Censor 0 = cows that had ovulated by 200 days postpartum

Censor 1 = cows that had not ovulated by 200 days postpartum

Figure 3.3 Relationship between date of calving and postpartum anoestrus period



Key S-censored represents cows in the supplemented group that had not ovulated by 200 days postpartum

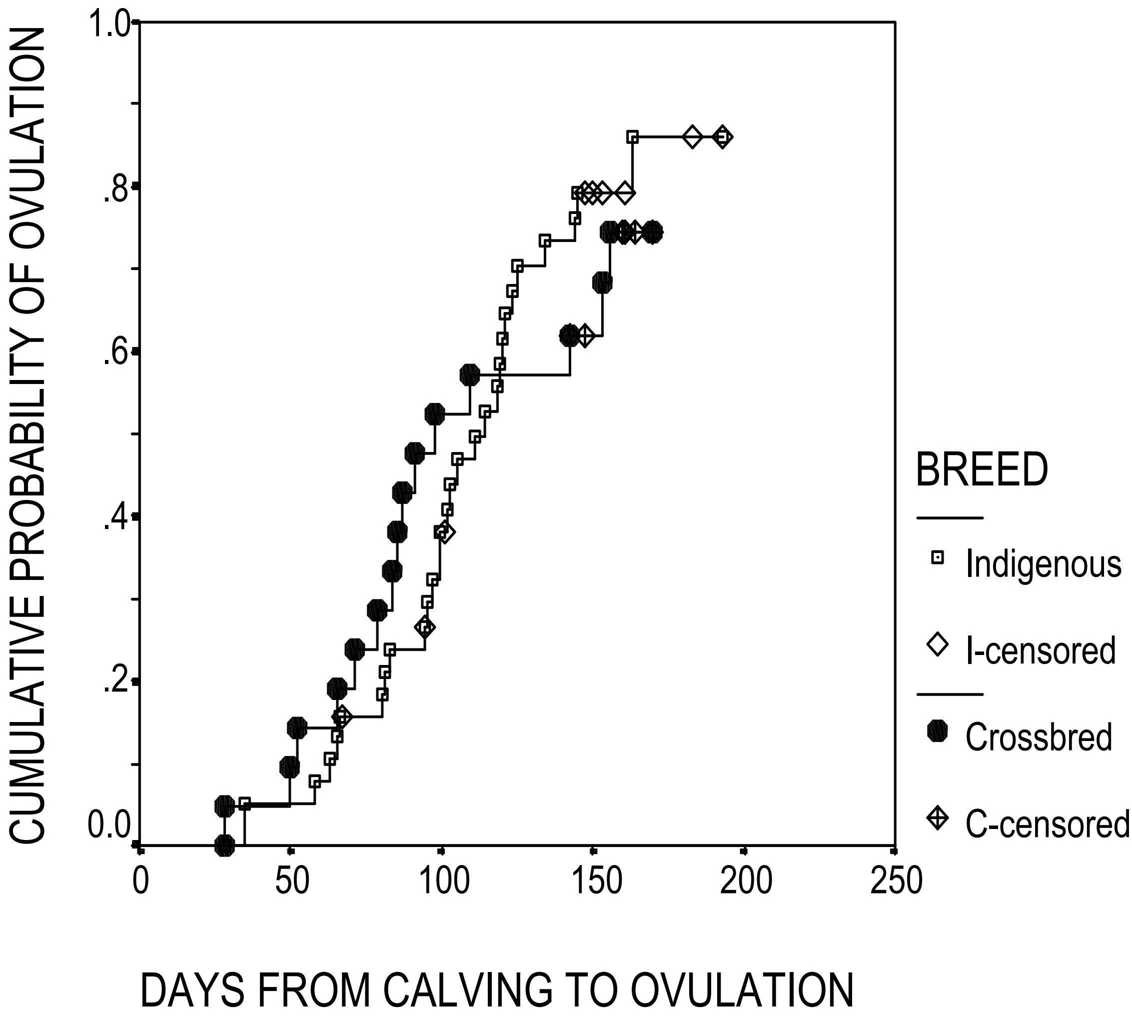
C-censored represents cows in the supplemented group that had not ovulated by 200 days postpartum

Figure 3.4 Cumulative probability of ovulation by diet

Figure 3.5 shows that the estimated probability of ovulation occurring by 200 days postpartum was 0.81 in indigenous cows compared to 0.71 in crossbred cows. These probabilities were not significantly different (Log rank statistic 0.11, $P = 0.736$).

The mean interval from calving to first ovulation, oestrus detection rates, assumed pregnancy rates, pregnancy losses, calving rates, mean milk yield, bodyweight and body condition scores for indigenous and crossbred cows in the control and supplemented treatment groups are shown in Table 3.1. The mean interval from calving to first ovulation in crossbred cows was 107 ± 39 days and similar ($P > 0.05$) to the interval of 108 ± 37 days obtained in indigenous cows. Supplementary feeding reduced ($P < 0.05$) the interval from calving to first ovulation in indigenous and crossbred cows. There was an interaction ($P < 0.05$) between breed and diet on the oestrus detection rates. The indigenous cows, which were supplemented, had the highest increase in oestrus detection rate. There was no difference in oestrus detection rates between the crossbred cows in the supplemented and control groups.

The assumed pregnancy rate, actual pregnancy rate and calving rate were higher ($P < 0.05$) in crossbred cows than in indigenous cows. The interaction between breed and diet on pregnancy and calving rates was significant ($P < 0.05$). Supplemented indigenous cows had the highest assumed pregnancy rate and supplemented crossbred cows had the highest actual pregnancy rate and



Key I-censored represents cows in the indigenous group that had not ovulated by 200 days postpartum

C-censored represents cows in the crossbred group that had not ovulated by 200 days postpartum

Figure 3.5 Cumulative ovulation probability by breed

Table 3.1 Oestrus detection rates, assumed pregnancy rate, pregnancy loss, mean milk yield, bodyweight and body condition score for indigenous and crossbred cows in the control and supplemented treatment groups.

	Indigenous		Crossbreds	
Diet	Control	Supplemented	Control	Supplemented
Number of cows	19	19	22	23
Number of cows that ovulated by 200 d postpartum	12	17	17	22
Mean interval from calving to first ovulation (days)	113[a] ± 36	103 [b] ± 39	116 [a] ± 40	98 [b] ± 39
Oestrus detection rates (%)	20[a]	43 [b]	59 [c]	59 [c]
Assumed pregnancy rate (%)	52.6 [a]	73.7 [b]	72.7 [b]	70 [b]
Actual pregnancy rate (%)	47 [a]	30 [a]	44 [a]	70 [b]
Assumed pregnancy loss (%)	10 [a]	57 [b]	38 [b]	0 [a]
Calving rate (%)	47 [a]	30 [a]	44 [a]	70 [b]
Mean milk yield (kg/d ± SD)	0.61 [a] ±	0.71 [a] ± 0.31	2.37 [b] ±	2.47 [b] ± 1.24
Bodyweight (kg)	332 [a]	339 [b]	323 [c]	329 [a]
Body condition score	2.6 [a]	3.4 [b]	2.5 [a]	2.7 [a]

[a,b] Within a row, means lacking a common superscript letter differ ($P < 0.05$).

calving rate. The assumed rate of pregnancy loss after day 30 of conception was significantly higher ($P < 0.05$) in supplemented indigenous cows than in unsupplemented indigenous cows. Supplementary feeding reduced ($P < 0.05$) the pregnancy loss rate in crossbred cows. All supplemented indigenous cows that lost pregnancies were in their first parity and all crossbreds that lost pregnancies were multiparous and were not supplemented.

The mean daily milk yield was significantly higher in crossbred than in indigenous cows ($P < 0.05$). Supplementary feeding did not have a significant effect on milk yield ($P > 0.05$). Supplemented cows in both breeds had higher ($P < 0.05$) bodyweights than control cows. There was an interaction ($P < 0.05$) between breed and diet on body condition scores. Supplemented indigenous cows had the highest body condition scores.

3.1.5 Discussion

The absence of significant breed differences in the probabilities of ovulation between the indigenous and the crossbred cows was probably caused by the differences in calving dates. Prior to calving, the indigenous cows were introduced to the bull one month earlier than crossbreds because it had been anticipated that the indigenous cows would form the beef herd. As a result, the indigenous cows calved earlier than crossbred cows.

The shorter interval from calving to ovulation for supplemented cows was probably due to adequate energy intake supplied by the supplementary diet, which promoted early ovarian activity. After parturition, the energy intake from the control diet was probably insufficient to meet the high energy demands for milk production and, as a result, most cows were in a negative energy balance, which increased the interval from calving to ovulation. Some workers have shown that cows in negative energy balance had long intervals from calving to ovulation (Canfield and Butler, 1990). The positive impact of nutrition in reducing the postpartum anoestrus period was also demonstrated by the fact that the cows calving during the wet season had the shortest postpartum anoestrus periods. There was sufficient grazing of good quality during the wet season and the cows that calved during this period ovulated earlier than those that calved during the dry season.

Supplementary feeding improved oestrus detection rates in indigenous cows. Markusfeld, Galon and Ezra (1997) found that cows calving with a high body condition score were less likely to have an unobserved oestrus than those calving with a lower body condition score. This observation confirmed that nutrition has an effect on the ability to exhibit oestrus. Ducker *et al.* (1985), working with first lactation dairy heifers receiving different levels of feeding before and after calving, found a high oestrus detection rate (75%) but it was not influenced by dietary treatment.

There are no other scientific reports on the use of milk progesterone profiles to determine the pregnancy rate and pregnancy loss in Sanga type cows and their Jersey crosses in Zimbabwe. The higher pregnancy rates in crossbred cows than in indigenous cows suggests that crossbred cows were more suitable for dairy production.

Supplemented indigenous cows had a higher assumed pregnancy rate than indigenous cows which were not supplemented but this beneficial effect of supplementation was masked by the high pregnancy losses in the supplemented group. A similar effect of a high feeding level on pregnancy loss has been reported in sheep (El-Sheikh, Hulet, Pope and Casida, 1955). Ashworth (1995) also reported that overfeeding ewes during early pregnancy was associated with a reduction in the proportion of embryos that survived. The author found an inverse relationship between plane of nutrition and progesterone concentrations, which was assumed to be caused by increased progesterone metabolism that was caused by increases in both hepatic mixed function oxidase activity and portal blood flow in well-fed animals. Thus, the low progesterone concentration might have been responsible for higher embryo losses in well-fed ewes. Ducker *et al.* (1985) also reported that high level of feeding during lactation resulted in poor conception rates and a higher embryo loss rate after 24 days postpartum in first lactation dairy heifers.

The effect of supplementary feeding on embryo loss in cows was in agreement with other research results. Robinson, Sinclair and McEvoy (1999) in a review, reported that the adverse effect of feeding levels during early pregnancy on fetal growth appeared to be specific to adolescent pregnancies. In contrast, reduced fetal growth and its associated alterations in fetal muscle development were usually a result of undernutrition during early pregnancy in non-adolescent pregnancies. Possibly, poor nutrition in the control crossbred cows eventually led to fetal losses since there were none in the supplemented group.

Crossbred cows produced more milk than indigenous cows although milk yield from both breeds was generally low. This was in accord with results of other researchers (Scaar, Brannang and Meskel, 1981; Agyemang and Nkhonjera, 1986) who found that crossbred dairy cows had higher milk yield when compared to Zebu cows. The advantage of exotic x Zebu cows over the Zebu resulted from a combination of gene complementarity and hybrid vigour for milk production (Rege, Aboagye, Akah and Ahunu, 1994; Mackinnon, Thorpe and Baker, 1996). The low milk yields in indigenous cows confirms results of studies by Brownlee (1977) in Nkone cows. The generally low milk yields across treatments were mainly attributed to the milking technique used in the present study. Some workers have reported low milk yields in indigenous cows milked in the absence of the suckling stimulus as in this study (Mahadevan, 1966; Brownlee, 1977). The other cause of low milk yields could be due to the fact that cows were milked once a day. Milking more than once a day was likely to increase the yield as reported by Bar-Peled, Lehrer, Bruckental, Kali, Maltz, Tagari, Robinzon and Folman (1996).

Supplementary feeding had no significant effect in improving milk production in either breed. This was in agreement with results obtained by Kurtu *et al.* (1999) who found insignificant improvements in milk yield in response to postpartum concentrate supplementation in indigenous Arsi cows of Ethiopia but reported significant increases in the milk yield of crossbred cows subjected to the same treatment. Muinga (1992) found daily supplementation of crossbred dairy cows with 1 kg DM of maize bran and 2 kg DM of leucaena to increase milk yield by 5 kg a day, and Mutsvangwa *et al.* (1989) found that daily supplementation of indigenous Mashona cows with 0.5 kg of poultry litter per kg of milk produced increased milk yield from 1.5 to 1.8 kg per day. According to Khombe and Dube (1988), the nature of the stimulus for milk release is very important and results in large variations in milk yield. The absence of the pre-milking stimulus required for milk let-down in indigenous breeds (Mahadevan, 1966) in this study could have confounded the effect of supplementary feeding in indigenous cows. The significantly higher bodyweights for supplemented indigenous cows when compared to unsupplemented indigenous cows suggests that extra feed provided to the indigenous cows was used to deposit body fat and not to increase milk production as reported by Mbah *et al.* (1987). The 2 kg per day concentrate supplementation given to crossbred cows did not significantly improve their body condition and could have been inadequate to improve milk yield.

3.1.6 Conclusion

Crossbreds of Jersey and indigenous Nkone or Tuli were superior to indigenous Nkone/Tuli cows in their reproductive performance and milk yield. They had higher pregnancy rates, lost fewer pregnancies and produced more milk than indigenous cows. In addition, supplementary feeding improved the pregnancy rates and reduced pregnancy loss in the crossbreds but not in the indigenous cows.

The limitations of this experiment were that the indigenous cows had calved earlier than the crossbred cows and that the milking technique may have been unsuitable for sufficient milk let-down. In Experiment 2, a different milking technique (introducing the calf without allowing it to suckle) was used and experimental cows were selected from cows that had calved during the same period across breeds. The experiment was designed to determine the effect of breed and feed supplementation on reproductive performance and milk yield of crossbred and indigenous cows.

3.2Experiment 2

3.2.1 Introduction

Results from Experiment 1 revealed that crossbreds were superior to indigenous cows in terms of milk yield. However, the milk yield from both breeds was generally low. The low milk yields was probably due to the milking technique used. The cows were milked in the absence of their calves. Indigenous cows milked in the absence of the suckling stimulus have been reported to produce less milk and to cease lactation quickly (Brownlee, 1977). It is not known whether crossbred cows behaved in a similar manner.

The results of Experiment 1 also showed no evidence of differences in intervals from calving to ovulation in the crossbred dairy cows and the indigenous cows used for milk production. However, the differences in calving dates between the crossbred cows and the indigenous cows could have masked the breed differences in probabilities of ovulation.

This experiment was therefore designed to study the effect of breed and feed supplementation on reproductive performance and milk yield of crossbred and indigenous cows.

3.2.2 Materials and methods

3.2.2.1 Site description

The study was conducted at Matopos Research Station, Matopos, Zimbabwe. The location and physical characteristics of the area were described in Section 3.1.2.1.

