AN EVALUATION OF REPRODUCTIVE PERFORMANCE OF HORRO CATTLE IN ETHIOPIA

by

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DEDICATION

- *To my late parents, Kebede Woldemichael and Tejtu Gebrekiros, without whose guidance and assistance, I could not have had a better education and orientation in life.*

- *To my wife, Shifaye Erena and my children for all their patience, encouragement and unreserved assistance in achieving my objective.*

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DECLARATION

I hereby declare that this dissertation submitted by me to the University of the Free State for the degree, **Philosophiae Doctor (Ph D) Agriculture**, has not previously been submitted for a degree at any other university. I further cede copyright of the thesis in favour of the University of the Free State.

Mulugeta Kebede Woldemichael
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER 1

GENERAL INTRODUCTION

Ethiopia is an agricultural orientated country, with a total livestock population of 30 million cattle, 23.2 million sheep and 17.3 million goats - with an annual growth rate of 1.2% and 0.01% per year for cattle and sheep respectively (ILCA, 1993). Of the total area, 57% of the country is utilized by grazing ruminants. Yet the contribution of this large resource to the national income is relatively small. This is mainly due to the low productivity of the livestock (particularly cattle) caused by poor husbandry practices, ineffective management systems and the high prevalence of diseases and malnutrition (Alemu, 1987). The majority of the Ethiopian cattle population is composed of indigenous breeds, most of them of non-descriptive Zebu types, resulting from extensive cross-breeding with Sanga types, existing in the eastern and north-eastern parts of the country. Alberro and Haile-Mariam (1982) reported the following main distinguishable cattle types in Ethiopia: The Abigar, Danakils, Arsi, Arab, Borana, Abyssinian Zebu, Arado, Fogera, Horro and Sheko, which have adapted to the local harsh environmental conditions where they are farmed and play a significant role in the economy of the rural communities.

The distribution and density of the cattle population varies according to the farming systems employed and the ecological and administrative regions of Ethiopia. The highest cattle population occurs in the mixed farming livestock zone. It consists of a crop livestock system where farmers farm both activities (Agrotec, 1974). According to Alemu (1987) 72.7% of the cattle population is found in the highlands and 28.3% in the low pastoral lands and sedentary farming areas of Ethiopia.

The reproductive performance of livestock in Ethiopia is in generally low, as is evidenced by the late age at first calving and long inter-calving intervals. The age at first parturition in cattle is above 4 years and the inter calving interval is on average 2 years (EARO, 1999). The annual calving rate is estimated to be about 50% and the mortality rate approximately 8.5%. Heifers do not calve before the age of 3.5 to 4

years of age and every 2 years thereafter (Alemu, 1987). The few reproductive studies conducted so far on Ethiopian livestock have focused mainly on female animals. Although the advantage of the use of superior and fertile males is well recognized, few studies have been done on bull fertility. Information on the patterns of reproductive development, reproductive potential and major factors influencing the reproductive performance of bulls and their behaviour in Ethiopia is scarce (Azage *et al.*, 1995a). In a study on some aspects of bull reproduction with emphasis on beef cattle in Ethiopia, Azage *et al.* (1995b) concluded that bulls with high productive genetic merit have to be evaluated for body growth, reproductive ability and fertility, if they are to be used effectively. It was further suggested that there are some uncertainties regarding many aspects of reproduction in bulls of Ethiopia, that warrant urgent attention. These include information on the reproductive potential and capacity of the indigenous breeds, the influence of factors of economic importance which affect bull reproduction and fertility, the effect of specific reproductive diseases in bulls and the seasonality of semen quality in bulls throughout the year.

The economic efficiency of livestock production is mainly determined by the reproductive performance of the individual herds. The efficient production of meat and milk therefore depends first and foremost upon successful reproduction (Herrick & Self, 1962). Maintaining a high reproductive rate is a major prerequisite for profitable livestock production. A high calving rate is thus the key to success. This determines the number of cattle born and raised and animals that must be retained to replace those animals lost from the breeding herd due to death or old age and those available for sale (Warwick & Legates, 1979).

The reproductive efficiency of an individual can vary considerably from parturition to parturition, due to the hereditary predisposition and subjective influence of environmental conditions (Sane *et al.*, 1982). Fertility in cattle is also affected by disease and managerial factors. This could affect the reproductive process at ovulation, fertilization, implantation or even during gestation and parturition. The fertility of Zebu cattle in Ethiopia is generally low, particularly in animals raised under traditional less desirable management practices (Mukasa-Mugerwa, 1989).

The heritability of the fertility rate in cattle is low and estimated as 0.14 by Bastidas and Verde (1981), while Cruz *et al.* (1976) obtained rates of 0.15 and 0.25 for conception rate and 0.09 and 0.11 for the calving rate for Brahman heifers and cows, respectively. This means that with selection for fertility slow progress is possible, but it is a long term process.

Although there is no formula for measuring fertility, the age at puberty and maturity, cyclic oestrous activity and oestrous behaviour, the number of services per conception, the interval to first post partum oestrus and the inter-calving interval could be indicative of the fertility status of the cow (Sane *et al.*, 1982). The ideal method for evaluating the potential fertility of a breeding male, other than the ability to induce pregnancy in females, is the evaluation of its semen. Thus the evaluation of the ejaculate can be seen as a most important part of the breeding soundness evaluation of the male (Jainudeen & Hafez, 1980).

In the female animal the use of accelerated breeding techniques such as oestrous synchronization and artificial insemination (AI) require a deeper understanding of the reproductive physiology of the species and the breed. Some aspects like the duration of oestrus, oestrous behaviour and time of ovulation, as well as the response to synchronizing agents may be breed specific.

One of the indigenous cattle breeds in Ethiopia, is the Horro. According to Alberro and Haile-Mariam (1982) Horro cattle are classified as an intermediate Sanga-Zebu type. This cattle breed clearly shows Sanga characteristics in terms of their horns and hump. The Horro cattle are uniform in colour (dark red to brown) and body conformation and have a medium frame size with a small and finely shaped head. These animals have medium to large horns that are generally larger than other Ethiopian Zebu breeds (Alberro & Haile-Mariam, 1982). The mature body weight at 6 years of age is 380 kg for bulls and 280 kg for cows (Mulugeta, 1991).

As reproduction is the nett result of both the male and female, it is imperative that both sexes are evaluated to assess the potential reproductive performance of a certain

breed, in this case, the Horro breed under Ethiopia farming conditions. Thus the aim of this study was to evaluate the reproductive performance of female and male Horro cattle and the factors affecting their reproductive performance under sub-humid environmental conditions in Ethiopia.

Plate 1 Natural pastures at Bako Research Center

Plate 2 A typical example of a Horro bull

Plate 3 A group of Horro bulls at Bako Research Center

Plate 4 A group of Horro heifers at Bako Research Center

CHAPTER 2

LITERATURE REVIEW

2.1 FACTORS AFFECTING PUBERTY IN HEIFERS

2.1.1 Effect of nutrition on the age at puberty

Puberty has been defined as the process whereby animals became capable of reproducing themselves (Robertson, *et al.,* 1991). Age at puberty is an important production trait in most farm animals. In cattle, most of the currently used management systems require that heifers be bred for the first time at 14 to 16 months of age so as to calve at approximately 24 months of age (Perry, 1997). The productivity of the cow is also related to her age at puberty and the earlier the cow matures, the more profitable it could be to the farmer. Early maturity lengthens the productive life of the cow, total milk yield and can affect economical aspects, such as milk yield, lactation length, intercalving period, etc.

Puberty in livestock females is defined as the first behavioral oestrus, accompanied by the development of a corpus luteum that is maintained for a period characteristic to the particular specie. The maturation process, which culminates at puberty, occurs in a gradual way. It is initiated before birth and continues throughout the pre-pubertal and post pubertal periods of the developing female. Some components of the endocrine system of pre-pubertal females are functional long before puberty (Kinder *et al.*, 1987).

The onset of puberty is more closely related to body weight than to age. Dairy cattle reach puberty when the body weight is 30% to 40% of the adult weight. In beef cattle this percentage is higher and occurs when the heifers reaches 45% to 55% of their adult weight (Kinder *et al.*, 1987).

The age at puberty in cattle is also affected by the physical environment, photo period, age and breed of dam, breed of sire, heterosis, environmental temperature, body

weight as affected by nutrition and growth rates before and after weaning (Hafez, 1987). There is ample evidence to show the profound effect on nutrition on the age at puberty and fertility in heifers. According to Gordon (1996), under good nutritional conditions, a heifer may be expected to reach puberty at about two thirds of her adult size. A high nutritional plane could advance the onset of puberty, while nutritional deficiencies or an overall low nutritional plane can delay puberty. The effect of nutrition on puberty was studied by Fleck *et al.* (1980), on Hereford heifers calving at 2 years of age and it was observed that heifers with higher weight gains during the first winter as weaners had a higher breeding efficiency when bred as yearlings. These first calf heifers also had larger pelvic areas as 2 year olds and had fewer calving difficulties at their first parturition and a higher breeding efficiency at subsequent breedings. Buskirk *et al.* (1995) demonstrated how an increase in post weaning body weight gain in beef heifers significantly enhanced fertility and milk production.

2.1.2 Breed (genetic) effect on puberty

Breed of cattle has an important influence on the age at which puberty is attained in both the male and female. So for example, dairy heifers attain puberty at approximately 7 to 9 months of age, while in beef breeds puberty is only reached between 12 and 13 months (Gordon 1996). *Bos indicus* breeds may not reach puberty until 24 months of age (Schillo, *et al.*, 1992). Inbreeding tends to delay puberty while crossbreeding in cattle tends to decrease the age at puberty, in addition to the effect of heterosis, expressed by liveweight gain. Early maturing heifers may be selected for early calving, which could be one way of improving lifetime production of calves (Gordon, 1996).

2.1.3 The effect of body weight and age on puberty

Age and body weight are critical factors determining when a heifer reaches puberty - with body weight being the most critical of the two factors. Beef heifers will tend to reach puberty at approximately 45-55% of their expected mature weight. For the English type of cattle (Angus, Hereford, etc.) this weight is around 300 kg if their mature weight is approximately 450 kg. For larger framed cattle, such as the

continental breeds (e.g. Charolais, Simmental) and Zebu cattle (Brahman) and their crosses with English breeds, the weight at puberty is approximately 340 kg. Again this weight at puberty will be 45-55% of the expected mature body weight (Gordon, 1996). Until a heifer reaches the appropriate weight when she is able to become pregnant, deliver a calf and provide milk for the calf, the heifer will normally not be cyclic. While age is an important attribute, weight is much more critical in determining the time of puberty. For continued reproductive performance, heifers must maintain an acceptable body condition and continue to grow and develop to maturity (Mukasa-Mugerwa, 1989).

Roy *et al.* (1980) reported several factors affecting puberty and claimed that Friesian heifers calves born during a period of increasing daylight length reached puberty approximately 2 months earlier than those born at other times of the year. According to Schillo *et al.* (1992) the seasonal environment in the early (birth to 6 months of age) and late (6-12 months of age) post natal period may influence the onset of puberty in beef heifers. It was also noted that spring born heifers attain puberty at a younger age than autumn born heifers. Exposure to spring and summer temperatures and photo periods during the second 6 months of life reduces the age at puberty - regardless of the season of birth. The same researchers state that photo period may be the major seasonal cue for the onset of puberty in cattle. It was noted that considerable evidence is available in the literature demonstrating that melatonin is involved in transforming photo period stimuli into neuro-endocrine signals that influence LH secretion in the animals. Separating light and heavy beef heifer calves at weaning and managing them in two groups, significantly reduces the average age at puberty, compared to heifers that are handled in one group (Gordon, 1996).

2.1.4 Endocrine mechanisms regulating the onset of puberty

It is believed that the major components of the endocrine mechanisms required for normal oestrous cycle control in beef heifers are present after about 5 months of age. It has been demonstrated that the hypothalamic-pituitary mechanisms are capable of responding to exogenous estradiol with a surge in the release of LH - that results in blood levels of this gonadotrophin similar to those required for ovulation (Gonzalez-

Padilla *et al.*, 1975a). An exact knowledge of the mechanisms involved in puberty, could contribute towards a better understanding of the problem of delayed puberty, which is known to occur in some cattle breeds. Unlike the events in the sexually mature cow the oestradiol and LH peaks that occur in the heifer before puberty are not synchronized, but rather occur at inconsistent and erratic intervals (MacDonald & Page, 1986; Evans *et al.*, 1994).

Information on the endocrine mechanisms that regulate the onset of puberty in tropical cattle is scarce. Information in particular is limited to the pattern of progesterone secretion and its regulation in these animals. In Nigeria, Gazal and Anderson (1965) observed that blood progesterone concentrations throughout most of the pre-pubertal period in Zebu heifers were lower than those previously recorded for *Bos taurus* breeds (Gonzalez-Padilla *et al.*, 1975b). Numerous studies have been undertaken to investigate the relationship between the occurrence of puberty in heifers and the endocrine mechanisms involved. All are in agreement that there is a strong relationship between the endocrine mechanisms and the occurrence of puberty in heifers (Moran *et al.*, 1989; Vizcarra *et al.*, 1991).

2.1.5 The effect of exposure to bulls on the age at puberty in heifers

Robertson *et al.* (1991), Kinder *et al.* (1994) and Hafez and Hafez (2000), in studies to evaluate the effect of growth rate and exposure to bulls on age at puberty in beef heifers, indicated that at 14 months of age, the proportion of heifers that reached puberty was higher (60.3%) in heifers exposed to bulls than in those not exposed (29.8%). A significant bull exposure x growth rate interaction was also recorded. The effect of bull exposure on age at puberty in heifers was greater for the faster growing than for the slower growing heifers.

2.2 FACTORS AFFECTING THE INTERCALVING PERIOD IN CATTLE

The post partum period is the time from parturition until the establishment of the next pregnancy. It is this interval which is the main determinant of the intercalving period and is thus the parameter that is usually manipulated in order to try to achieve the target calving interval (one calf/cow/year) (Peters & Ball, 1987; Gordon, 1996). In

order to achieve a 365 day calving interval, the calving to conception interval should not be more than 80 to 85 days. The calving to conception interval is subdivided into two components, the calving to first service interval and the first service to conception interval (Hinks, 1976; Maff, 1984).

The calving to first service interval depends on the re-establishment of ovarian cycles after calving and the occurrence and detection of oestrus. The first service to conception interval again is dependant on the ability to conceive and maintain pregnancy after a given service and the continuation of ovarian cycles and correct detection of oestrus in those cows, which do not conceive following the initial services. Fitzpatrick (1994) reviewed the effects of nutrition, body condition, season and suckling on post partum reproductive efficiency of Zebu cattle in the dry tropics. It was concluded that a prolonged post partum period in such cattle, result from an interaction of chronic undernutrition and suckling which results in a long anoestrous period.

2.2.1 The effect of nutrition on the post partum period

Francos *et al.* (1977) and Bogin *et al.* 1982 reported a relationship between nutrition and fertility. It is well known that nutrition influences the reproductive efficiency in cattle (Holter *et al.*, 1990; Lucy *et al.*, 1992).

Nutrition during the last 50 to 60 days prior to calving has a profound effect on the resumption of cyclicity after calving. This is further exaggerated by the BCS of the cow. A cow in a moderate BCS (5-6, on a 1-9 scale), that loses weight pre-calving is much more vulnerable to post partum nutrient levels than an animal in a similar or even poorer condition that is gaining weight prior to calving. Mudgal (1985) reported that low nutrient intakes result in a loss of weight in cattle, both before and after calving, resulting in infrequent oestrous cycles and low fertility rates during the subsequent breeding season. The post partum interval from calving until first oestrus and ovulation in cattle depends primarily on the plane of nutrition offered to the dam during pregnancy (Kaltenbatch & Dunn, 1980; Mukasa-Mugerwa & Azage, 1991).

Loss in body weight in early lactation is often associated with a decline in the reproductive efficiency - primarily stemming from a delay in the resumption of ovarian activity and a lowered conception rate. Cows losing weight around the time of mating are less likely to conceive than cows gaining weight (Kaltenbatch & Dunn, 1980).

In dairy cattle there is a period of negative energy balance during the first few weeks post partum, as feed consumption increases to meet the high energy demands of lactation (Rocha *et al.*, 2000). In beef cattle, despite their lower milk production there is also a negative energy balance period, caused by inadequate energy intake to meet the demands of lactation. Restrictions in energy intake can clearly increase the time to first ovulation in beef cows (Stagg *et al.*, 1995). Dietary energy restrictions have been shown to suppress the LH pulses in post partum cows. The energy level also influences the pregnancy rate. A low pregnancy rate is obtained in cows fed a low energy level after calving, as these cows fail to show oestrus (Dunn *et al.*, 1969). Dry matter intake increases and cows change to a positive energy balance by about 8 weeks (4 to 14 weeks) after calving. The time to first ovulation in dairy cattle varies between individual cows and is related to the timing of the negative energy balance for an individual cow. A return to a more neutral or positive energy balance allows an increase in pulsatile LH secretion, increased maximal size of the dominant follicle and increased follicular estradiol production (Staples *et al.*, 1990; Beam & Butler, 1999).

2.2.2 The effect of suckling on the post partum period

The suckling stimulus of the calf on the dam has a negative effect on cyclic activity during the post partum period. However, animals in a positive energy balance and with an acceptable body condition generally overcome this negative stimulus prior to the breeding season (Hanzen, 1986; Odde *et al.*, 1986; Whittier *et al.*, 1995).

Suckling has been shown to affect the post partum interval (Dawuda *et al.*, 1988a). It is, however, a phenomenon more commonly observed in Zebu than in European cattle breeds (Maule, 1973).

Suckling is responsible for extending the duration of the post partum anoestrous period and hence the intercalving period (Coetzer *et al.*, 1978). Stewart *et al.* (1993a, b) suggested that suckling may induce a delay in ovulation, which may be associated with the suppression in the release of gonadotrophins and ovarian activity. Suckling or the presence of a calf is believed to exercise its inhibitory effect by inhibiting oestrogen synthesis by the follicular cells and reduce the positive feedback effect on the hypothalamic-pituitary axis. Cow-calf interactions, independent of suckling and lactation, may also increase the length of the post partum anoestrus in beef cows (Hanzen, 1986).

Although the hypothalamic content of GnRH is apparently not affected by the cow's suckling status, GnRH concentrations in the hypophyseal portal system are known to be suppressed by suckling (Zalesky *et al.*, 1990). For this reason, although the anterior pituitary content of LH is believed to be replenished in suckled cows within about 2 to 3 weeks following calving, secretion of LH remains below that required for the normal development of the ovarian follicles. Resumption of ovarian activity is delayed until the frequency of LH pulses increases to the levels found during pro-oestrus. Once daily suckling can promote ovarian activity (Odde *et al.*, 1986). A favourable effect following temporary weaning has been reported by Callejas *et al.* (1993), Stewart *et al.* (1993a) and Ewel *et al.* (1995). A study conducted on small East African Zebu cows indicated that a significantly larger percentage of cows on restricted suckling exhibiting oestrus, compared to continuous suckling cows. The post partum oestrous interval was shortened by 54 days in supplemented, compared to control cows and by 13 days in restricted compared to continuously suckled cows (Tegegne *et al.*, 1992b).

2.2.3 Effect of maternal behaviour on the post partum period

It has been found that visual, auditory or olfactory cues from the calf might be sufficient to prolong the post partum anoestrous period (Diskin *et al.*, 1995). Evidence regarding maternal behaviour as a prerequisite link in the suckling-mediated anoestrus in beef cows has been reported by Silveira *et al.* (1993). These workers

concluded that the maternal bond is an important, essential link in this anoestrous period.

In other studies in the USA, it has been found that presence of a non-suckling calf lengthens the interval to the first post partum ovulation, compared to complete weaning of the calf. It appears that the presence of the calf without suckling, was a component of the inhibitory mechanism that delays the onset of ovarian cyclicity in post partum beef cows (Hoffman & Stevenson, 1994).

2.2.4 The bull effect on post partum anoestrus

The effect of a teaser bull on the onset of post partum oestrous activity in beef cattle has been evaluated by various researchers. In Argentina, Bonavera *et al.* (1990) concluded that exposure of beef cows to the bull 33 days after calving did not improve the post partum reproductive performance. In the same country work by Monje *et al.* (1992) showed a bull effect on post partum breeding activity in cows maintained on two nutritional levels. The presence of the bull stimulated post partum reproductive activity and the response was modified by the BCS of the cows. In the USA, post partum anoestrus was found to be significantly shorter for cows exposed to bulls, compared to animals kept isolated from bulls (61 vs 72 days) (Cupp *et al.*, 1993). In the UK, Pullar *et al.* (1994) recorded the effect of a teaser bull on the oestrous activity of newly calved cows by way of milk progesterone concentration determinations and oestrous detection.

In Japan, Sato *et al.* (1994) studied the behavioural interaction of a bull with cows over a 40 day period. Animals running with a bull recorded a shorter uterine involution period, than cows subjected to daily visual and olfactory stimulation, but no tactile stimuli from a bull. It was also noted that the frequency of bull cow interaction was highest 30 to 50 days after calving and this was associated with the occurrence of silent oestrus. Hornbuckle *et al.* (1995) concluded the use of the male effect to mitigate the post partum anoestrous period could benefit the commercial cattle industry, as the proportion of animals mated or inseminated during the breeding

season could be increased. This effect can be induced by the use of sterile teaser bulls a few weeks before the onset of the breeding season.

2.2.5 Effect of year of calving on intercalving period

A calving interval of 365 days is generally considered as optimal. This implies that the cows are pregnant by 85 days post partum. Year of calving has been shown to significantly affect the calving interval. Year effects are caused by variations in rainfall, in the quality and quantity of available pasture and in management practices (Warren, 1984; Moller *et al.*, 1986; Dawuda *et al.*, 1988a, b; Dawuda *et al.*, 1989; Galina & Arthur, 1989a).

Year of mating has also been reported to significantly affect dam weight at mating, parturition and weaning in different breeds (Dionisio, 1989; Hetzel *et al.*, 1989). Year of calving also affects the dam weight at calving and weaning (Dionisio, 1989).

2.2.6 Effect of season/month of calving on intercalving period

Seasonal effects on the intercalving interval may be direct or indirect. Direct effects are related to the influence of weather changes on the physiology of the animal. Indirect effects are associated with the effect of climate on the pastures and the appetite of the animal. Seasonality in the quality and quantity of fodder is closely related to the animals performance and the intake and digestibility of the feed. During the rainy season pastures are abundant in grass of fairly high nutritional value and intake and digestibility is thus high enough to meet the maintenance, growth and reproductive requirements of the animal. Short *et al.* (1990) reported that nutrition, breed and suckling can modify the seasonal effect. Galina and Arthur (1989a) also noted the possible effects of photoperiod, humidity and solar radiation on the reproductive performance of beef cows. Mukasa-Mugerwa *et al.* (1991a) reported a shorter calving interval for Arsi (*Bos indicus*) cows calving during the rainy season, compared to those calving in the dry season in Ethiopia. Extensive evidence links nutrition to the duration of the post partum interval and calf crop production (Dionisio, 1989; Galina & Arthur, 1989a). The importance of nutrition and BCS on the calving interval has been recorded by many researchers (Mukasa-Mugerwa *et al.*,

1991a, b; Rasby, *et al.*, 1991; Sawyer *et al.*, 1991). Based on results obtained for Hereford cows, Rasby *et al.* (1991), recorded a low BCS to be associated with reduced ovarian activity, low *corpora lutea* weights and cessation or lack of initiation of oestrous cycles. Factors that mostly effect the calving interval are oestrous detection, conception rate and days to first breeding (Holroyd *et al.*, 1977; Sasser *et al.*, 1988; Mukasa-Mugerwa, 1989; Fordyce, *et al.*, 1990; Kasa, 1990; Bekele *et al.*, 1992; Lafi & Kaneene, 1992; Yamada *et al.*, 1994, Barton, *et al.*, 1996).

Another seasonal effect was reported by Dawuda *et al.* (1989), who found heat stress to alter serum progesterone patterns in post partum cows. Heat was also considered by Camothe-Zavaleta *et al.* (1991) as being responsible for increased secretion of adrenocecticotrophin (ACTH), which stimulates the secretion of progesterone from the adrenal glands.

2.2.7 Breed and intercalving period

Breed has been reported to significantly affect the calving interval (Short *et al.*, 1990; Moyo, 1996). In recording the post partum interval, an important component of calving interval, Short *et al.* (1990) demonstrated that when managed satisfactory, dairy breeds have a longer post partum interval than beef breeds. It was further suggested that the effect of breed may be due to true physiological differences between breeds and/or to the confounding effects of factors such as differences in the amount of milk produced or appetite and feed intake.

Mukasa-Mugerwa *et al.* (1991a, b) reported the differences in duration of the post partum interval in Arsi and Ethiopian Highland Zebu cows, as being responsible for the differences in intercalving period between these two breeds. Galina and Arthur (1989a, b) reviewed factors affecting the length of the post partum period in tropical cattle and found little evidence of metabolic diseases or uterine infections recorded after calving. The most important factors prolonging the interval from calving to conception seemed to be breed of cow, BCS, time of the year when calving occurred, when suckling was allowed and the stimulus exerted by the calf.

2.2.8 Effect of age of dam and parity on intercalving period

Calving intervals are significantly affected by the age of dam and parity (Rao, 1990; Newman & Deland, 1991; De Souza *et al.*, 1995; Legide, 1996). First-calf heifers and younger cows exhibit a longer post partum interval compared to older cows. Dawuda *et al.* (1988a,b) reported ovarian activity to increase with parity or age. Peak fertility in beef cows was reported to be at the age group of 6 to 7 years (Galina & Arthur, 1989a) or 5 to 10 years (Legide, 1996). The general indications are that fertility increases with age until a certain age (5-8 years) and then decreases with increasing age of the cow (Hodel *et al.*, 1995a, b).

2.2.9 Effect of cow size/weight on intercalving period

Milk production is positively correlated to cow weight and size (Morris & Wilton, 1976; Swanepoel & Hoogenboezem, 1994). Smaller cows generally produce less milk, wean lighter calves and have shorter calving intervals than larger cows. Dam weight and condition at calving have a crucial effect on the calving interval (Swanepoel & Hoogenboezem, 1994).

2.2.10 Effect of sex of the calf on the intercalving period

Male calves are associated with a longer gestation period and a heavier weaning weight than female calves (Holland & Odde, 1992; Rege & Moyo, 1993). However, Mukasa-Mugerwa *et al.* (1991b) found no significant effect of sex of the calf on the length of post partum interval and intercalving interval in Ethiopian Zebu cows.

2.3 FACTORS AFFECTING WEIGHT AT BIRTH, 6 MONTHS, 12 MONTHS, 18 MONTHS AND 24 MONTHS OF AGE

2.3.1 Effect of year and season of birth on calf growth rate

The effect of year of birth has been found to be significant on birth, 6, 12, 18 and 24 month body weights (Lubout *et al.*, 1986; Bothma, 1993; Rege & Moyo, 1993; Rico & Planas, 1994; Plasse *et al.*, 1995; Taylor, 1995). This could be related to climatic and managerial variation from year to year, affecting the nutritional status of the animals (Oni *et al.*, 1988; Dionisio, 1989; Nesamvuni, 1995; Taylor, 1995).

Season of birth has been reported to significantly affect birth weight, 6, 12, 18 and 24 months weight (Mabesa, 1994; Rico & Planas, 1994). Mabesa (1994) reported summer-born Bonsmara calves to be lighter than their winter-born contemporaries at 12 and 18 months of age. To the contrary, Lubout *et al.* (1986) and Lubout (1987) recorded no significant differences in the month of birth on the 12-month body weight of Nguni and Pedi calves. Similarly Bothma (1993) did not record any significant effect of month of birth on 18 month weight of Pedi and Nguni calves. Similar findings were reported by Dionisio (1989) for Afrikaner and Landin calves in Mozambique. The majority of researchers recorded a significant difference in weight between animals born in different seasons of the year (Herd, 1990; Maille *et al.*, 1991; Otto *et al.*, 1993; Wichtel, *et al.*, 1994; Shem, *et al.*, 1995).

2.3.2 Effect of age and parity of the dam on calf growth rate

The age of the dam has been shown to significantly affect birth weight, 6, 12, 18 and 24 month weight of offspring (Mabesa, 1994; Marques, 1995). Mabesa (1994) reported higher weights for offspring of younger cows (less than 3 years old) compared to those of older cows (more than 3 years old). Marques (1995) recorded 12 month weights to be greater for cows 4 to 8 years old, compared to younger and extremely old cows. However, Tawonezvi (1989), Bothma (1993) and Carvalheira *et al.* (1995a,b) did not detect any significant effect of age of the cow on 12 and 18 month weights of the offspring. Tawonezvi (1989) suggested that maternal influences diminish after weaning, thereafter growth depends mostly on the interaction between animal's genotype and the surrounding environment, especially nutrition and health.

2.3.3 Effect of sex of the calf on growth rate

At young ages, male calves grow faster than female calves. Male calves have been shown to have a consistent birth weight advantage of approximately 5.8% over female calves (Holland & Odde, 1992; Nesamvuni, 1995). One possible reason for this dimorphism has been reported to be the longer gestation period of male calves, compared to that of female calves (Holland & Odde, 1992; Rege & Moyo, 1993).

Male weaners tend to be 5 to 6% heavier than their female counterparts (Carvalheira *et al.*, 1995a; Plassa *et al.*, 1995).

Sex of the calf has been reported to exert a significant effect on 12 and 18 month body weight (Bothma, 1993; Rege & Moyo, 1993). Sex was also found to significantly affect the 12 month weight of Nguni and 18 month weight in Pedi calves. At the above ages, males outweighed their female counterparts (Bothma, 1993).

2.3.4 Effect of breed on growth rate

Breed significantly affected the 12 month and 18 month weight of offspring in cattle (Rege & Moyo, 1993; Plasse *et al.*, 1995). *Bos taurus* cattle demonstrated higher growth rates than Zebu cattle (Bonsma, 1980; Turner, 1980; Rege, 1993; De Lange, 1997).

2.4 FACTORS AFFECTING THE ABORTION RATE IN COWS

2.4.1 Embryonic resorption in cows

Embryonic resorption can be defined as the death of a fertilized ovum or embryo prior to implantation. More than 3% occur during the fetal stage (greater than 40 days of development) of gestation (Bellows and Staigmiller, 1994). Furthermore, failure of fertilization appears to occur at a rate of approximately 10%. Thus most embryonic losses occur during the period from fertilization to day 40 of gestation. In the past it was believed that the bovine conceptus was resorbed, but transrectal ultrasound examination have demonstrated that the conceptus and its breakdown products are apparently eliminated by expulsion through the cervix, which either goes unnoticed or appears as a vulva/discharge of clear mucus (Kastelic *et al.*, 1991).

Embryonic mortality after natural breeding or artificial insemination accounts for the majority of reproductive failures in the cattle, with a mortality rate as high as 40% of all fertilized ova (Sreenan & Diskin, 1986). Embryonic mortalities can occur due to endocrine abnormalities, nutritional deficiencies, chromosomal aberrations,

environmental factors such as high ambient and humidity, immunological reactions, uterine infection and lactation (Jainudeen & Hafez, 2000).

2.4.2 Fetal abortion in cows

Abortion is the termination of pregnancy with the expulsion of a fetus of recognizable size before it is viable - before 260 days of gestation in cattle. Various causative factors are involved in abortions, which could be spontaneous or induced, infectious or non-infectious (Blowy, 1985). In farm animals, spontaneous abortions are more prevalent in cattle, particularly dairy cattle. The cause of abortions have been extensively studied and report the causes of abortion to be infectious or non-infectious (Gardner, *et al.*, 1999; Gardner & James, 1999; Kindahl *et al.*, 1999; Langoni *et al.*, 1999; Suteeraparp *et al.*, 1999; Atkinson *et al.*, 2000; Hum *et al.*, 2000).

2.5 MORTALITY RATES IN CATTLE

Mortality rates are reported to be a major limiting factor in animal productivity and, therefore, also total herd efficiency (Du Toit *et al.*, 1995). Information regarding the incidence of calf mortality in tropical cattle indicates season of calving to play a significant role. Galina and Arthur (1989a) reported that, in the tropics and sub-tropics, 30% of the cows lose at least one calf before weaning. Calf survival rates reflect both breed and management differences. Moyo (1996) demonstrated that pre-weaning calf mortality rates were significantly affected by the time of the year of birth and previous calving status of the dam.

Beffa (1988) reported inbreeding of the dam to have a marked depressive effect on calving rate, by reducing foetal survival beyond the 41st day post breeding. It was also found that inbreeding of the calf was more detrimental to calf survival from birth to weaning than inbreeding of dam.

2.6 PROGESTERONE CONCENTRATIONS IN POST PARTUM COWS

Progesterone is a hormone produced by the corpus luteum on the ovary following ovulation and can be detected in milk or serum samples. Progesterone levels rise and

fall according to the different stages of the reproductive cycle. A typical oestrous cycle in the cow lasts approximately 21 days (Hunter, 1980).

The monitoring of the serum progesterone concentration has been found to be a practical method for improving reproduction efficiency in farm animals. Progesterone is also monitored for confirmation of cyclic activity in cattle and also for the purpose of pregnancy diagnosis in cattle (Robertson & Sarda 1971; Heap *et al.*, 1973; Van de Wiel *et al.*, 1978; Booth *et al.*, 1979; Pieterse & Van de Wile, 1981; Foulkes *et al.*, 1982). As progesterone concentrations follow a certain pattern during the cow's oestrous cycle, it is possible to take samples from a cow and predict when the next oestrus is likely to occur and thus also the best time to inseminate. A low progesterone level on the day of insemination gives a good indication that the cow was in oestrus and subsequent levels (serum or milk) should increase and remain high during pregnancy (Bulman & Lamming, 1978; Karg, 1981; Chang & Estergreen, 1984).

A further use in determining the level of progesterone is to determine the pregnancy status of a cow. A progesterone test (serum or milk) may be employed on the farm to determine whether cows are eligible for treatment with prostaglandin to induce oestrus in an AI programme. Stevenson and Pursley (1994) concluded that such a test would be warranted if its cost were significantly lower than the cost of a prostaglandin injection. It is well established that non-pregnancy in cattle can be naturally detected with almost 100% accuracy, by way of a serum or milk progesterone assay (Robertson & Sarda., 1971; Nakao, 1980; Sauer *et al.*, 1981). The stockman can confidently take appropriate action with females that have not conceived, and at much earlier stage than was previously possible – as rectal pregnancy diagnosis is only possible at 45 days of pregnancy or beyond. In India the accuracy of pregnancy diagnosis in Zebu and crossbred cattle by milk progesterone determinations (days 20 to 24 post mating) was confirmed by Kaul and Prakash (1994). Positive pregnancy diagnosis for the Zebu cattle was 91% and negative diagnosis was 100%. The measurement of progesterone concentration for the purpose of pregnancy diagnosis and for confirmation of oestrus in cattle was also

confirmed by various researchers (Dawuda *et al.*, 1989; Stahringer *et al.*, 1990; Del Vecchio *et al.*, 1992; Baruah, *et al.*, 1994; Lammoglia *et al.*, 1995, 1999; Carden *et al.*, 1998; Gazal *et al.*, 1999; Rekwot, 2000).

2.7 THE INFLUENCE OF CLIMATIC FACTORS ON CATTLE REPRODUCTION

Factors such as high ambient temperature and humidity are associated with marked seasonal variations in the reproductive efficiency of cattle (Ryan *et al.*, 1993; Wolfenson *et al.*, 1993, 1994; Early *et al.*, 1994; Wilson *et al.*, 1995). The literature quotes that conception rates in Holstein cows to show a decrease from 52% in winter to 24% during summer (Barker *et al.*, 1994). Other reports also confirm a fertility reduction in cows during the summer months (Gordon *et al.*, 1987; Fernandez *et al.*, 1990). In South Africa, Du Preez *et al.* (1991) recorded low conception rates at first service (33%) when the temperature-humidity index was highest and a conception rate of 74% when the index was the lowest during the year.

Maternal heat stress results in lower levels of serum progesterone, abnormal patterns of progesterone secretion, a shorter corpus luteum lifespan, higher oestrogen levels in the pre-ovulatory phase, a higher incidence of ovulation without behavioural oestrus (silent oestrus), smaller mammary glands, reduced calf birth weights and decreased milk yields (Berman, 1991). Badinga *et al.* (1992) found evidence that summer heat stress alters the timing and duration of follicular dominance and have a long lasting detrimental effect on the quality of ovarian follicles in lactating Holstein cows. Follicle stimulating hormone (FSH) secretion is reduced by heat stress and this effect is most pronounced in cows with a low concentration of plasma oestradiol. Further, cows are more sensitive to maternal heat stress, particularly during the first 2 weeks after breeding (Ryan *et al.*, 1993).

The use of AI has largely removed the physical contribution of the bull as a cause of lowered fertility, due to heat stress. There is a possibility that this heat stress may affect the function of sperm after they have been deposited in the reproductive tract of a cow (Monterroso *et al.*, 1994).

The reproductive processes in both male and female farm animals are highly sensitive to increases in environmental heat load imposed on the animal. The effects of the thermal environment on reproduction have been extensively reviewed by Hafez (1959), Bianca (1965), Shelton (1965) and Meyer and Van Fossen (1971). The severity of heat stress imposed varies considerably, depending on the ambient temperature, humidity, wind speed and thermal radiation. Spermatozoa pass through a number of developmental stages during and after formation in the testes. This process of spermatogenesis normally requires several weeks for completion prior to ejaculation in the semen and seasonal variation in semen quality and reproductive performance has been noted in bulls. Increasing testicular temperature causes decreased spermatogenesis with a simultaneous rise in the initial fructose content of the semen and a reduction in motility, sperm density and total sperm count (Igboeli & Rakha, 1971).

2.7.1 Indicators of semen quality, sexual and testicular characteristics

2.7.1.1 Semen volume

Total volume of an ejaculate is influenced by the age of the bull, season of the year, elapsed time since the last ejaculation, breed and individual variation of the bull (Swierstra, 1968; Amann, 1981). Semen production, as reflected by semen volume or ejaculate volume in bulls, is also influenced by nutrition (over-feeding, under-feeding or malnutrition). During over-feeding, fat may accumulate in the scrotum - which can lead to the under development and malfunction of the testis. Due to this fat accumulation the temperature regulation is hampered and this leads to low sperm production (Labuschagne *et al.*, 2002). Under-nutrition has the effect on ejaculate volume of slowing the growth rate and delaying puberty. Shortage of minerals, trace elements and vitamins also have a negative effect on efficient spermatogenesis (Amann, 1970a; Berndson, 1977).

Environmental and ambient temperature fluctuations, hormonal abnormalities, seasonal changes, testicular degeneration and diseases effect the ejaculate volume in

bulls (Galina & Arthur, 1991; Salah *et al.*, 1992; Stalhammar *et al.*, 1994; Rode *et al.*, 1995). Daily sperm production is also highly correlated with testicular weight. Considerable fluctuation exists in ejaculates from the same bull, especially during periods of warm weather. High summer temperatures generally decrease the volume and the number of spermatozoa per ejaculate. Pre-collection stimulation e.g. exposure to a cow in oestrus, increases the volume obtained with artificial vagina semen collection.

2.7.1.2 Semen colour

Bull semen varies from milky white to a creamy colour. Appearance is an important aspect in recording the occurrence of contamination, e.g. material such as dirt, hair, urine and blood. Some bulls (up to 10%) produce semen that is normally yellow in colour - which should not be confused with urine contamination. This is due to riboflavin pigmentation that is characteristic to certain bulls. This pigment is harmless to the sperm cell and does not influence fertility (Herrick & Self, 1962). Contamination of the ejaculate can thus be assessed by abnormal semen colour occurrences. So for example a reddish discoloration of the ejaculate could be indication of blood being present in the sample. Urine or faeces cause a varying degree of brown colour, depending on the degree of contamination. In general, colour is not affected by factors such as age, season, breed and management (Hafez & Hafez, 2000). Colour is also an indication of the sperm density (concentration) in a semen sample (Hafez, 1987).

2.7.1.3 Sperm motility

The motility of a semen sample is defined as the percentage and rate of forward motion of sperm in the sample. It is an indicator of the ability of sperm to move forward to the ovum, after ejaculation and semen deposition in the fornix region of the vagina has occurred (Hafez & Hafez, 2000).

Sperm motility evaluation involves the subjective estimation of the viability of spermatozoa and the degree of motility. Light microscopic evaluation of sperm motility is most commonly used. The evaluation of sperm motility can be conducted

on raw or extended semen. Sperm motility is extremely susceptible to temperature, especially excessive heat or cold. A bull producing semen containing sperm that are immobile, will have significantly reduced, if any, fertility. Sperm abnormalities, particularly those in the tail are one of the most common causes of reduced motility. Factors such as time of the day, temperature, concentration, contamination and the method of semen collection all affect the motility score (Belorkar *et al.*, 1990; Osman *et al.*, 1990; Singh & Sharma, 2001).

The parameters used to evaluate sperm motility thus include the percentage of sperm that are motile (normally 70 to 90%), the percentage of sperm which show progressive movement, sperm velocity (based on a subjective scale of 0- stationary, or 5 for fast moving sperm) and longevity of sperm motility in raw semen at room (20° to 25°C) or a cold (4° to 6°C) temperatures (Hafez & Hafez, 2000).

The accuracy in evaluating sperm motility is achieved only if standard conditions are established for each sample being evaluated and the sample is maintained at body temperature and examined immediately after collection. Cooling produces decrease sperm motility. Spermatozoa in every semen sample should be of approximately the same concentration as samples previously evaluated. A sample with a high concentration or density of spermatozoa creates greater activity than a more diluted sample (Herrick & Self, 1962). Motility or the degree of vigor is a combination of progressive movement of the individual spermatozoa and the collective movement of all spermatozoa. The latter is often referred to as mass movement. Semen samples improperly collected, carelessly handled, chilled or agitated will not give a true picture of the vitality of the sperm. Warm slides, a warm room or box and a microscope with a low power objective should be routinely used for motility evaluation or type of vigor determinations (Kitiyanant *et al.*, 1999).

Malnutrition, particularly a low energy intake by the male, reduces the growth rate, thus delays puberty and if severe enough, can permanently impair sperm output and is associated with a reduction of inter alia, sperm motility (Hafez & Hafez, 2000). Different semen collection techniques, e.g. the use of the artificial vagina (better

semen quality) or electrical stimulation (poorer semen quality) can also influence the degree of sperm motility (Omar, 1997; Mathevon *et al.*, 1998).

2.7.1.4 Sperm concentration per ejaculate

Sperm concentration is always expressed as the number of cells per ml of semen. For acceptable fertility, a minimum semen concentration is required. This must be known for each ejaculate in order to determine the maximum number of breeding units (straws) that can be produced from a given number of motile sperm per unit of semen sample (Hafez & Hafez, 2000). The average concentration of bull semen ranges from 800 million to 1½ billion sperm per ml. The concentration of sperm in beef bulls' semen is lower than that of dairy bulls. With natural service, a bull with a concentration of as low as 300 million to 500 million sperm cells/ml can successfully fertilize a cow. Most commercial enterprises use bulls that produce semen with a concentration of 900 million sperm per ml. The number of spermatozoa required for optimum fertilization has been recorded to be approximately 7 million to 10 million spermatozoa per insemination, when the cow is bred artificially. This is considered to be the standard number to obtain maximum conception efficiency in an artificial insemination program. Semen samples that are white to bluish in colour with a slight yellowish tinge usually contain 350 to 800 million sperm per ml. Most beef bulls will fall in this category (Herrick & Self, 1962).

Seasonal variation in semen quality has been comprehensively reviewed and differences in the sperm cell concentration have been attributed to the feeding regime, season of year and different geographic localities. (Ortavant *et al.*, 1964; Lodge & Salisbury, 1970). Where climates are so hot and humid that housing and shade do not prevent an increase in body temperature, the number of sperm ejaculated, motility and semen concentration often declines, while the percentage of abnormal sperm increases. These effects may be more pronounced a few weeks after a heat wave, because of the time required to produce and transport sperm to the point of ejaculation. The detrimental effect of light appears to have a minimal effect on semen quality in bulls (Rodriquez, 1964). Fertility differences with seasonal variation also continue when bulls are housed in air-conditioned barns (Lodge &

Salisbury, 1970). The influence of different semen collection techniques and season on sperm concentration was recorded by Amann (1970a), who found the density or sperm on the ejaculate collected by means of an artificial vagina to be significantly higher, compared to that of semen collected by means of the electro ejaculator.

2.7.1.5 Percentage live sperm in the ejaculate

The percentage of live spermatozoa in a given sample can be accurately determined by using a stain (e.g. Nigrosine Eosine) that differentiates between dead and live cells. The stain will not be absorbed by the live sperm, while the dead sperm absorbs the stain, particularly in the head piece. According to Hafez and Hafez (2000) the total number of live sperm per insemination is more important than the percentage of abnormal sperm, and it is accepted that the percentage of live sperm and the sperm motility are the most important determinants of semen quality. The percentage of live sperm, as an indication of semen quality, is markedly affected by a high ambient temperature (Lincoln & Short, 1980). A significant difference in the percentage of live sperm was noted between months (seasons), with the lowest live sperm values being recorded in summer and the highest in winter. The effect of season on percentage live sperm have also been reported by Hanada *et al.* (1997), Mathevon *et al.* (1998) and Al-Janabi *et al.* (1999). At body temperature and higher, the sperm motility increases and sperm exhaust themselves sooner, than at lower temperatures (30-32%). At a temperature of 47°C, sperm are destroyed (Hafez & Hafez, 2000).

The validity of this live/dead staining technique depends on the technician, the accuracy of sampling from the original semen sample and the preciseness of staining the individual slide with a semen smear. Semen samples of low concentration are difficult to stain, and the results are extremely variable (Jainudeen & Hafez, 1980).

2.7.1.6 Percentage abnormal sperm

Abnormalities in the sperm cell structure may be evaluated and described with respect to the part of the cell affected, namely the head, mid-piece or tail. Various researchers have used a variety of terms to describe the same sperm abnormalities and

no uniformity in the usage exists (Johanson *et al.*, 1998; Chacon *et al.*, 1999; Dragileva *et al.*, 1999).

A number of researchers have classified sperm cell abnormalities as primary, secondary or tertiary. Primary sperm cell abnormalities are presumed to be the result of faulty spermatogenesis and secondary abnormalities due to alterations in the maturation or storage stage of cells in the epididymis. Tertiary abnormalities are often considered as artifacts of poor semen smear techniques. Any abnormality in the formation of the head or mid-piece is considered primary. Detached normal heads, protoplasmic droplets and bent tails constitute the major portion of secondary sperm cell abnormalities (Johansson, 1997; Soderquist *et al.*, 1997; Van Camp & Van Camp, 1997). Reduced fertility usually occurs when the number of primary defects is greater than 20%. Secondary defects are not generally as serious and do not affect fertility unless a large number are present. Abnormalities are inherited or acquired through stress, infection, increased testicular temperature or other factors. Depending on the cause, a large number of abnormal sperm in the semen may either be temporary or permanent (Johansson, 1960; Fechheimer, 1970).

According to Hafez and Hafez (2000) heat stress is the major cause of a large number of damaged or abnormal sperm. Periods of high ambient temperature, combined with high humidity or high fever may render a male temporarily infertile for a period of up to 6 weeks. From studies on the morphology of sperm collected from inbred and out-bred Hereford bulls, Salisbury and Baker (1966) reported significant sire differences and generally fewer abnormal sperm nuclei between breeds of bulls than when comparing line bred bulls. This was interpreted to indicate a genetic basis for controlling morphological sperm development.

The effect of heat stress on low fertility in females is well recognized. Less information is available on the bull. The effect of water sprinkling during the summer season on semen quality in Holstein bulls in Saudi Arabia was addressed by Salah *et al.* (1992). It would seem that cooling lowers the rectal temperature and significantly increases sperm motility and has a decreased incidence of dead and

abnormal sperm in the ejaculate. In Spain, Perez-Gutierrez *et al.* (1993) has reported the use of devices for cooling part of the bull genital tract to improve ejaculate volume and semen quality. Scrotal insulation and cortico-steroid treatment were applied by Barth and Bowman (1994) to compare the effect of testicular warming and stress on spermatogenesis in bulls with a marked increase in sperm defects being evident. It was concluded that the two most common forms of interference in sperm production in the bull, are heat and stress, resulting in similar spermiograms.

2.7.1.7 Semen pH

The pH of freshly ejaculated bull semen samples depend on the varying proportion of accessory gland secretions involved. Most normal semen samples are on the acid side of neutrality, varying from a pH of 6.5 to 6.9 with a mean of 6.75 (Salisbury & Van Demark, 1961). The pH generally varies from about 6.0 (acid) or lower to 8.0 (alkaline) or slightly higher. Semen of good quality is usually more acid (lower pH) than, semen of a lower sperm cell concentration. Poor quality semen contains a proportionality larger amount of seminal fluid from the urethra and accessory glands. As spermatozoa break down fructose in semen to lactic acid under anaerobic conditions, which usually exist in Nauru collection tubes, the pH of semen is likely to decrease with increased time from collection to measurement. Bacterially contaminated semen and that containing many dead spermatozoa may produce ammonia and the pH will also thus increase (Salisbury & Van Demark, 1961).

Semen collected by means of an artificial vagina usually has a lower pH than semen collected by an electro-ejaculator. Successive ejaculates also tend to increase in pH and semen containing no spermatozoa or semen from bulls with inflammation of the epididymis, tend to have high (alkaline) pH (Salisbury & Van Demark, 1961). In studies on Hartana and Murrah bulls in India, Tomar *et al.* (1965), reported a seasonal variation in pH of semen and the month to month variation in pH of semen of Zebu and buffalo bulls, was found to be highly significant.

2.7.1.8 Scrotal circumference

Scrotal circumference as an indicator of testis size is highly correlated with sperm production and semen quality (Ott, 1991; Brinks, 1994). It is also an easily obtained, highly repeatable measurement, which has a high heritability (Bellows & Staigmiller, 1994).

In Canada, scrotal size of yearling bulls and its relationship with early calving in beef heifers was investigated by Thompson and Johnson (1995). The importance of scrotal circumference in the fertility of Zebu bulls was also tested by Glauber *et al.* (1990), Tegegne *et al.* (1992a), Brinks (1994), Rocha *et al.* (1994) and Silva-Mena *et al.* (2000). Scrotal circumference is an important aspect in bull evaluation for breeding soundness. Breeding soundness evaluation, which has been developed over the years, has become a relatively quick and accurate testing procedure for bull fertility (potential fertility).

Scrotal circumference is favourably correlated to testes mass, sperm production, semen quality, age at puberty, body mass and age in young bulls (Swanepoel & Heyns, 1990). Many factors, such as breed, age, season and body weight influence testes size or scrotal circumferences and are functions of birth weight, pre-weaning weight and feedlot growth rate and age, all of which may influence testes development (Makarechian *et al.*, 1984). Research has shown testicular size in bulls to be an heritable trait. A producer who selects for bulls with a large scrotum is selecting for reproductive rather than productive traits such as growth rate or frame size (Makarechian *et al.*, 1984; Meyer *et al.*, 1990; Mukasa-Mugerwa & Ezaz, 1992).

Scrotal circumference varies with breed and age of the bull. The most significant testicular growth in a bull occurs from the age of 6 to 36 months and this is based on scrotal circumference. Maximum testicular size is usually attained at 4 to 6 years of age - with advancing age, testicular tissue may lose some of its sperm-producing ability. Therefore scrotal circumference measurements are not very accurate

predictors of sperm production capacity after this age (Wildeus & Entwistle, 1982; Makarechian *et al.*, 1984; Wildeus, 1993).

The vast majority of reports in the literature on bull fertility quote studies involving *Bos taurus* breeds. However, it is important to be careful when extrapolating from *Bos taurus* to *Bos indicus* genotypes, as breed differences may be significant. Genotypic and phenotypic differences exist regarding scrotal circumference between *Bos taurus* and *Bos indicus* cattle types. Entwistle (1980) showed that differences exist in the physical structure of the *Bos indicus* testes in length and width, compared to those of *Bos taurus*. The length:width scrotal ratio of 2:0 in *Bos indicus* was much higher than the 1:8 in *Bos taurus*. Swanepoel (1985) reported breed type differences in the rate of increase in scrotal circumference. *Bos taurus* breeds (Hereford & Simmentaler) have a relatively low rate of increase in scrotal circumference, when compared to the *Bos indicus* and/or Zebu breeds (e.g. Afrikaner).

A strong relationship exists between the plane of nutrition, body weight and scrotal development (Venter *et al.*, 1977; Rekwot *et al.*, 1988; Tegegne *et al.*, 1992a). However, such relationship occurs predominantly under extensive grazing conditions. The effect of location and season on body and testicular growth in Brahman and Hereford bulls were studied by Godfrey *et al.* (1990), who confirmed a marked seasonal fluctuation in testes size, with an increase during the summer and a decrease during the winter season.

2.7.1.9 Testicular volume

Testis size (volume) is correlated with semen volume and is a good indicator of the sperm quality that can be produced. It has been reported that nutritional management may influence testicular growth and the onset of puberty in bulls and thus testes volume (Herrick & Self, 1962). The pubertal period is associated with rapid testicular growth, changes in the LH release pattern, an increase in plasma testosterone concentrations and the initiation of spermatogenesis. Stages in testicular development have been defined for dairy bulls and the following is a summary of the classification: Neonatal development and lumenization of tubules and appearance of

spermatocytes. The pre-pubertal appearance of secondary spermatocytes and spermatids. Circumpubertal appearance of spermatozoa in the testis and epididymis. Post pubertal hyperplasia of testicular tissue (Peters & Ball, 1987).

The total length of the testis, including the epididymis is of great importance. In order to function properly and at maximum efficiency both testis should be of a length that is within the given range of the optimal classification corresponding with the age of the bull (Drayson, 1982). The effect of season, breed and age on testes volume must be taken into account (Patel *et al.*, 1988; Singh & Pangawkar, 1989; Mohanty *et al.*, 1991; Nwakalor & Obasi, 1991).

2.7.1.10 Scrotal skin thickness

The external skin of the scrotum have some elastic properties which provide the testis with protection, without being binding. Internally the scrotum contains the Dartos muscle, a sheet of muscle that lies under the skin of the lower half of the scrotum and affords it with the additional elasticity to maintain normal temperature. The Dartos muscle contracts in cold weather, pulling the testes closer to the body for warmth. In hot weather it completely relaxes and allows the testes to be cooled in the pendulous sac away from the body (Drayson, 1982).

Damage to the scrotum is generally caused by a sudden drop in atmospheric temperature below 0°C. The exterior skin of the scrotum may suffer frost damage, which could range from slight to very severe. Scrotal skin thickness is generally measured as a possible indicator of subcutaneous fat deposition around the testes. In studies on the testicular biometry and semen quality in cattle and buffalo, Das and Tomer (1995) recorded differences in scrotal skin thickness, paired testicular volume, semen characteristics, reaction time and serum testosterone levels in cattle and buffalo over a 6 week period. Significant correlations were also found between testicular measurements and both semen characteristics and serum testosterone concentration. In another study Blazquez *et al.* (1994), indicated that the rate of evaporation from the perineal and scrotal regions of bulls was significantly higher than that in the lumbo-dorsal areas. The lumbo-dorsal rate of evaporation increased significantly as bulls

were transferred from a thermo-neutral to a hot environment. The rate of evaporation from the scrotum of bulls showed a similar increase.

2.7.1.11 Libido

Libido can be defined as the sex drive, or in other words, the eagerness of a bull to mate a cow. The male hormone, testosterone is responsible for this sex drive or libido in the male and for the development of the male secondary sex characteristics (Salisbury & Van Demark, 1961). Libido is largely under hormonal control of testosterone secreted by the cells of Leydig in the testes. Libido can practically be measured by measuring the reaction time, the time interval between consecutive matings - in other words, the duration of the recovery phase and the number of matings per time unit or the mating frequency. In practice libido is measured by the number of cows mated by a bull, in a given period of time (Panwar & Nagpaul, 1989; Byerley *et al.*, 1990; Price & Wallach, 1990). Libido or sex drive can be influenced by genetic factors, climate, season, level of nutrition, age and sexual experience, neural stimuli and physical factors (Osborne *et al.*, 1971; Crichton *et al.*, 1987).

Chenoweth (1981) reviewed the use and value of libido tests and the influence of environmental and genetic factors on libido. The field studies of Chenoweth (1981) and others validate the predictive ability of the libido test for fertility (Farin *et al.*, 1989). The test has also been used to demonstrate breed differences, where *Bos indicus* bulls have been shown to have a lower libido than British or *Bos taurus* bulls (Chenoweth & Osborne, 1975). Differences in libido for *Bos indicus* and *Bos taurus* bulls are well documented. Crichton (1986), Jacobi (1989) and Maree *et al.*, (1989) claimed Zebu bulls to exhibit a marked sexual sluggishness or a tendency only to mount cows in full oestrus. This suggests that Zebu and *Bos indicus* bulls are more sensitive to the oestrous stimuli of teaser females compared to *Bos taurus* bulls. Bonsma (1980) however, claimed that under tropical heat stress, indigenous Sanga bulls have a higher libido than *Bos taurus* bulls.

In a study by Henney *et al.* (1990) it was reported that bulls with low libido tended to have a higher ratio of oestradiol, to testosterone in the blood, compared to those with

high libido. Prolactin and cortisol concentrations in the blood increased during ejaculation. Pathak *et al.* (1990) recorded the reaction time to be longer in younger than in older bulls. Sharma *et al.* (1994) reported that in sexually mature bulls, libido score was significantly correlated to the progressive sperm motility, semen fructose content and citric acid content.

2.7.1.12 Serum testosterone concentration

The testis is the site of production of the male sex hormone, testosterone. This hormone belongs to the class known as androgens and possesses the property of stimulating the male sexual characteristics and libido. Androgens stimulate the development of the secondary sexual characteristics, which are specific for the male such as e.g. body conformation. Androgens stimulate sexual behaviour and libido in the male (Davidson & Sawyer, 1961). This male hormone is responsible for sex drive or libido in the male and for the development of the male secondary sex characteristics. A limited quantity of androgen is also secreted by the adrenal cortex. Androgens stimulate spermatogenesis in the hypophysectomized animal and hasten the onset of spermatogenesis in seasonal breeders. Androgens also prolong the life span of epididymal sperm. Furthermore, androgens promote growth, development and secretory activity of the accessory sexual organs such as the prostate, vesicular glands, bulbo-urethral gland, vas deferens, Cowper's gland, penis and scrotum (Salisbury & Van Demark, 1961).