3.2.2.3 Animals

Forty indigenous (20 Nkone and 20 Tuli) and 40 crossbred (20 Nkone x Jersey and 20 Tuli x Jersey) cows were used in this experiment. Among the indigenous cows, four were in their first parity, 26 were in their second parity and 10 cows were in their third parity. The ages for the indigenous cows ranged from four to six years. Among the crossbred cows, twelve were in their first parity, six were in their second parity, eight in their third parity, and 14 were in their fourth parity. The ages for the crossbred cows ranged from two to seven years. The mean bodyweight of the indigenous cows was 337 ± 32 kg with a mean body condition score of 3.0 ± 0.4. The mean bodyweight of the crossbred cows was 296 ± 50 kg and their mean body condition score was 1.76 ± 0.3. Unlike the previous experiment in which the crossbred and indigenous cows came from different herds under different management, these cows were previously under the same management unit and therefore they calved during the same period.

3.2.2.4 Experimental design and treatments

Apart from the differences in the number of cows, the experimental design and treatments were similar to those described in Section 3.1.2.3.

3.2.2.5 Experimental procedure

The experimental procedure was similar to that described in Section 3.1.2.4 except that each cow was milked in the presence of its calf. During milking, the cow and the calf were separated by a wire mesh which prevented suckling from taking place but allowed visual contact between the calf and the dam.

3.2.2.6 Laboratory analysis

Progesterone concentration was measured in the milk samples using the Self-Coating Milk Progesterone RIA kit (Animal Production Unit, FAO/IAEA Agriculture Laboratory, Agency's Laboratories, Seibersdorf, Austria). The details of the assay procedures are shown in Appendix 2. Sixty assays, in each assay seven standards, two QC samples and 80 milk samples were analysed. Based on QC values of 2 and 10 ng/ml, the intra-assay and inter-assay coefficients of variation were 9.8% and 10.9%, respectively.

3.2.3 Statistical analysis

A progesterone profile was plotted for each of the cows under observation. The interval from parturition to first ovulation, the oestrus detection rate and the effect of breed and diet on the interval from calving to first ovulation of the cows were calculated as described in Section 3.1.3. Assumed pregnancy rates, actual pregnancy rates, the rates of pregnancy loss and calving rates were calculated using the method described in Section 3.1.3.

The association between pregnancy status and dietary and breed treatment combinations was determined by the Chi-square test using the PROC FREQ procedure (SAS, 1995). The effect of breed and diet on milk yield, interval from calving to first ovulation, transformed body condition scores and cow bodyweight were analysed by analysis of variance using the PROC GLM procedure (SAS, 1995). The model used was:

$$Y_{ijkl} = \mu + B_i + D_j + A_k + P_l + (BD)_{ij} + (BDAP)_{ijkl} + e_{ijkl}$$

Where:

Y_{ijkl} = dependent variable (average daily milk yield, interval from calving to first ovulation, body condition scores and bodyweight)

μ = overall mean common to all observations

B_i = effect of breed (i = 1,2)

D_j = effect of diet (j = 1,2)

A_k = effect of age (k = 1,2..6)

P_l = effect of parity (l = 1,2..4)

$(BD)_{ij}$ = breed x diet interaction

$(BDAP)_{ijkl}$ = breed x diet x age x parity

e_{ijkl} = random residual error associated with the $ijkl^{th}$ observation

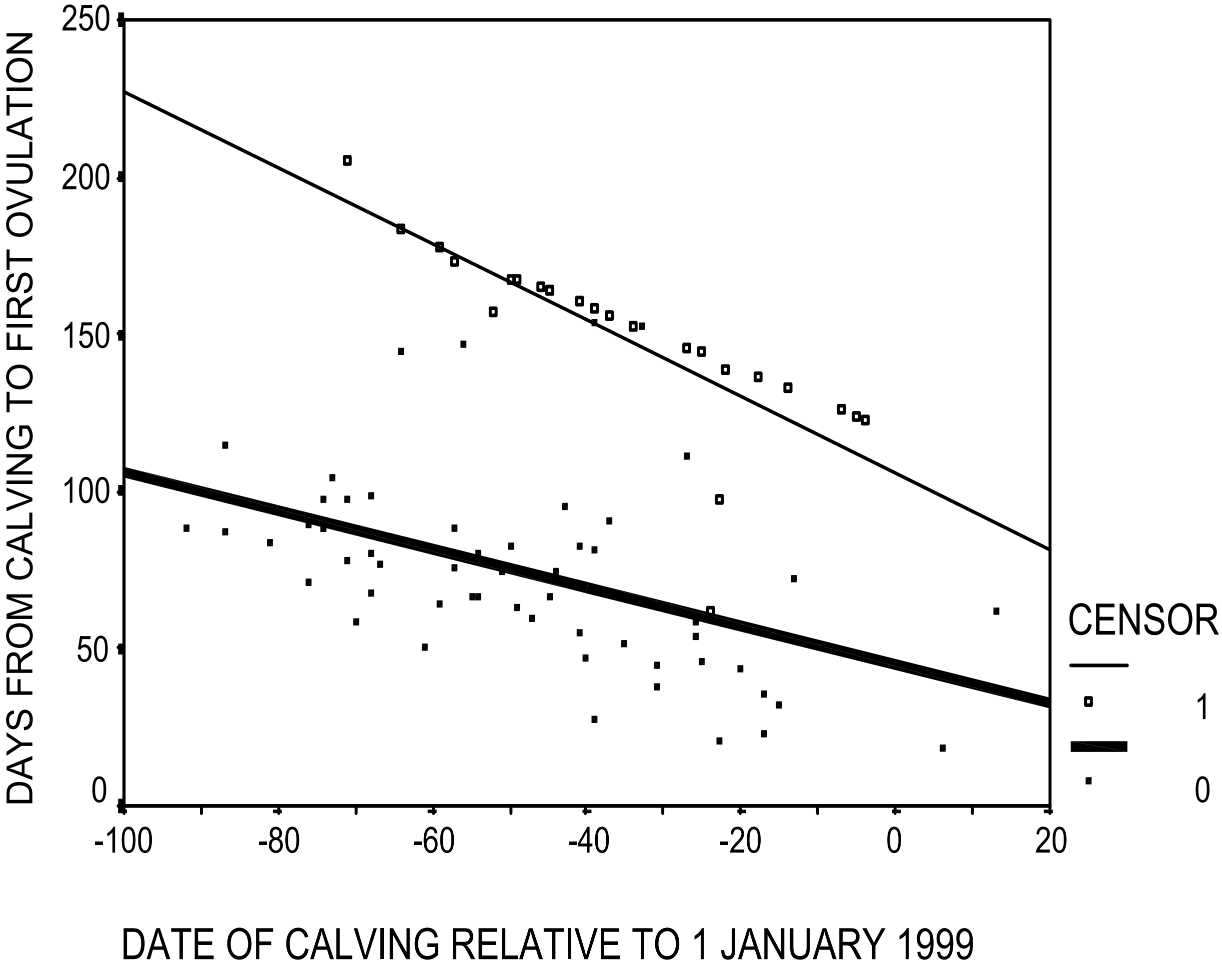
Differences between pairs of means for the treatment combinations were determined using the PDiff statistic (SAS, 1995).

3.2.4 Results

There was a strong negative correlation (r= -0.91, $P < 0.001$) between the interval from calving to first ovulation and the time of calving relative to the 1st of January. The cows that calved at the beginning of the season had the longest postpartum anoestrus periods (Figure 3.6).

Figure 3.7 shows the estimated cumulative probability of ovulation plotted against the interval from calving to ovulation for the indigenous and the crossbred cows. The estimated cumulative probability of ovulation occurring by 200 days postpartum for crossbred cows was 0.9 and higher than the probability of 0.6 obtained for indigenous cows (Log rank statistic 12.83, $P < 0.001$). The estimated probability of ovulation occurring by 200 days postpartum was 0.75 in the control group compared to 0.7 in the supplemented group (Figure 3.8) and was not statistically significant (Log rank statistic 1.28, $P > 0.05$).

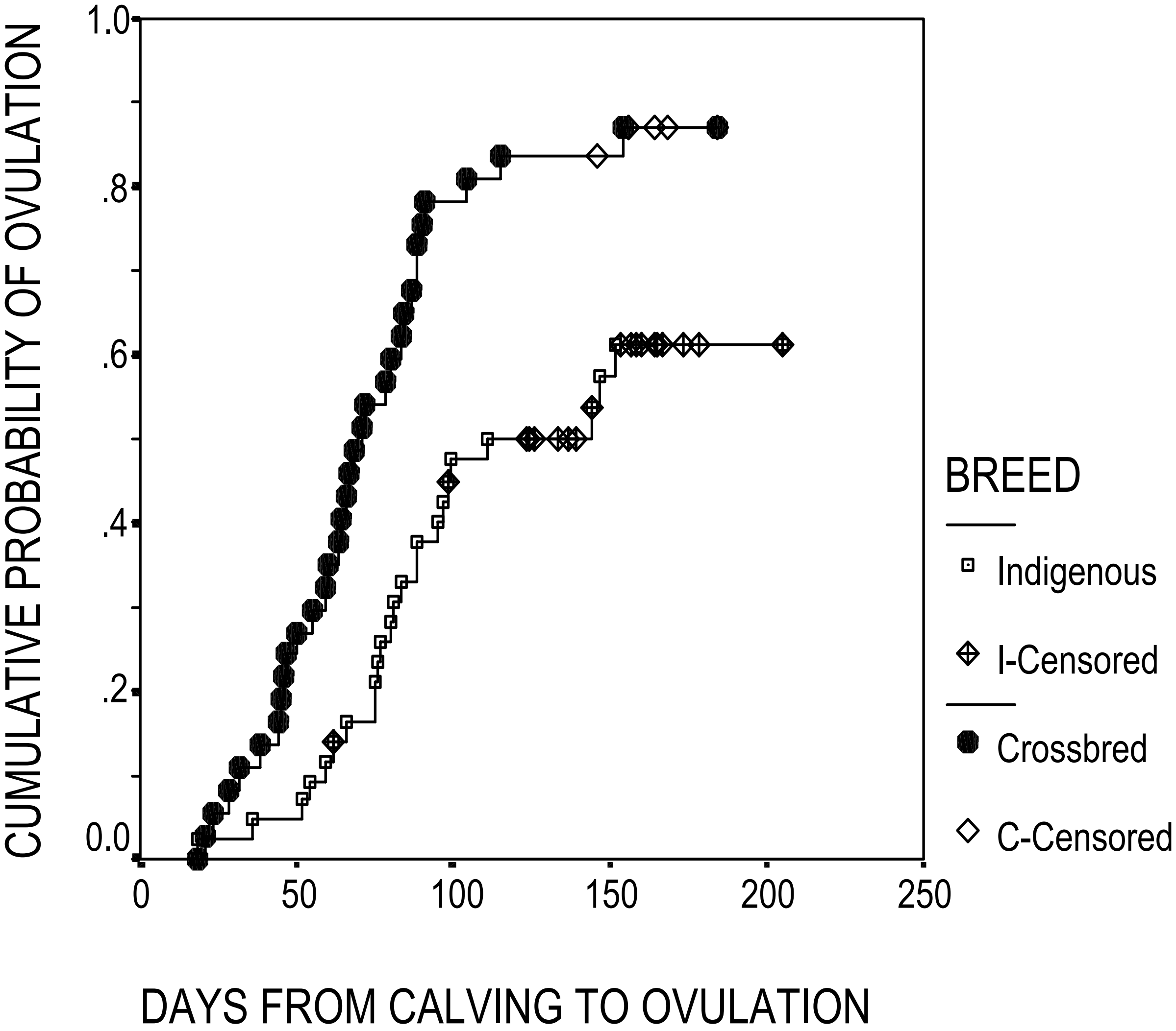
The mean interval from calving to ovulation, oestrus detection rates, assumed pregnancy rates, pregnancy losses, calving rates, mean milk yield, bodyweight



Key: Censor 0 = cows that had ovulated by 200 days postpartum

Censor 1 = cows that had not ovulated by 200 days postpartum

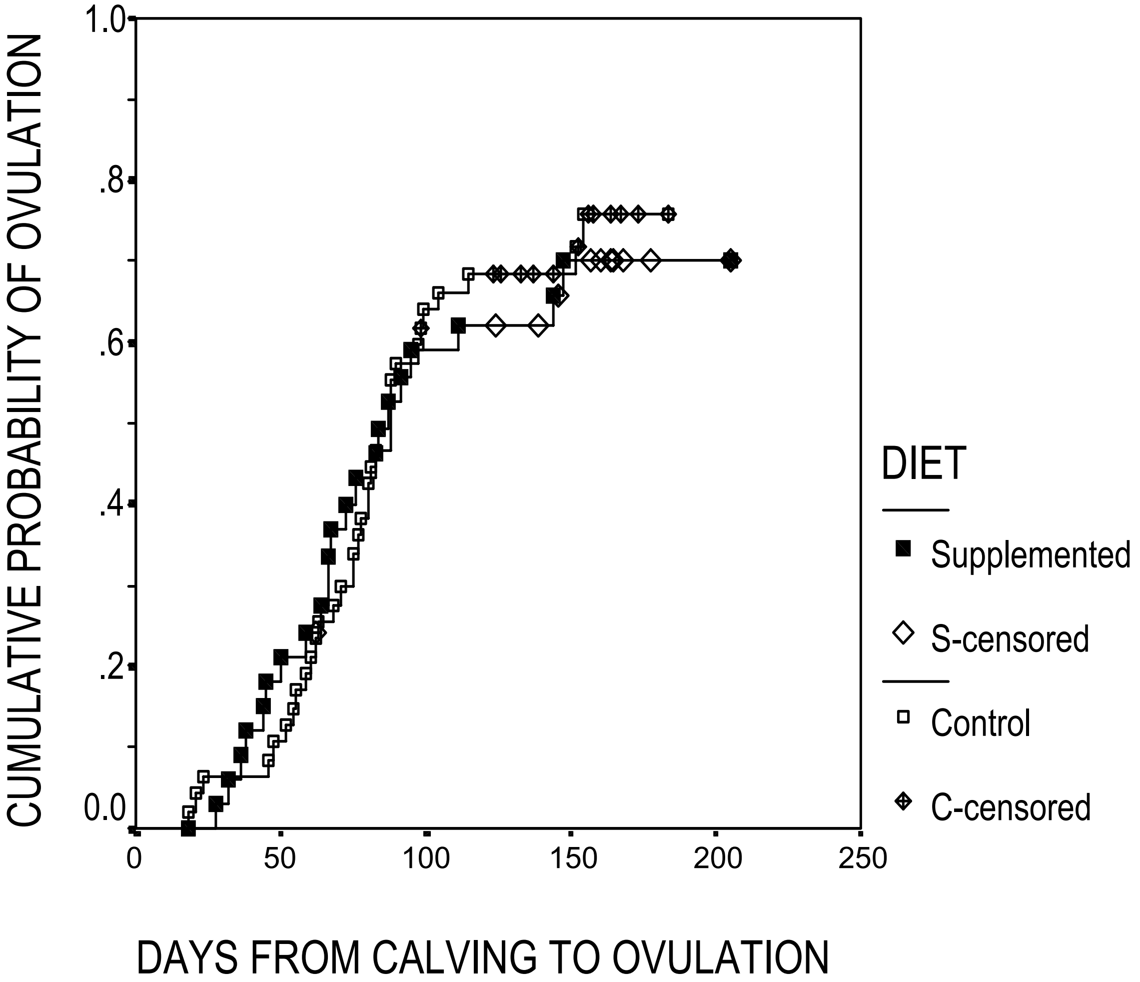
Figure 3.6 Relationship between date of calving and postpartum anoestrus period



Key I-censored represents cows in the indigenous group that had not ovulated by 200 days postpartum

C-censored represents animals in the crossbred group that had not ovulated by 200 days postpartum

Figure 3.7 Cumulative ovulation probability by breed



Key S-censored represents animals in the supplemented group that had not ovulated by 200 days postpartum

C-censored represents animals in the control group that had not ovulated by 200 days postpartum

Figure 3.8 Cumulative probability of ovulation by diet

and body condition scores for indigenous and crossbred cows in the control and supplemented treatment groups are shown in Table 3.2. The mean interval from calving to first ovulation for crossbred cows was 76 ± 41 d and shorter ($P < 0.05$) than the interval of 106 ± 38 d obtained in indigenous cows. Supplementary feeding reduced ($P < 0.05$) the interval from calving to first ovulation in both breeds.