Stumpf *et al.* (1993), has shown season of the year to affect the concentration and pattern of gonadotrophin and testosterone secretion in the circulation of beef bulls. In the bull these characteristics include big horns, a well-developed fore-quarter, deep voice and certain other external features. Testosterone is needed to maintain the functional integrity of the "*tunica dartos*" muscle and the epididymis. It also has important effects on the general body metabolism, including protein utilization and nitrogen retention. Verma and Singh (1992) found histopathological changes in relation to testosterone levels in bulls, with complete loss of libido in testes of all animals showing a degeneration of the seminiferous tubules.

2.7.1.13 Body weight

Many reports have shown the onset of puberty in bulls to be more determined by body weight than age. Both body weight and age are likely to be profoundly influenced by level of nutrition and the post weaning rate of weight gain. Continuous intensive feeding of young bulls can lead to a decrease in reproductive performance. In over-fed bulls additional scrotal lipid and accumulation or deposition of fat around the *pampiniform* plexus is possible, resulting from high energy (concentrate) diets (Labuschagne *et al.*, 2002). This fat deposition may impair thermo regulation of the testis and have an adverse effect on semen quality (Peters & Ball, 1987; Brown, 1994).

CHAPTER 3

MATERIALS AND METHODS

This study consists of two parts. In part one, the female reproductive indicators such as age and weight at puberty, conception and calving, post partum anoestrous interval, post partum period, intercalving period, growth rate from birth to 24 months of age and abortion rate as well as the general herd mortality rate were analysed from data obtained in records between 1974-2001 from the Bako Agricultural Research Center. In the second part, post partum live weight changes of cows, their serum progesterone profiles, the seasonal changes in bull semen and testicular characteristics and testosterone profiles were obtained from experiments conducted between February 2001 and January 2002 at the same center.

3.1 LOCATION OF THE STUDY

This study was undertaken in Ethiopia at the Bako Agricultural Research Center, located in the western part of the country, 250 km from Addis Ababa at an altitude of 1650 m, 37°09'E longitude and 09°6'N latitude. The center receives an average annual rainfall of 1300 mm, more than 80% of which falls between May and September (wet season). The average annual temperature ranges between 23.9°C and 31.9°C, with a mean of 27.8°C. The environment is hot and humid, with a relative mean humidity of 60%.

3.2 GENERAL HERD MANAGEMENT AT THE BAKO RESEARCH CENTER

The feeding regime used at the center is based on grazing natural pastures for approximately 8 hours per day (08:00 to 17:00). The dominant pasture species include hyperhenya (*Hyperhenia anamesa*) and sporobolus (*Sporobolus praminmidales*) grasses and the legumes Neonotonia (*Neonotonia wights*) (Gebre-Igziabher, 2001). Supplementation with silage or hay (maize and grass, respectively) at night is *ad lib* for all these animals, depending on the availability of hay and silage

and the grazing conditions of the natural pasture. The total number of animals in the center varies from year to year. However, supplementation of a concentrate (oil cake meal, 49%; ground maize 49%; bone meal 1% and salt 1%) mixed at the research center, is restricted to lactating and pregnant cows during the last trimester of pregnancy.

The breeding system practiced at the center is continuous (year-round) mating. Both natural and artificial mating systems are used.

The female animals (cows and heifers) are housed separately as a group in barns at night. These animals are vaccinated yearly for all major diseases (Anthrax, Black leg, etc.) and sprayed with an acaridae fortnightly and drenched against external and internal parasites at the onset and end of rainy season.

3.2.1 Management of male and female calves from birth until weaning at 6 months of age

Calves are separated from their dams at birth, weighed and bucket fed colostrum for the first 5 days of life. Thereafter, whole milk and a concentrate mix (49% ground maize, 49% oil cake meal, 1% salt and 1% bone meal) is offered *ad lib* until weaning. Both calves (male and female) are kept indoors (day and night) until 6 months of age in individual pens, except for about 2 hours of exercise in a nearby paddock every day. Weaned calves are then maintained on natural pastures for approximately 8 hours a day and supplemented with silage or hay *ad lib* during the night and were kept as a group (males and females separately). The available concentrate is customary preferentially supplemented to heifer calves only.

3.2.2 Management of male calves from 6 months of age until culling

Except a few bull calves retained for breeding, feeding and traction experiments, the remaining bulls are culled as soon as possible to reduce maintenance costs. Bulls are disposed of at various ages. At the center there is no established criterion for age at culling.

3.2.3 Management of breeding bulls

Bulls retained for breeding purposes are kept in an individual pen day and night and supplemented hay and silage *ad lib*, and 2 kg of concentrate per head per day to improve their growth rate - so as to reach a breeding age earlier. Mature breeding bulls were also kept in individual pens and supplemented with 1 kg of concentrate per head per day.

3.2.4 Management of heifers from 6 months of age until first calving

In addition to 8 hours grazing on natural pasture, heifers are supplemented *ad lib* with hay or silage at night and 2 kg of concentrate per head per day to accelerate their growth rate. Heifers are bred at 2 years of age when they attain an average body weight of approximately 200 kg (range of 180-200kg). Oestrous detection was done visually (06:00-08:00 and 17:00-18:00) by a trained inseminator and throughout the grazing time by the herdsmen. Heifers observed in oestrus are bred either naturally (local or crossbred bulls) or inseminated with exotic semen (Friesian, Jersey or Simmental semen) (Gebre-Igziabher, 2001).

3.2.5 Management of mature breeding cows

The feeding programme for dry cows was based on natural pasture (08:00-17:00), supplemented *ad lib* with hay (Rhodes grass and natural pasture) or silage (Rhodes grass and maize) at night. Concentrate supplementation is restricted to the lactating cows (at time of milking) and pregnant cows during the last trimester of pregnancy. All cows are monitored for any health problems and annually vaccinated against Black quarter, Anthrax and Foot and Mouth disease (Gebre-Igziabher, 2001).

Oestrous detection procedures are similar to that described under heifer management (section 3.2.4.). Cows observed in oestrus are bred either naturally or inseminated artificially. However, those cows, which are not bred, were recorded with a reason why they were not bred. The most commonly used reasons were:

- Inability of bull to serve
- Delayed breeding after oestrous detection

- No liquid nitrogen available (stored semen)
- No inseminator available
- No semen found
- Cow served repeatedly
- Heifer too young for breeding due to age
- Oestrus observed less than 6 weeks after calving
- Doubtful oestrous observation
- False oestrus during pregnancy
- Sick cow
- Oestrus very soon after the previous oestrus, etc. (Gebre-Igziabher & Mulugeta, 1996)

3.3 PART ONE

3.3.1 Data obtained from the Research Center records

3.3.1.1 Animals

Data regarding reproductive and productive performance, abortion and mortality rates of Horro cattle were extracted from the herd records collected between 1974-2001 and analysed. Data from the following animals were used for this analysis:

- 99 heifers were used to study the age and weight at puberty, 1st conception and 1st calving
- 657 calvings were used to record post partum oestrous interval (from parturition to first oestrus)
- 474 calvings were used to study the post partum period (the period from calving until conception)
- 673 calvings were used to monitor the intercalving period (the period between two consecutive calvings)
- 320 cows were used to record the abortion rate
- 400 male and female calves were used to evaluate birth, 3, 6, 12, 18 and 24 month body weights (pre- and post weaning weight gains)

- 225 death records were used to determine the age at death (mortality)

Data from the above-mentioned animals of different ages and sexes were extracted from Bako Agricultural Research Center records for reproduction, growth and health parameters.

3.3.2 Age at puberty, 1st conception and 1st calving in heifers

The data used for this part of the study included age and weight at first oestrus, age and weight at first conception and age and weight at first calving retrieved from the records of the Bako Agricultural Research Center between 1977 and 2001.

3.3.3 Birth, 6, 12, 18 and 24 month weights of male and female calves

The data used for this part of the study included calf birth weight and the body weight of animals at 6, 12, 18 and 24 months of age, compiled from the records of the Bako Agricultural Research Center, Animal Production Research Division between 1977 and 2001. Average daily gain (ADG) was calculated from birth to 6 months of age (pre-weaning ADG) and from 6 months of age to 24 months of age (post weaning ADG).

3.3.4 Post partum anoestrous interval

The data recorded for this part of the study included calving dates, the time of first oestrus following calving, calf birth weight and sex of the calf between 1977 and 2001. This period can be defined as the period from parturition to first overt oestrus.

3.3.5 Intercalving period

Data from the center's reproductive records between 1977 and 2001 were used in this part of the study. Data used for this study included all cows with 2 or more calvings.

3.3.6 Mortality rate and age at death

The occurrence of mortalities as well as the age at which it occurred in female and male animals at the center are recorded. The data used for this part included birth

date, sex of the animal and age at death. The cause of death is currently not recorded at the center and therefore this aspect could not be analysed.

3.3.7 Abortion rate and stage of pregnancy when abortion occurred

Abortion was defined as the termination of pregnancy with the expulsion of a fetus before 260 days of gestation. The data used in this study included the date that the cow was served, the positive pregnancy diagnosis performed and the date of abortion. No causes for abortion are recorded - thus this aspect could not be included in the analysis.

3.4 PART TWO

3.4.1 Data obtained from trials conducted between February 2001 and January 2002, over a period of 50 weeks

3.4.1.1 Experimental animals

- Twenty mature Horro (Zebu) cows (average age of 5 years and body weight of 214 kg) that had calved during the wet (n=10) and the dry season (n=10) were used to study the post partum weight changes and serum progesterone concentrations.
- Thirty-two mature Horro (Zebu) bulls (average age of 6 years and body weight of 211 kg) were used to evaluate the effect of nutritional supplementation and seasonal variation in semen and testicular characteristics, libido, body weight and serum testosterone levels between February 2001 and January 2002.

3.4.1.2 Nutrition and management of experimental cows

The experimental cows that calved in the wet (n=10) or dry (n=10) season were maintained on natural pastures without supplementation. These cows were housed in groups in a barn at night. Health and other managerial aspects were similar to those described under general management (section 3.2).

3.4.1.3 Collection of blood samples and live weight measurements in post partum cows

Blood samples were collected from 20 cows, 10 of which calved during the wet season (May to September) and 10 during the dry season (October to April). The blood was collected weekly starting at 20 days post partum until 42 days, and thereafter every 14 days, for a period of 120 days. The blood samples were taken by veni puncture (jugular vein) using an 18-gauge needle attached to a 7-ml vacutainer blood collection tube with no anti-clotting agent. Blood was allowed to clot in the vacutainer tubes for 30-45 minutes at room temperature. Serum was collected from each tube following centrifugation for 15 minutes at 2500 r.p.m. The serum was then separated and stored in a vial at -20°C until assayed for serum progesterone concentration. The live weights of the cows were recorded at calving and thereafter every 2 weeks for the entire observation period of 120 days.

3.4.1.4 The serum progesterone concentration assay

The serum progesterone concentration was assayed with the aid of an Automated Chemiluminescence system (Chiron Diagonistics ACS.180, USA). The system is based on a competitive immunoassay technique, using direct chemiluminescent technology. Progesterone in the sample binds to an acridinium ester-labeled mouse monoclonal anti-progesterone antibody in the light reagent and the unbound antibody binds to a progesterone derivative covalently, coupled to paramagnetic particles in the solid phase. The amount of progesterone present in the sample is inversely related to the amount of relative light units detected by the system. The ACS: 180 progesterone assay measures progesterone concentrations up to 60ng/ml with a minimum detectable concentration of 0.11ng/ml. The analytical sensitivity is defined as the concentration of serum progesterone that corresponds to the relative light units (RLU's) of 20 replicate determinations of the progesterone zero standards.

3.4.1.5 Nutrition and management of the experimental bulls

The 32 Horro bulls used to study the seasonal variation in semen and testicular characteristics, as well as libido and testosterone levels, were randomly divided into two groups of 16 animals each. One group of the bulls was given a supplementary

feed concentrate at a rate of 1.5 kg/bull/day. The concentrate consisted of 20% crude protein and was formulated from ground maize, oil cake meal (*Gizota abesinica*), bone and blood meal. The supplementation was given early in the morning (07:00), before the bulls went out to graze. The second group served as the control (no supplement). During the day, the bulls were maintained on natural pastures for approximately 8 hours per day (08:00 to 17:00).

3.4.1.6 Housing and health management

The bulls (n = 32) used for the semen evaluation study were housed in individual pens at night. During the experimental period, no diseases were diagnosed, except for two bulls; one with a skin disease and the other which was treated for a hoof injury. All bulls were sprayed fortnightly with an acaridae for external parasites.

3.4.1.7 The adaptation period

The experimental bulls used for semen evaluation study under supplementation were fed a concentrate mixture of 49% ground maize, 49% oil cake meal, 1% common salt and 1% bone meal *ad lib* for an adaptation period of 2 weeks. At the same time bulls were trained to become familiar to the electro-ejaculator and semen collection procedures prior to the start of the actual experimental period.

3.4.1.8 Experimental period

The experiment started in February 2001 and was terminated in January 2002 – a total observation period of 50 weeks was used for semen evaluation.

3.4.1.9 Seasonal variation in Horro bull fertility

A total of 32 mature Horro bulls (16 supplemented and 16 control) were used to evaluate semen and testicular characteristics.

3.4.1.10 Semen collection

Semen was collected from each bull using an electro-ejaculator (ELTORO II type), manufactured in South Africa by an Electronics Research Group. The collection was performed every 2 weeks throughout the 50 week observation period and each semen

collection was performed between 09:00 and 12:00. A small amount of paraffin lubricant was applied to the probe to prevent damage on insertion into the rectum of the bull. The contents of the rectum (dung) were cleaned prior to probe insertion so that the electrodes could make a good contact with the rectal mucosae and easily stimulate the sympathetic and parasympathetic nerves of the pelvic plexus. These nerves are responsible for erection of the penis, ejaculation, and emission of semen (Elmore, 1985).

The semen collection area was near to the semen evaluation laboratory, to facilitate the fast evaluation of the semen samples obtained. As soon as the semen samples were collected, they were evaluated for volume, colour and mass motility. A semen smear stained with nigrosine/eosine (2:1) was immediately prepared for later evaluation. The remaining samples were placed in a water bath (32°C) for about 2 hours to be evaluated for sperm concentration.

To prepare a semen smear, a small drop of semen and a drop of nigrosine/eosine stain were placed at one end of a clean dry microscope slide. The edge of a second slide was placed across both the drop of semen and the drop of stain, and then it was rocked back and forth several times to mix the two. This slide was then pulled across that of the other slide leaving a thin stained smear. The stained slide was then air-dried and later used (within 24 hours) to study sperm morphology using an oil emersion objective (x 1000 magnification) (Elmore, 1985).

3.4.1.11 Macroscopic evaluation of the semen

The volume of the ejaculate was recorded immediately after collection by reading the calibrated collection test tubes used to collect the ejaculate from the funnel shaped rubber cone.

The colour of the ejaculate (creamy, milky or watery) was recorded as an indicator of the semen density and the possibility of semen contamination (Herrick & Self, 1962; Hafez & Hafez, 2000).

The semen pH was recorded by using a pH strip (Macherey-Nagel, Germany). The pH strips measures a 0-7 range in accuracy of 0.2 units. The strips were immersed in the semen sample immediately after collection. The colour change was compared to that of a colour chart provided to determine the pH.

3.4.1.12 Microscopic evaluation of the semen

The sperm mass motility was assessed and recorded immediately after collection. The ejaculate was assessed microscopically (x1000 magnification) and a value allocated on a subjective scale of 0 to 5 (Elmore, 1985).

The scale for sperm mass motility evaluation was the following:

5	-	Very strong progressive, dark waves (90% plus live cells)
4	-	Strong progressive undulations (70 to 85% live cells)
3	-	Weak undulations (50 to 65% live cells)
2	-	Very few, weak, non-progressive undulations (30 to 45% alive)
1	-	No undulations (5 to 25 live cells)
0	-	No movement (all cells dead)

Sperm concentration determinations were performed using a hemocytometer (Improved Neubaner, Marienfeld, Germany) (dilution rate of 1:300) to calculate the density or concentration of the ejaculate (x 10^6/ml) (Elmore, 1985).

The percentage of live sperm per ejaculate was determined by microscopic observation (x 400 magnification) of a semen smear stained with nigrosine/eosine. All sperm cells that stained pink/red were classified as dead. A total of 100 sperm on the smear from randomly selected areas were counted to determine the percentage live and dead as well as for the determination of the percentage abnormal sperm. This slide was also used for determining the percentage of abnormalities (x 1000 magnification). Sperm cell abnormalities were expressed as total of the cells counted as well as a percentage of the head, mid-piece and tail abnormalities.

The sperm morphological defects observed were divided into primary and secondary defects (Elmore, 1985) and are set out in Table 3.1.

Table 3.1 Criteria to define sperm abnormalities (Elmore, 1985)

Primary defects	Secondary defects
○ All head abnormalities	○ Normal detached heads
○ Tightly coiled tails	○ Distally bent tails
○ Double tails	○ Reverse tails
○ Ab-axial mid pieces	○ Distal protoplasmic droplets
○ Spheroids	
○ Proximal protoplasmic droplets	

3.4.1.13 Serum testosterone levels

Blood samples were collected weekly from a total of 10 bulls, 5 from the supplemented and 5 from the control group. The blood samples were taken by veni puncture (jugular vein) using an 18-gauge needle attached to a 7 ml vacutainer blood collection tube with no anti-coagulation agent. Blood was allowed to clot in the vacutainer tubes for 30-45 minutes at room temperature. Serum was recovered from each blood sample after centrifugation of the blood for 15 minutes at 2500 r.p.m. The serum was then separated and stored in a vial at -20°C until assayed for serum testosterone concentration.

3.4.1.14 Serum testosterone concentration assay

The serum testosterone concentrations were determined using a automated chemiluminescence system (Automated chemiluminescence ACS:180 Bayer). The ACS: 180 Testosterone assay is a competitive immunoassay using direct, chemiluminescent technology. Testosterone in the sample competes with acridinium ester-labeled testosterone in the lit reagent for a limited amount of polyclonal rabbit anti-testosterone antibody bound to monoclonal mouse anti-rabbit antibody, which is coupled to paramagnetic particles in the solid phase. The assay uses testosterone-releasing agent to release bound testosterone from the endogenous binding proteins in the sample.

3.4.1.15 Scrotal circumference and volume (as indicators of testicular size)

Scrotal circumference (cm) of each bull was measured with a measuring tape placed around the broadest part of the scrotum, as an indicator of testis size (Herrick & Self, 1962; Drayson, 1982). These measurements were recorded every second week, for the 50 week trial period.

The testicular volume (scrotal volume) was determined by submerging the entire scrotum containing the testes up to the basis of the neck of the scrotum in a calibrated plastic bucket filled with water. The quantity of water displaced by the submerged scrotum containing the testis was recovered and measured in a graduated cylinder as an estimate of the testis volume. The testicular volume was measured from the rear, between the bull's legs, while standing. These measurements were taken at the same time every second week (09:00–11:00) (Lodge & Salisbury, 1970; Mohanty *et al.*, 1991).

3.4.1.16 Scrotal skin thickness

The scrotal skin thickness was measured fortnightly with the aid of a caliper. The skin thickness was measured in the middle of the right lateral side of the scrotum and the scrotal skin was folded and the measured skin fold thickness was divided by two to get the scrotal skin thickness. Skin thickness was measured as a possible indicator of subcutaneous fat deposition in the scrotum.

3.4.1.17 Libido

A total of 16 bulls, 8 from supplemented and 8 from the control group were used in the libido test. Bulls were tested every 14 days, the same week as semen collection, with the aid of teaser cows. The teaser cows used to test bull libido were adult Horro cows in which oestrus had been induced by a subcutaneous injection of 4mg estradiol Cipionate ECP™ (Pharmacia & Upjohn®). Cows were administered a 2 ml sterile solution 3 days prior to the test. Each bull to be tested was released in a pen of 10m by 20m for a period of 5 minutes with a cow in oestrus. Observers at a distance did not interfere while the animals were being tested. The behavior of each bull was

observed and scored according to the system described by Osborne *et al.* (1971). This scoring system is recommended by the Australian Veterinary Association for the examination of bulls.

The scoring system was:

0 = No sexual interest within 5 minutes

1 = Some interest but no attempt to mount within 5 minutes

2 = Mounted or attempted to mount once within 5 minutes

3 = Mounted or attempted to mount more than once but did not complete a service within 5 minutes

4 = Mounted and completed one service within 5 minutes

3.4.1.18 Rectal temperature

Rectal temperatures (°C) in all the bulls were recorded every two weeks just prior to semen collection (between 09:00 and 11:00) with the aid of a clinical thermometer. Temperatures were noted after insertion of the clinical thermometer in the rectum, for a minimum period of 1 minute, and were later correlated with seminal parameters.

3.4.1.19 Body weight

The body weight (kg) of all bulls was taken initially at the beginning of the experiment and thereafter every two weeks (06:00 to 08:00) with the aid of an oil scale after a fasting period of 14 hours (no food and water). Body weight was used as an indicator of nutritional status of the animals.

3.4.1.20 Environmental factors

The ambient temperature, rainfall and relative humidity for the whole experimental period was obtained from the meteorology section at Bako Agricultural Research Center.

3.4.1.21 Statistical analysis

General linear model (GLM) procedures of SAS (SAS, 1994) were used to analyse the data. To compare calving interval, oestrous interval and post partum period, the

variables used as independent variables included season of calving, year of calving, parity, sex of the calf and birth weight. To evaluate age and weight at puberty, 1st conception and 1st calving in heifers, the independent variables used were: season of birth, year of birth and birth weight.

To analyse post partum body weight changes and serum progesterone concentration in cows, the independent variable used in the model was the season of calving, which included the wet (May to September) and dry season (October to April). To evaluate the abortion rate, season and the year when the abortion occurred were used as independent variables.

To further study growth performance traits such as, weight at birth, 3, 6, 12, 18 and 24 months, the variables sex, season of birth and year of birth were used as independent variables. For mortality rate, season, year, sex of the calf and age of the animal were used as independent variables. The probability option in the GLM procedure SAS was used to estimate the least square differences for the year effects (SAS, 1994).

Semen testicular characteristics, libido, bull body weight and serum testosterone concentration were analysed using the repeated measure analysis of variance procedure of SAS (SAS, 1994). Analysis of testosterone was carried out using 2 models. In the first model, nutritional supplementation was analysed using a repeated measure analysis and body weight was included as a covariant. In the second model, a repeated analysis was carried out to see the effect of season on serum testosterone concentration. Mean separation was performed using Duncan's multiple range test.

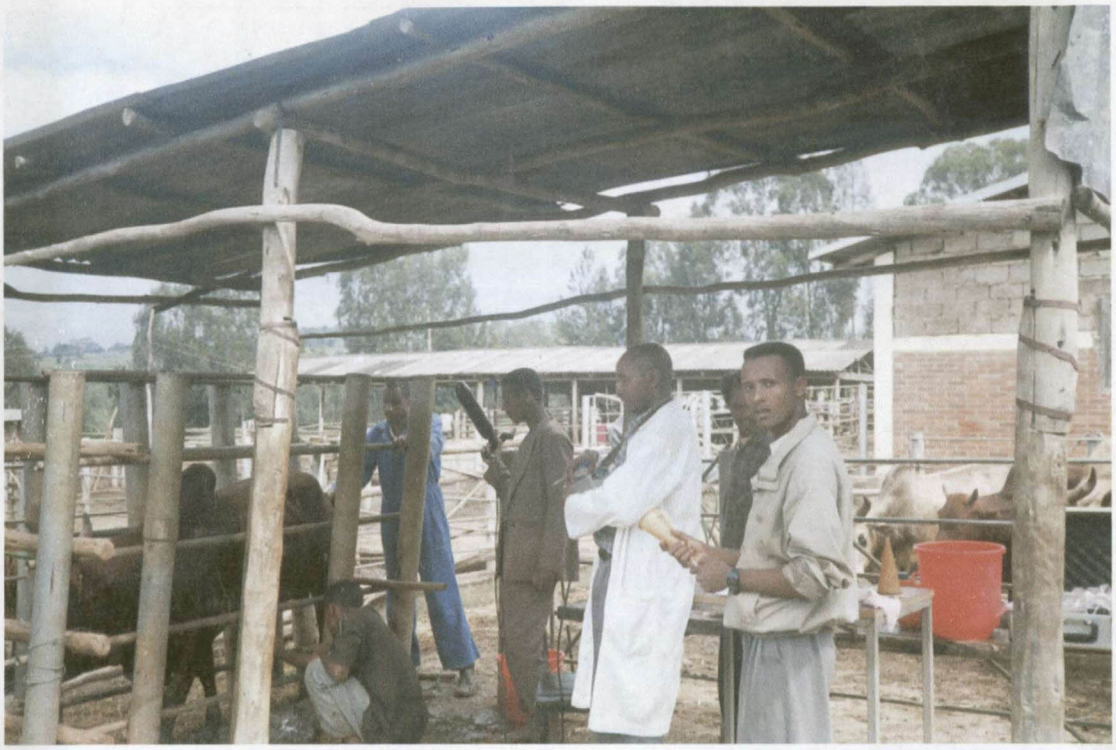

Plate 5 Semen collection using an electro-ejaculator

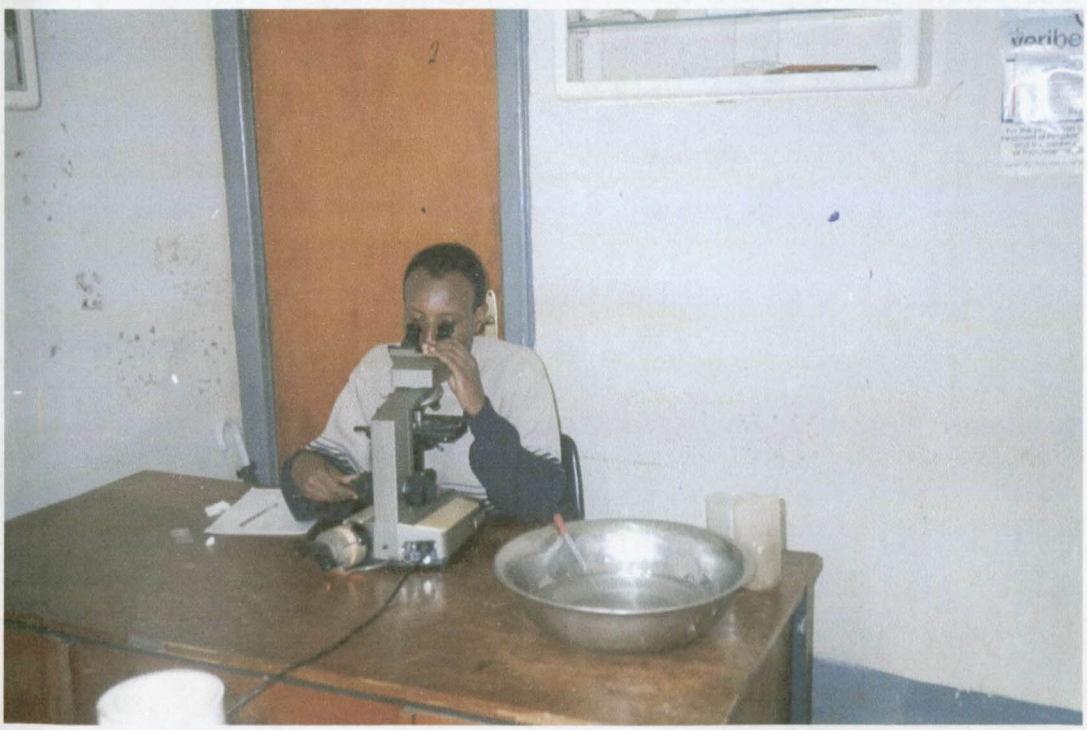

Plate 6 Microscopic evaluation of semen

CHAPTER 4

RESULTS

4.1 AGE AND BODY WEIGHT AT PUBERTY IN HORRO HEIFERS

The mean age and body weight of Horro heifers at puberty are set out in Table 4.1 and Figures 4.1 to 4.4. The overall least square mean for age at puberty for all seasons was 39.4 months, ranging from 33.8 ± 2.0 to 46.9 ± 3.8 months. Age at puberty was not affected by season of birth, year of birth or birth weight of the heifer. The overall least square mean body weight at puberty was 202.9 kg (ranging from 180.8 ± 17.4 kg to 227.0 ± 17.3 kg) and was not affected by season of birth, year of birth and birth weight respectively.

4.2 AGE AND BODY WEIGHT AT CONCEPTION IN HORRO HEIFERS

The least square means for age and body weight at first conception are set out in Table 4.2 and Figures 4.5 to 4.8. The overall least square mean age at 1st conception was 50.1 months, ranging from 40.9 ± 5.7 to 60.4 ± 5.7 months. Age at 1st conception was not significantly affected by the season of birth and birth weight. Year of birth significantly ($P<0.05$) affected the age at conception in heifers. The overall least square means for all heifers regarding body weight recorded at first conception was 226.7 kg (ranging between 190.5 ± 24.4 kg and 254.2 ± 13.8 kg). Body weight at 1st conception was not affected by season of birth or birth weight. Year of birth however, significantly ($P<0.05$) affected weight at 1st conception in Horro heifers. It would seem that the body weight at 1st conception decreased over the years (1975-1995). This was however, not accompanied by a corresponding decrease in age at 1st conception (Table 4.2).