There was an interaction ($P < 0.05$) between breed and diet on the oestrus detection rates. Supplemented indigenous cows had the highest increase in oestrus detection rate ($P < 0.05$). The assumed pregnancy rate, the actual pregnancy rate and the calving rates were higher ($P < 0.05$) in the crossbred cows than in indigenous cows. Supplemented indigenous and crossbred cows had similar assumed pregnancy, actual pregnancy and calving rates. There was no significant difference in embryo and fetal loss rates between the breeds ($P > 0.05$) and between the treatment diets ($P > 0.05$).

The mean milk yield was higher ($P < 0.05$) in crossbred cows than in indigenous cows. However, feed supplementation did not increase milk yield in both indigenous and crossbred cows. Indigenous cows had higher ($P < 0.05$) bodyweights and body condition scores than crossbreds irrespective of diet. The interaction between breed and diet on bodyweights was significant ($P < 0.05$). Supplemented crossbred cows had the highest increase in bodyweights. Supplementary feeding did not have any significant effect on body condition scores in both breeds.

Table 3.2 Oestrus detection rates, assumed pregnancy rate, pregnancy loss, mean milk yield, bodyweight and body condition score for indigenous and crossbred cows in the control and supplemented treatment groups.

	Indigenous		Crossbreds	
Diet	Control	Supplemente	Control	Supplemente
Number of cows	20	20	20	20
Number of cows that ovulated by 200 days postpartum	12	10	17	17
Mean interval from calving to first ovulation (days)	109 [a] ± 39	103 [a] ± 40	80 [b] ± 44	73 [b] ± 39
Oestrus detection rates (%)	45.5[a]	65 [b]	44.4[a]	45.5 [a]
Assumed pregnancy rate (%)	38.5 [a]	41.2 [a]	68.2 [b]	62.5[b]
Actual pregnancy rate (%)	34.6 [a]	35.3 [a]	59.1 [b]	56.3 [b]
Assumed pregnancy loss (%)	10 [a]	14 [a]	13.3 [a]	10 [a]
Calving rate (%)	34.6 [a]	35.3 [a]	59.1 [b]	56.3 [b]
Mean milk yield (kg/d ± SD)	0.55 [a] ±	0.61 [a] ± 0.3	1.69 [b] ± 1.02	1.88 [b] ± 1.02
Bodyweight (kg)	375 [a]	382 [a]	319 [b]	340 [c]
Body condition score	2.5 [a]	2.6 [a]	2.0 [b]	2.1 [b]

[a,b] Within a row, means lacking a common superscript letter differ ($P < 0.05$).

3.2.5 Discussion

The higher probability of ovulation in the crossbred than indigenous cows did not agree with the results obtained in Experiment 1. The indigenous and the crossbred cows in the current study had calved during the same period unlike in Experiment 1 were indigenous cows had calved earlier than crossbred cows and did not show any differences in the probability of ovulation.

Supplementary feeding improved oestrus detection in indigenous cows. Markusfeld, Galon and Ezra (1997) found that cows calving with a high body condition score were less likely to have an unobserved oestrus than those calving with a low body condition score. This finding confirmed that nutrition had an effect on the ability of the cows to exhibit oestrus. Ducker *et al.* (1985), working with first lactation dairy heifers receiving different levels of feeding before and after calving found oestrus detection rate to be high (75%) and that it was not influenced by dietary treatment.

The higher pregnancy rates recorded in crossbred cows compared to that determined in indigenous cows showed that under smallholder farming conditions crossbred cows were more fertile than indigenous cows. In addition, crossbred cows produced more milk than indigenous cows. However, milk yield from both breeds was too low. This was probably due to the poor season experienced during the experiment and the fact that the cows were milked once a day. Despite the presence of the calf was present at milking, milk yield was not improved. Similar results were obtained by Mahadevan (1966) and Brownlee

(1977) who reported low milk yields in indigenous cows milked in the absence of the suckling stimulus. The absence of an effect due to supplementary feeding contrary to Experiment 1 could be that in Experiment 1 there was a parity effect.

3.2.6 Conclusion

This study established that crossbred cows ovulated earlier, had higher pregnancy rates and higher milk yield when compared to indigenous cows. Supplementary feeding improved oestrus detection rate in indigenous cows and bodyweight in crossbred cows. Cows in the current experiment were supplemented using concentrates. However, concentrate feeds are expensive and most smallholder farmers cannot afford to purchase them (Jingura, 2000). There was therefore a need to investigate the reproductive performance and milk yield of crossbred cows when they were offered feed supplements based on potentially cheaper home-grown forages.

CHAPTER 4

4. EFFECTS OF BREED AND PREPARTUM SUPPLEMENTATION WITH SORGHUM LABLAB SILAGE ON REPRODUCTIVE PERFORMANCE IN COWS

4.1 Introduction

Because of the high cost of concentrates in Zimbabwe, smallholder dairy farmers have started using farm-grown supplements in the diets of their dairy cows (Khalili, Osuji, Umunna and Crosse, 1994). Research studies have identified appropriate homegrown forages and forage conservation techniques suitable for smallholder farmers (Titterton, Maasdorp, Mhere and Nyoni, 1999). Unfortunately, there is a dearth of information on the effect of the forages on the reproductive performance and milk yield of the dairy cows kept by the farmers. During the dry season, the quantity and quality of natural pastures is poor and, as a result, animals lose bodyweight and body condition (Topps, 1977). Van de Merwe (1995) reported that animals that calved in poor body condition produced low milk yields and had poor fertility. The feeding of conserved forages to pregnant cows during the dry season is aimed at allowing the cows to calve in good body condition.

The aim of this study was therefore to assess the reproductive performance and milk yield in crossbred and indigenous (Nkone/Tuli) cows offered different amounts of *Sorghum bicolor* (forage sorghum) and *Lablab purpureus* (lablab) mixed silage, as a supplement during late pregnancy and to determine the effect of introducing the suckling stimulus on milk yield.

4.2 Materials and Methods

4.2.1 Site description

The study was conducted at Matopos Research Station, Matopos, Zimbabwe. The location and physical characteristics of the area have been described in Section 3.1.2.1.

4.2.2 Animals

Twenty indigenous breed (8 Nkone and 12 Tuli) and 20 crossbred cows (six Nkone x Jersey and 14 Tuli x Jersey) were used in the study. Six of the indigenous cows were in their third parity and the other 14 were in their fourth parity. The ages of the cows ranged from five to seven years. Four crossbred cows were in their first parity, six were in their second parity, four were in their third parity and the other six were in their fourth parity. The crossbred cows had ages ranging from two to six years. In this study, the Nkone and Tuli cows were collectively regarded as indigenous breeds and the Nkone x Jersey and Tuli x Jersey crosses were considered as crossbreds. This was done because during the previous study, using the same types of animals there were no statistical differences in relation to reproductive performance and milk yield between the Nkone and the Tuli breeds and also between the Jersey x Nkone and the Jersey x Tuli crossbreds (Garwe and Ball, 1999). The mean bodyweight of the indigenous cows was 376 ± 40 kg with a mean body condition score of 2.9 ± 0.3.

The mean bodyweight of the crossbred cows was 321 ± 49 kg and their mean body condition score was 2.3 ± 0.5.

4.2.3 Experimental design and procedures

Ten weeks before the expected date of calving, the crossbred and indigenous cows were randomly allocated to four dietary treatments. The treatments were as follows: One group of animals did not receive any supplementary feeding during the study (NS). These animals were allowed to graze on natural grass and browse (basal diet) at a stocking rate of 1LU:15ha. The second group of cows was supplemented with 3 kg (1.11 kg DM) *Sorghum bicolor* and *Lablab purpureus* mixed silage, which supplied 0.16 times of their maintenance energy requirements (0.16 M) in addition to the basal diet. The cows were collected from the paddocks and given the supplements once a day between 0800 and 0900 h. Cows in the third group were supplemented with 6 kg (2.22 kg DM) *Sorghum bicolor* and *Lablab purpureus* mixed silage, which supplied 0.32 times of their maintenance energy requirements (0.32 M) in addition to the basal diet. The cows were collected from the paddocks and given the supplements once a day between 0800 and 1000 h. The fourth group of cows were individually housed throughout the study period and offered 24 kg (8.88 kg DM) *Sorghum bicolor* and *Lablab purpureus* mixed silage, which supplied two times of their maintenance energy requirements (2 M). The *Sorghum bicolor* and *Lablab purpureus* mixed silage was ensiled in plastic bags using a technique described by Titterton *et al.* (1999). The silage had a dry matter content of 37%, 9.33% crude protein and 35% acid detergent fibre on a dry matter basis. All cows had free access to water.

The cows were allowed a two-week adaptation period on the silage diets before data collection was commenced about eight weeks prior to calving. The silage supplement was offered for 56 days. After calving all cows received 2 kg/day of a maize/soyabean-based commercial dairy meal (Urelac® 14% CP, National Foods, Zimbabwe) and were allowed to graze natural grass and browse at a stocking rate of 1LU:15ha.

Sixty days after the last cow had calved, bulls were allowed to run with the herd for a period of three months. This strategy was adopted in order to prevent any mating within 60 days of the postpartum period since this reduces conception rates (Mutsvangwa and Hamudikuwanda, 1994). Pregnancy diagnosis by rectal palpation was carried out by a veterinarian four months after the withdrawal of bulls.

Milking of the cows commenced five days after the cows had calved. The five-day delay in milking allowed the calves to get enough colostrum from their dams. During milking the cows were brought in from the paddocks at 0730 h every day. All the cows were then given 2 kg of dairy meal prior to milking. Udder washing was carried out before application of the milking salve to the teats. The milking was carried out once a day and was done by hand. The calves were allowed to suckle briefly before milking to elicit the milk let-down response. After milking, the calves were allowed to run with their dams until sunset when the calves were separated for overnight penning. The daily milk yield for each cow was measured using a graduated cylinder. Each cow was milked until the daily milk yield fell to below 0.2 kg for five consecutive days. At this point, the cows were considered to have dried off and data collection was stopped.

Milk samples for progesterone analysis were collected from each cow every Monday, Wednesday and Friday of the week. Collection of the samples commenced from 10 days postpartum until the cows dried off or up to a maximum of 200 days post calving whichever came first. The milk from each cow was thoroughly mixed using a stirring rod and a sample was collected into 1.5 ml plastic vials containing 10 ng of potassium dichromate as a preservative. The samples were then refrigerated at 4^0C pending analysis.

The bodyweights and body condition scores of the cows were recorded fortnightly from calving until the cows were dried off. The cows were weighed using a cattle scale (Kattleway Scale, Marondera, Zimbabwe). Body condition was assessed by two trained technicians using the 1 (very thin) to 5 (obese) scale described by Mulvany (1981).

4.2.4 Laboratory analysis

Progesterone concentration was measured in the milk samples using the Self-Coating Milk Progesterone RIA kit (Animal Production Unit, FAO/IAEA Agriculture Laboratory, Agency's Laboratories, Seibersdorf, Austria). The details of the assay procedures are shown in Appendix 2. Thirty assays, each assay analysed seven standards, two QC samples and 80 milk samples were carried out. Based on QC values of 2 and 10 ng/ml, the intra-assay and inter-assay coefficients of variation were 9.5% and 10.2%, respectively.

4.3 Statistical Analysis

The data were analysed for all the forty experimental cows. Body condition scores were subjected to square root transformations before statistical analysis as described by Gomez and Gomez (1984). The effects of breed and supplementation level on the transformed body condition scores and bodyweights in the treatment groups were tested using the PROC MIXED procedure (SAS, 1995) for repeated measures as described by Littell, Henry and Ammerman (1998). The model used was as follows:

$$Y_{ijkl} = \mu + D_i + B_j + W_k + (DB)_{ij} + (DW)_{ik} + BW_{jk} + C(TB)_{ijl} + (DBW)_{ijk} + e_{ijkl}$$

Where:

Y_{ijkl} = response variable (body condition score, bodyweight)

μ = population mean

D_i = fixed effect of i^{th} diet (i = 1,2,3,4)

B_j = fixed effect of j^{th} breed (j = 1,2)

W_k = fixed effect of w^{th} period of feeding (w = 1,2 ….8 weeks)

$(DB)_{ij}$ = effect of interaction between the i^{th} diet and the j^{th} breed

$(DW)_{ik}$ = effect of interaction between the i^{th} diet and the k^{th} period of feeding

$(BW)_{jk}$ = effect of interaction between the j^{th} breed and the k^{th} period of feeding

$C(DB)_{ijl}$ = random effect of l^{th} cow in the i^{th} diet and the j^{th} breed (l = 1,2…40)

$(DBW)_{ijl}$ = diet x breed x time interaction

e_{ijkl} = random residual error

A progesterone profile was plotted for each of the cows under study. The date of first ovulation was determined from the progesterone profiles as the day with the lowest concentration of progesterone occurring immediately before the first rise in progesterone concentration of equal or greater than 3 ng/ml for more than two consecutive dates (Darwash *et al*., 1999). The interval from parturition to first ovulation was determined by calculating the number of days from calving to first ovulation.

Pregnancy rates were determined by expressing the number of cows confirmed to be pregnant by rectal palpation at 3 months after the removal of bulls as a percentage of all cows mated. The association between pregnancy status and dietary and breed combinations was determined by the Chi-square test using the PROC FREQ procedure (SAS, 1995).

The effects of breed and supplementation level and the interaction of breed x supplementation level on interval from calving to first ovulation and milk yield were analysed by analysis of variance using the PROC GLM procedure (SAS, 1995). The model used was:

$$Y_{ijkl} = \mu + B_i + D_j + A_k + P_l + (BD)_{ij} + e_{ijkl}$$

Where:

Y_{ijkl} = dependent variable (average daily milk yield, interval from calving to ovulation and cow bodyweight)

μ = overall mean common to all observations

B_i = effect of breed (i = 1,2)

D_j = effect of level of supplementation (j = 1,2,3,4)

$(BD)_{ij}$ = breed x supplementation level interaction

A_k = effect of age (k = 1,2..5)

P_l = effect of parity (l = 1,2..4)

e_{ijkl} = random residual error associated with the $ijkl^{th}$ observation

Differences between pairs of means for the treatment combinations were determined using the PDiff statistic (SAS, 1995).

4.4 Results

Prepartum supplementary feeding at the level of 0.32M and 2M significantly improved (P < 0.05) body condition scores at calving. There was an interaction (P < 0.05) between breed and supplementary level with crossbred cows in the 2M treatment group having the largest increase in body condition scores. Within each supplementation level, indigenous cows had higher body condition scores compared to crossbreds (Table 4.1).

Table 4.1 Effect of breed and prepartum silage supplementation level on mean body condition scores at calving

Silage supplementation level (multiples of maintenance energy requirements)	Crossbreds	Indigenous
Control (NS)	$1.6^{ac} \pm 0.005$	$1.9^{bc} \pm 0.0003$
0.16 M (1.11 kg DM)	$1.6^{ac} \pm 0.005$	$2.0^{bc} \pm 0.006$
0.32 M (2.22 kg DM)	$2.0^{ad} \pm 0.001$	$2.6^{bd} \pm 0.001$
2 M (8.88 kg DM)	$2.7^{ae} \pm 0.007$	$3.0^{be} \pm 0.002$

$^{a\text{-}b}$ Within a row, means with different superscript letters differ ($P < 0.05$).

$^{c\text{-}e}$ Within a column, means with different superscript letters differ ($P < 0.05$).

Table 4.2 shows the effect of prepartum feed supplementation on the interval from calving to ovulation. The interaction between breed and supplementary level for the interval from calving to ovulation was significant ($P < 0.05$). Unsupplemented crossbred cows had the longest interval from calving to postpartum ovulation. Indigenous cows in the 0.32 M and 2 M groups had similar but shorter postpartum intervals to first ovulation when compared to indigenous cows in the control and 0.16 M groups.

The pregnancy rates for the different treatment groups are shown in Table 4.3. Prepartum feed supplementation did not influence the subsequent postpartum pregnancy rates in both indigenous and crossbred cows ($P > 0.05$). Crossbred cows had higher pregnancy rates than indigenous cows across all supplementary feeding levels.

The crossbred cows produced higher ($P < 0.001$) mean daily milk yields than indigenous cows (Table 4.4). Milk yields were similar ($P > 0.05$) across prepartum supplementation levels. The interaction between breed and prepartum supplementation level on milk yield was not significant.

4.5 Discussion

The cows supplemented with silage at 0.32 M and 2 M levels calved in a good body condition highlighting the importance of dry season prepartum feed supplementation for pregnant cows. It is likely that supplementation at these levels during the prepartum period reduced the use of body reserves to support

Table 4.2 Effect of breed and prepartum silage supplementary feeding level on interval from calving to ovulation (days)

Silage supplementation level (multiples of maintenance energy requirements)	Crossbreds	Indigenous
Control (NS)	$116^{ac} \pm 66$	$104^{be} \pm 24$
0.16 M (1.11 kg DM)	$53^{ad} \pm 15$	$97^{be} \pm 35$
0.32 M (2.22 kg DM)	$49^{ad} \pm 66$	$81^{bf} \pm 11$
2 M (8.88 kg DM)	$53^{ad} \pm 32$	$74^{bf} \pm 26$

$^{a\text{-}b}$ Within a row, means with different superscript letters differ ($P < 0.05$).

$^{c\text{-}f}$ Within a column, means with different superscript letters differ ($P < 0.05$).

Table 4.3 Effects of breed and prepartum silage supplementation on postpartum pregnancy rates (%)

Silage supplementation level (multiples of maintenance energy requirements)	Crossbreds	Indigenous
Control (NS)	80^{ac}	60^{bc}
0.16 M (1.11 kg DM)	80^{ac}	60^{bc}
0.32 M (2.22 kg DM)	80^{ac}	60^{bc}
2 M (8.88 kg DM)	80^{ac}	60^{bc}

$^{a\text{-}b}$ Within a row, means lacking a common superscript letter differ ($P < 0.05$).

^{c} Within a column, means lacking a common superscript letter differ ($P < 0.05$).

Table 4.4 The effect of breed and prepartum supplementation on subsequent lactation milk yield (kg/d)

Silage supplementation level (multiples of maintenance energy requirements)	Crossbreds	Indigenous
Control (NS)	$2.9^{ac} \pm 0.7$	$1.4^{bc} \pm 0.4$
0.16 M (1.11 kg DM)	$3.0^{ac} \pm 0.6$	$1.3^{bc} \pm 0.6^{c}$
0.32 M (2.22 kg DM)	$3.1^{ac} \pm 0.6$	$1.4^{bc} \pm 0.4$
2 M (8.88 kg DM)	$3.6^{ac} \pm 0.3$	$1.3^{bc} \pm 0.7$

$^{a\text{-}b}$ Within a row, means lacking a common superscript letter differ ($P < 0.001$).

^{c} Within a column, means lacking a common superscript letter differ ($P < 0.001$).

foetal growth during the last trimester of pregnancy as reported by Echevarria and Dela-Torre (1996). The observation that indigenous cows had a better prepartum body condition score irrespective of the level of supplementation suggest that they utilised low quality feeds better than crossbred cows. Hunter and Siebert (1985) found that indigenous cows utilised low quality feeds more efficiently than exotic dairy cows. The good body condition recorded at calving in the cows receiving the 0.32 M and 2 M levels of silage supplementation shortened the postpartum anoestrus period. A similar observation was reported by Ducker *et al.* (1985). Peters and Ball (1995) also reported an accelerated return to ovarian cyclicity postpartum when pregnant beef cows received a prepartum energy supplement. Richards, Spitzer and Warner (1986) found body condition at calving to be the most important factor influencing early resumption of ovulation.

The shorter intervals from calving to ovulation observed in crossbred cows when compared to indigenous cows across all prepartum supplementation levels indicated that there was a breed advantage in terms of fertility. The observation was consistent with the finding that crossbred cows had higher pregnancy rates when compared to indigenous cows (Hamudikuwanda *et al.,* 2000). The absence of a significant difference in pregnancy rates between the control and supplemented cows does not agree with the findings of Richards *et al.* (1986) and Zerbini, Gemeda, Franceschini, Sherington and Wold (1993) who reported that prepartum supplementation led to better conception rates in the subsequent lactation.

The superiority of the crossbred cows over indigenous cows in milk yield was consistent with other research results (Nyoni, 2000). The mean milk yield of the indigenous cows was three times more than the yield of similar cows reported in Chapter 3. This showed the importance of the suckling stimulus in eliciting milk let-down in indigenous cows as previously reported (Brownlee, 1977). The suckling stimulus also appeared to increase the milk yield in the crossbreds by 77% in this study compared the milk yield of similar cows reported in Chapter 3. However, Kurtu *et al.* (1999) did not find any milk let-down problems in crossbred cows. Prepartum supplementation did not improve milk yield in both the indigenous and crossbred cows. Other workers (Mbah *et al.,* 1987) reported that indigenous cows tended to gain bodyweight rather than increase milk yield when they were offered supplementary feeding. It appears that a similar partition of energy towards body reserves rather than milk yield occurred in the indigenous cows.

4.6 Conclusion

Prepartum feed supplementation of cows across breeds with *Sorghum bicolor* and *Lablab purpureus* mixed silage at the level of 0.32M and 2M improved body condition at calving and reduced intervals from calving to ovulation. Crossbred cows had higher pregnancy rates and higher milk yields than their indigenous counterparts across diets.

The current experiment and the experiments reported in Chapter 3 were conducted at a research station and the results obtained might not directly apply to the smallholder farming areas. There was therefore a need to carry out similar studies under on-farm conditions and also to determine the extent of use of crossbred cattle and their reproductive performance and milk yield.

CHAPTER 5

5. A SURVEY OF PRODUCTIVITY OF CATTLE IN GULATHI COMMUNAL AREA AND IRISVALE RESETTLEMENT AREA IN MATEBELELAND SOUTH PROVINCE OF ZIMBABWE.

5.1 Introduction

Scoones (1992) reported that cattle were recognised as multi-purpose animals in the smallholder sector in Zimbabwe. Cattle provide draught power, manure, meat and milk and they also perform social and cultural functions. However, only 50% of households in communal areas owned at least one animal (GFA, 1987; CSO, 1989). This poor ownership pattern was mainly attributed to poor nutrition and poor reproductive performance of the cattle (Sibanda, 1993). Calving intervals of up to four years and annual calving rates of between 30% and 52% were reported in the communal areas (Gubbins and Frankherd, 1983; Masunda, 2001).

The government of Zimbabwe introduced a land resettlement programme in the early 1980’s. Resettled farmers were each allocated at least 5 ha of arable land and communal grazing areas enough to support at least 12 livestock units per settler. The expectations were that the land allocated was enough to grow fodder crops and food crops. Cattle production was expected to improve due to the expanded animal feed base comprising of natural grazing, fodder and crop residues. Few studies have been conducted to assess the cattle production and reproductive performance of cows in resettlement areas.

The current study was therefore carried out to establish and compare household characteristics, agricultural enterprises, cattle numbers and breeds, dairy cattle feeding management and production characteristics and the constraints faced by the dairy farmers in Gulathi communal and Irisvale resettlement areas in Matebeleland South province of Zimbabwe.

5.2 Materials and Methods

5.2.1 The study area

The study was undertaken in Gulathi, Matopos and in Irisvale, Umzingwane both in Matebeleland South Province of Zimbabwe.

Gulathi is approximately 40 km south of Bulawayo and lies at an altitude of approximately 1340 m. It is in Natural Region IV of Zimbabwe and is located 20^0 S and 28^0 E. It comprises of three villages Tohwe, Nyumbane and Mkokha. The mean annual rainfall in the area is 570 mm. The area also experiences periodic droughts. The mean annual minimum and maximum daily temperatures experienced at the site are 20^0C and 30^0C, respectively. The soils are broadly referred to as granitic sands. The vegetation is mainly tree bush Savanna with *Hyparrhenia* and *Acacia* species as the predominant grass and tree species, respectively.

Irisvale is located 80km from Bulawayo city and 50 km from Gwanda town and lies at 20^0 S and 29^0 E at an altitude of 1300m. It is in Natural Region IV. The annual rainfall in the area ranges from 400 to 600 mm. The mean annual minimum and maximum daily temperatures experienced at the site are 20^0C and 30^0C, respectively. It comprises of 12 village clusters that are up to 20 km apart. The farmers moved into this area in 1984 and were each given 5 ha of cropping land but have communal grazing area enough to sustain 10 Livestock Units per settler. The vegetation type in Irisvale is tree bush savannah. The predominant trees are *Colophospermum mopane* and *Acacia* species. The predominant grasses are *Hyparrhenia* and *aristida* species.

5.2.2 Data collection

The survey targeted all fully paid members of the Gulathi and Irisvale Dairy Associations. The members consisted of 40 farmers from Gulathi and 40 farmers from Irisvale Dairy Associations. The survey was carried out by means of a structured questionnaire that focused mainly on cattle production systems but also captured household statistics and crop production systems. Six trained enumerators were involved in the administration of the questionnaire in both Gulathi and Irisvale. The farmers were interviewed individually. A total of 80 farmers were interviewed, 40 farmers in Irisvale and 40 farmers in Gulathi.

5.2.3 Data analysis

Descriptive statistics (percentages, means and standard deviations) for the measurements including numbers of cattle and lactating cows per household, calving intervals and milk yield per cow were computed using the PROC MEANS procedure (SAS, 1995). Comparison of means of cattle numbers, number of household and hired labour and number of cows in lactation per year per household for Gulathi and Irisvale data were compared using the Chi-square test using the PROC FREQ procedure (SAS, 1995).

5.3 Results

5.3.1 Household characteristics

The characteristics of the farmers sampled are shown in Table 5.1. The percentage of full time female farmers in Irisvale was 70% and was not statistically different from the 67% in Gulathi. The farmers did most of the farm work and some hired labour (20% in Gulathi and 95% in Irisvale). There was no significant difference ($P > 0.05$) in the number of family labourers in Gulathi and in Irisvale. However, Irisvale farmers hired more people ($P < 0.05$) to assist them during peak labour periods than Gulathi farmers. The period of peak labour demand was during the crop planting, weeding and harvesting time which occurred from December to March.

5.3.2 Agricultural enterprises

The farmers in both areas were involved in livestock and fodder production, crop production and market gardening. However, due to frequent droughts, livestock production was their main source of livelihood. The classes of livestock owned by farmers were predominantly beef and dairy cattle, donkeys, goats and poultry. The major crops grown were maize, sorghum, groundnuts,

Table 5.1 Characteristics of farmers belonging to the Gulathi and Irisvale Dairy Associations

Farmer characteristic	Gulathi	Irisvale
Total number of farmers interviewed	40	40
Percentage of full time female farmers (%)	67^{a}	70^{a}
Number of household members working on-farm	$3^{a} \pm 1$	$3^{a} \pm 1.2$
Percentage of farmers that hired labour (%)	20^{a}	95^{b}
Average number of hired labourers	$1^{a} \pm 1$	$2^{b} \pm 0.9$

^{a,b} Within a row, means lacking a common superscript letter differ ($P < 0.05$).

sunflower, fingermillet and sweet sorghum. Market gardening involved the production of sweet potatoes, tomatoes, onions and leaf vegetables in gardens of various sizes, which were located either at the homestead or near water sources such as wells or rivers. Fodder crops grown were mainly Bana grass, forage sorghum, dolichos beans and cowpeas. The agricultural enterprises in Gulathi and Irisvale are shown in Table 5.2.

5.3.3 Cattle numbers and breeds

The number of cattle and the breeds of cattle kept by the farmers in the two areas are shown in Table 5.3. Irisvale farmers owned more cattle ($P < 0.001$) than Gulathi farmers. The average number of cattle per farmer was 22 ± 14 in Irisvale and 10 ± 6 in Gulathi. The distribution of cattle numbers per farmer is shown in Figure 5.1. The most common breeds in Gulathi were the Tuli, Nkone, Brahman, and non-descript crossbreds. Only five Tuli/Jersey and Nkone/Jersey crosses were present in the 40 households studied. In Irisvale, the major breeds were the Brahman, Nkone, Tuli and various crosses containing Brahman, Sussex and Friesland blood. In some cases, it was difficult to identify the breed types due to the uncontrolled crossbreeding that has occurred in the villages. Fifteen purebred Friesland cows that had been sourced for a dairy project in Irisvale were reported to have all died.

5.3.4 Feeding management

The farmers in Gulathi reported that there was extensive overgrazing of the grasslands, which caused shortages of livestock feeds. This shortage of feed was felt especially during the dry season and it compelled the farmers to drive

Table 5.2 Agricultural enterprises and the percentage of farmers engaged in each enterprise in Gulathi and Irisvale

Enterprise	Gulathi (%)	Irisvale (%)
Livestock production	100	100
Crop production	100	100
Fodder production	100	40
Market gardening	80	20

Table 5.3 Numbers and breeds of cattle kept in Gulathi communal and Irisvale resettlement areas

Breed	Number in Gulathi	Number in Irisvale
Tuli	51	95
Nkone	65	118
Tuli x Jersey	2	0
Nkone x Jersey	3	0
Brahman	38	300
Tuli x Friesland	0	15
Nkone x Friesland	0	10
Non-descript crossbreds	253	328
Total	412	866
Average per household	$10^{b} \pm 6$	$22^{a} \pm 14$

[a,b] Within a row, means lacking a common superscript letter differ ($P < 0.001$).