4.3 AGE AND BODY WEIGHT AT 1ST CALVING IN HORRO HEIFERS

The least square means for age and body weight at 1st calving in Horro heifers is set out in Table 4.3 and Figures 4.9 to 4.12. The overall least square mean for age at 1st calving in all heifers was 58.7 months - ranging from 51.5 ± 5.2 to 70.7 ± 3.0 months.

Table 4.1 Least square means (± SE) age and body weight at puberty for Horro heifers between 1977 and 1996 at the Bako Research Center

Source of variability	n	Mean age ± SE (month)	n	Mean weight ± SE (kg)
Overall	81	39.4	96	202.9
Season of birth				
Wet		39.3 ± 1.4^{NS}		198.6 ± 6.3^{NS}
Dry		41.0 ± 0.9^{NS}		206.5 ± 5.0^{NS}
Year of birth		NS		NS
1977		36.9 ± 1.6		205.1 ± 8.7
1978		39.9 ± 2.4		203.8 ± 13.1
1979		38.3 ± 4.4		197.1 ± 24.2
1980		43.3 ± 4.3		186.4 ± 23.9
1981		46.9 ± 3.1		190.1 ± 12.8
1982		44.7 ± 2.9		215.1 ± 11.4
1984		37.0 ± 3.1		212.1 ± 15.2
1985		42.5 ± 4.4		224.9 ± 24.2
1986		36.8 ± 3.1		206.1 ± 15.3
1987		34.7 ± 3.1		214.8 ± 19.6
1988		42.1 ± 2.6		192.8 ± 12.0
1989		42.2 ± 3.2		227.0 ± 17.1
1990		40.9 ± 3.2		193.6 ± 17.4
1991		446. ± 3.6		208.9 ± 17.5
1994		33.8 ± 2.0		194.9 ± 9.0
1995		37.4 ± 6.3		185.9 ± 19.6
1996		40.3 ± 1.2		180.8 ± 17.4

NS = no significant difference

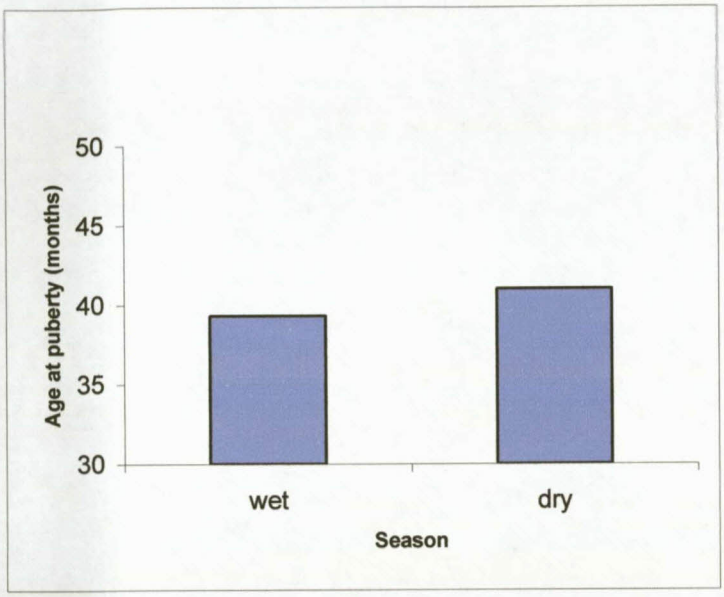

Figure 4.1 Effect of season (wet or dry) on age at puberty in Horro heifers

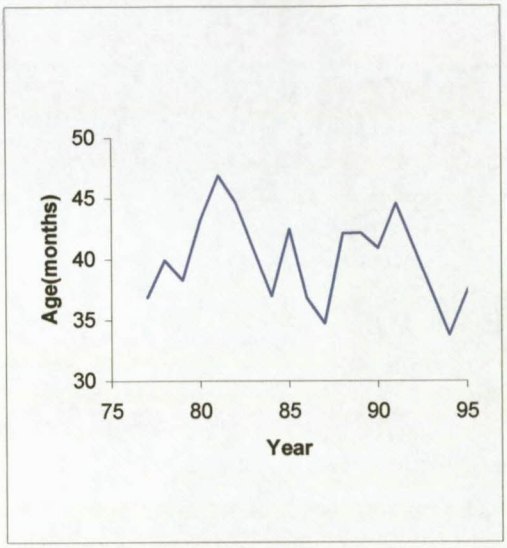

Figure 4.2 Least square mean age at puberty in Horro heifers from 1975-1995

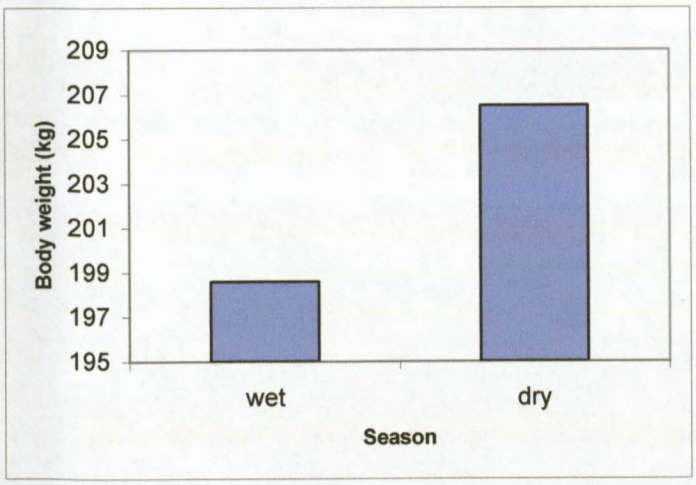

Figure 4.3 Effect of season on body weight at puberty in Horro heifers

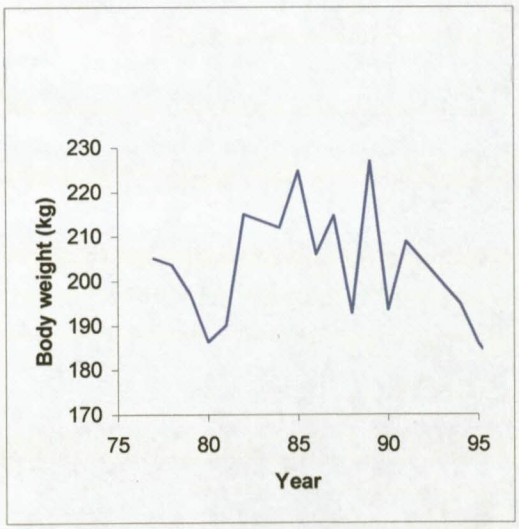

Figure 4.4 Least square mean body weight of Horro heifers at puberty from 1975-1995

Table 4.2 Least square means (± SE) age and body weight at 1st conception in Horro heifers between 1977 and 1996 at the Bako Research Center

Source of variability	n	Mean age (month)	n	Mean weight (kg)
Season of birth	64	50.1	87	226.7
Wet		49.9 ± 1.5^{NS}		221.1 ± 4.1^{NS}
Dry		50.8 ± 1.0^{NS}		229.6 ± 3.7^{NS}
Year of birth				
1977		43.5 ± 1.8^{de}		232.2 ± 6.3^{abc}
1978		48.5 ± 2.3^{abcde}		228.5 ± 9.2^{abc}
1979		40.9 ± 5.7^{e}		229.5 ± 17.1^{abc}
1980		60.4 ± 5.7^{a}		232.3 ± 16.9^{abc}
1981		59.1 ± 2.8^{ab}		235.2 ± 9.1^{abc}
1982		54.3 ± 2.4^{abcd}		216.8 ± 9.9^{abc}
1984		54.8 ± 4.1^{abc}		233.0 ± 11.0^{abc}
1985		45.4 ± 4.1^{cde}		246.5 ± 17.1^{a}
1986		44.2 ± 4.1^{cde}		233.0 ± 10.8^{abc}
1987		54.5 ± 4.1^{abc}		254.2 ± 13.8^{a}
1988		50.8 ± 2.1^{abcde}		243.8 ± 8.5^{ab}
1989		49.2 ± 2.9^{bcde}		225.7 ± 12.3^{abc}
1990		48.1 ± 2.9^{bcde}		208.1 ± 12.3^{abc}
1991		50.9 ± 3.4^{abcde}		220.2 ± 14.2^{abc}
1994		50.3 ± 2.4^{abcde}		202.6 ± 7.7^{bc}
1995		-		190.5 ± 24.4^{c}
1996		49.7 ± 2.9^{abcde}		199.3 ± 12.3^{bc}

^{NS} = no significant difference

^{abcde} = Means in the same column with different superscripts differ significantly ($P<0.05$)

Age at 1st calving was not significantly affected by season of birth or birth weight as such, although year of birth significantly ($P<0.05$) affected the age at calving in Horro heifers. The overall least square mean body weight at calving was 259.2 kg (ranging from 216.5 ± 21.3 kg to 308.8 ± 14.5 kg) and was not affected by neither season of birth nor birth weight. Year of birth significantly ($P<0.05$) effected the weight at

calving in these animals. However, no clear trend could be observed regarding the age and body weight at 1st calving over the years.

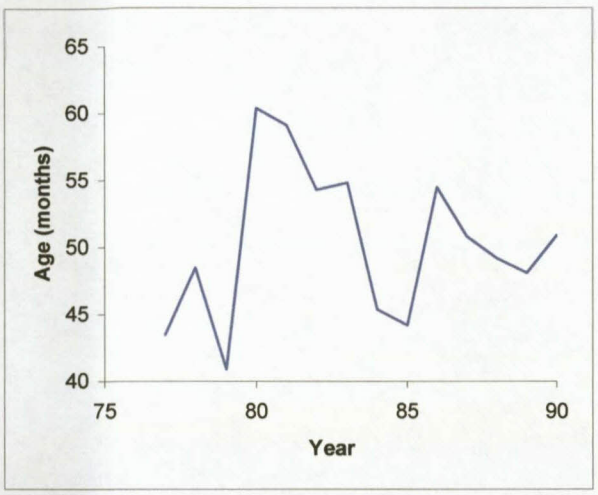

Figure 4.5 Least square mean age at 1st conception in Horro heifers for the period 1975-1996

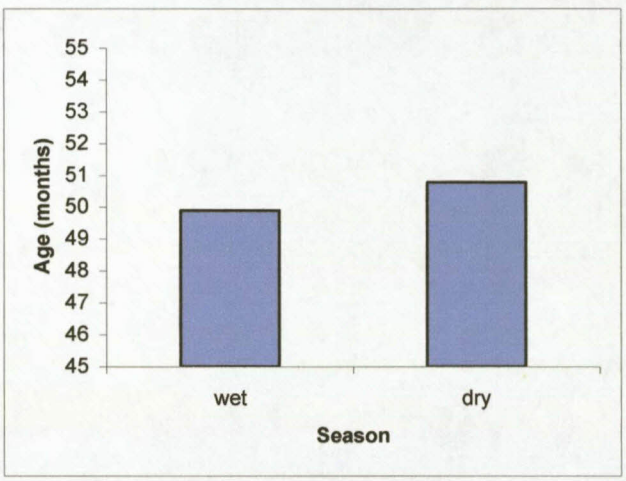

Figure 4.6 Effect of season on the age at 1st conception in Horro heifers

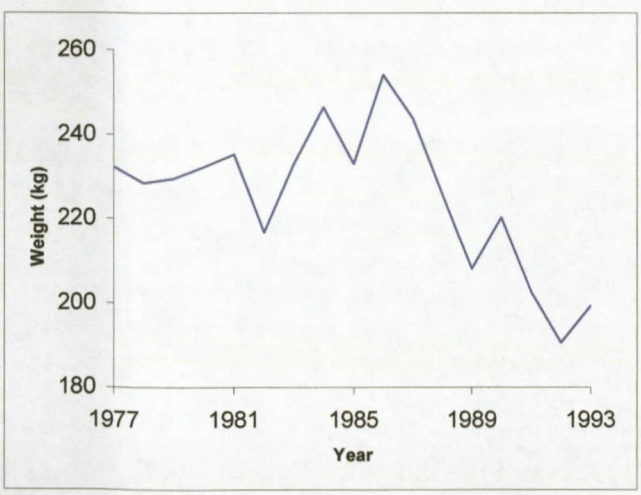

Figure 4.7 Least square mean body weight at conception in Horro heifers from 1977-1993

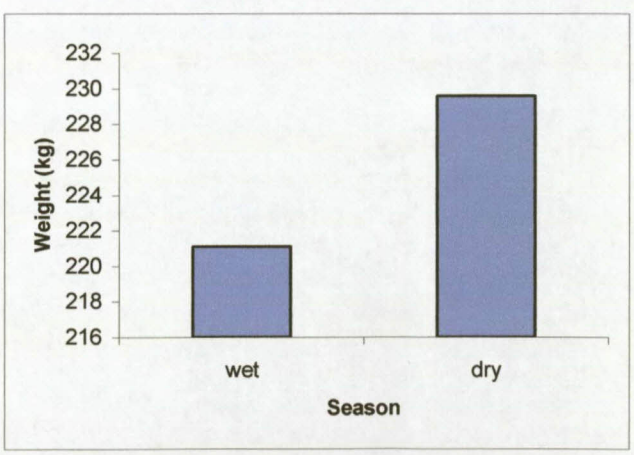

Figure 4.8 Effect of season (wet or dry) on weight at conception in Horro heifers

Table 4.3 Least square means (± SE) for age and body weight at calving in Horro heifers

Source of variability	n	Mean age ±SE (month)	n	Mean weight ±SE (kg)
Season of birth	53	58.7	76	259.2
Wet		59.9 ± 1.8^{NS}		259.2 ± 6.4^{NS}
Dry		58.5 ± 1.0^{NS}		204.0 ± 4.9^{NS}
Year of birth				
1977		53.3 ± 1.6^{cd}		248.3 ± 7.7^{bc}
1978		55.4 ± 2.1^{bcd}		229.7 ± 15.1^{bd}
1979		51.5 ± 5.2^{dd}		256.5 ± 20.7^{abc}
1980		53.7 ± 5.2^{cd}		262.4 ± 20.4^{abc}
1981		70.7 ± 3.0^{a}		246.4 ± 10.9^{bc}
1982		63.6 ± 2.1^{abc}		255.8 ± 11.2^{bc}
1984		65.5 ± 3.7^{ab}		261.1 ± 12.9^{bc}
1985		56.1 ± 3.7^{bcd}		274.1 ± 29.4^{abc}
1986		54.2 ± 3.8^{bcd}		308.8 ± 14.5^{a}
1987		62.9 ± 3.7^{abc}		273.9 ± 16.7^{abc}
1988		59.1 ± 2.7^{abcd}		280.8 ± 11.7^{abc}
1989		59.8 ± 2.7^{bcd}		293.9 ± 14.9^{abc}
1990		58.7 ± 3.1^{bcd}		279.1 ± 17.2^{abc}
1991		59.7 ± 3.1^{abcd}		253.8 ± 17.3^{abc}
1994		65.4 ± 3.1^{ab}		$244.5 \pm 10.^{2abc}$
1996		57.7 ± 5.3^{abcd}		216.5 ± 21.3^{c}

^{NS} = no significant difference

^{abcd} = Means in the same column with different superscripts differ significantly ($P<0.05$)

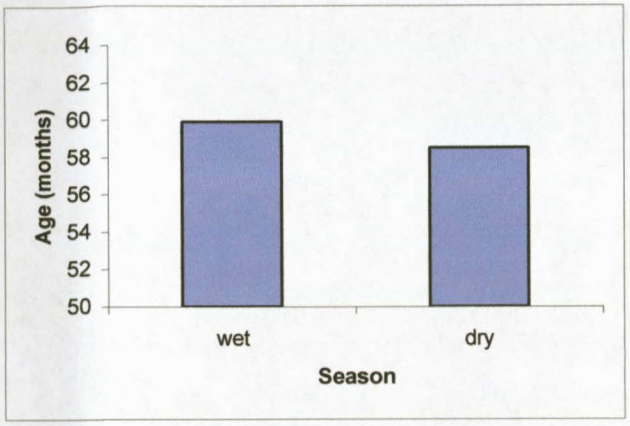

Figure 4.9 Effect of season (wet or dry) on age at calving in Horro heifers

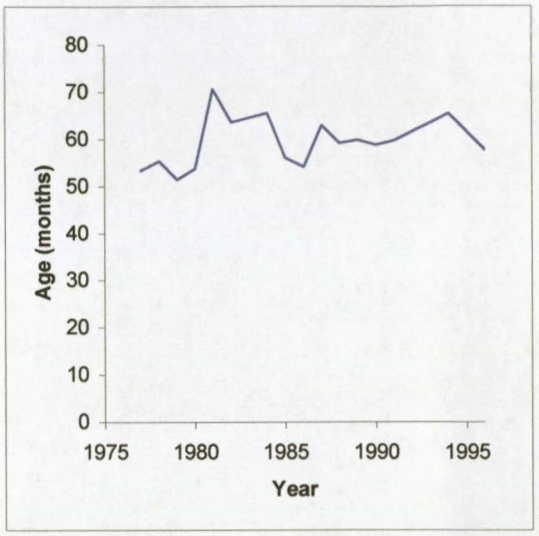

Figure 4.10 Least square mean age at calving in Horro cows for the period 1977-1996

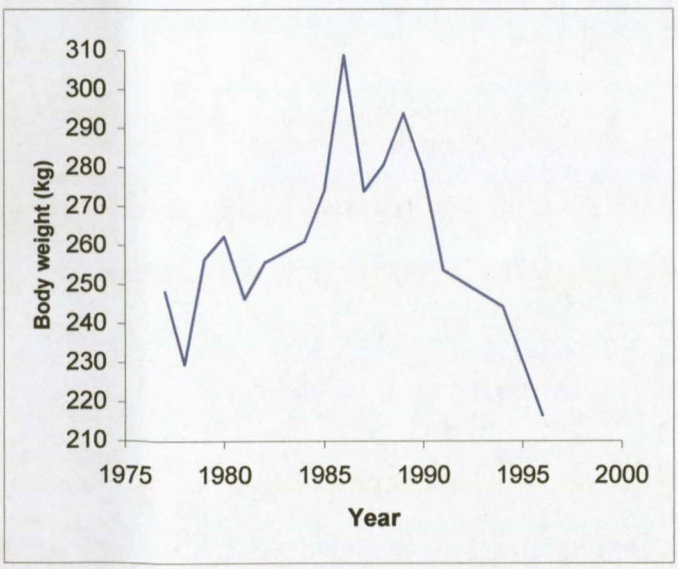

Figure 4.11 Least square mean body weight of Horro heifers at calving for the period 1977-1996

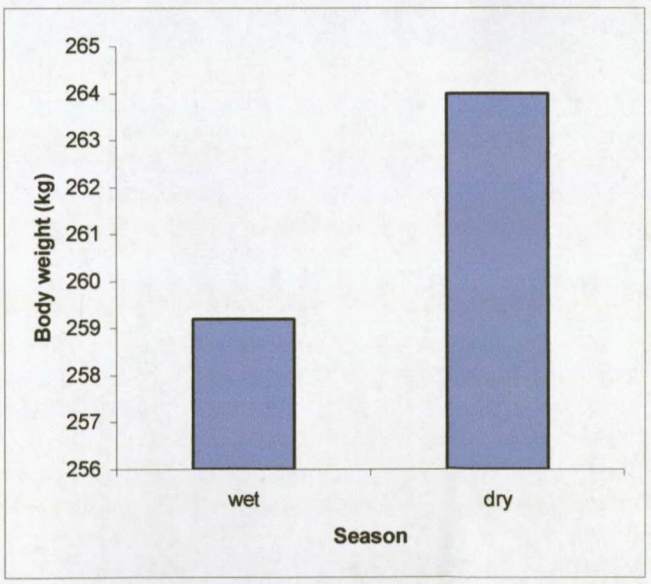

Figure 4.12 Effect of season (wet or dry) on the weight at calving in Horro heifers

4.4 THE POST PARTUM ANOESTROUS INTERVAL AND THE POST PARTUM PERIOD IN HORRO COWS

The least square means for the post partum anoestrous interval and the post partum period are set out in Figures 4.13 to 4.15 and Table 4.4.

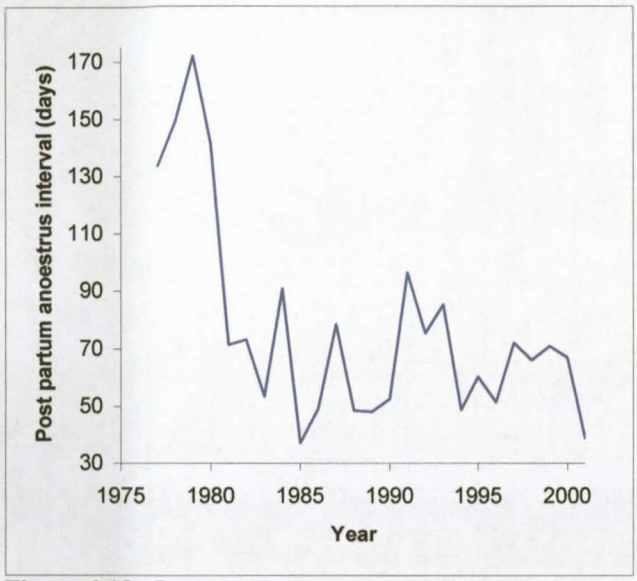

Figure 4.13 Least square mean post partum anoestrous interval in Horro cattle for the period 1977-2001

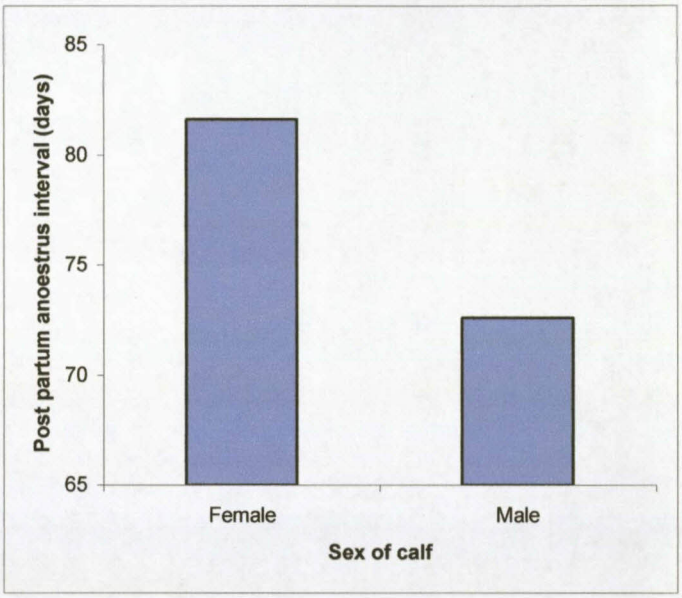

Figure 4.14 Effect of sex of the calf on the post partum anoestrous interval in Horro cows

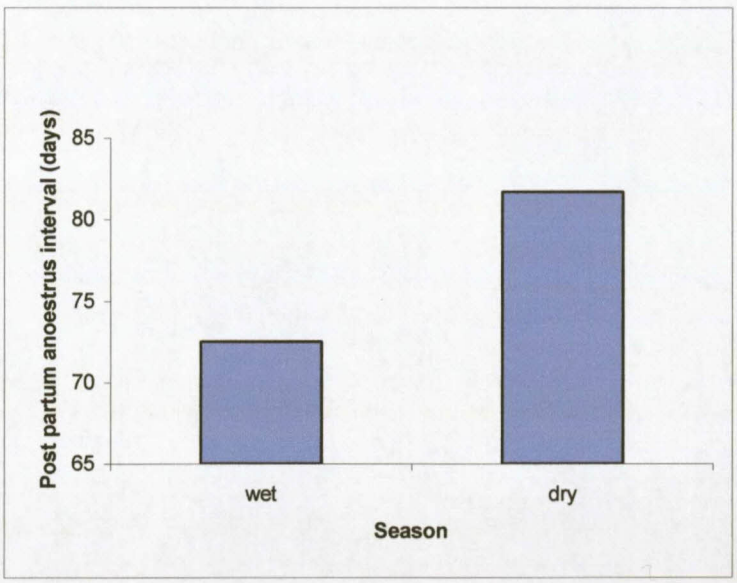

Figure 4.15 The effect of season of calving on the post partum anoestrous interval in Horro cattle

Table 4.4 Least square means (± SE) for post partum anoestrous interval and post partum period in Horro cows

Source of variability	n	Mean post partum anoestrous interval (days) ±SE	n	Mean post partum period (days) ±SE
Overall	75	77.2	473	117.5
Season of calving*				
Wet		72.5 ± 3.4^{a}		118.9 ± 4.4^{NS}
Dry		81.7 ± 2.9^{b}		122.4 ± 3.8^{NS}
Year of calving**				
1977		133.6 ± 7.2^{b}		149.8 ± 7.5^{abcd}
1978		148.9 ± 12.6^{ab}		179.5 ± 14.1^{a}
1979		171.6 ± 11.9^{a}		175.9 ± 11.6^{ab}
1980		141.1 ± 8.8^{ab}		160.6 ± 9.7^{abc}
1981		71.2 ± 8.7^{cde}		122.2 ± 9.0^{abcdef}
1982		73.1 ± 7.1^{cde}		120.3 ± 13.4^{abcdef}
1983		53.2 ± 13.0^{cde}		104.4 ± 14.9^{cdef}
1984		90.8 ± 14.9^{c}		140.9 ± 22.3^{abcd}
1985		37.2 ± 17.7^{e}		104.9 ± 18.2^{cdef}
1986		49.1 ± 13.5^{de}		142.3 ± 16.9^{abcde}
1987		78.4 ± 13.5^{cd}		114.9 ± 14.1^{cdef}
1988		48.4 ± 11.7^{de}		89.7 ± 18.3^{def}
1989		47.9 ± 16.6^{de}		83.7 ± 19.9^{ef}
1990		52.3 ± 10.8^{cde}		105.9 ± 15.7^{cdef}
1991		96.4 ± 15.6^{c}		125.4 ± 25.7^{abcdef}
1992		75.2 ± 23.4^{cde}		141.9 ± 25.7^{abcde}
1993		85.1 ± 13.6^{cd}		134.3 ± 15.8^{abcdef}
1994		48.6 ± 8.0^{de}		104.9 ± 7.9^{cdef}
1995		60.2 ± 7.8^{cde}		105.4 ± 7.8^{cdef}
1996		51.3 ± 8.3^{de}		91.1 ± 8.3^{def}
1997		71.9 ± 7.2^{cde}		138.4 ± 8.2^{abcde}
1998		65.9 ± 6.2^{cde}		96.9 ± 6.7^{def}
1999		70.9 ± 5.3^{cde}		98.1 ± 5.9^{def}
2000		66.8 ± 5.1^{cde}		107.4 ± 5.9^{cdef}
2001		38.8 ± 19.2^{de}		77.1 ± 44.4^{f}
Sex of calf*				
Female		81.6 ± 3.2^{a}		123.1 ± 4.1^{NS}
Male		72.6 ± 3.0^{b}		118.2 ± 3.9^{NS}

NS = no significant difference

abcdef = Means in the same column for the same factor with different superscripts differ significantly

* = (P<0.05)

** = (P<0.01)

The overall least square mean for the post partum anoestrous interval in Horro cattle recorded was 77.2 days (ranging from 37.2 ± 17.7 days to 171.6 ± 11.9 days). Season of calving significantly ($P<0.05$) affected the post partum anoestrous interval. Cows that calved during the dry season recorded a longer post partum anoestrous interval, compared to cows calving during the wet season (81.7 ± 2.9 days for dry season vs 72.5 ± 3.4 for wet season, respectively).

Year of calving significantly ($P<0.01$) affected the post partum anoestrous interval with significant differences between some years. Sex of the calf (Table 4.4 and Figure 4.14) significantly ($P<0.01$) affected the post partum anoestrous interval. Cows that gave birth to female calves recorded a longer post partum oestrous interval, compared to cows that gave birth to male calves (81.6 ± 3.2 days for female and 72.6 ± 3.0 for male calves, respectively).

There was a trend for the mean post partum anoestrous period to decrease over years (Figure 4.13). This seems to be reflected in the corresponding decreasing interval to first service following calving. The overall least square means for the post partum period was 117.5 days (77.1 ± 44.4 days to 179.5 ± 14.1 days) and was not affected by season of calving, calf birth weight or sex of the calf. However the year of calving significantly ($P<0.01$) affected the post partum period (Table 4.4 and Figures 4.16, 4.17 and 4.18).

4.5 THE INTERCALVING PERIOD (ICP) AND GESTATION LENGTH IN HORRO CATTLE

The least square mean (± SE) for intercalving period and gestation length are set out in Table 4.5 and Figures 14.19 to 4.26 respectively. The overall mean intercalving period recorded over the years was ± 475.2 days, ranging from 342.9 ± 34.9 to 671.1 ± 32.2 days. The intercalving period was not significantly affected by the season of calving, sex of the calf or calf birth weight. However, both year of calving ($P<0.01$) and parity ($P<0.05$) affected the intercalving period of the dam. Cows in their first two parities recorded a longer intercalving period (503.7 ± 8.8 days), compared to

cows in their 3rd or higher parity. Cows that calved in the wet season recorded a longer intercalving period (473.9 ± 8.1 days), compared to cows that calved during the dry season (465.5 ± 6.8 days). These differences were however not significant (Figure 4.20). The sex of the calf did not have a significant effect on the intercalving period of their dams (Figure 4.23).