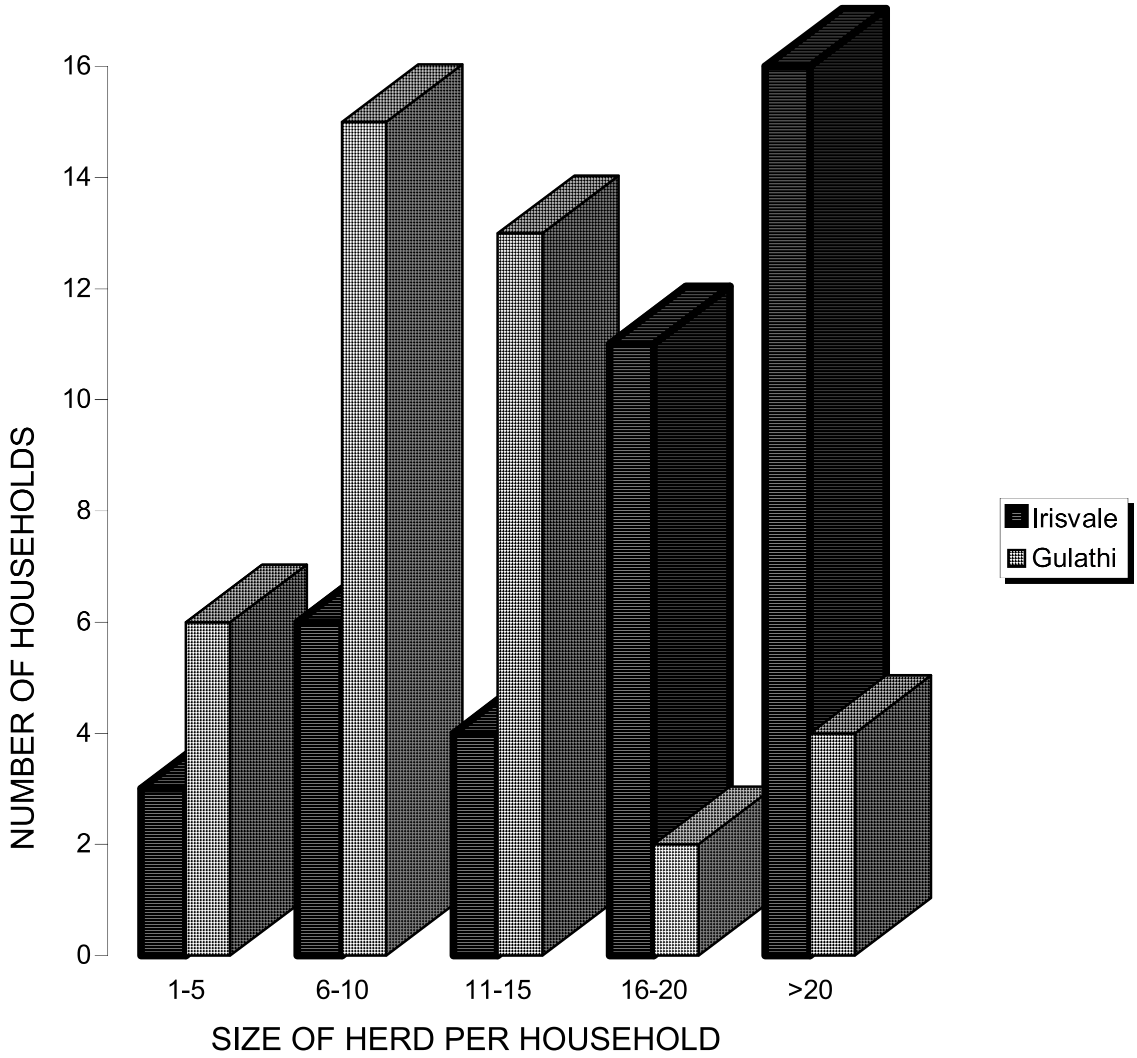


Figure 5.1 Number of households holding various herd sizes in Gulathi and Irisvale

their animals to neighbouring large-scale commercial farms in search for forages. From September up to the start of the rain season, the animals survived on foraging crop residues which farmers stored in their fenced fields.

In Irisvale, the farmers indicated that the natural pastures were abundant and were of good quality during the rain season, however during the dry season the quantity and quality of the pastures declined. The farmers then supplemented their animals with maize stover in addition to foraging from the crop residues left in the fields. Some of the farmers supplemented their dairy cows with bought-in concentrates during the dry season.

5.3.5 Dairy production characteristics and constraints

The number of cows in lactation per farmer per year averaged 1 ± 0.3 in Gulathi and 5 ± 1.4 in Irisvale. The percentage of cows calving in the rain season (September to March) was 96% in Gulathi and 68% in Irisvale (Figure 5.2).

The dairy production characteristics and farmer knowledge on reproductive performance characteristics in Gulathi and Irisvale are shown in Table 5.4. Calving intervals were longer ($P < 0.05$) in Gulathi than in Irisvale. Some farmers did not milk their lactating cows due to various reasons. Shortage of labour during summer was the main reason since the farmers concentrated on their cropping activities. In winter, the cattle were let out to graze far from the

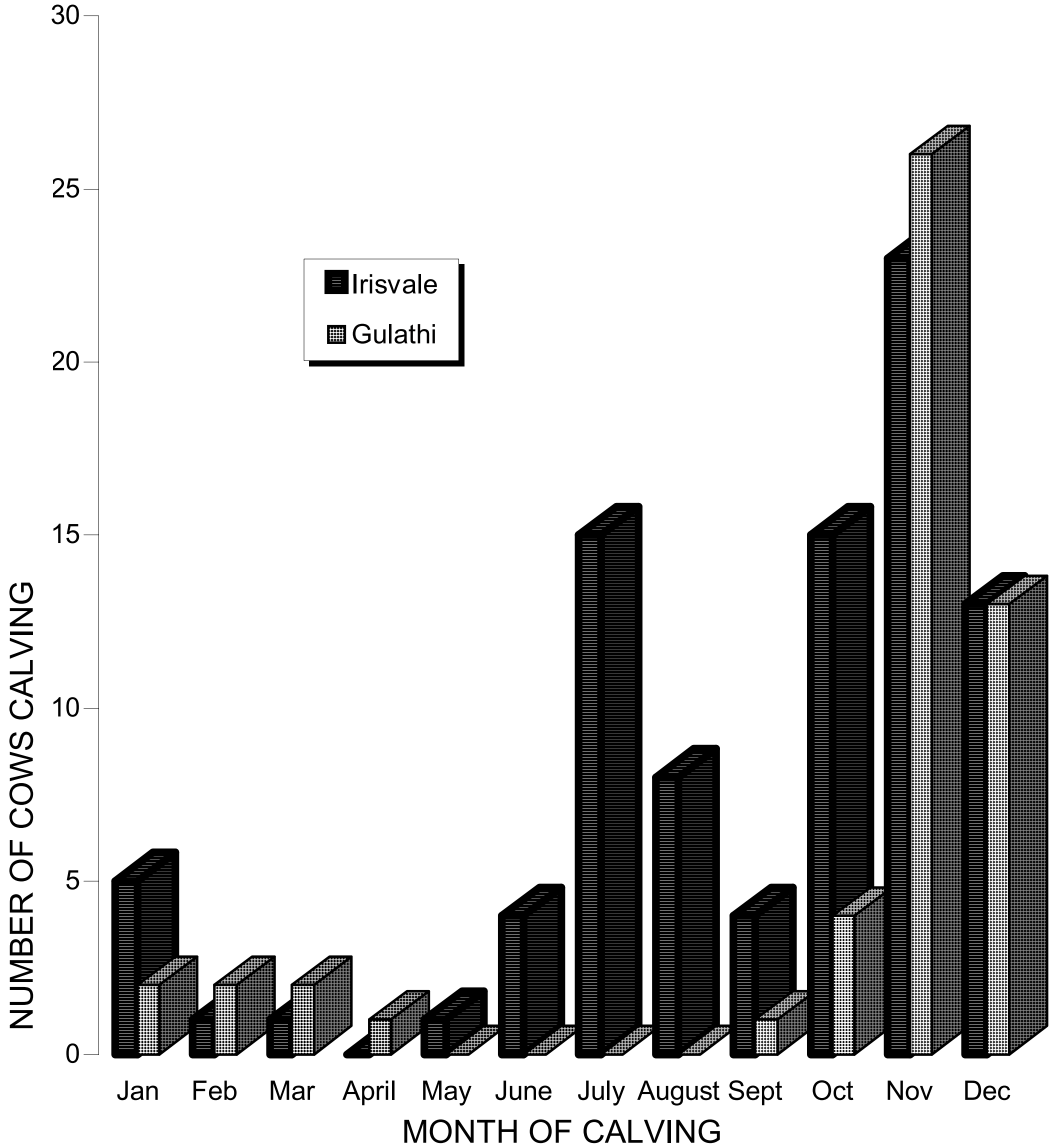


Figure 5.2 Number of cows calving per month in Gulathi and Irisvale

Table 5.4 Cattle production characteristics and farmer knowledge of some cattle management practices

Production characteristic/ Farmer knowledge	Gulathi	Irisvale
Calving interval (years)	$3^{a} \pm 0.9$	$2^{b} \pm 0.5$
Percentage of farmers milking cows (%)	10	31
Average daily milk yield (kg/d)	unknown	1.5 ± 0.7
Farmers who could detect oestrus (%)	5	20
Farmers who could detect pregnancy (%)	7	30
Farmers who had received dairy training (%)	12	60

[a,b] Within a row, means lacking a common superscript letter differ ($P < 0.05$).

homestead without a herder and it was therefore difficult to round up the animals daily for milking. The farmers considered the milking of cows with stillbirths or calves that died as a taboo. Farmers also avoided milking cows that were in poor condition.

For those Gulathi farmers that milked on a daily basis, exact milk yields were not known since measuring jugs were not used. However, the farmers stated that the milk yield from their cows was low. Most farmers in Gulathi had little knowledge in dairy management. They could not detect oestrus and could not identify pregnant cows. However, Irisvale farmers claimed that they had received dairy training and that most of them were able to detect oestrus and identify pregnant cows.

The problems affecting livestock production highlighted by farmers in Gulathi and Irisvale are shown in Table 5.5. Farmers in Gulathi cited the shortage of feed resources as the major livestock problem followed by diseases, livestock mortalities and lastly access to finance. The ranking order for livestock problems in Irisvale was shortage of feed, access to finance, diseases and livestock mortalities.

5.4 Discussion

The female farmers in both areas played a more active role than male farmers in carrying out on-farm duties. This was because the majority of the women resided in the communal areas (Central Statistical Office, 1989) and; as a

Table 5.5 Major problems affecting livestock production in Gulathi and Irisvale and the percentage of farmers affected

Problem	Gulathi (%)	Irisvale (%)
Feed shortage	100	100
Failure to access finance	40	85
Tick-borne diseases	90	60
Internal parasites	90	60
Livestock mortalities	70	30

result they contributed more to farm labour compared to men who preferred to seek off-farm employment (Chiduza, 1994). It appears that availability of more land per household in Irisvale resettlement than in Gulathi communal area has not reduced migration of males most probably to urban areas. This could have led to a gender bias because women and children are often largely involved in dairy farming (Chiduza, 1994). The larger average number of hired labourers in Irisvale than in Gulathi was primarily due to larger areas for cropping and cattle herd sizes that had to be attended to. Family labour which was of similar size with Gulathi would not suffice.

The production of crops including maize is not ideal for the natural region where Gulathi and Irisvale are located. However this has been observed across communal areas in Zimbabwe (Central Statistical Office, 1997). This is because crops such as maize provide staple food for the farmers. Market gardening was particularly popular in Gulathi because of abundance of wetlands suitable for horticulture. Livestock production especially crop production was considered to be more important than the crop based enterprises. Fodder production was practiced by all Gulathi farmers mainly because there was a perennial shortage of livestock feeds. The farmers were also exposed to forage research work at the nearby Matopos Research Station and this influenced them to go into forage production.

The farmers interviewed from Gulathi and Irisvale owned more cattle than the farmers from other smallholder farming areas. Masunda (2001) reported that the average number of cattle per farmer in Sanyati smallholder farming area was 6 ±

0.9. The reason for this difference was that the farmers in the current study were small scale dairy farmers who own more cattle than non-dairy farmers. Irisvale farmers kept more cattle than Gulathi farmers probably because of larger land areas for grazing and cropping. Farmers in Irisvale appeared to be more commercially oriented than Gulathi farmers.

Irisvale had more crossbred cows than Gulathi probably because the former area had better livestock feeds and the farmers had better financial resources. In addition, Irisvale resettlement area was located next to large scale commercial farms where the farmers from Irisvale bought cattle. Purebred Friesland cows that had been sourced for a dairy project in Irisvale died, ostensibly due to poor management and the lack of adequate nutrition. Gandiya (1999) reported that several farmers in various smallholder schemes across Zimbabwe had lost purebred cows because these exotic animals could not survive on poor quality feeds whose supply was limited

Irisvale farmers supplemented their cattle using bought-in concentrates indicating that the farmers had more resources than Gulathi farmers who did not feed any bought-in concentrates to their animals. Jingura (2000) also found out that the concept of feed supplementation was readily accepted by smallholder farmers in Gokwe.

Calving in the areas under study was seasonal and was concentrated during the rainy season and this finding was similar in other provinces of Zimbabwe (Mutsvangwa *et al.*, 1989). The high number of cows calving during the dry season in Irisvale was due to the greater availability of pastures in the grazing area and supplementary feeding practices during the dry season. It was reported that the seasonal calving, which was concentrated in the period of September to March, was the result of the relatively high cow fertility which occurred during the previous rain season (Mutsvangwa *et al.*, 1989). During this period, the quantity and quality of grazing was adequate to promote high fertility.

The long calving intervals of up to three years in Gulathi and Irisvale are similar to the findings of Mukasa-Mugerwa (1989) and Honhold *et al.* (1992) that long calving intervals were a sign of cow infertility in smallholder farming areas. Inadequate nutrition was the main cause of the long calving intervals (Burke *et al.*, 1996), which occurred because of the extended postpartum anoestrous periods. In communal areas of Zimbabwe, forages were scarce or of poor quality. In addition, overnight penning of cattle and long walking distances in search of grazing and water that reduced grazing time and thus feed intake by animals (Manteca and Smith, 1994). Furthermore, the use of cows for draught also reduced the time available for feeding and this negatively affected their ovarian activity and fertility (Mupeta, 1990; Francis, 1993; Chimonyo, 1998).

The shortage of grazing in Gulathi was in agreement with the reports by Gammon (1983) that good quality pastures and browse were in short supply in many communal areas of Zimbabwe resulting in high stocking rates and this resulted in overgrazing. Honhold *et al.* (1992) estimated that the stocking rates were about 2.7 hectares per livestock unit whereas the recommended average stocking rate for hot dry regions such as Matebeleland South Province were in the region of 8 to 12 hectares per livestock unit (Cattle Producers Association, 1989).