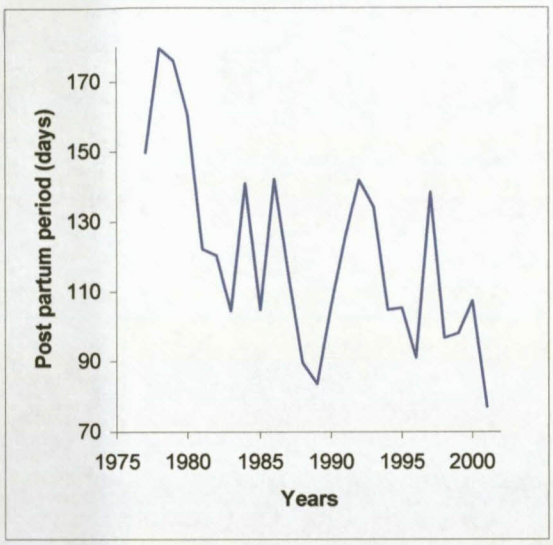

Figure 4.16 Effect of year on post partum period for the period 1977-2000

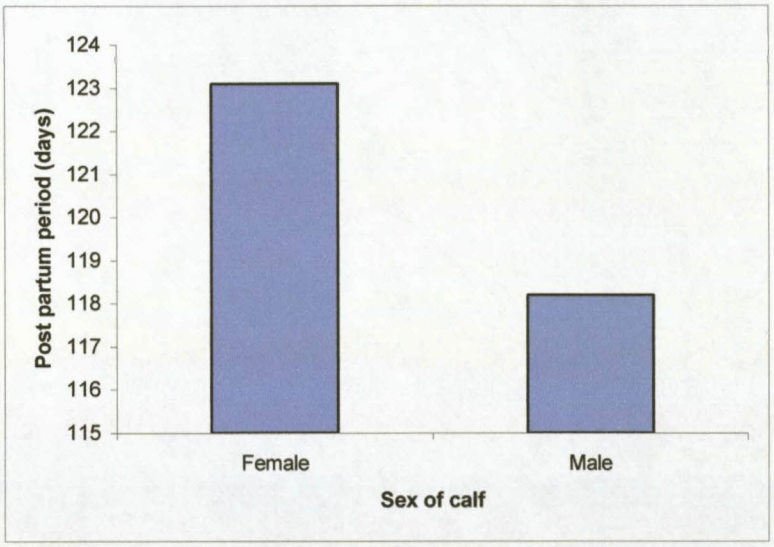

Figure 4.17 The effect of sex of the calf on post partum period in Horro cows (1977-2000)

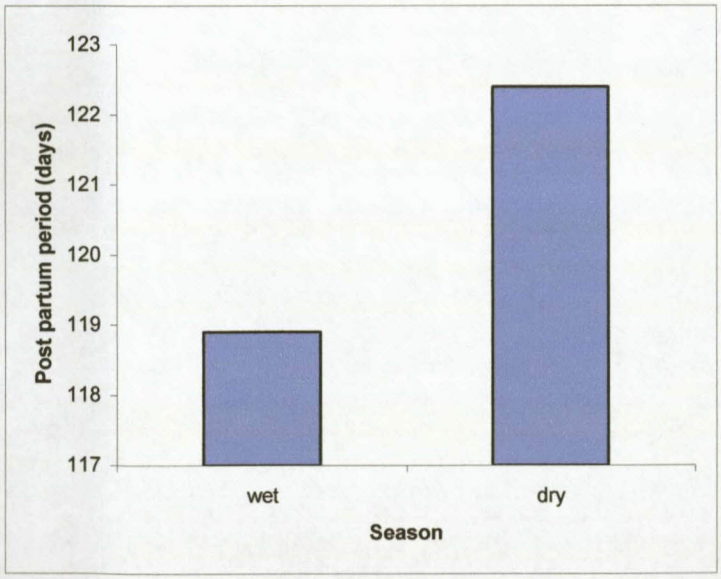

Figure 4.18 Effect of season on post partum period in Horro cows (1977-2000)

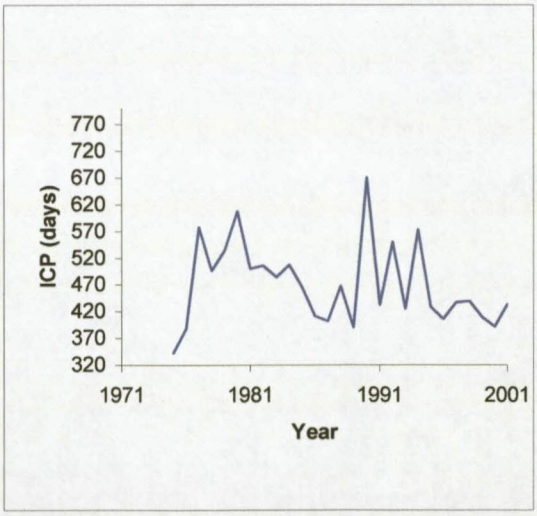

Figure 4.19 Effect of year of calving on the intercalving period for the period 1977-2001 in Horro cattle

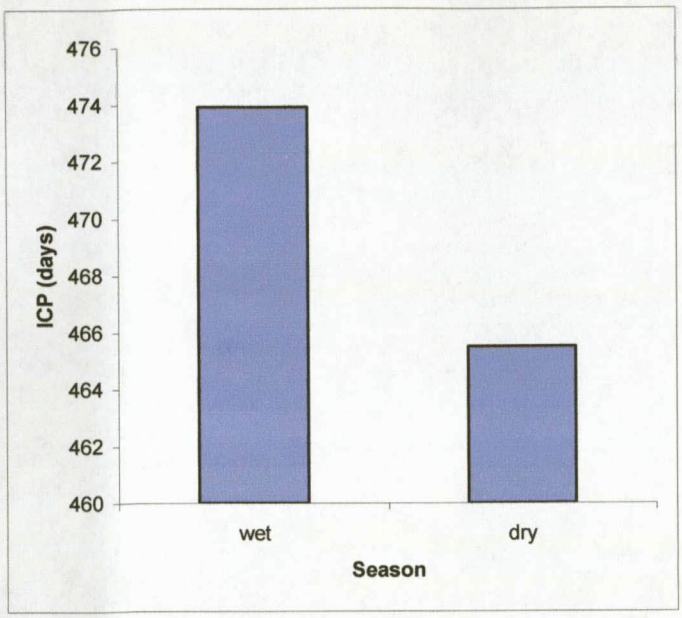

Figure 4.20 The effect of season of calving on the intercalving period in Horro cattle

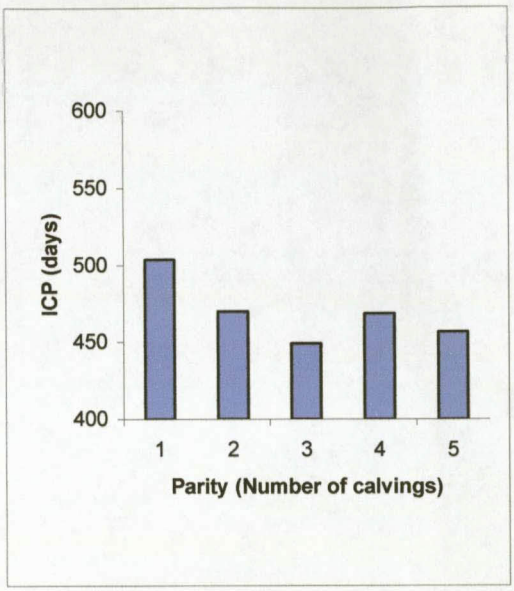

Figure 4.21 The effect of parity on inter-calving period in Horro cattle

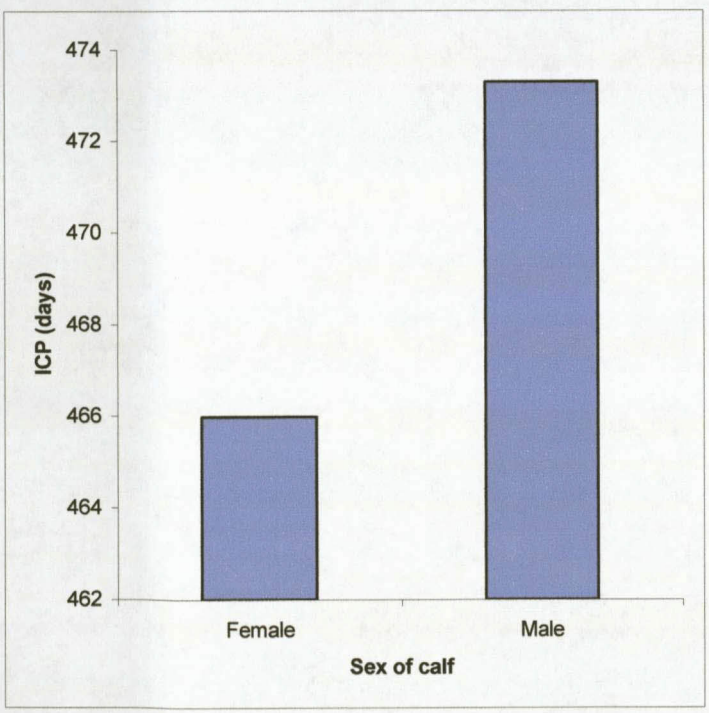

Figure 4.22 The effect of sex of calf on the intercalving period in Horro cattle

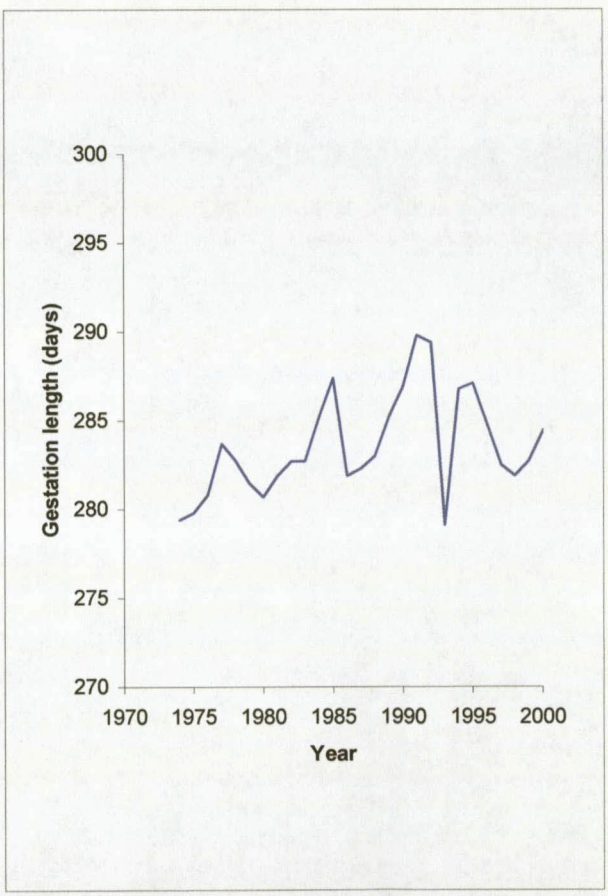

Figure 4.23 The effect of year of calving on the gestation length in Horro cattle

Table 4.5 **Least square means (± SE) for intercalving period and gestation length in Horro cows for the period 1975 to 2001**

Source of variability	n	Intercalving period mean ± SE (days)	n	Gestation period mean ± SE (days)
Overall	673	475.2	884	283.0
Parity				
1-2		503.7 ± 8.8^{a}		283.4^{a}
2-3		469.0 ± 9.7^{b}		282.9^{a}
3-4		449.2 ± 11.2^{b}		283.7^{a}
4-5		468.6 ± 13.3^{b}		284.0^{a}
5-6		456.8 ± 16.4^{b}		283.8^{a}
Season of calving^{NS}				
Wet		473.9 ± 8.1^{NS}		284.1 ± 0.4^{NS}
Dry		465.5 ± 6.8^{NS}		283.2 ± 0.3^{NS}
Sex of calf*				
Female		466.0 ± 7.6^{NS}		283.1 ± 0.3^{a}
Male		473.3 ± 7.2^{NS}		284.2 ± 0.3^{b}
Year of calving**				
1975		342.9 ± 34.9^{mnopq}		279.8 ± 0.9^{hijklm}
1976		387.9 ± 29.5^{mnopq}		280.8 ± 1.4^{hijklm}
1977		577.6 ± 18.1^{abc}		283.7 ± 0.8^{ghijkl}
1978		496.2 ± 21.9^{efghij}		282.8 ± 0.9^{hijklm}
1979		533.72 ± 23.2^{cdef}		281.5 ± 1.2^{hijklm}
1980		608.2 ± 20.2^{ab}		280.7 ± 0.9^{hijklm}
1981		500.7 ± 21.0^{efghi}		281.9 ± 0.9^{a}
1982		506.3 ± 18.5^{efghi}		282.7 ± 0.9^{hijklm}
1983		484.4 ± 26.6^{efghijk}		282.7 ± 1.5^{hijklm}
1984		507.2 ± 27.8^{defg}		285.2 ± 1.5^{bcdefghi}
1985		$465.4 \pm 32.9^{fghijklm}$		287.4 ± 1.6^{abc}
1986		411.5 ± 31.1^{klmnopq}		281.9 ± 1.3^{hijklm}
1987		402.6 ± 31.2^{imnpq}		$282.3 \pm 1.6^{iokl;,}$
1988		468.0 ± 29.0^{fghijkl}		283.0 ± 1.4^{ghijklm}
1989		390.5 ± 50.5^{imnopq}		285.2 ± 2.4^{bcdefgh}
1990		671.1 ± 32.2^{a}		286.9 ± 1.2^{abcde}
1991		432.4 ± 42.6^{kimnopq}		289.8 ± 1.9^{a}
1992		550.2 ± 29.1^{bcde}		$289.4 \pm 2.7^{ab}*$
1993		425.4 ± 35.4^{klmnopq}		$279.1 \pm 1.8^{m}*$
1994		572.7 ± 23.3^{bcd}		286.8 ± 1.0^{abcdef}
1995		429.1 ± 20.2^{klmnopq}		287.1 ± 1.0^{abcd}
1996		406.2 ± 22.3^{imnopq}		$284.8 \pm 1.0^{bcdefghij}$
1997		436.6 ± 20.6^{klmno}		282.5 ± 0.8^{hijklm}
1998		$439.3 \pm 26.3^{ghijklmn}$		281.9 ± 0.7^{hijklm}
1999		409.6 ± 17.5^{imnopq}		282.7 ± 0.6^{hijklm}
2000		392.0 ± 13.2^{imnopq}		$284.4 \pm 0.6^{bcdefghijk}$
2001		432.9 ± 16.5^{klmnop}		285.5 ± 0.7^{bcdefg}

NS = no significant difference

a to q = Means in the same column for the same factor with different superscripts differ significantly

* = $P<0.05$

** = $P<0.01$

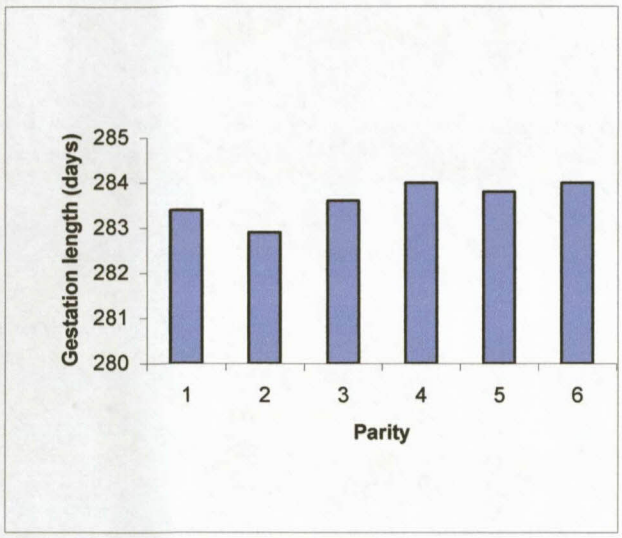

Figure 4.24 The effect of parity on gestation length in Horro cattle

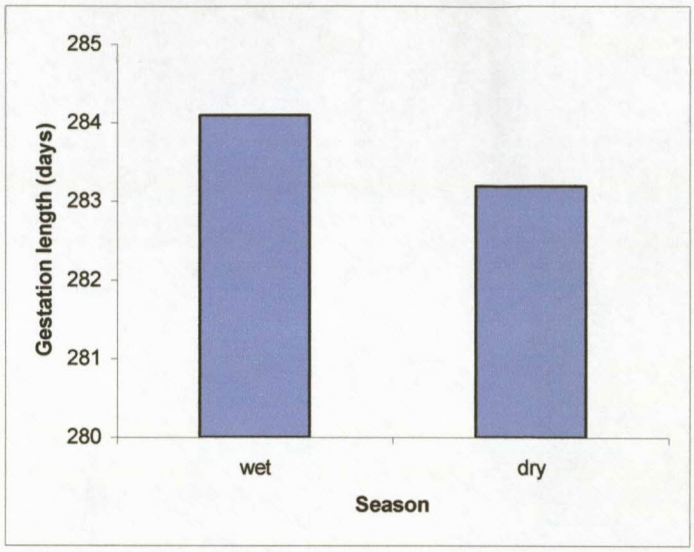

Figure 4.25 The effect of season of calving on gestation length in Horro cattle

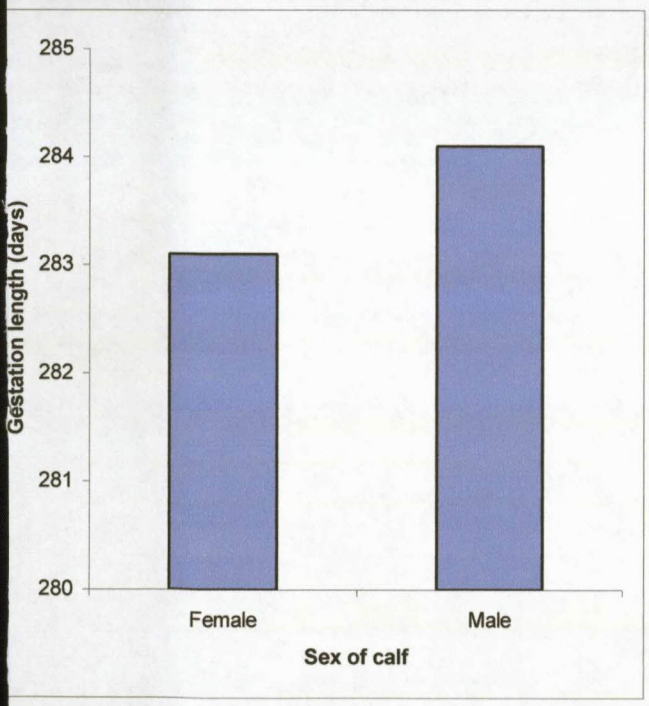

Figure 4.26 The effect of sex of calf on the gestation length in Horro cattle

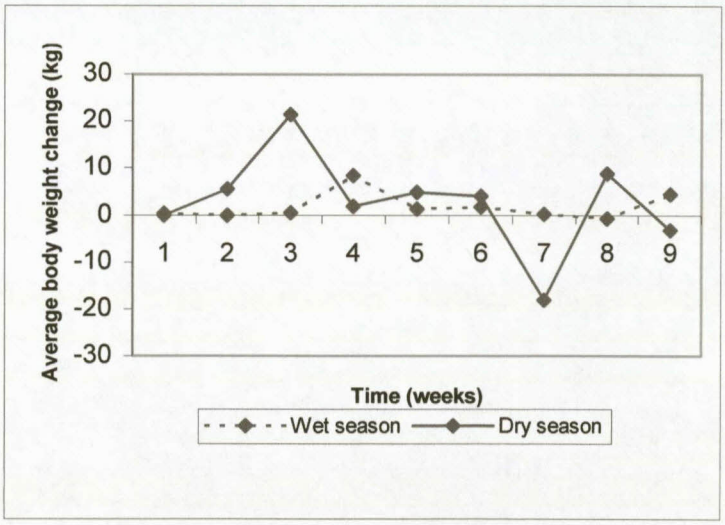

Figure 4.27 Live body weight changes of post partum Horro cows during the wet and dry seasons

The overall least square mean gestation length over the observation period was 283 days (279.8 ± 0.9 to 289.8 ± 1.9 days) (Figure 4.23). The gestation length was not affected by parity. However, the year of calving significantly ($P<0.01$) affected gestation length. Similarly the season of calving significantly ($P<0.05$) affected the gestation length, with those cows calving during the wet season having a longer gestation length. The sex of the calf also significantly ($P<0.05$) affected gestation length with the male calves inducing a longer gestation period (Figure 4.26). Calf birth weight was not affected by the gestation length in Horro cows.

4.6 LIVE WEIGHT CHANGES IN POST PARTUM HORRO COWS

The live weight changes in post partum cows are set out in Figure 4.27. Cows that calved during the dry season lost more weight during the post partum period (from parturition until conception), compared to those that calved during the wet season. Cows that calved during the dry season were heavier, but subsequently lost more weight. Cows that calved during the wet season tended to better maintain their body weight throughout the post partum period. Of the cows that calved during the dry season, 50% did not show oestrus by 90 days post partum, whereas those that calved during the wet season, only 20% did not exhibit oestrus. Of the total number of cows that calved during the dry season, only 20% became pregnant within 90 days post partum, compared to 60% that calved during the wet season and conceived.

4.7 POST PARTUM SERUM PROGESTERONE CONCENTRATION IN HORRO COWS

The least square means for post partum serum progesterone concentrations are illustrated in Figure 4.28. The mean progesterone level during the wet season (8.5 ± 0.77 ng/ml) was significantly ($P<0.01$) higher than the level during the dry season (2.8 ± 0.92 ng/ml). The initial body weight of the cows at calving also significantly ($P<0.01$) affected the post partum serum progesterone concentration.

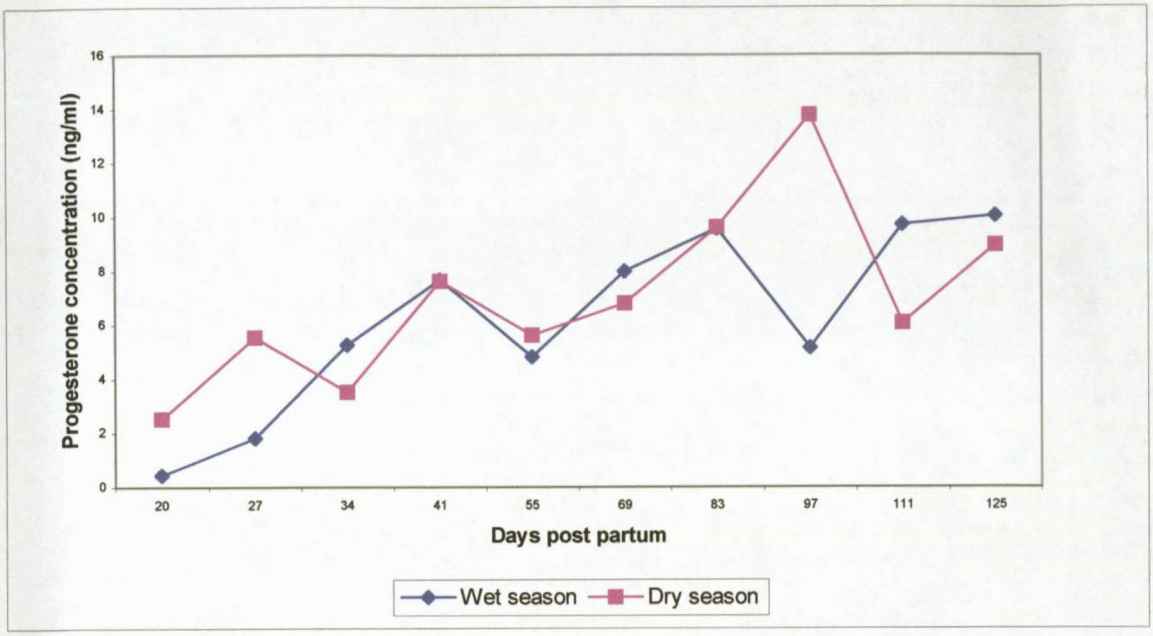

Figure 4.28 Serum progesterone profile of post partum Horro cows calving during wet and dry season

4.8 BODY WEIGHT IN HORRO CATTLE

4.8.1 Birth and 3 month of age weights in Horro calves

The least square means (± SE) for birth weight of the calves are set out in Table 4.6 and Figures 4.29 to 4.31. The overall least square mean birth weight of the calves in the present study was 18.4 kg (18.1 ± 0.25 kg and 19.3 ± 0.22 kg for females and males respectively). From Table 4.6 it is evident that sex significantly ($P<0.01$) affected the birth weight of the calf, with male calves being 6.6% heavier than their female counterparts. Season of birth had no effect on calf birth weight. However, the year of birth (Figure 4.29) played a significant role ($P<0.05$) in calf birth weight. Calves born in 1979 (21.5 ± 1.3 kg) were significantly heavier than in all other years and those born in 1984 (16.8 ± 0.8 kg) lighter. The mean weight at 3 months of age was 48.9 kg (ranging from 33.8 ± 5.2 kg to 68.5 ± 1.9 kg) and was not affected by the sex of the calf. Season of birth (Figure 4.32) significantly ($P<0.05$) affected body weight at 3 months. Calves born during the wet season were 4.5% heavier, than those born during the dry season. The year of birth significantly ($P<0.01$) affected 3

month body weight of the calves. In 1977, the calves were significantly heavier at 3 months than in the other years. To the contrary, those born in 2001 were lighter. Calf birth weight (Figure 4.34) did not affect the weight of calves at 3 months of age. From Figure 4.32 it is evident that the body weight of the calves at 3 months of age decreases gradually over the 25 year observation period.