The prevalence of livestock diseases caused by ticks and internal parasites was in agreement with the studyby Francis (1993) in the smallholder farming areas. The author reported that farmers were restricted from dipping their animals during the dry season because of water shortage. The shortage of dipping chemicals also meant that animals were not dipped at regular intervals.

Ulrich and Kjaer (1994) reported that many farmers did not pen their animals at night, especially during the dry season after harvesting. Because of this practice, animals could not be rounded up for dipping and this aggravated the occurrence of tick-borne diseases. Deworming of animals depends on the availability of cash to buy the dosing remedies (Francis, 1993). Since the farmers did not have financial resources, animals were often not dosed and where dosing was practised, only useful animals such as draught cattle received the attention (Scoones, 1992).

5.5 Conclusion

Cattle production was the most important livestock enterprise in both Gulathi and Irisvale. Crops including maize and sorghum are grown in both areas. The major constraint to livestock production was inadequate and poor quality feed, especially during the dry season. Feed shortage was less in Irisvale than Gulathi. As a result, cattle in Irisvale were reported to be in better condition and had better reproductive performance than in Gulathi. The farmers did not provide information on other reproductive performance parameters such as interval to first ovulation, pregnancy and calving rates. Information on lactation lengths and lactation yield was also unavailable. It was therefore felt that the monitoring of the reproductive performance and milk yield of cows in smallholder farming areas was necessary to capture some of this missing information.

CHAPTER 6

6. A MONITORING/OBSERVATIONAL STUDY ON REPRODUCTIVE PERFORMANCE AND MILK PRODUCTION OF COWS IN GULATHI SMALLHOLDER FARMING AREA

6.1 Introduction

Research studies in Sanyati communal area (Masunda, 2001) showed that the reproductive performance of cows was poor. The author found that calving intervals and calving rates averaged 2.5 years and 33%, respectively. The survey results in Chapter 5 were that the reproductive performance and milk yield of cows in Gulathi and Irisvale smallholder farming areas was reported by farmers to be poor. Reproductive performance and milk production are considered to be the most important economic traits in dairy cattle (Hodel, Moll and Kuenzi, 1995). The current study was therefore carried out to determine milk production and reproductive performance of cows in Gulathi smallholder farming area.

6.2 Materials and Methods

6.2.1 The study site

The study was carried out in Gulathi smallholder farming area, which is described in Section 5.2.1. The study was conducted over two years from October 1998 to July 2000.

6.2.2 Data collection

The study was targeted at farmers belonging to Gulathi Dairy Association who had cows that had calved between October 1998 and January 2000. Although the original aim of the study was to monitor sixty cows per season, only 36 cows calved during the first season and 14 cows calved during the second season. The 36 cows that calved during the first season consisted of six Tuli, 10 Nkone, four Brahman, two Jersey x Tuli, one Jersey x Nkone, and 13 non-descript breeds. The 14 cows that calved during the second season consisted of five Tuli, one Nkone, one Brahman, two Jersey/Nkone and six non-descript breeds.

After calving, the calves were allowed to run with their dams during the day. During penning at sunset, the calves were separated from their dams to prevent them from suckling during the night. The calves were re-united with their dams at sunrise. The farmers started milking their cows five days after calving. This delay in milking allowed the calves to get enough colostrum from their dams. All the farmers milked their cows by hand, once a day at sunrise. The calves were allowed to suckle briefly before milking. This provided the pre-milking stimulus necessary for milk let-down in indigenous cows (Brownlee, 1977). The daily milk yield for each cow was measured using a graduated container. The cows were milked until they stopped giving any milk for five consecutive days.

Milk samples for progesterone analysis were collected from each cow every Monday, Wednesday and Friday from 10 days postpartum until the cows stopped giving milk or up to a maximum of 180 days post calving, whichever occurred first. The milk from each cow was thoroughly mixed using a stirring rod before samples were collected into 1.5 ml plastic vials containing 10 ng of potassium dichromate preservative. The milk samples were stored at a central point and delivered once every week to Matopos Research Station where the samples were refrigerated at 4^0C pending progesterone analysis.

Three trained technicians weighed the cows once every fortnight. During the weighing, each cow was enclosed in a pen and restrained by means of ropes. A weigh band was used to determine the bodyweight of the cows. Body condition score was assessed by the same three technicians once every fortnight. The body condition score scale used was 1 (very thin) to 5 (obese) scale described by Mulvany (1981). The mean body condition score from the values obtained by the three technicians was recorded.

The cows were grazed on natural pasture and had access to water *ad libitum*. On average, they had access to the grazing area for about nine hours between 8.00 h and 17.00 h inclusive. The estimated stocking rate was 1LU:3ha. The cows were then kept in kraals overnight and released at sunset for milking. Oestrus detection was carried out by the farmers on a daily basis during milking and also when they were herding the cows. The cows on heat had access to bulls during the grazing period and overnight depending on the availability of the bulls in the herds. Pregnancy diagnosis by rectal palpation was carried out by a veterinarian during the month of June every year.

6.2.3 Laboratory analysis

Progesterone concentration was measured in whole milk samples using the

Self-Coating Milk Progesterone RIA kit (Animal Production Unit, FAO/IAEA Agriculture Laboratory, Agency's Laboratories, Seibersdorf, Austria). Details of the assay procedures are shown in Appendix 2. Twenty-six assays each of which analysed seven standards, two QC samples and 80 milk samples were run. Based on QC values of 2 and 10 ng/ml, the intra-assay and inter-assay coefficients of variation were 9.6% and 10.4%, respectively.

6.3 Statistical Analysis

Out of the 36 cows that were observed during the first season, three cows were removed from the study because their calves had died within three weeks of birth and the farmers had stopped milking and collecting milk samples from the affected cows. Data from the remaining 33 cows were used for the analysis. The data for all the 14 cows that were monitored during the second season were analysed.

The interval from calving to first ovulation was determined from progesterone profiles as the number of days from calving to first ovulation. The oestrus detection rate was calculated by expressing the number of oestruses observed by the stockmen as a percentage of the total number of ovulations determined from the progesterone analysis. Conception rate was determined by expressing the number of cows confirmed to be pregnant by rectal palpation at as a percentage of all cows given to the bull. Calving rate was determined by expressing the number of cows that calved during the subsequent season as a percentage of all experimental cows that were presented to the bull.

The means for bodyweight, body condition score, daily milk yield, total lactation yield and lactation length were calculated using the PROC MEANS procedure of the Statistical Analysis Systems (SAS, 1995) programme.

6.4 Results

Table 6.1 shows reproductive performance and milk yield data of the cows that were monitored in Gulathi over two seasons. Only three cows (two Jersey x Tuli and one Jersey x Nkone) and one (Jersey x Nkone) cow had ovulated by 180 days postpartum during the first and the second season. This represented 100% and 50% of crossbred cows that ovulated compared to no ovulation in other breeds. The mean interval from calving to first ovulation was 63 ± 29 d during the first season and 67 d in the second season. The oestrus detection rate was 6% and 20% during the first and the second season, respectively. The conception rate was 8% and 9% during the first and the second season, respectively. Results from progesterone analysis revealed that all the cows that failed to conceive had not resumed cycling by 180 days postpartum. The calving rate was 3% and 9% during the first and the second season, respectively.

Table 6.1 Reproductive performance and milk yield data for Gulathi cows monitored over two seasons.

	1998/99	1999/00
Number of cows monitored	33	14

[M]Mean interval from calving to ovulation (days)	63 ± 29	67
Oestrus detection rate (%)	6	20
Conception rate (%)	8	9
Calving rate (%)	3	9
Mean body condition score	1.9 ± 0.5	1.8 ± 0.5
Mean bodyweight (kg)	282 ± 37	264 ± 24
Mean daily milk yield (kg)	1.2 ± 0.9	1.3 ± 0.8
Mean total lactation milk yield (kg)	209 ± 0.9	234 ± 0.8
Mean lactation length (days)	174 ± 47	180 ± 45

[M]Only three cows were used in computation for 1998/99 and only one in1999/00

6.5 Discussion

The study found that it was possible to achieve a short interval from calving to first ovulation for the cows in Gulathi communal area. However, this interval was computed from only 8% of the experimental cows that had ovulated by 180 days postpartum. All the cows that ovulated were either the Jersey x Tuli or Jersey x Nkone crossbreds. Garwe and Ball (1999) found that crossbred Jersey x Nkone or Tuli cows had better reproductive performance than indigenous cows.

Gulathi communal area experienced serious feed shortages during the study period as evidenced by the poor body condition scores of the cows. The 3% and 9% calving rates obtained in the study for the first and second season were very low when compared to those reported from other studies. Gubbins and Frankherd (1983) carried out a survey and reported that annual calving rates in smallholder farming areas of Zimbabwe ranged from 40 to 52%. Masunda (2001) reported annual calving rates of 33% in Sanyati smallholder farming area. The author used faecal progesterone as a means of assessing ovarian activity in non-lactating cows. However, the current study used milk progesterone and therefore all cows that were assessed were lactating. Williams (1990) in a review, reported that both lactational stress and suckling increased the postpartum anoestrus period and reduce calving rates. In a study by Short, Bellows, Moody and Howland (1972) the postpartum intervals to first oestrus for suckled, nonsuckled and nonsuckled mastectomised cows were 65 d, 25 d and 12 d, respectively. The study by Short *et al.* (1972) provides evidence that non-lactating cows have a greater opportunity to re-conceive than lactating and suckled cows. The implication is that farmers wishing to produce milk commercially need to pay more attention to cow fertility than those keeping cows for calf production only.

The mean bodyweights of the cows in this study were similar to those of cows found in most communal areas of Zimbabwe (Mutsvangwa *et al.,* 1989). The daily milk offtake (1.3 kg) was lower than the offtake reported by Tawonezvi *et al.* (1987). They reported an average milk yield per cow of 2.4 kg for Mashona cows on the range. However, their study was carried out under controlled conditions. In addition, the cows in the current study were milked once a day whereas those reported by Tawonezvi *et al.* (1987) were milked twice per day. Mutsvangwa *et al.* (1989) reported daily milk yield of 1.5 kg for unsupplemented cows in Chiweshe communal area of Zimbabwe under farming conditions, which were similar to those of the current study. The higher daily milk yield in their study was probably because Chiweshe smallholder area has a high rainfall compared to Gulathi smallholder farming area (Zimbabwe Government, 1983) and feed availability was higher than in Gulathi. The 264 kg total lactation milk yield obtained over 180 days of lactation was much lower than the 577 to 799 kg reported by Richardson *et al.* (1979) during the first 98 days of lactation for Nkone cows.

6.6 Conclusion

Although crossbred Jersey x Nkone or Tuli had better reproductive performance than other breeds in Gulathi, reproductive performance and milk yield of cows in

Gulathi was too low for a sustainable dairy production enterprise. It was apparent that the reproductive performance and milk yield of cows were limited by the inadequate feed supply. There is therefore a need to evaluate the effect of feed supplementation on the reproductive performance and milk yield of cows in smallholder farming areas.

CHAPTER 7

7. THE EFFECT OF FEED SUPPLEMENTATION ON REPRODUCTIVE PERFORMANCE AND MILK YIELD OF COWS IN IRISVALE SMALLHOLDER FARMING AREA

7.1 Introduction

Syrstad (1988) reported that cattle indigenous to the semi-arid areas have poor dairy potential. Winrock International (1992) added that the milk production potential of these cattle is constrained by feed shortages and nutrient deficiencies, particularly in the dry season. While there is abundant evidence of the beneficial effects of high feeding levels on milk yield and reproductive performance in cows (Robinson, 1990; Schillo, 1992), the effects of low levels of supplementary feeding as practiced in the smallholder dairy sector are not clear. In addition, there is little in formation on the reproductive performance and the influence of supplementary feeding in the Nkone/Tuli and their crosses in the semi-arid areas of Zimbabwe. The current study was therefore carried out to assess the effect of low levels of feed supplementation on the reproductive performance and milk yield of cows in Irisvale smallholder farming area.

7.2 Materials and Methods

7.2.1 The study site

The study site was described in Section 5.2.1. The monitoring and supplementation study was conducted from October 1998 to July 2000.

7.2.2 Experimental procedure

The farmers belonging to Irisvale Dairy Association who had cows that calved between October 1998 and January 2000 participated in the study. One hundred and twenty cows were selected for the study. They consisted of 40 Tuli, 20 Nkone, 20 Brahman, 10 Friesland x Tuli, 10 Friesland x Nkone, and 20 non-descript breeds. Twenty five farms supplied the cows for the study. Only farms with at least two lactating cows were included to ensure that the two dietary treatments were allocated to each farm. In total, 60 cows received supplementary feeding in addition to grazing of natural pastures and 60 cows were not supplemented but had access to grazing. The estimated stocking rate on the grazing area was 1LU:20ha. The supplemented cows received 2 kg/day (93% DM) of a maize/soyabean-based commercial dairy meal (Urelac® 14% CP, National Foods, Zimbabwe). The supplementary feed was given to individual cows once a day during milking. The provision of the supplement started immediately after calving and continued for 180 days. Pregnancy diagnosis by rectal palpation was performed by a veterinarian eight months after the first cow from the 120 cows had calved. Supplementary feeding of all cows that were confirmed pregnant and all cows that had been in lactation for 180 days was stopped on the day the cows were diagnosed for pregnancy.

The farmers received lectures and demonstrations on milk sampling, oestrus detection, weighing the cows and their general management and disease control. The farmers started milking their cows five days after calving. This delay in milking allowed the calves to get enough colostrum from their dams. The calves were allowed to run with their dams during the day. At sunset, the calves were removed from their dams and penned separately to prevent them from suckling during the night. The calves were re-united with their dams at sunrise. All farmers milked their cows by hand once a day at sunrise. The calves were allowed to suckle briefly before milking. This provided the pre-milking stimulus necessary for milk let-down in indigenous cows (Brownlee, 1977). The daily milk yield for each cow was measured using a graduated container and recorded. The cows were milked until they stopped giving milk for five consecutive days.

Milk samples for progesterone analysis were collected from each cow every Monday, Wednesday and Friday starting at about 10 days postpartum until 180 days postpartum or when a cow stopped giving milk for five consecutive days. The milk from each cow was thoroughly mixed using a stirring rod before the samples were collected into 1.5 ml plastic vials containing 10 ng of potassium dichromate preservative. The milk samples were stored at a central point and collected once every week for delivery to Matopos Research Station where they were refrigerated at 4^0C pending progesterone analysis.

The bodyweight of each cow was estimated using a weighband once every fortnight. Body condition score was determined by two technicians once every fortnight at weighing time using the 1 (very thin) to 5 (obese) scale described by Mulvany (1981). The average body condition score for each animal was recorded.

All the cows were let out to graze on rangeland at 8.00 h and they were penned overnight at 17.00 h. They had access to water *ad libitum*. Oestrus detection was carried out by farmers on a daily basis during milking and when the cows were driven to and from the paddocks. The cows in heat had access to bulls during the grazing period and in the kraals at night.

7.2.3 Laboratory analysis

The concentration of progesterone was measured in whole milk using the Self-Coating Milk Progesterone RIA kit (Animal Production Unit, FAO/IAEA Agriculture Laboratory, Agency's Laboratories, Seibersdorf, Austria). The details of the assay procedures are shown in Appendix 2. One hundred and ten assays, each of which analysed seven standards, two QC samples and 80 milk samples were run. Based on QC values of 2 and 10 ng/ml, the intra- and inter-assay coefficients of variation were 9.6% and 13.4%, respectively.