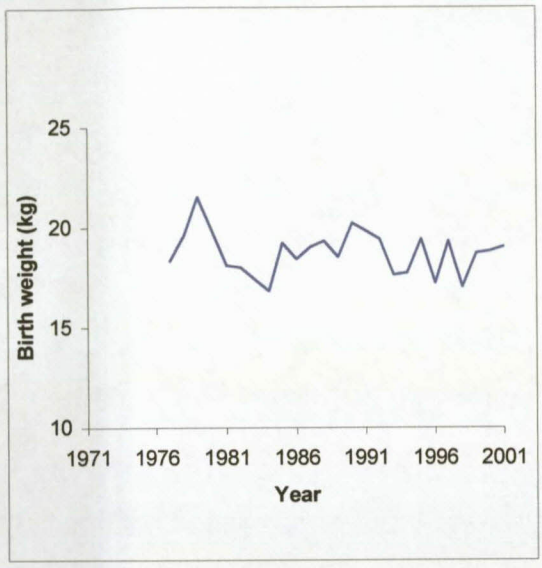

Figure 4.29 Effect of year of birth on calf birth weight for the period 1977-2001

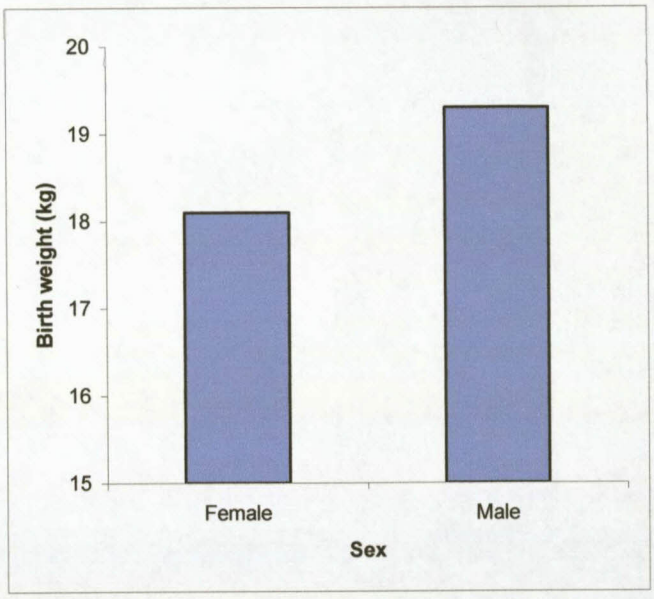

Figure 4.30 Effect of sex of the calf on calf birth weight of Horro calves

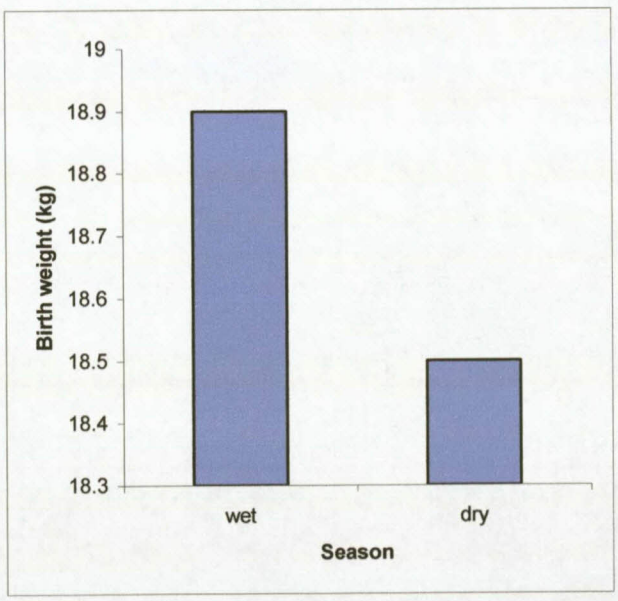

Figure 4.31 Effect of season (wet or dry) of birth on Horro calf birth weight

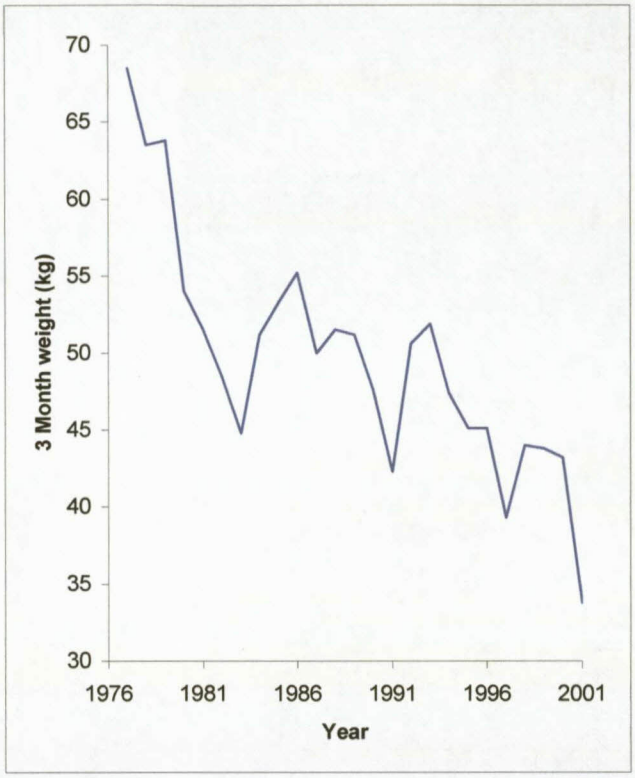

Figure 4.32 Effect of year of birth on 3 month body weight in Horro calves (1977-2001)

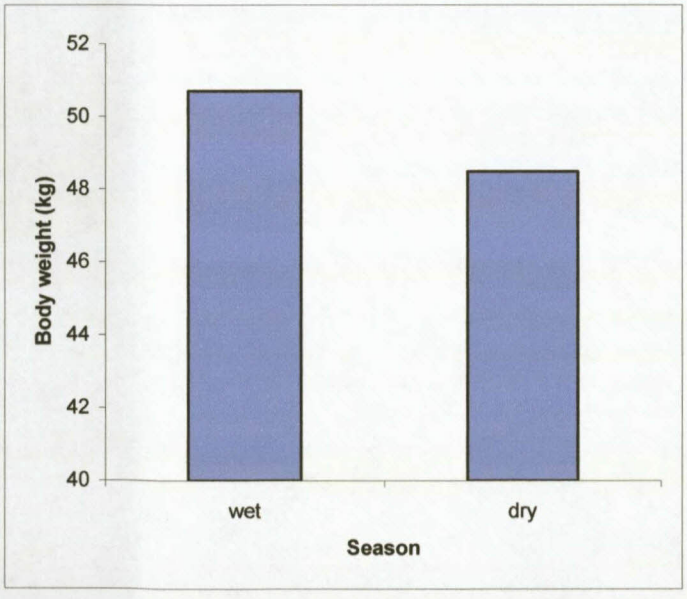

Figure 4.33 Effect of season of birth (wet of dry) on 3 month calf weight in Horro calves

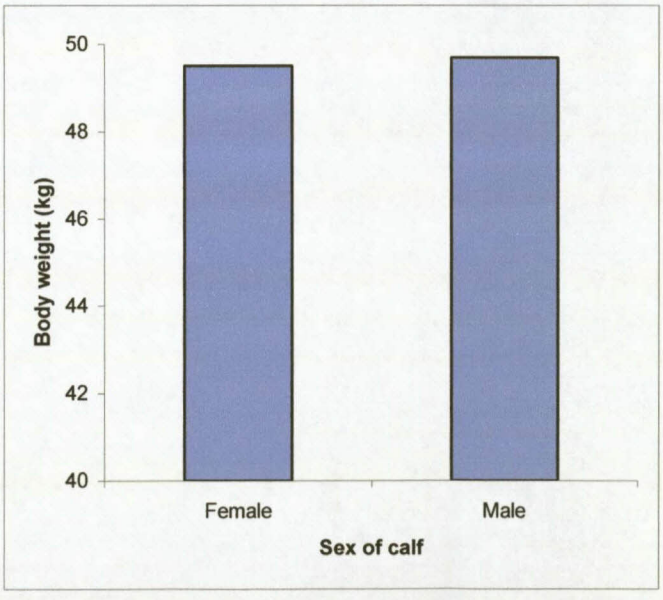

Figure 4.34 Effect of sex of the calf on the 3 month body weight (kg) in Horro cattle

Table 4.6 Least square means (± SE) for birth and 3 month body weight in Horro calves

Source of variability	Birth weight		Three month weight	
	n	Mean (kg) ± SE	n	Mean (kg) ± SE
Overall	464	18.4	370	48.9
Sex of calf**				
Female		18.1 ± 0.3^{a}		49.5 ± 1.0^{NS}
Male		19.3 ± 0.2^{b}		49.7 ± 0.9^{NS}
Season of birth				
Wet		18.9 ± 0.3^{NS}		50.7 ± 1.0^{a}
Dry		18.5 ± 0.2^{NS}		48.5 ± 0.8^{b}
Year of birth*				
1977		18.3 ± 0.6^{abc}		68.5 ± 1.9^{a}
1978		19.6 ± 0.7^{abc}		63.5 ± 2.4^{ab}
1979		21.5 ± 1.3^{a}		63.8 ± 4.1^{ab}
1980		19.8 ± 1.1^{ab}		54.0 ± 3.4^{bc}
1981		18.1 ± 0.7^{abc}		51.5 ± 2.2^{de}
1982		18.0 ± 0.5^{abc}		48.5 ± 1.8^{dc}
1983		17.4 ± 1.0^{bc}		44.8 ± 3.2^{cde}
1984		16.8 ± 0.8^{c}		51.2 ± 3.2^{de}
1985		19.2 ± 1.0^{abc}		53.3 ± 3.2^{bc}
1986		18.4 ± 0.8^{abc}		55.2 ± 2.7^{bc}
1987		19.0 ± 1.0^{ab}		50.0 ± 3.2^{de}
1988		19.3 ± 0.6^{abc}		51.5 ± 2.2^{e}
1989		18.5 ± 0.9^{abc}		51.2 ± 2.9^{de}
1990		20.2 ± 0.7^{ab}		47.6 ± 2.7^{de}
1991		19.8 ± 1.0^{ab}		42.3 ± 3.7^{dce}
1992		19.4 ± 2.0^{ab}		50.6 ± 9.0^{e}
1993		17.6 ± 2.0^{abc}		51.9 ± 9.0^{de}
1994		17.7 ± 0.5^{bc}		47.4 ± 1.5^{de}
1995		19.4 ± 0.5^{abc}		45.1 ± 1.7^{dce}
1996		17.2 ± 0.5^{bc}		45.1 ± 1.9^{dce}
1997		19.3 ± 1.0^{abc}		39.3 ± 3.4^{de}
1998		17.0 ± 1.2^{bc}		44.0 ± 3.7^{dce}
1999		18.7 ± 0.5^{abc}		43.8 ± 1.8^{dce}
2000		17.8 ± 0.3^{bc}		43.2 ± 1.1^{dce}
2001		19.0 ± 0.8^{abc}		33.8 ± 5.2^{e}

NS = no significant difference

abcde = means in the same column for the same factor with different superscripts differ significantly

* = $P<0.05$

** = $P<0.01$

4.8.2 The 6 and 12 month body weight in Horro calves

The least square mean for 6 and 12 month calf weights are presented in Table 4.7 and set out in Figures 4.35 to 4.40. The mean 6 month weight recorded was 68 kg (58.9 ± 5.2 kg to 94.3 ± 2.6 kg) and this was not affected by either the sex of the calf or the season of birth. Year of birth and birth weight had a significant ($P<0.01$) affect on calf weight at 6 months of age. The 6 month weight (Table 4.7) of the calves decreased drastically between 1977 and 1982 and thereafter remained reasonably constant. An overall average 12 month weight of 85.7 kg was recorded for the period of 1977 to 2000 (Table 4.7) - ranging from 62.9 ± 16.9 kg to 121.7 ± 8.5 kg with the lowest weights being recorded in 1982. The sex of the calf (Figure 4.39) significantly ($P<0.05$) affected the calf weight at 12 months with female calves being heavier than the male calves at that age (5.8% difference). The season of birth (wet or dry) significantly ($P<0.05$) affected the weight at 12 months of age with calves born during the wet season being heavier than those born during the dry season (difference of 14.8%) (Table 4.7). Year of birth significantly ($P<0.01$) affected the weight at 12 months in calves, when comparing the 24 years data (1977-2000). Similarly birth weight was positively and significantly ($P<0.05$) correlated with the 6 month ($r = 0.21$) and 12 month ($r = 0.19$) body weight respectively.

4.8.3 The 18 and 24 month body weight in Horro cattle

The mean (± SE) for 18 and 24 month weights are presented in Table 4.8 and set out in Figures 4.41 to 4.46.

The overall average 18 month weight recorded over the 22 years (1977-1999) was 109.7 kg (ranging from 83.2 ± 14.6 kg to 142.8 ± 14.7 kg). Heifers were significantly ($P<0.01$) heavier than young bulls (Figure 4.42) at 18 months of age. Season of birth however, did not affect the weight of the animals at 18 months of age. The year of birth significantly ($P<0.01$) affected the weight of the animals at 18 months of age with the years 1980 to 1982 and 1997 and 1998 producing significant lighter animals (Table 4.8). Similarly the weight at birth significantly ($P<0.05$) affected the weight of animals at 18 months of age with the heavier calves at birth also being heavier at a later age. The overall least square means weight at 24 month

weight was 140.9 kg, ranging from 109.2 ± 10.1 kg to 172.0 ± 18.9 kg. The sex of the calves (Figure 4.46) had a significant (P<0.05) effect on the weight of the animal at 24 months of age, with females being 3.2% heavier than their male counterparts at that age. The season of birth significantly (P<0.01) affected the weight at 24 months of age with the wet season born calves being heavier at 24 months than those born during the dry season (Table 4.8). The year of birth (Table 4.8 and Figure 4.44) also significantly affected the weight at 24 months in certain years.

Table 4.7 Least square means (± SE) for 6 and 12 month body weight in Horro calves

Source of variability	6 Month weight		12 Month weight	
	n	Mean (kg) ± SE	n	Mean (kg) ± SE
Overall	344	68	279	85.7
Sex of calf				
Female		69.1 ± 1.3^{NS}		89.4 ± 1.9^{a}
Male		69.2 ± 1.2^{NS}		84.5 ± 1.8^{b}
Season of birth				
Wet		69.3 ± 1.4^{NS}		93.2 ± 2.1^{a}
Dry		68.3 ± 1.2^{NS}		80.7 ± 1.7^{b}
Year of birth**				
1977		94.3 ± 2.6^{a}		112.8 ± 3.9^{a}
1978		88.5 ± 3.3^{ab}		99.5 ± 4.4^{abc}
1979		98.3 ± 5.7^{a}		121.7 ± 8.5^{a}
1980		66.4 ± 4.8^{dc}		75.9 ± 6.5^{fe}
1981		62.4 ± 3.0^{dc}		71.1 ± 4.4^{fe}
1982		57.8 ± 2.6^{d}		64.3 ± 3.8^{f}
1983		67.2 ± 5.2^{dc}		85.8 ± 12.2^{fe}
1984		62.9 ± 4.5^{de}		83.9 ± 6.0^{efd}
1985		71.5 ± 4.5^{dc}		87.2 ± 6.0^{cdef}
1986		72.2 ± 3.8^{bc}		04.6 ± 5.1^{abcd}
1987		71.0 ± 4.5^{dc}		109.0 ± 6.4^{ab}
1988		73.4 ± 3.1^{dc}		91.4 ± 4.1^{abcde}
1989		67.9 ± 4.0^{dc}		90.9 ± 5.7^{cdef}
1990		66.9 ± 4.8^{dc}		80.5 ± 6.0^{fde}
1991		59.1 ± 4.5^{dc}		70.4 ± 6.0^{fe}
1992		63.8 ± 12.6^{dc}		62.9 ± 16.9^{fe}
1993		69.8 ± 12.6^{dc}		-
1994		60.5 ± 2.1^{dc}		80.8 ± 3.0^{fde}
1995		69.2 ± 2.4^{dc}		84.8 ± 3.4^{cdef}
1996		73.3 ± 2.8^{dc}		88.2 ± 3.9^{cde}
1997		58.9 ± 5.2^{d}		87.9 ± 9.8^{fde}
1998		59.9 ± 5.2^{d}		76.9 ± 12.0^{fe}*
1999		59.1 ± 2.5^{d}		91.9 ± 3.5^{bcde}
2000		59.5 ± 1.9^{d}		76.5 ± 4.7^{fe}

NS = no significant difference

abcdef = means in the same column for the same factor with different superscripts differ significantly

** = (P<0.01)

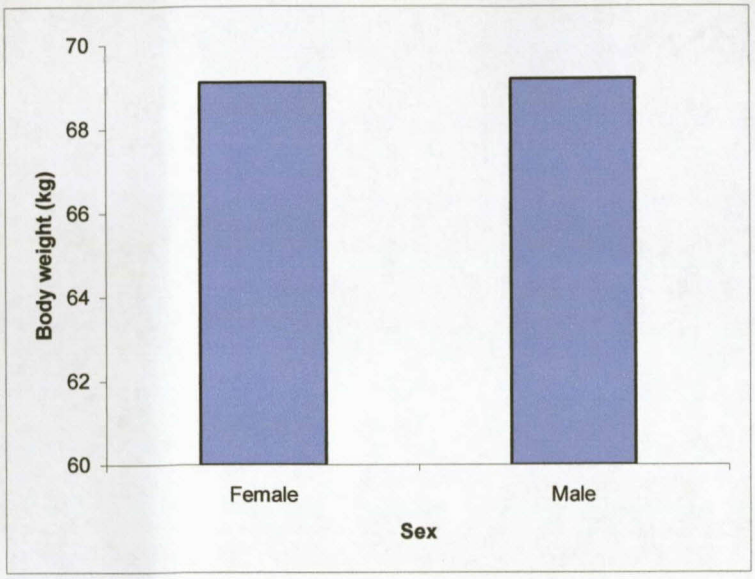

Figure 4.35 Effect of sex of the calf on the 6 month body weight in Horro calves

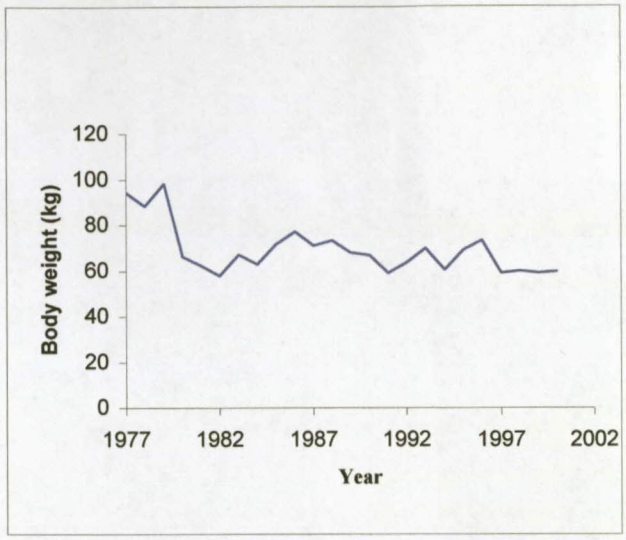

Figure 4.36 Effect of year of birth on the 6 month weight of Horro calves for the period 1977-2001

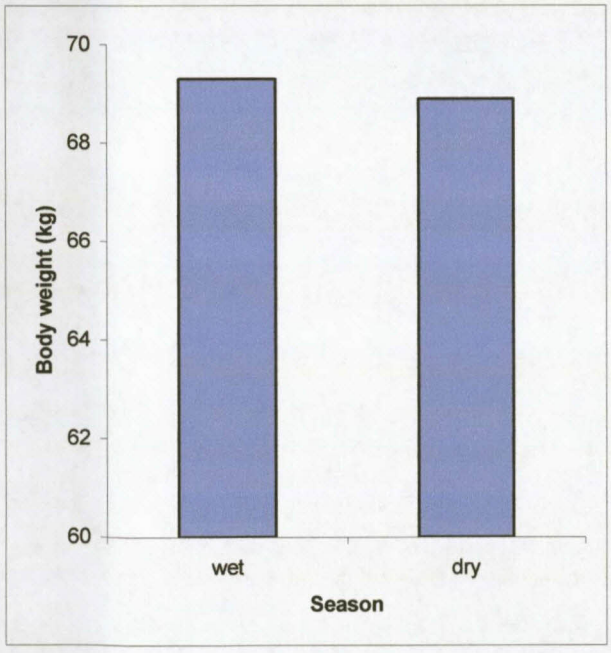

Figure 4.37 Effect of season of birth (wet or dry) on 6 month body weight in Horro calves

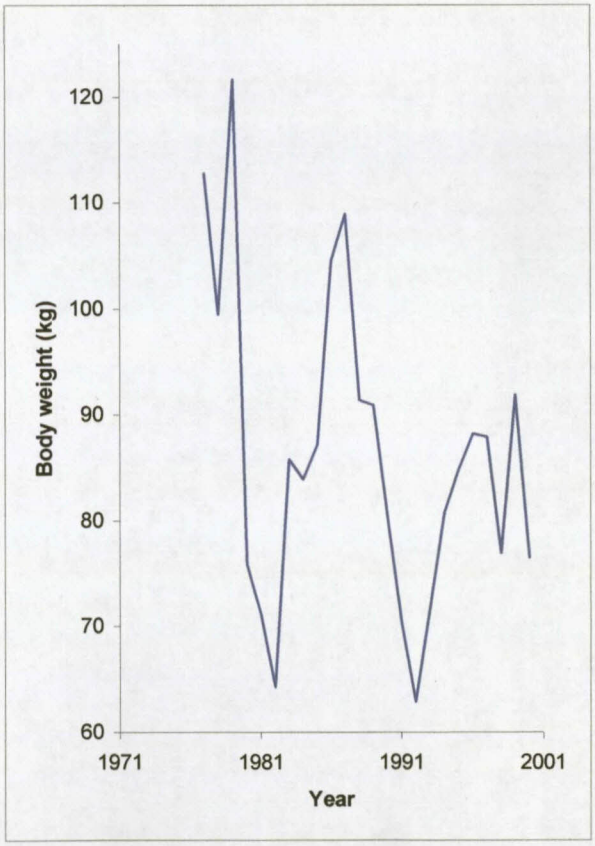

Figure 4.38 Effect of year of birth on yearling weight (kg) in Horro cattle for the period 1977-2001

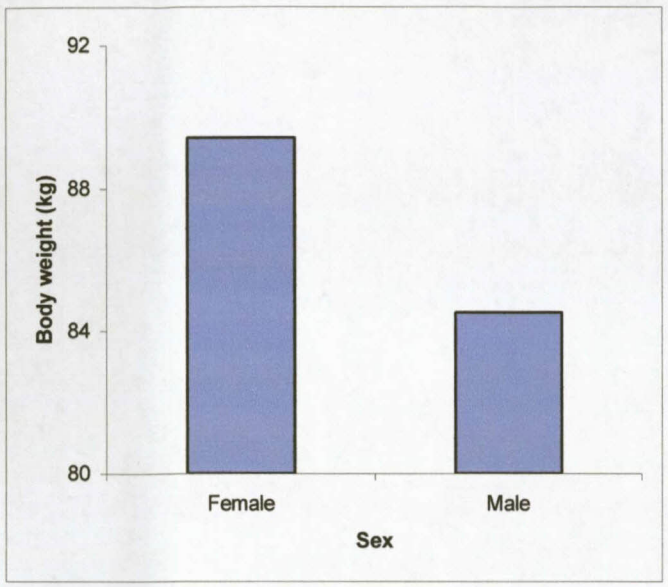

Figure 4.39 Effect of sex of the calf on yearling weight of Horro cattle

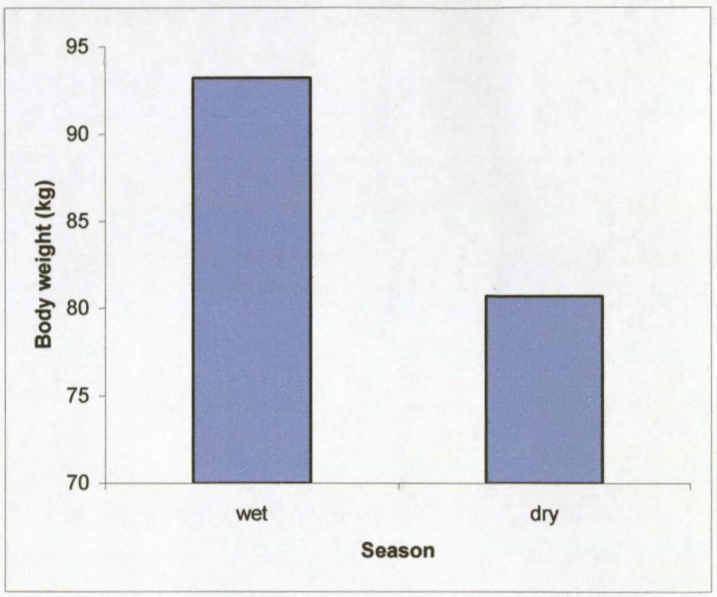

Figure 4.40 Effect of season of birth (wet or dry) on yearling weight of Horro cattle

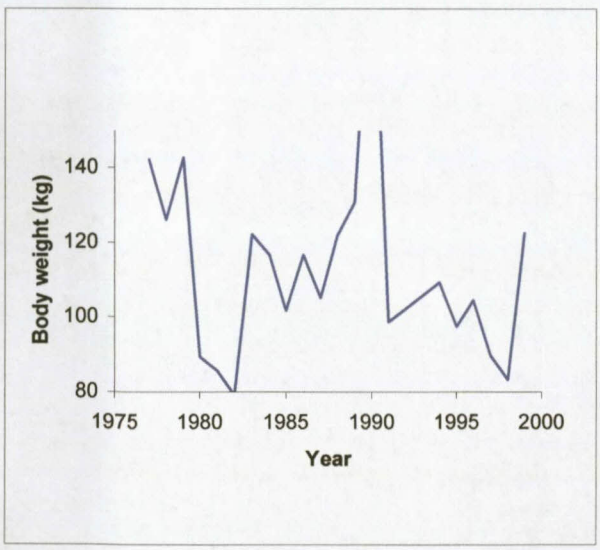

Figure 4.41 Effect of year of birth (1977-2000) on 18 month body weight in Horro cattle

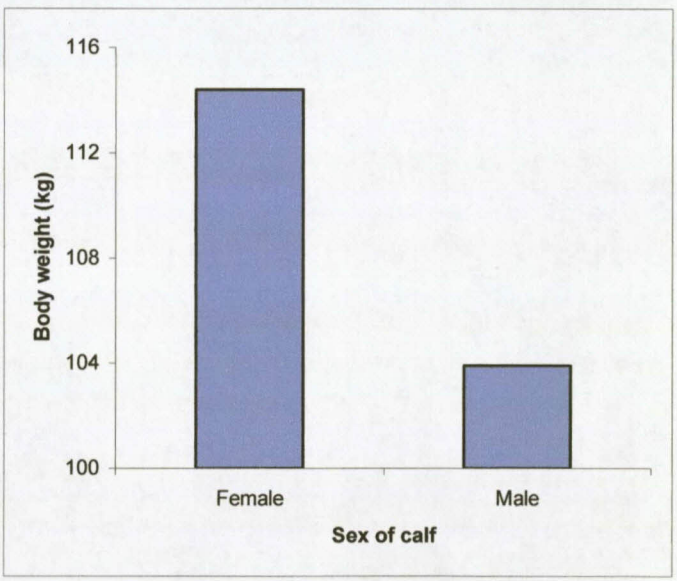

Figure 4.42 Effect of sex of calf on body weight in 18 month Horro cattle

Table 4.8 Least square means (± SE) for 18 and 24 month body weight in Horro calves

Source of variability	18 Month weight		24 Month weight	
	n	Mean (kg) ± SE	n	Mean (kg) ± SE
Overall	214	109.7	185	140.9
Sex of calf*				
Female		114.4 ± 2.4^{a}		145.6 ± 3.3^{a}
Male		103.9 ± 2.8^{b}		140.9 ± 4.1^{b}
Season of birth				
Wet		108.6 ± 2.9^{NS}		149.5 ± 4.1^{a}
Dry		109.7 ± 2.3^{NS}		136.9 ± 3.2^{b}
Year of birth**				
1977		142.3 ± 5.0^{ab}		169.9 ± 6.8^{a}
1978		126.2 ± 5.4^{abcd}		152.8 ± 9.1^{abc}
1979		142.8 ± 14.7^{a}		172.02 ± 18.9^{ab}
1980		89.4 ± 8.5^{fghi}		126.6 ± 13.3^{cde}
1981		85.7 ± 5.7^{ghi}		121.4 ± 7.4^{cde}
1982		79.2 ± 5.2^{i}		110.3 ± 7.7^{e}
1983		122.2 ± 14.9^{bcdefg}		163.9 ± 19.3^{abcd}
1984		116.8 ± 7.8^{abcdef}		159.6 ± 10.1^{abc}
1985		101.8 ± 7.5^{cdefghi}		143.2 ± 12.0^{abcde}
1986		116.7 ± 7.3^{bcdefgh}		164.6 ± 11.0^{abc}
1987		105.2 ± 10.3^{cdefghi}		152.9 ± 15.4^{abcd}
1988		121.8 ± 5.5^{abcde}		167.1 ± 7.7^{ab}
1989		130.8 ± 8.4^{abc}		159.6 ± 10.1^{abcd}
1990		106.2 ± 6.3^{cdefghi}		131.1 ± 8.1^{bcde}
1991		98.7 ± 8.4^{eidfgh}		109.2 ± 10.1^{de}
1994		109.4 ± 3.7^{cdefghi}		149.2 ± 4.7^{abcde}
1995		97.5 ± 4.1^{defghi}		122.6 ± 5.4^{cde}
1996		104.6 ± 5.8^{cdefghi}		130.6 ± 8.5^{bcde}
1997		89.7 ± 20.6^{efghi}		114.4 ± 26.6^{e}
1998		83.2 ± 14.6^{hi}		145.5 ± 18.9^{abcde}
1999		122.6 ± 7.9^{abcde}		-

NS = no significant difference

a to i = means in the same column for the same factor with different superscripts differ significantly

* = $P<0.05$

** = $P<0.01$

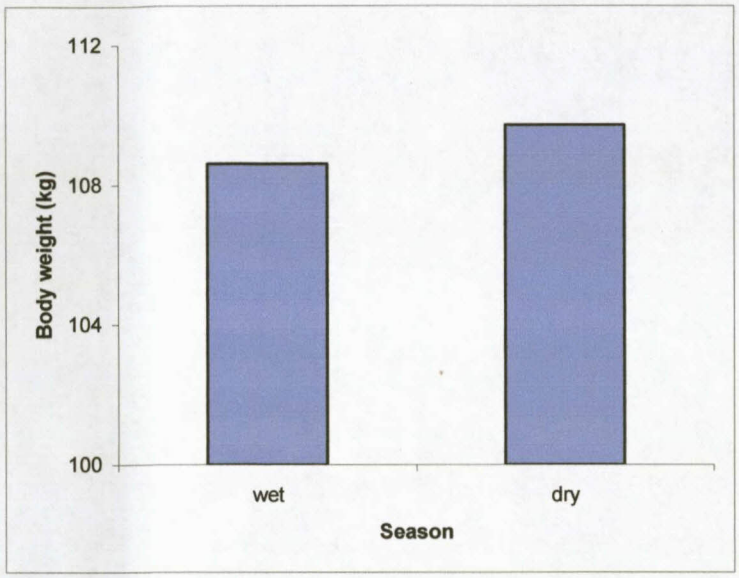

Figure 4.43 Effect of season of birth (wet or dry) on body weight in 18 month old Horro cattle

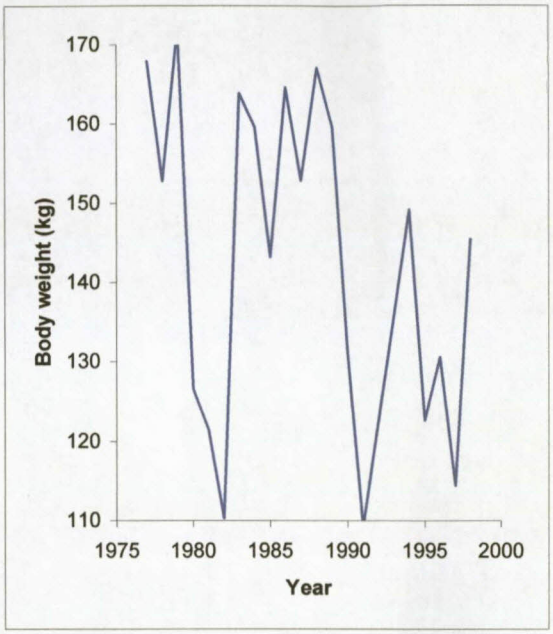

Figure 4.44 Effect of year of birth on 24 month body weight in Horro cattle for the period 1977-1999

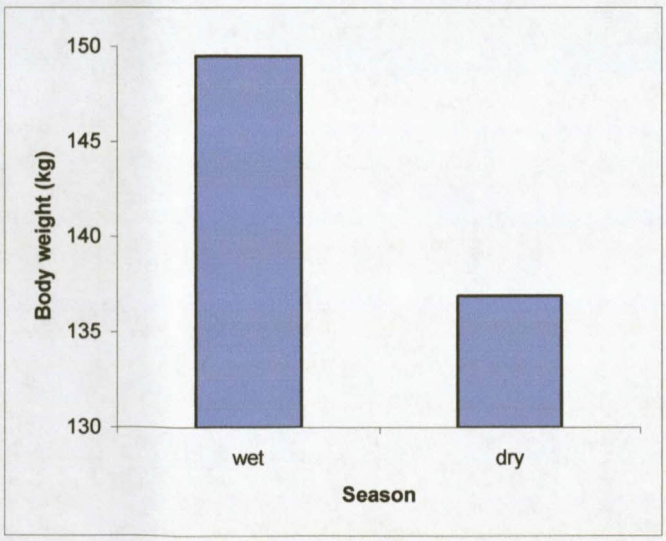

Figure 4.45 Effect of season of birth (wet or dry) on the body weight at 24 months of age in Horro cattle

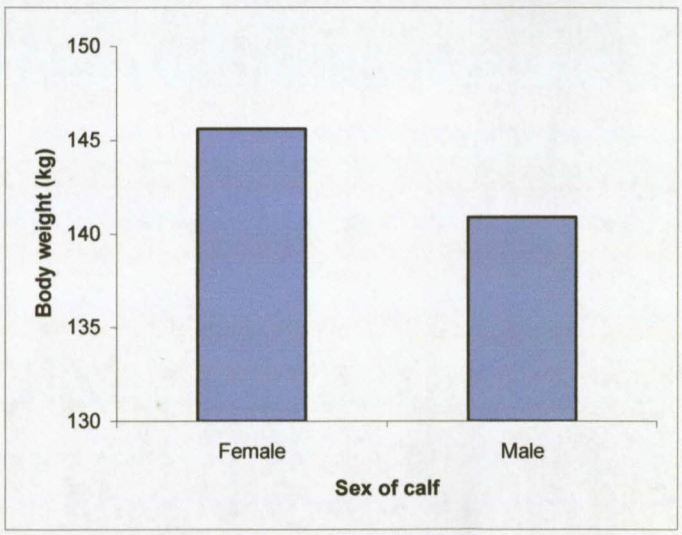

Figure 4.46 Effect of sex of the calf on the weight at 24 months of age in Horro cattle

4.8.4 The pre- and post weaning average daily gain (ADG) in Horro calves

Weaning of Horro calves at the Bako Research Center is performed at 180 days of age. The mean pre-weaning ADG is set out in Table 4.9 and illustrated in Figures 4.47 to 4.52. The mean pre-weaning ADG was 275 g/day (225.5 to 443.4 g/day). The season of birth did not affect pre-weaning ADG while year of birth (Figure 4.47) significantly ($P<0.01$) affected pre-weaning ADG. The mean post weaning ADG between birth and 180 days, was 130.9 g/day. This ADG was not affected by either the sex of the calf or by the calf birth weight. However, the season of birth (Figure 4.51) significantly ($P<0.01$) affected the post weaning ADG. Calves born during the wet season recorded a heavier pre- and post weaning ADG. The year of birth also significantly affected ($P<0.01$) the post weaning ADG during certain years (Table 4.9). No significant correlation was recorded between birth weight and pre-weaning daily gain and between birth weight and both pre- or post weaning ADG.