7.2.4 Economic analysis

Overhead and labour costs were similar across treatments. In September 1999, one kilogram of Urelac 14% dairy meal cost $8.07 and 1 kg of milk was sold for $20.00. The extra 2.04 kg of milk resulting from supplementing cows with 2 kg of dairy meal gave farmers an estimated margin of $23.66 per day.

7.3 Statistical Analysis

Out of the 60 supplemented and the 60 control cows that were in the experiment, eight unsupplemented cows were removed from the trial. This was because six calves died within three weeks of birth and as a result, their dams were removed from the experiment. In addition, two unsupplemented Friesland x Nkone cows died. Therefore, only data from 60 supplemented and 52 control cows was analysed.

Progesterone profiles were plotted for all the cows in the experiment. The date of first ovulation was determined from the progesterone profiles as the day with the lowest concentration of progesterone occurring immediately before the first increase in progesterone concentration of equal or greater than 3 ng/ml for more than two consecutive sampling dates (Darwash *et al*., 1999). The interval from parturition to first ovulation was calculated as the number of days from calving to first ovulation. Survival analysis as described in section 3.1.3 was used to determine the effect of supplementation on the probability ovulating and conceiving postpartum.

The oestrus detection rate was calculated by expressing the number of oestruses observed by the stockmen as a percentage of the total number of possible ovulations detected by progesterone analysis. Conception rate was determined by expressing the number of cows confirmed to be pregnant by rectal palpation as a percentage of all experimental cows given to the bull. Calving rate was determined by expressing the number of cows that calved during the subsequent season as a percentage of all experimental cows that were given to the bull.

The means for bodyweight, body condition score, daily milk yield, total lactation yield and lactation length were calculated using the PROC MEANS procedure

(SAS, 1995) programme. The effect of supplementary feeding on bodyweight, transformed body condition score, average daily milk yield, total lactation milk yield and lactation length were analysed using the PROC MIXED Models procedure (SAS, 1992). The following model was fitted to the data:

Y_{ijklm} = $\mu + D_i + B_j + S_k + C_l + e_{ijklm}$

Where:

Y_{ijklm} = dependent variable (bodyweight, body condition score, average daily milk yield, total lactation milk yield and lactation length)

μ = overall mean common to all observations

D_i = effect of i^{th} diet (i = 1,2)

B_j = effect of j^{th} breed (j = 1,2..5)

S_k = effect of k^{th} season (k = 1,2,3,4)

H_l = effect of l^{th} herd (l = 1,2..30)

C_m = random effect of the m^{th} cow (m = 1,2..137)

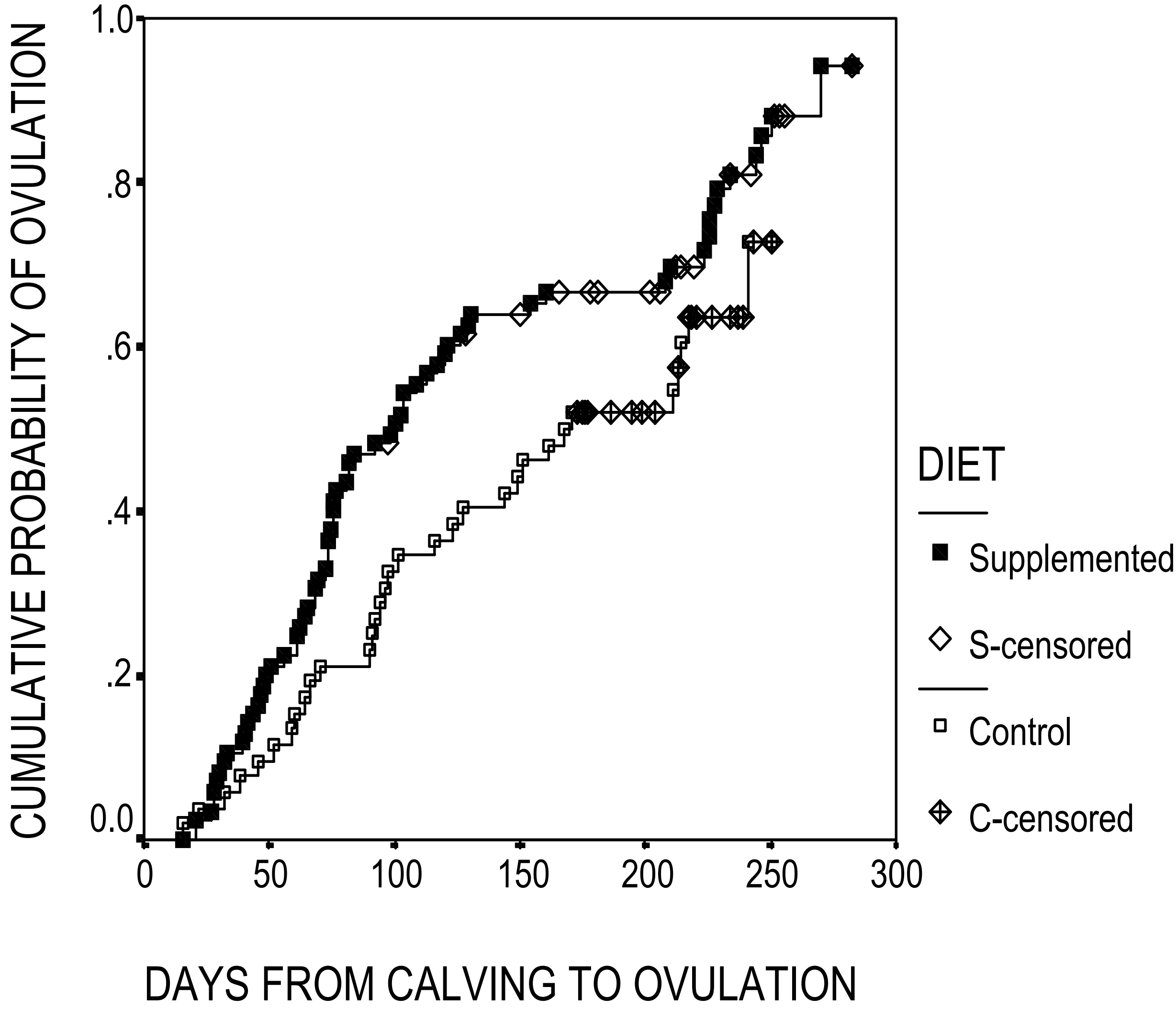
e_{ijklm} = random residual error associated with the $ijkl^{th}$ observation

The association between pregnancy status and diet, and calving status and diet were determined by the Chi-square test using the PROC FREQ procedure (SAS, 1995).

7.4 Results

In general, the cows calved throughout the year. However, 68% of the births occurred during the rain season (September to March) and 32% during the dry season (April to August). Figure 7.1 shows that the probability of ovulation in the supplemented cows was higher (Log rank statistic = 3.74, $P < 0.05$) compared to that in the unsupplemented cows.

The reproductive performance and milk yield data of the cows in Irisvale is shown in Table 7.1. The mean interval from calving to ovulation was shorter ($P < 0.05$) in the supplemented cows than in the control cows. The oestrus detection rate in the supplemented group was higher ($P < 0.05$) than in the unsupplemented group. Supplementary feeding led to high conception rate and high calving rate ($P < 0.05$) in cows. The differences between conception and calving rates in Table 1 suggest embryo loss in both supplemented and unsupplemented cows. The supplemented cows were heavier than the unsupplemented cows ($P < 0.05$). Body condition scores of the supplemented cows were higher ($P < 0.05$) than in unsupplemented cows. The average daily milk yield, average total lactation yield and average lactation lengths were higher ($P < 0.05$) in the supplemented cows compared to those in the control cows. Supplemented cows produced approximately three times more milk than control cows.



Key S-censored represents cows in the supplemented group that had not ovulated by 300 days postpartum

C-censored represents cows in the supplemented group that had not ovulated by 300 days postpartum

Figure 7.1 Cumulative ovulation probability by diet

Table 7.1 Reproductive performance data for Irisvale cows

	Control	Supplemented
Number of cows	52	60
Number of cows that had ovulated by 300 days postpartum	32	47
Mean interval from calving to ovulation (d)	132[a] ± 63	108[b] ± 56
Oestrus detection rate (%)	10[a]	38[b]
Conception rate (%) for 1999/00	35[a]	47[b]
Conception rate (%) for 2000/01	50[a]	80[b]
Calving rate (%) for 1999/00	18[a]	33[b]
Calving rate (%) for 2000/01	38[a]	65[b]
Mean body condition score	2.8[a] ± 0.21	3.1[b] ± 0.2
Mean bodyweight (kg)	391[a] ± 64	423[b] ± 56
Mean daily milk yield (kg)	1.26[a] ± 0.5	3.1[b] ± 1.1
Mean total lactation milk yield (kg)	252[a] ± 1.0	698[b] ± 1.5
Mean lactation length (days)	200[a] ± 25	225[b] ± 45

[a,b] Within a row, means lacking a common superscript letter differ ($P < 0.05$).

7.5 Discussion

Although several research studies have reported long calving intervals of up to two years (Shumba and Whingwiri, 1988; Mutswangwa *et al.,* 1989) in smallholder farming areas of Zimbabwe, there appear to be no reports on the interval from calving to ovulation, which is an important component of the calving interval (Peters and Ball, 1995). The current study found a shorter calving to first ovulation interval of 103 ± 63 d for supplemented cows compared to 132 ± 69 d for unsupplemented cows. Since 40% of unsupplemented cows had not ovulated by 300 days postpartum, the actual mean interval from calving to first ovulation was longer than 132 days. The shorter interval from calving to ovulation for supplemented cows resulted from a greater supply of nutrients to the cows during the postpartum period. Supplementary feeding improved bodyweight and body condition scores resulting in a positive energy balance postpartum.

The higher oestrus detection rates observed in supplemented cows resulted from their better body condition scores when compared to unsupplemented cows. Markusfeld, Galon and Ezra (1997) found that cows with high body condition scores were less likely to have an unobserved oestrus than those with lower body condition scores.

Annual calving rates from studies carried out in smallholder farming areas of Zimbabwe ranged from 40 to 52% (Gubbins and Frankherd, 1983; GFA, 1987) and poor nutrition was reported to be the cause of the these low calving rates.

The annual calving rates from this experiment were lower than those obtained from other studies. This was because the current study was carried out in a low rainfall area where feed availability was poor. However, supplementary feeding increased the calving rates. The beneficial effects of supplementary feeding were evidenced by the higher conception and calving rates in the second year of study.

The prevalence of pregnancy losses in both supplemented and unsupplemented cows suggest the presence of factors other than nutrition *per se* in determining good fertility. These foetal losses were critical because they occurred during advanced pregnancy and as a result, the re-establishment of normal cycles and conception were delayed (Ball. 1997).

The significant improvements in milk yield and lactation length observed in the current study were in agreement with the findings of Mutsvangwa *et al*. (1989) who reported that there were significant improvements in milk yield and lactation length in indigenous cattle supplemented with poultry litter. However, supplementary feeding in this study improved milk yield by a great magnitude. This may be due to the differences in the type of supplementary feed that was used.

The additional income generated from the sale of the extra milk produced by supplemented cows justified the cost of buying feed.

7.6 Conclusion

This study demonstrated that appropriate feeding practices could make a difference to the income and benefits accruing to smallholder dairy farmers. Supplementary feeding increased the number of calves born per year, milk yield and profit from the sale of milk. Farmers practicing supplementary feeding produced more milk for home consumption and for sale. Their cows calved frequently and produced more cattle for draught power and for sale.

CHAPTER 8

8 GENERAL DISCUSSION AND CONCLUSIONS

At the beginning of this study, it was hypothesized that crossbred cows had better reproductive performance; shorter intervals from calving to first ovulation, higher observed oestrus and higher pregnancy rates than indigenous cows. It was also hypothesized that crossbreds produced more milk than indigenous cows and that supplementary feeding improved reproductive performance and milk yield in both crossbred and indigenous cows. Results from the studies conducted largely confirmed these hypotheses.

8.1 Interval from calving to ovulation

The study established that the mean intervals from calving to ovulation in Nkone x Jersey/Tuli x Jersey cows was 76 ± 41 d and was shorter than the interval of 106 ± 38 d observed in the Nkone/Tuli cows. Although the interval from calving to ovulation recorded in the crossbred cows in Gulathi smallholder farming area was 63 ± 29 d, this interval was calculated from only three cows. This was because only these three cows out of all the cows under observation had ovulated by 200 days postpartum. However, this information showed that under smallholder farming areas, it is possible to obtain short intervals to first ovulation.

Both postpartum and prepartum feed supplementation reduced the interval from calving to ovulation. Postpartum supplementary feeding with concentrates reduced the interval from calving to first ovulation in both Nkone/Tuli and Nkone x Jersey/Tuli x Jersey cows. In Irisvale smallholder resettlement area, postpartum supplementary feeding of cows also reduced the interval from calving to ovulation. The postpartum feed supplementation provided adequate energy levels, which improved body condition, prevented weight loss and promoted early ovarian activity. The cows that were not supplemented lost body condition probably because they mobilized body energy reserves to make up for the low dietary energy intake and high energy output through milk production and maintenance requirements. This negative energy balance was reported to increase the interval from calving to ovulation (Canfield and Butler, 1990). A study by Butler, Everret and Coppock (1981) revealed that there was a 2.75-day increase in the interval to first oestrus for every 1 Mcal of energy deficit experienced during the first 20 days of lactation. In another study (Ducker et al., 1985), cows that had negative energy balances during the first five weeks of lactation took longer to ovulate compared to those that were in positive energy balance.

Prepartum silage supplementation at the levels of 0.32 times maintenance energy requirements and 2 times maintenance energy requirements improved body condition at calving and shortened the interval from calving to first ovulation in Nkone/Tuli cows. Some workers reported that prepartum supplementary feeding resulted in cows calving in good body condition (Roche and Diskin, 1995). These cows did not experience a severe energy deficit in early lactation and therefore ovulated earlier after calving compared to unsupplemented cows. Wright, Rhind, Russell, Whyte, McPean and McMillen

(1987) showed that a rise of 1 unit in the body condition within the range of 1.5 to 2.75 was associated with a decrease of 43 days on the interval from calving to first ovulation. Smallholder dairy farmers will benefit by supplementing their pregnant cows in late lactation to ensure good body condition scores at calving. After calving, supplemented cows maintain body condition and they ovulate early and have good chances of re-conceiving.

8.2 Oestrus detection rate

The results from Experiment 1 and Experiment 2 showed that there was an interaction between breed and diet on oestrus detection rates. Supplemented indigenous cows had the highest oestrus detection rates both on-station and on-farm. Markusfeld, Galon and Ezra (1997) found that cows calving with a high body condition score were less likely to have an unobserved oestrus than those calving with a lower body condition score thus confirming that nutrition has an effect on the ability of cows to exhibit oestrus. This finding is of major importance to many smallholder dairy farmers who have to rely mostly on good oestrus detection since they depend on communal bulls and they have to bring cows observed in oestrus to the bull. Senger (1994) reported that failure to detect oestrus led to substantial losses in income because of the subsequent low conception rates.