4.9 MORTALITY AGE IN HORRO CATTLE BETWEEN 1977 AND 2001

The least square mean age at death is set out in Table 4.10. The sex of the animal significantly ($P<0.01$) affected the mean age at mortality - with males dying at a younger age, compared to their female counterparts. Male animals died at an average age of 1.1 ± 0.4 years, compared to an age of 2.4 ± 0.4 years in females. Season (wet or dry) had no effect on the age at which animals died in this study.

4.10 THE STAGE AND RATE OF ABORTION IN HORRO COWS

The annual abortion rate and the mean stage of pregnancy at which abortion occurred in Horro cows at Bako Research Center between 1974 and 2000 are presented in Table 4.11. The average stage of abortion was recorded as 7.8 months of pregnancy. Season did not have any significant effect on the stage of pregnancy at which abortion occurred in the Horro cow. Similarly the year when abortion occurred did not have any significant effect on the stage of abortion. Of the total abortions recorded in this study, 21.6% were stillbirths. It was evident that abortions occurred late in pregnancy (last trimester). The rate of abortion showed a decreasing trend from 1974 to 2000. The highest abortion rate (6.9%) was recorded in 1988 and the lowest (2.1%) in 2000.

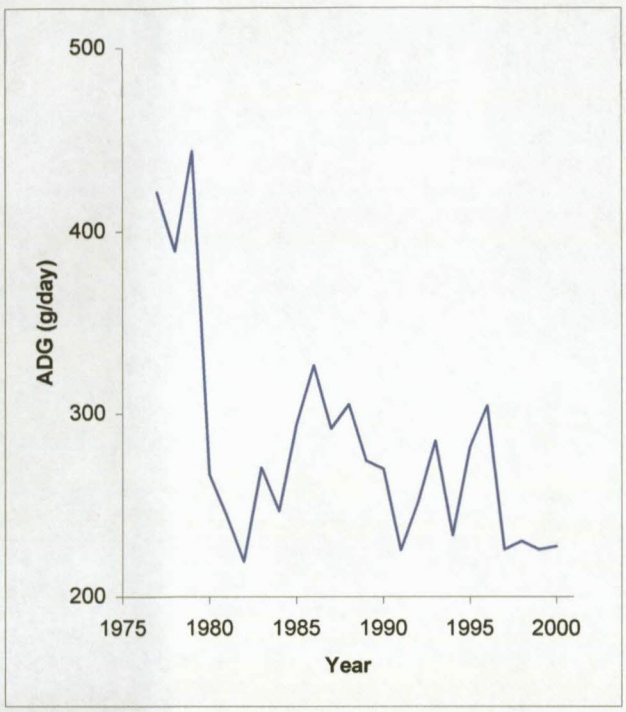

Figure 4.47 Effect of year of birth on pre-weaning ADG in Horro calves (1977 to 2001)

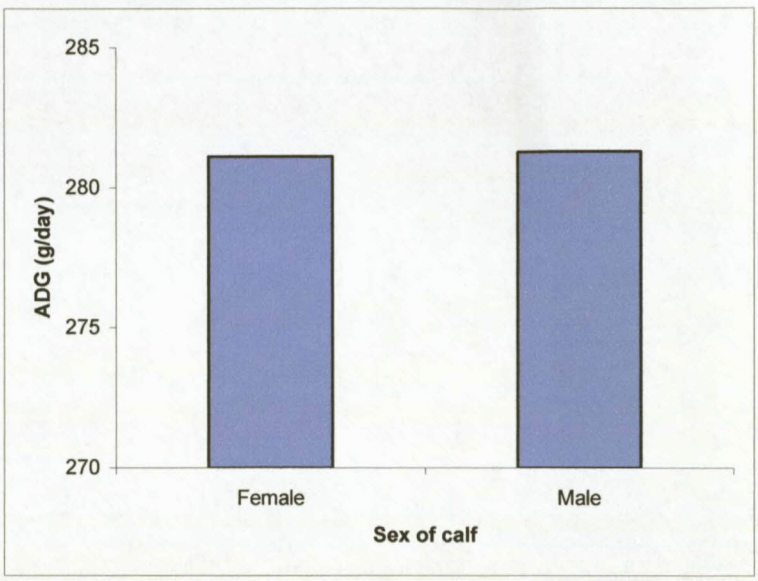

Figure 4.48 Effect of sex of the calf on pre-weaning ADG in Horro calves

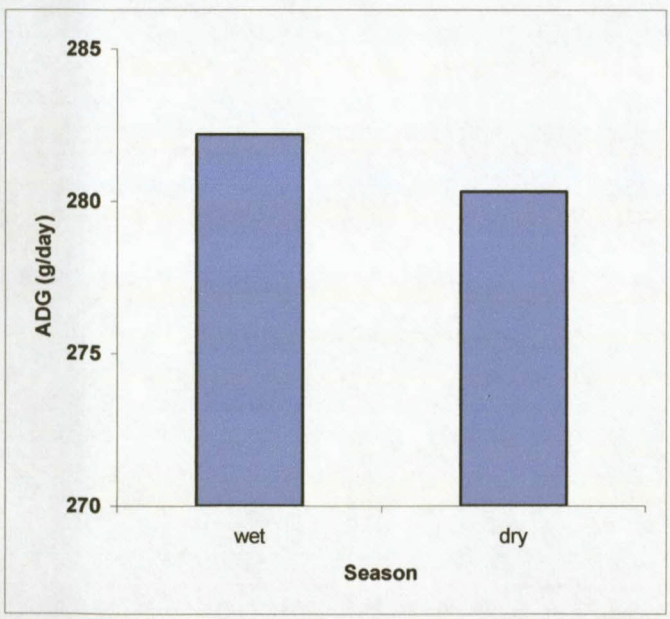

Figure 4.49 Effect of season of birth (wet or dry) on pre-weaning ADG in Horro calves

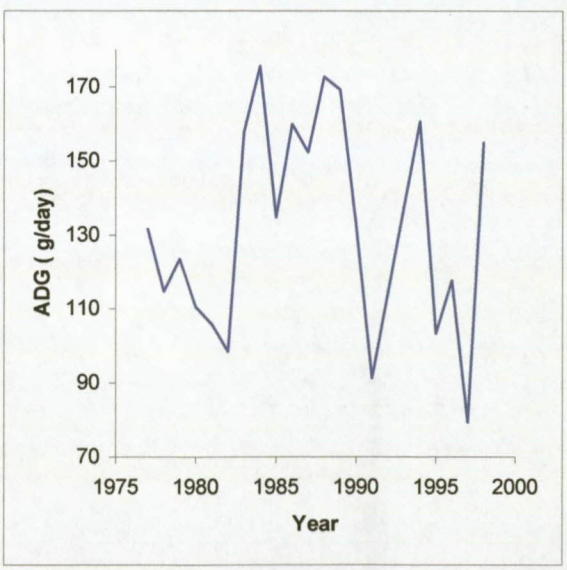

Figure 4.50 Effect of year of birth on post weaning ADG (g/day) in Horro calves (1977-2000)

Table 4.9 **Least square means (± SE) for pre- and post weaning average daily gain in Horro calves**

Source of variability	Pre-weaning ADG		Post weaning ADG	
	n	Mean (g) ± SE	n	Mean (g) ± SE
Overall	344	275	179	130.9
Sex of calf				
Female		281.1 ± 0.0^{NS}		134.6 ± 0.0^{NS}
Male		281.3 ± 0.0^{NS}		130.1 ± 0.0^{NS}
Season of birth				
Wet		282.2 ± 0.0^{NS}		145.8 ± 0.0^{a}
Dry		280.3 ± 0.0^{NS}		118.9 ± 0.0^{b}
Year of birth**				
1977		421.1 ± 0.0^{a}		131.6 ± 0.0^{ab}
1978		388.8 ± 0.0^{ab}		114.8 ± 0.0^{abc}
1979		443.4 ± 0.0^{a}		123.6 ± 0.0^{abc}
1980		266.8 ± 0.0^{cd}		110.5 ± 0.0^{abc}
1981		244.4 ± 0.0^{cd}		106.0 ± 0.0^{abc}
1982		219.2 ± 0.0^{d}		98.5 ± 0.0^{bc}
1983		270.6 ± 0.0^{cd}		157.7 ± 0.0^{ab}
1984		246.9 ± 0.0^{cd}		175.7 ± 0.0^{a}
1985		294.3 ± 0.0^{cd}		134.8 ± 0.0^{abc}
1986		326.2 ± 0.0^{bc}		159.9 ± 0.0^{ab}
1987		291.6 ± 0.0^{cd}		152.4 ± 0.0^{ab}
1988		305.1 ± 0.0^{bcd}		172.7 ± 0.0^{a}
1989		274.4 ± 0.0^{cd}		169.3 ± 0.0^{ab}
1990		269.7 ± 0.0^{cd}		132.7 ± 0.0^{abc}
1991		225.5 ± 0.0^{d}		91.2 ± 0.0^{bc}
1992		251.6 ± 0.1^{cd}		-
1993		285.0 ± 0.1^{cd}		-
1995		281.7 ± 0.0^{cd}		-
1996		304.4 ± 0.0^{bcd}		117.7 ± 0.0^{abc}
1997		225.7 ± 0.0^{d}		79.3 ± 0.0^{c}
1998		230.2 ± 0.0^{bcd}		154.9 ± 0.0^{ab}
1999		225.7 ± 0.0^{cd}		-
2000		227.5 ± 0.0^{cd}		-

NS = no significant difference

abdc = means in the same column for the same factor with different superscripts differ significantly

xy = means in the same column with different superscripts differ significantly (P<0.01)

** = P<0.01

Table 4.10 Least square mean (± SE) for age (years) at mortality in Horro cattle

Source of variability	n	Mean age (year) ± SE
Overall	225	1.7
Sex		
Female		2.4 ± 0.4^{a}
Male		1.1 ± 0.4^{b}
Season of mortality		
Wet		1.6 ± 0.4^{NS}
Dry		1.8 ± 0.3^{NS}
Year of mortality		
1977		1.0 ± 1.8^{b}
1978		0.6 ± 1.8^{b}
1979		1.3 ± 2.6^{b}
1980		0.6 ± 1.8^{b}
1981		4.2 ± 2.6^{ab}
1982		0.4 ± 0.9^{b}
1983		1.4 ± 0.7^{b}
1984		0.8 ± 0.7^{b}
1985		8.4 ± 2.6^{a}
1986		0.6 ± 2.6^{b}
1987		1.9 ± 1.3^{b}
1988		0.8 ± 1.3^{b}
1989		7.4 ± 2.6^{a}
1990		0.4 ± 1.2^{b}
1991		4.4 ± 1.5^{ab}
1992		0.5 ± 1.1^{b}
1993		1.3 ± 1.5^{b}
1994		0.1 ± 1.0^{b}
1995		0.7 ± 0.8^{b}
1996		1.6 ± 0.6^{b}
1997		4.0 ± 0.4^{ab}
1998		2.3 ± 1.0^{b}
1999		0.6 ± 0.6^{b}
2000		1.1 ± 0.7^{b}
2001		0.3 ± 0.5^{b}

^{NS} = no significant difference

^{ab} = means in the same column with different superscripts differ significantly ($P<0.05$)

Table 4.11 Abortion rate (%) and least square mean (± SE) for the stage of pregnancy at which abortion occurred in Horro cows

Source of variability	n	Abortion rate %	Mean stage of abortion (months) ± SE
Overall	320		7.8
Season of abortion			
Wet		3.6	8.4^{NS}
Dry		2.7	8.3^{NS}
Year of abortion			
1974		3.8	8.4^{ab}
1975		4.8	8.3^{ab}
1977		3.2	9.3^{ab}
1978		3.9	7.7^{ab}
1983		4.4	9.5^{ab}
1986		5.3	6.6^{b}
1987		3.2	9.1^{ab}
1988		6.9	7.8^{ab}
1991		3.6	8.8^{ab}
1992		4.8	7.6^{ab}
1993		3.7	6.4^{ab}
1994		3.2	9.7^{a}
1995		3.3	8.0^{ab}
1996		4.2	6.4^{b}
1997		4.9	7.8^{ab}
1998		2.6	8.7^{ab}
1999		2.2	8.1^{ab}
2000		2.1	8.3^{ab}

^{NS} = no significant difference

^{ab} = means in the same column with different superscripts differ significantly ($P<0.05$)

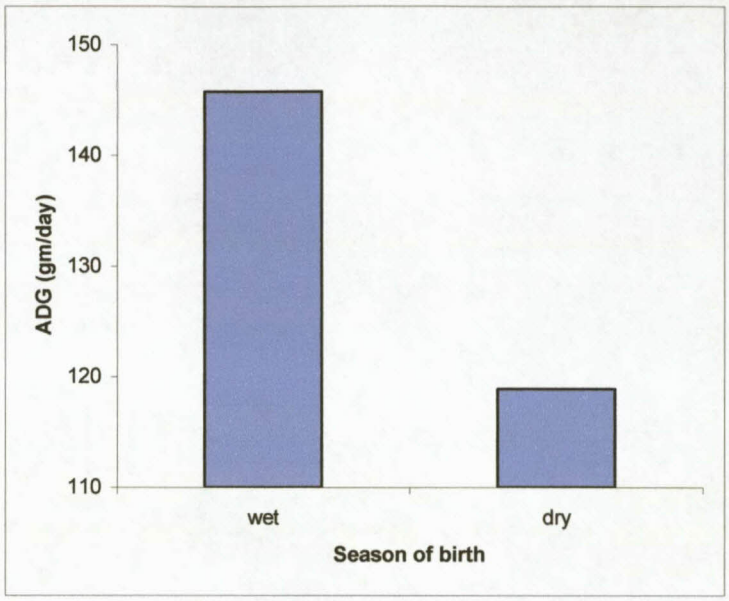

Figure 4.51 Effect of season of birth (wet or dry) on post weaning ADG in Horro calves

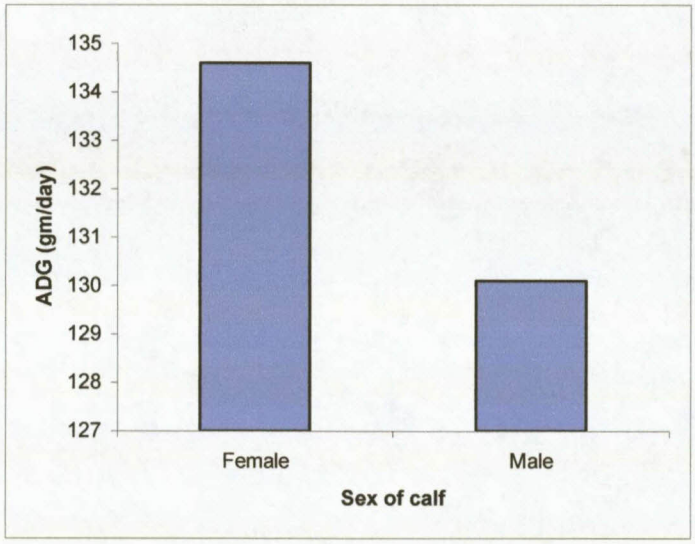

Figure 4.52 Effect of sex of calf on post weaning ADG in Horro calves

4.11 EVALUATION OF SEMEN CHARACTERISTICS IN HORRO BULLS

4.11.1 Semen volume

The least square mean semen volume recorded over the 50 weeks of the trial is set out in Table 4.12 and Figure 4.53. The season of the year did not affect the semen volume, which remained relatively constant (ranging between 2.8 ± 0.3 to 3.7 ± 0.9ml for the nutritionally supplemented and between 2.3 ± 0.3ml to 2.6 ± 0.1ml for the non-

supplemented bulls). From week 6 until the end of the trial, there was a tendency for animals in the supplemented group to have a higher ejaculate volume, compared to the non-supplemented group (Figure 4.53). Throughout the observation period (except weeks 0, 2, and 4 - Table 4.12) significant differences ($P<0.05$) were recorded between the two treatment groups. The correlation recorded between the volume of the ejaculate and scrotal circumference was significant, but extremely low ($r = 0.09$; $P<0.01$). Scrotal skin thickness was negatively correlated ($r = -0.1$) with ejaculate volume. Ejaculate volume was also positively and significantly ($r = 0.2$; $P<0.01$) correlated with testis volume and testis length and body weight ($r = 0.2$ and $r = 0.4$) were positively correlated to ejaculate volume.

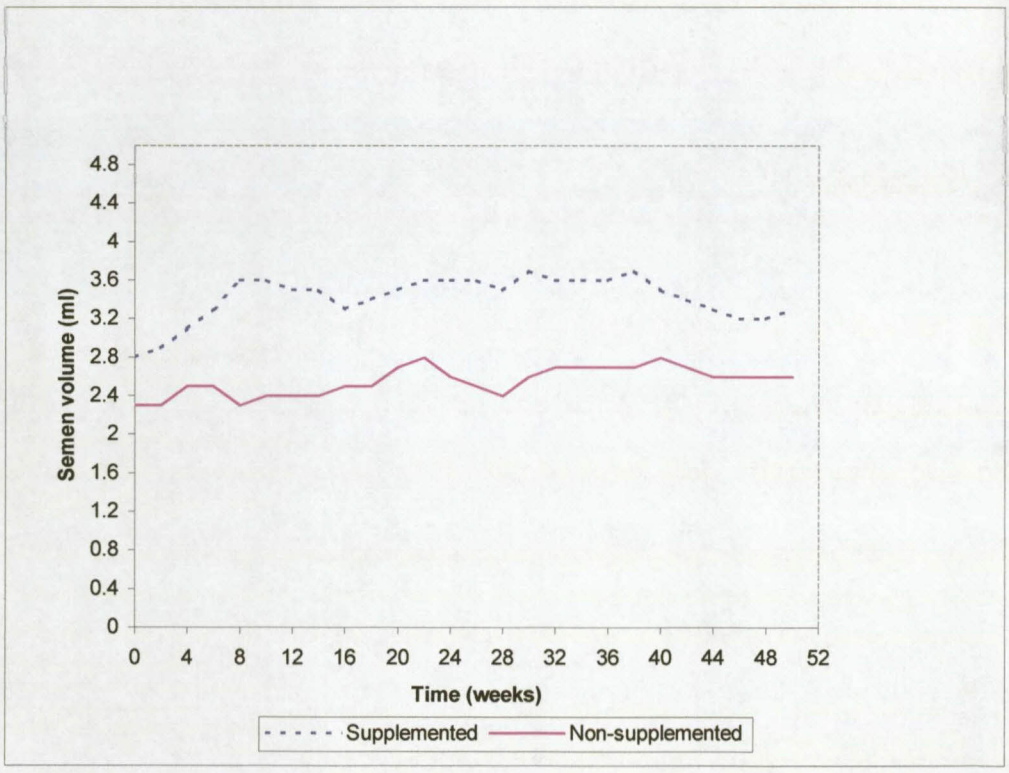

Figure 4.53 Mean semen volume as affected by feed supplementation over time in Horro bulls

Table 4.12 Least square mean (± SE) for semen volume in nutritionally supplemented and non-supplemented Horro bulls

Week of collection	Semen volume (ml)	
	Supplemented bulls	Non-supplemented bulls
0	2.8 ± 0.3^{NS}	2.3 ± 0.3^{NS}
2	2.9 ± 0.3^{NS}	2.3 ± 0.3^{NS}
4	3.1 ± 0.2^{NS}	2.5 ± 0.2^{NS}
6	3.3 ± 0.2^{a}	2.5 ± 0.2^{b}
8	3.6 ± 0.2^{a}	2.3 ± 0.2^{b}
10	3.6 ± 0.2^{c}	2.4 ± 0.2^{d}
12	3.5 ± 0.1^{c}	2.4 ± 0.1^{d}
14	$35. \pm 0.1^{c}$	2.4 ± 0.1^{d}
16	3.3 ± 0.1^{a}	2.5 ± 0.1^{b}
18	3.4 ± 0.2^{a}	2.5 ± 0.1^{b}
20	3.5 ± 0.1^{a}	2.7 ± 0.1^{b}
22	3.6 ± 0.2^{a}	2.8 ± 0.2^{b}
24	3.6 ± 0.2^{a}	2.6 ± 0.2^{b}
26	3.6 ± 0.2^{a}	2.5 ± 0.2^{b}
28	3.5 ± 0.2^{c}	2.4 ± 0.2^{d}
30	3.7 ± 0.1^{c}	2.6 ± 0.1^{d}
32	3.6 ± 0.1^{c}	2.7 ± 0.1^{d}
34	3.6 ± 0.1^{c}	2.7 ± 0.1^{d}
36	3.6 ± 0.1^{c}	2.7 ± 0.1^{d}
38	3.7 ± 0.1^{c}	2.7 ± 0.1^{d}
40	3.5 ± 0.1^{c}	2.8 ± 0.1^{d}
42	3.4 ± 0.1^{c}	2.7 ± 0.1^{d}
44	3.3 ± 0.1^{c}	2.6 ± 0.1^{d}
46	3.2 ± 0.1^{a}	2.6 ± 0.1^{b}
48	3.2 ± 0.1^{a}	2.6 ± 0.1^{b}
50	3.3 ± 0.1^{c}	2.6 ± 0.1^{d}

^{NS} = no significant difference

^{ab} = means in the same row with different superscripts differ significantly ($P<0.05$)

^{cd} = means in the same row with different superscripts differ significantly ($P<0.01$)

4.11.2 Semen colour

During the observation period three semen colour types namely, creamy, milky white and a watery appearance were observed (Table 4.13). The majority of the semen samples were in the creamy to milky white colour range. Being a subjective and not qualitative measurement of the ejaculate, no additional statistical analysis was done. The correlation between semen colour with semen concentration was very low (r = 0.01) and not significant. No significant correlation was also found between semen colour and sperm mass motility. However, semen colour was negatively and significantly correlated with % live sperm, % abnormal sperm, % head abnormalities and tail abnormalities (r = -0.4; r = -0.2; r = -0.1 and r = –0.1 respectively).

4.11.3 Sperm mass motility

The least square mean (± SE) for sperm mass motility (1 to 5) over a period of a year is presented in Table 4.14 and Figure 4.54. The week of collection significantly ($P<0.05$) affected the sperm mass motility for both the supplemented and non-supplemented bulls during certain weeks of the year. A significant ($P<0.05$) interaction between time and nutritional management (treatments) was also recorded - which complicates the interpretation of these differences. There was a general tendency for the bulls from the supplemented group to maintain a higher sperm motility during the experimental period - ranging from a 2.6 ± 0.2 to 3.6 ± 0.2 score for the supplemented, compared to 1.7 ± 0.2 to 3.0 ± 0.3 in the non-supplemented group. No significant correlations were recorded for sperm motility, scrotal circumference and scrotal skin thickness. Sperm mass motility was however, positively and significantly ($P<0.01$) correlated with testis volume (r = 0.1), body weight (r = 0.3) and % live sperm (r = 0.7). The correlation between sperm motility and sperm abnormalities, sperm head abnormalities, sperm tail abnormalities, mid-piece abnormalities, rectal temperature, mean monthly rainfall, minimum temperature and maximum temperature were not significant. The correlation between sperm motility and mean monthly relative humidity on the day of collection was positive, but low (r = 0.08) and significant ($P<0.01$).