8.3 Pregnancy rate

The current study established that both the assumed pregnancy rate and the actual pregnancy rate were higher in Nkone x Jersey/Tuli x Jersey cows than in Nkone/Tuli cows. Supplemented indigenous cows had a higher assumed pregnancy rate than unsupplemented indigenous cows but this beneficial effect of supplementation was masked by the higher pregnancy losses in the supplemented group. These high embryo losses may have resulted from over-conditioning of the indigenous cows. Ducker *et al.* (1985) also reported that a high level of feeding during lactation resulted in poor conception rates and a high rate of embryo loss that occurred from 24 days postpartum in first lactation dairy heifers. The supplemented cows in smallholder farming areas had higher conception rate than unsupplemented cows. Supplementary feeding of cows is the best way of improving conception rates in smallholder farming areas. However, care must be taken not to over-condition the cows (body condition scores of above 4 on the 1-5 scale described by Mulvany, 1981) as this results in pregnancy losses in low milk producing cows. In smallholder farming areas, the prevalence of foetal losses in both supplemented and unsupplemented cows suggested the presence of factors other than nutrition *per se* in determining good fertility. It is therefore important for smallholder farmers to make sure that their cows are always in good health and that the highest level of management is kept.

8.4 Milk production

Nkone x Jersey/Tuli x Jersey cows produced more milk than Nkone/Tuli cows. This was in accord with results of other researchers (Scaar *et al.,* 1981; Agyemang and Nkhonjera, 1986) who found that the use of crossbred dairy cows led to a significant improvement in milk yield when compared to using indigenous cows. The advantage of crossbreds (exotic x indigenous) over the indigenous cows was a result of a combination of gene complementarity and hybrid vigour for milk production (Rege *et al.,* 1994; Mackinnon *et al.,* 1996).

The low milk yield recorded in Experiments 1 and 2 was mainly attributed to the absence of the suckling stimulus necessary for milk let-down. Other researchers reported a similar observation (Mahadevan, 1966; Brownlee, 1977). In the third on-station experiment, the suckling stimulus was introduced and this resulted in improved milk yields in both indigenous and crossbred cows. These results suggested that the pre-milking stimulus was important in crossbred cows. Following the death of a calf, smallholder farmers stop milking Nkone/Tuli cows because the cows will cease giving milk in the absence of a calf. However, smallholder farmers who keep crossbred cows can continue milking even after the death of a calf. However, crossbred cows would still give more milk in the presence of the suckling stimulus of a calf.

Prepartum supplementary feeding of sorghum-lablab silage 8 weeks before calving, at levels of 0.16, 0.32 and two times maintenance energy requirements per cow per day did not have any significant effect on milk yield of the indigenous and crossbred cows on-station. In addition, the on-station concentrate feeding as a supplement did not have any effect on milk yield of the crossbred and indigenous cows. However, the on-farm postpartum concentrate feeding significantly improved milk yield. These different responses to supplementary feeding in cows reared on-station and cows kept in smallholder farming areas were likely to have been caused by the differences in the condition of the natural pastures. The stocking rate for on-station pastures was

1LU:15ha and the natural pastures provided adequate nutrients to cows. Therefore, the 2 kg/cow/d supplementary feed offered was not sufficient to cause a significant change in milk yield. On the other hand, the high stocking rate of 1LU:3ha in Gulathi and 1LU:7ha in Irisvale resulted in shortage of grass and browse. Therefore, the quantity of nutrients provided by the grazing in the smallholder farming areas was insufficient to meet the requirements of the cows. As a result, supplementary feeding of the cows significantly improved milk yield. Feed intake in cows in the smallholder areas was also limited by overnight penning, which was not practiced on-station. Manteca and Smith (1994) also reported that the grazing time in cattle from smallholder farming areas was reduced by overnight penning and long distances walked by the animals to watering places. Cows in smallholder farming areas will give more milk if they receive adequate nutrients though supplementary feeding given during lactation.

8.5 Conclusion

The crossbred Jersey x Nkone and Jersey x Tuli cows are more suitable for dairying in the smallholder farming sector because they had better reproductive performance and milk yield than the indigenous Tuli and Nkone cows. The crossbred cows had shorter calving to first ovulation intervals and higher pregnancy and calving rates than indigenous cows. Crossbred cows let-down milk in the absence of the calf allowing the farmer the chance to continue milking the cow after the death of the calf. In addition, the crossbred cows produced more milk than indigenous cows.

This study also demonstrated how appropriate feeding practices could make a difference to the income and benefits accruing to smallholder dairy farmers. Supplementary feeding of dairy cows has the potential of improving the health and income of smallholder farmers through improved and sustained milk production. Low levels of supplementary feeding also improved the number of calves born every year. This is important in ensuring cattle herd growth and the provision of adequate draught power.

8.6 Implications and Future Work

There is current global interest in technological packages, including animal genotypes and feeding systems, appropriate for smallholder dairying in the tropics (Kurtu *et al.,* 1999). This study provides reproductive performance and milk production data on Sanga cattle and crossbreds under different nutrition interventions and therefore contributes to the information on smallholder milk production in semi-arid areas.

The influence of breed on reproductive performance and milk yield of cows was not fully addressed under smallholder farming conditions because of the presence on only small numbers of crossbreds. Future research would benefit by the inclusion of larger numbers of crossbreds in on-farm studies. It is also important to explore the performance of different types of crossbreds for example Jersey, Friesland and Red Dane crosses with Tuli, Nkone or Mashona in order to access their suitability in smallholder farming areas.

For purposes of simplicity and cost reduction, this study used a flat rate level of postpartum supplementary feeding. However, supplementary feeding should be related to milk yield of individual cows (Smallholder Dairy Handbook, 1993). Future research should therefore focus on the effect of performance related feed supplementation on reproductive performance.

This study did not assess the effect of breed and feed supplementation on the quality of milk. It is important that any future research conducted include this important aspect.

CHAPTER 9

9 REFERENCES

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APPENDICES

Appendix 1 Survival Analysis

Censoring arises frequently in medical studies where patients can only be followed up for a limited time, at the end of which the event of interest (e.g. death) may not have yet occurred. Even though some data are censored, they still provide valuable information. As such, censoring must be taken into account in any subsequent analysis. It would be very inappropriate to analyse these data at a series of cut points. Consequently, a range of statistical techniques, collectively known as “survival analysis” (Everitt, 1994) have been developed to handle such data. The name simply reflects the medical origins of the technique where the time (survival time) to the event of interest (death or relapse) is studied. However, survival analysis has a much wider applicability than for medical studies only and the terms “survival” and “death” can be re-defined. Therefore, in this study, the event of interest is first ovulation and conception instead of death and the cow “survives” until she ovulates or conceives.

One key assumption of virtually all survival analysis techniques is that the censoring should be non-informative i.e., it is assumed that the only information conveyed by knowledge of censoring is that ovulation must occur after the censoring time. It provides no extra information about when the ovulation is most likely to occur. However, this assumption would be invalidated if, for example, a cow drying off early in the season (censored) indicated that ovulation was likely to occur within a very short period, since animals not censored at the same time might be expected to ovulate later. Non-informative censoring requires that cows which dry off at an early date are likely to have the same pattern of later ovulation as other animals observed at the same time point but have not been censored because they did not dry off.

There are two key functions in survival analysis. The first of these – the survivor function, *S(t)*, - is defined to be the probability that an individual cow first ovulates beyond some date *t*. One of the simplest forms of survival analysis is the Kaplan-Meier empirical estimate of the survivor function. The Kaplan-Meier estimate of the survivor function, S(t), can be computed separately for each treatment group and then compare them using the log-rank test. In this study, 1-S(t) has been plotted in preference to S(t) against time. This is because interest is focused on the event of interest (ovulation/conception) occurring as early as possible rather than as late as possible in the conventional medical case (e.g. death).

Uncontrollable concomitant variables such as date of calving, age at calving and bodyweight and body condition score at calving can be recorded. These covariates can explain some of the underlying variations in the ovulation dates within breeds. If this is so, then their inclusion in an analysis will enable more sensitive tests of differences between breeds and between diets. Consequently, the statistical significance of including covariates in the survival model must be assessed. Kaplan-Meier is unable to accommodate covariates and hence a more complex model such as the proportional hazards model must be fitted.

Central to the proportional hazards model is the hazard function, *h(t)*. This is defined as the probability that the first ovulation takes place at time *t*, on condition that ovulation does not occur before time *t*. Naturally, this hazard will change as the breeding season progresses. In the simplest case where there is a single factor (e.g. diet) but no covariates, let the hazard functions for the control and supplemented diet groups be denoted by $h_c(t)$ and $h_s(t)$ respectively. Under the proportional hazards model the relative hazard, Ψ, (where $\Psi = h_s(t)/h_c(t)$) is assumed to be constant over time. Therefore, the hazards are proportional to each other over time. More generally, for a vector of covariates recorded for animal i denoted by $\mathbf{x_i}$, the hazard for that animal ($\Psi(\mathbf{x_i})$) relative to a baseline hazard function can be modeled as :-

$$\Psi(\mathbf{x_i}) = \exp\left(\sum_{j=1}^{p} \beta j \, x_{ji} \right)$$

where x_{ji} denotes the j^{th} response on the i^{th} animal.

There is, however, an additional complication when considering the inclusion of covariates in the model to compare ovulation patterns between breeds and between diets. Unfortunately, there are differences between breeds in these covariates. Consequently, breed comparisons of ovulation patterns are confounded with covariate differences between breeds. In other words, if any breed differences in ovulation were detected, it would be impossible to determine whether these were actually due to breed differences *per se*, or to breed differences in a covariate or a combination of these sources. In such cases, great care is required in both the analysis and interpretation of the results since misleading conclusions can easily be drawn.

For example, consider a situation where there were significant breed differences in both ovulation and a covariate. In such a situation, ovulation differences could be explained either in terms of breed or covariate differences but both would not be needed together. In such circumstances, the covariate would provide no additional information over and above that afforded by breed and would therefore not be statistically significant if included in a model after breed has been considered. Conversely, breed would provide no additional information over and above that provided by the covariate and consequently would not be statistically significant if included in the model after adjusting for differences in ovulation due to the covariate. This would occur despite the fact that there were breed differences in the ovulation pattern.

In order to compare ovulation between breeds, it is therefore necessary to make the assumption that observed breed differences in the covariates reflect genuine differences intrinsic to the breeds rather than simply reflecting the animals selected for study. This clearly alters the interpretation of what is meant by “breed”, which now must incorporate any breed differences in covariates or indeed in management practice. For example, prior to the previous pregnancy, indigenous breeds had been introduced to the bull one month earlier than crossbreds since it had been anticipated they would form the beef herd rather than the dairy herd.

The definition of “breed” differences must also encompass age differences between breeds. As stated, the covariates (such as date of calving, body condition score and bodyweight) included in the survival analysis model are only useful if they explain variation due to the differences between animals of the same age and breed in order to provide the most sensitive test of breed differences. However, breed and age differences in ovulation must be maintained when covariates are included so that breed comparisons are not prejudiced, as illustrated by the example above. In order to do this, bodyweight is regressed on both breed and age simultaneously and the residuals computed. Inclusion of these residuals in a proportional hazards survival analysis model has been tested to determine whether taking into account the weight differences within breed and age while maintaining breed differences due to breed and age significantly reduces the variation in the ovulation date data. The same approach was adopted for date of calving and body condition score. Since the inclusion of none of the three covariates of residuals approached statistical significance, it was possible to compare the ovulation patterns between breeds and diets using Kaplan-Meier estimates and the log-rank test, thus avoiding the necessity of assuming hazards are proportional. If any of the covariates had indeed approached statistical significance, then the proportional hazards model would have been fitted.

Appendix 2 RIA Self Coating Technique

The Self Coating Technique was performed over a period of three days. The procedure is described below:

Day 1: Preparation of assay reagents

1. Coating buffer

   Place 70 ml of distilled/deionised water in a 100 ml volumetric flask, add one carbonate/bicarbonate tablet and shake gently (using a shaker) until completely dissolved (may take up to 15 minutes). Add distilled water to make up to the 100 ml mark (This is a 0.05M carbonate buffer with pH 9.6 ± 0.05). Label (include date of preparation), cover with parafilm and store at 4^0C for up to one month.

2. Diluent buffer (PBS)

   Place 1000 ml distilled/deionised water in a conical flask. Add one PBS tablet (0.14 M Nacl, 3 mM KCL) and stir until completely dissolved (This is 0.01 M phosphate buffered saline with pH 7.4 ± 0.2). Label, cover with parafilm and store at 4^0C for up to two months.

3. Antibody stock solution

   Reconstitute one vial of the lyophilized monoclonal antibody with 250 µl of diluent (sterile filtered distilled water) to obtain the antibody stock solution (1:10 dilution). This should be aliquoted into 25 µl volumes in Nunc 1 ml cryovials or similar small tubes with caps. Store these vials at -20^0C up to six months.

4. Antibody coating solution

Transfer one aliquot (25 µl) of the antibody stock solution into a 50 ml volumetric flask. Ensure complete transfer of antibody by repeated rinsing of the aliquot tube with the coating buffer (0.05M carbonate buffer). Fill the flask up to the mark with the same buffer. This gives an antibody coating solution of 1:20 000 dilution; 50 ml is sufficient for coating 150 tubes. Label and store at 4^0C for up to two days.

5. Milk standards

   To reconstitute lyophilized milk standards, add exactly 1 ml of distilled water to each vial. Shake gently until completely dissolved. Allow them to stand overnight at 4^0C. Reconstituted standards should be stored for no more than one month.

6. Washing solution

   Add 1 g of Tween 20 to 1 l distilled water to obtain a 0.1% washing solution. Mix well until completely dissolved. Label and store at room temperature for no longer than two weeks.

7. Coat tubes

   Place Nunc 'star' tubes in the rubberfoam racks. Dispense 300 µl of antibody coating solution into each tube except the total count (TC) tubes. Cover the tubes with parafilm or similar sealing material and incubate overnight (at least 12 h) in the refrigerator at 4^0C.

8. Radioactive tracer working solution

   Weigh 100 mg Bovine Serum Albumin (BSA) and transfer into a glass beaker with 100ml of diluent buffer (PBS). Dissolve completely using a clean glass rod or a pipette. Pipette 33 ml of this into a plastic tracer bottle. Add 20 µl of stock tracer solution (^{125}I-Progesterone) and mix well to obtain the tracer working solution. Label, cover and store at 4^0C overnight.

Day 2: Radioimmunoassays

1. Decant the tubes. Add 500 µl of washing solution to each tube and decant. Allow draining for one minute. Repeat.
2. Put 200 µl of tracer solution into a Nunc tube and count the radioactivity.
3. Pipette 40 µl of standards, milk samples and quality controls. Make sure the pipette tip touches the side of the star tube close to the bottom where the antibody is coated.
4. Dispense 200 µl of tracer solution into each of the tube following the pipetting order. Make sure the pipette tip touches the side of the tube about 2 cm from the top of the tube.
5. Cover with parafilm. Incubate overnight at 4^0C.

Day 3: Radioactive counting

Read radioactive counts from a counter. Plot a standard curve and the calculate the concentration of progesterone in the milk samples. Use the QC values to calculate the intra- and inter- assay coefficients of variation.