Table 4.13 The colour distribution (%) of ejaculates in nutritionally supplemented and non-supplemented Horro bulls

Week	Ejaculate colour					
	Supplemented bulls			Non-supplemented bulls		
	Creamy %	Milky %	Watery %	Creamy %	Milky %	Watery %
0	50.0	25.0	25.0	47.0	33.0	20.0
2	56.2	18.8	18.8	-	-	-
4	62.4	18.8	18.8	43.8	43.8	12.5
6	56.3	25.0	25.0	50.0	25.0	25.0
8	68.8	25.0	25.0	56.3	25.0	18.7
10	81.3	12.6	12.6	48.9	32.5	18.8
12	87.6	6.3	6.3	37.5	25.0	37.5
14	50.0	18.8	18.8	43.8	18.8	37.4
16	87.5	6.3	6.3	42.7	25.9	31.4
18	87.5	12.5	12.5	62.4	31.3	6.3
20	81.2	18.8	18.8	50.0	31.3	18.7
22	50.0	37.5	37.5	62.4	18.8	18.8
24	81.2	18.8	18.8	68.7	25.0	6.3
26	93.8	6.2	6.2	37.5	37.5	25.0
28	81.2	18.8	18.8	56.2	31.3	12.5
30	62.5	37.5	37.5	56.2	37.5	6.3
32	87.5	12.5	12.5	62.5	37.5	-
34	93.7	-	-	56.3	31.3	12.4
36	93.8	6.2	6.2	68.8	25.0	6.2
38	100.0	-	-	68.7	25.0	6.3
40	100.0	-	-	56.2	37.5	6.3
42	93.8	6.2	6.2	62.4	31.3	6.3
44	93.8	6.2	6.2	50.0	31.2	18.8
46	93.8	6.2	6.2	62.3	25.0	12.7
48	87.5	12.5	12.5	50.0	31.2	18.8
50	75.0	25.0	-	50.0	37.5	12.5

Table 4.14 Least square mean (±SE) sperm mass motility score of Horro bulls over a one year period

Week	Supplemented bulls (1-5)	Non-supplemented bulls (1-5)
0	2.9 ± 0.4^{NS}	2.3 ± 0.4^{NS}
2	2.7 ± 0.3^{a}	1.9 ± 0.3^{b}
4	2.7 ± 0.3^{NS}	2.2 ± 0.3^{NS}
6	2.8 ± 0.3^{NS}	2.1 ± 0.3^{NS}
8	3.1 ± 0.3^{a}	1.9 ± 0.3^{b}
10	2.7 ± 0.3^{a}	1.9 ± 0.3^{b}
12	3.1 ± 0.3^{a}	2.0 ± 0.3^{b}
14	3.0 ± 0.2^{a}	1.7 ± 0.2^{b}
16	3.1 ± 0.2^{a}	2.3 ± 0.2^{b}
18	3.0 ± 0.2^{NS}	2.5 ± 0.2^{NS}
20	3.4 ± 0.2^{a}	2.5 ± 0.2^{b}
22	3.5 ± 0.3^{a}	2.7 ± 0.3^{b}
24	3.4 ± 0.2^{a}	2.2 ± 0.2^{b}
26	3.0 ± 0.2^{a}	2.0 ± 0.2^{b}
28	2.6 ± 0.3^{NS}	2.2 ± 0.3^{NS}
30	3.4 ± 0.2^{a}	2.2 ± 0.2^{b}
32	2.9 ± 0.2^{NS}	2.5 ± 0.2^{NS}
34	3.6 ± 0.2^{a}	2.5 ± 0.2^{b}
36	3.3 ± 0.2^{a}	2.3 ± 0.2^{b}
38	3.8 ± 0.3^{NS}	3.1 ± 0.3^{NS}
40	2.9 ± 0.3^{NS}	2.3 ± 0.3^{NS}
42	2.9 ± 0.3^{NS}	2.5 ± 0.3^{NS}
44	2.9 ± 0.2^{a}	1.7 ± 0.3^{b}
46	2.3 ± 0.3^{NS}	2.7 ± 0.3^{NS}
48	3.7 ± 0.2^{c}	1.7 ± 0.2^{d}
50	2.6 ± 0.2^{a}	1.9 ± 0.2^{b}

NS = no significant difference

ab = means in the same row with different superscripts differ significantly ($P<0.05$)

cd = means in the same row with different superscripts differ significantly ($P<0.01$)

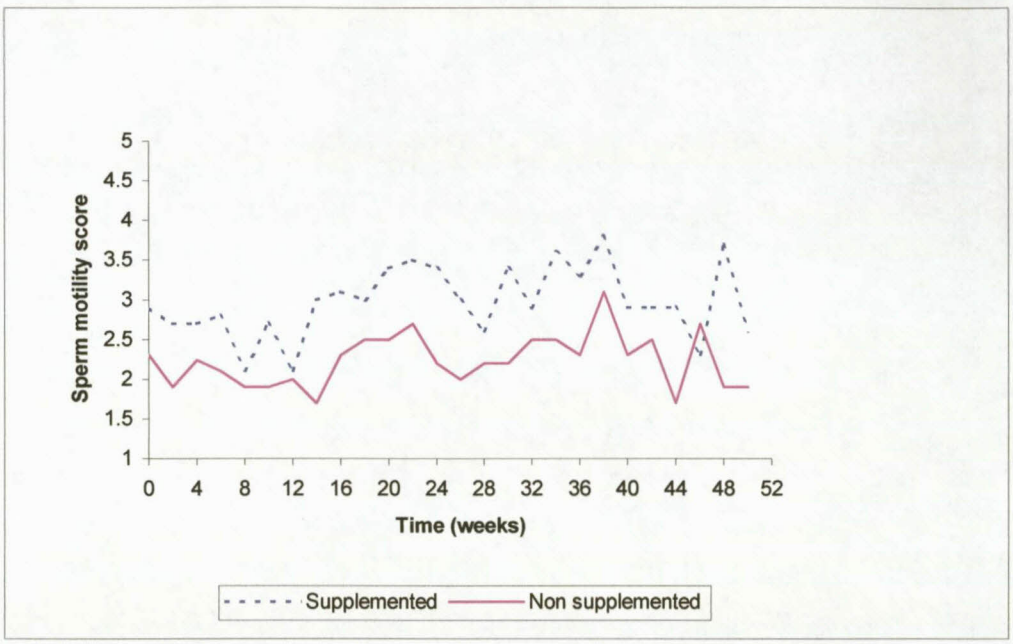

Figure 4.54 Sperm mass motility as influenced by feed supplementation over a 50 week period in Horro bulls

4.11.4 Percentage live sperm in Horro bulls

The least square mean percentage live sperm is set out in Table 4.15 and Figure 4.55. The percentage live sperm tended to be higher in the supplemented group throughout the 50 week trial period. Until week 17 of the trial there were no significant differences however, starting at week 18 there were significant differences between the two treatment groups - except for week 26. Thereafter significant differences were recorded until week 38. From week 40 no significant differences were observed between the two groups in respect of percentage live sperm (except week 48) (Table 4.15). No clear trend in seasonal fluctuation of the percentage live sperm was observed during the trial period of 50 weeks. The correlations between the percentage live sperm and testis volume, testis length, body weight, sperm abnormalities, head, tail and mid-piece abnormalities, sperm mass motility and sperm concentration were not significant. The correlation between the percentage live sperm and rectal temperature at the day of collection ($r = -0.06$) was also not significant.

Table 4.15 Mean (± SE) percentage live sperm in nutritionally supplemented and control Horro bulls over a 50 week period

Week	Supplemented mean (%) ± SE	Control mean (%) ± SE
0	68.7 ± 1.9^{NS}	69.9 ± 2.2^{NS}
2	68.3 ± 1.8^{NS}	64.1 ± 2.0^{NS}
4	71.5 ± 1.2^{NS}	70.4 ± 1.4^{NS}
6	71.3 ± 1.6^{NS}	66.2 ± 1.8^{NS}
8	73.4 ± 1.2^{NS}	66.6 ± 1.3^{NS}
10	70.9 ± 1.5^{NS}	65.8 ± 1.7^{NS}
12	73.5 ± 1.4^{NS}	69.1 ± 1.5^{NS}
14	72.5 ± 1.0^{NS}	67.9 ± 1.1^{NS}
16	70.5 ± 1.1^{NS}	67.4 ± 1.3^{NS}
18	73.0 ± 1.3^{a}	68.9 ± 1.4^{b}
20	73.3 ± 1.0^{a}	69.5 ± 1.2^{b}
22	74.5 ± 1.2^{a}	67.6 ± 1.3^{b}
24	74.3 ± 1.1^{a}	67.2 ± 1.8^{b}
26	70.7 ± 1.1^{NS}	67.9 ± 1.3^{NS}
28	72.6 ± 1.0^{a}	68.4 ± 1.1^{b}
30	73.9 ± 0.9^{c}	67.1 ± 1.0^{d}
32	71.8 ± 0.3^{a}	67.7 ± 1.1^{b}
34	74.2 ± 0.9^{a}	69.12 ± 1.0^{b}
36	71.7 ± 0.9^{a}	68.9 ± 1.0^{b}
38	75.4 ± 1.3^{a}	70.7 ± 1.5^{b}
40	71.4 ± 1.0^{NS}	69.2 ± 1.2^{NS}
42	71.3 ± 1.3^{NS}	69.3 ± 1.4^{NS}
44	71.4 ± 0.9^{NS}	68.1 ± 1.0^{NS}
46	69.5 ± 0.7^{NS}	69.9 ± 0.7^{NS}
48	73.7 ± 0.8^{c}	67.4 ± 1.0^{d}
50	69.9 ± 0.9^{NS}	69.1 ± 1.0^{NS}

^{NS} = no significant difference

^{ab} = means in the same row with different superscripts differ significantly ($P<0.05$)

^{cd} = means in the same row with different superscripts differ significantly ($P<0.01$)

4.11.5 Percentage total abnormal sperm in Horro bulls

The percentage total abnormal sperm in the ejaculate of Horro bulls is presented in Table 4.16 and Figure 4.56. Season (week) during which the semen samples were collected had no significant effect on the percentage of abnormal sperm in both treatment groups (supplemented and non-supplemented). A time x treatment interaction was significant for the percentage abnormal sperm. At the start of the trial (week 0) the nutritionally supplemented group had a higher occurrence of sperm abnormalities (11.4 ± 1.1%), compared to 8.3 ± 1.3% in the control group. Thereafter sperm abnormalities declined rapidly in the supplemented group (except for week 50). The sperm abnormalities for the non-supplemented group showed a tendency to increase during the entire observation period (Figure 4.56). The percentage sperm abnormalities were positively and significantly ($P<0.01$) correlated to scrotal circumference ($r = 0.4$), scrotal skin thickness ($r = 0.4$), testis volume ($r = 0.6$), testis length ($r = 0.5$) and body weight ($r = 0.5$). The maximum mean monthly temperature was positively ($P<0.05$) correlated with the percentage abnormal sperm ($r = 0.1$) in the ejaculate. The correlation between the percentage abnormal sperm cells and relative humidity was positive ($r = 0.01$), but not significant.

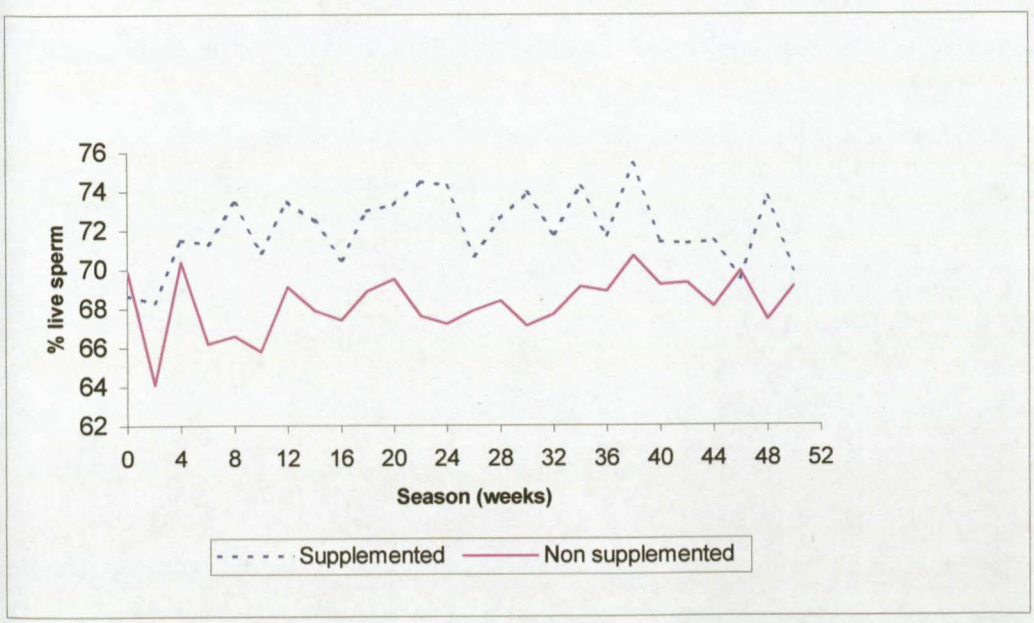

Figure 4.55 Percentage live sperm as influenced by feed supplementation in Horro bulls

Table 4.16 **Least square mean (± SE) total abnormal sperm cells (%) in the ejaculate of supplemented and control Horro bulls for a 50 week period**

Collection week	Supplemented bulls (%)	Control bulls (%)
0	11.4 ± 1.1^{NS}	8.3 ± 1.3^{NS}
2	7.8 ± 0.5^{NS}	7.3 ± 0.6^{NS}
4	7.7 ± 0.6^{a}	7.9 ± 0.6^{NS}
6	7.8 ± 0.6^{NS}	7.9 ± 0.7^{NS}
8	6.7 ± 1.2^{NS}	8.7 ± 1.3^{NS}
10	9.1 ± 0.5^{NS}	8.5 ± 0.6^{NS}
12	8.3 ± 0.3^{NS}	7.8 ± 0.3^{NS}
14	9.3 ± 0.4^{NS}	8.3 ± 0.5^{NS}
16	8.9 ± 0.4^{NS}	9.2 ± 0.5^{NS}
18	8.9 ± 0.4^{NS}	9.9 ± 0.5^{NS}
20	9.7 ± 0.3^{NS}	9.6 ± 0.4^{NS}
22	10.2 ± 0.4^{NS}	9.8 ± 0.5^{NS}
24	9.9 ± 0.4^{NS}	10.2 ± 0.5^{NS}
26	9.9 ± 0.4^{NS}	10.8 ± 0.4^{NS}
28	10.0 ± 0.5^{NS}	11.8 ± 0.5^{NS}
30	9.7 ± 0.2^{c}	11.7 ± 0.3^{d}
32	10.5 ± 0.3^{NS}	11.1 ± 0.4^{NS}
34	10.1 ± 0.3^{NS}	11.0 ± 0.3^{NS}
36	10.8 ± 0.3^{NS}	11.0 ± 0.4^{NS}
38	10.4 ± 0.3^{a}	12.0 ± 0.4^{b}
40	11.7 ± 0.3^{NS}	12.0 ± 0.4^{NS}
42	10.9 ± 0.4^{NS}	11.7 ± 0.4^{NS}
44	11.2 ± 0.3^{NS}	11.8 ± 0.4^{NS}
46	11.4 ± 0.3^{NS}	11.20 ± 0.4^{NS}
48	11.0 ± 0.3^{NS}	12.1 ± 0.3^{NS}
50	12.4 ± 0.2^{NS}	12.4 ± 0.2^{NS}

NS = no significant difference
ab = means in the same row with different superscripts differ significantly ($P<0.05$)
cd = means in the same row with different superscripts differ significantly ($P<0.01$)

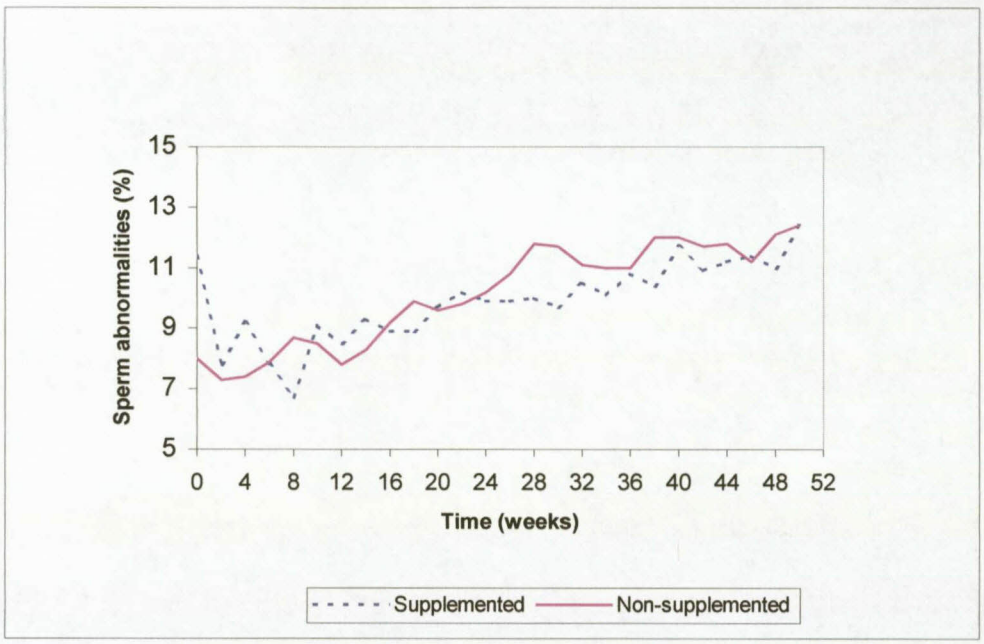

Figure 4.56 Total sperm abnormalities in Horro bulls as influenced by feed supplementation over a 50 week period

The least square means (± SE) for head, mid-piece and tail sperm abnormalities are presented in Table 4.17, 4.18 and 4.19 and Figures 4.57 to 4.59 respectively. Time/season (week) when semen was collected did not have any significant effect on sperm head abnormalities. Week of collection and nutritional treatment showed a significant ($P<0.05$) interaction on the occurrence of sperm head abnormalities. At the onset of the experiment the supplemented group had the highest (but not significant) percentage of head abnormalities, compared to the non-supplemented group, but this tendency was reversed later in the trial. During the observation period sperm head abnormalities increased in both groups (supplemented and non-supplemented) until the end of the experiment (week 50). In the same manner, time (week) did not have any significant effect on sperm tail abnormalities (Table 4.18) (Figure 4.58). Time (week) and nutritional treatment interaction significantly ($P<0.05$) affected sperm tail abnormalities. Sperm tail abnormalities were higher in

the supplemented group at the onset of the trial (week 0) 3.3 ± 0.4% compared to 1.9 ± 0.4 in the non-supplemented group, but this tendency reversed later and thereafter the sperm tail abnormality in both (supplemented and non-supplemented) increased steadily until the end of the experiment (week 50). Time also had no effect on the occurrence of sperm mid-piece abnormalities in Horro bulls. A time x treatment (supplementation) interaction ($P<0.05$) was recorded regarding sperm mid-piece abnormalities. The occurrence of sperm mid-piece abnormalities was high for the supplemented group at the onset of the experiment (3.6 ± 0.8%), compared to the non-supplemented group (2.4 ± 0.5%). Sperm head abnormalities were positively and significantly ($P<0.05$) correlated to scrotal circumference ($r = 0.3$), scrotal skin thickness ($r = 0.3$), testis volume ($r = 0.5$), testis length ($r = 0.4$) and body weight ($r = 0.4$). Relative humidity was negatively and significantly ($P<0.05$) correlated with sperm head abnormalities ($r = 0.16$).

Rectal temperature at time of semen collection ($r = -0.09$), rainfall ($r = -0.1$) and minimum temperature ($r = 0.2$) were negatively and significantly ($P<0.05$) correlated with sperm tail abnormalities.

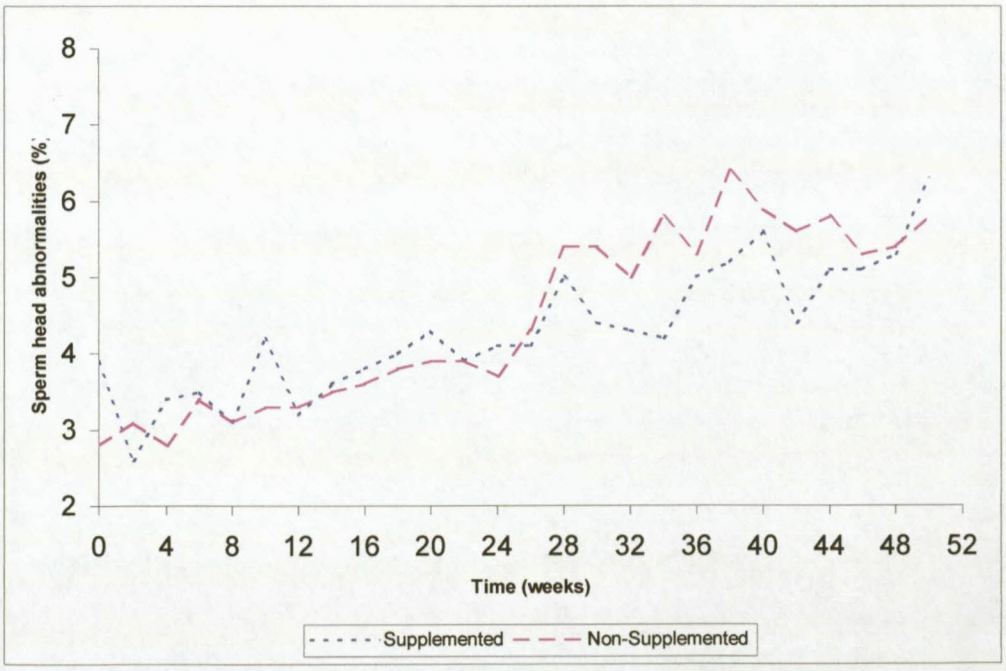

Figure 4.57 Percentage sperm head abnormalities as influenced by feed supplementation in Horro bulls over a 50 week period

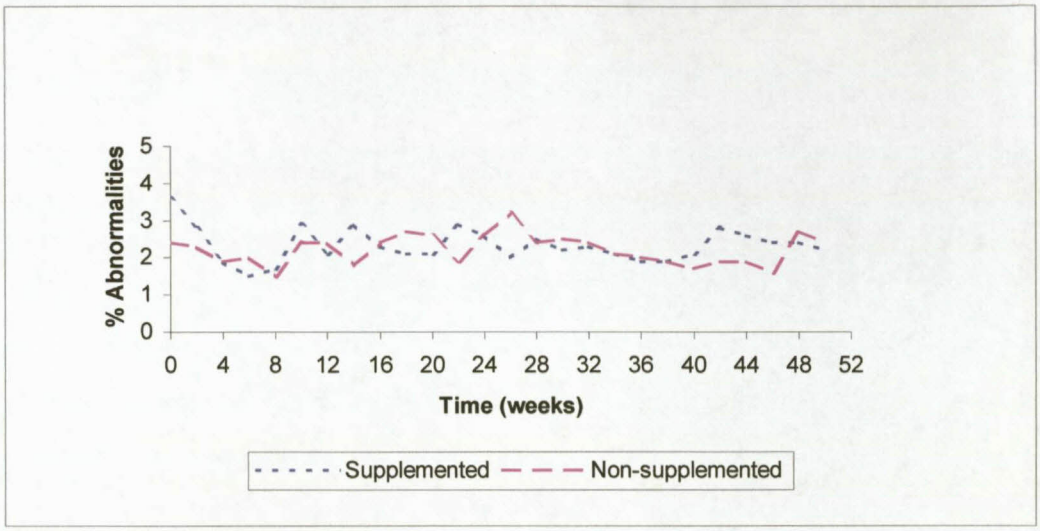

Figure 4.58 Percentage mid-piece sperm abnormalities as influenced by feed supplementation in Horro bulls over a 50 week period

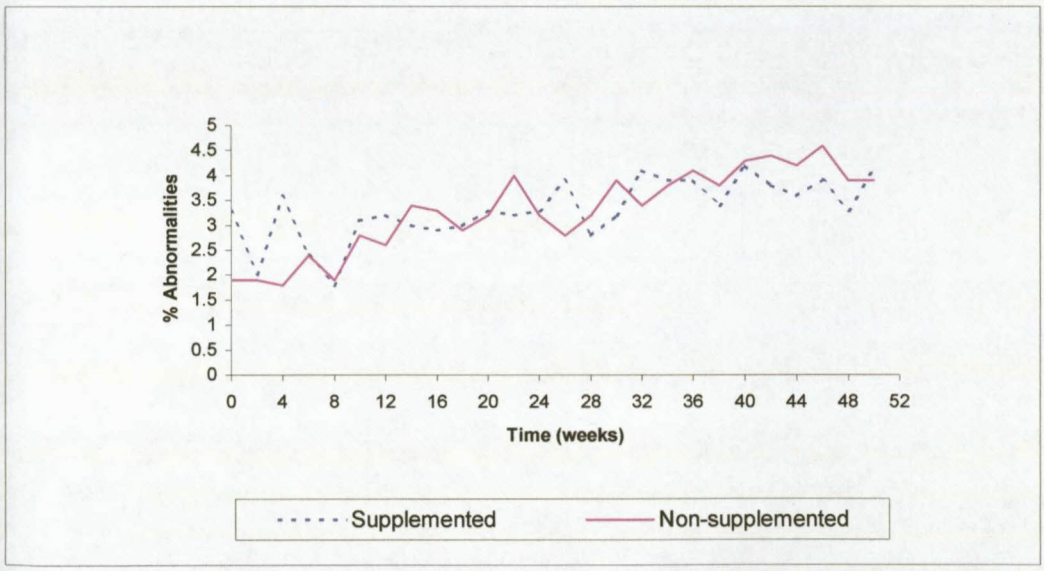

Figure 4.59 Percentage sperm tail abnormalities as affected by feed supplementation in Horro bulls over a 50 week period

Table 4.17 **Least square mean (± SE) head sperm abnormalities in the ejaculate of supplemented and non-supplemented Horro bulls over a 50 week period**

Week	Mean (%) ± SE supplemented bulls	Mean (%) ± SE non-supplemented bulls
0	3.9 ± 0.5^{NS}	2.8 ± 0.5^{NS}
2	2.6 ± 0.4^{NS}	3.1 ± 0.4^{NS}
4	3.4 ± 0.4^{NS}	2.8 ± 0.4^{NS}
6	3.5 ± 0.4^{NS}	3.4 ± 0.4^{NS}
8	3.1 ± 0.5^{NS}	3.1 ± 0.5^{NS}
10	4.2 ± 0.4^{NS}	3.3 ± 0.4^{NS}
12	3.2 ± 0.2^{NS}	3.3 ± 0.2^{NS}
14	3.6 ± 0.3^{NS}	3.5 ± 0.3^{NS}
16	3.8 ± 0.3^{NS}	3.6 ± 0.3^{NS}
18	4.0 ± 0.3^{NS}	3.8 ± 0.3^{NS}
20	4.3 ± 0.2^{NS}	3.9 ± 0.2^{NS}
22	3.9 ± 0.3^{NS}	3.9 ± 0.3^{NS}
24	4.1 ± 0.4^{NS}	3.7 ± 0.4^{NS}
26	4.1 ± 0.3^{NS}	4.3 ± 0.3^{NS}
28	5.0 ± 0.4^{NS}	5.4 ± 0.4^{NS}
30	4.4 ± 0.2^{a}	5.4 ± 0.2^{b}
32	4.3 ± 0.2^{a}	5.0 ± 0.2^{b}
34	4.2 ± 0.2^{c}	5.8 ± 0.2^{d}
36	5.0 ± 0.3^{NS}	5.3 ± 0.3^{NS}
38	5.2 ± 0.4^{a}	6.4 ± 0.4^{b}
40	5.6 ± 0.3^{NS}	5.9 ± 0.3^{NS}
42	4.4 ± 0.3^{a}	5.6 ± 0.3^{b}
44	5.1 ± 0.3^{NS}	5.8 ± 0.3^{NS}
46	5.1 ± 0.3^{NS}	5.3 ± 0.3^{NS}
48	5.3 ± 0.3^{NS}	5.4 ± 0.3^{NS}
50	6.3 ± 0.2^{NS}	5.8 ± 0.2^{NS}

NS = no significant difference

ab = means in the same row with different superscripts differ significantly ($P<0.05$)

cd = means in the same row with different superscripts differ significantly ($P<0.01$)

Table 4.18 **Least square mean (± SE) mid-piece sperm abnormalities in supplemented and control Horro bulls over a 50 week period**

Week	Mean (%) ± SE supplemented bulls	Mean (%) ± SE control bulls
0	3.6 ± 0.5^{NS}	2.4 ± 0.5^{NS}
2	2.8 ± 0.3^{NS}	2.3 ± 0.3^{NS}
4	1.9 ± 0.3^{NS}	1.9 ± 0.3^{NS}
6	1.5 ± 0.3^{NS}	2.0 ± 0.3^{NS}
8	1.7 ± 0.3^{NS}	1.5 ± 0.3^{NS}
10	2.9 ± 0.4^{NS}	2.4 ± 0.4^{NS}
12	2.1 ± 0.2^{NS}	2.4 ± 0.2^{NS}
14	2.9 ± 0.2^{NS}	1.8 ± 0.2^{NS}
16	2.3 ± 0.2^{NS}	2.4 ± 0.2^{NS}
18	2.1 ± 0.3^{NS}	2.7 ± 0.3^{NS}
20	2.1 ± 0.3^{NS}	2.6 ± 0.3^{NS}
22	2.9 ± 0.3^{a}	1.9 ± 0.3^{b}
24	2.6 ± 0.2^{NS}	2.6 ± 0.2^{NS}
26	2.0 ± 0.3^{a}	3.2 ± 0.3^{b}
28	2.5 ± 0.3^{NS}	2.4 ± 0.3^{NS}
30	2.2 ± 0.2^{NS}	2.5 ± 0.2^{NS}
32	2.3 ± 0.3^{NS}	2.4 ± 0.3^{NS}
34	2.1 ± 0.3^{NS}	2.1 ± 0.3^{NS}
36	1.9 ± 0.2^{NS}	2.0 ± 0.2^{NS}
38	1.9 ± 0.3^{NS}	1.9 ± 0.3^{NS}
40	2.1 ± 0.3^{NS}	1.7 ± 0.3^{NS}
42	2.8 ± 0.3^{a}	1.9 ± 0.3^{b}
44	2.6 ± 0.2^{a}	1.9 ± 0.2^{b}
46	2.4 ± 0.2^{a}	1.6 ± 0.2^{b}
48	2.4 ± 0.3^{NS}	2.7 ± 0.3^{NS}
50	2.2 ± 0.2^{NS}	2.4 ± 0.2^{NS}

^{NS} = no significant difference

^{ab} = means in the same row with different superscripts differ significantly ($P<0.05$)

Table 4.19 Least square mean (± SE) sperm tail abnormalities in supplemented and control Horro bulls for a 50 week period

Week	Mean (%) ± SE supplemented bulls	Mean (%) ± SE control bulls
0	3.3 ± 0.4^{a}	1.9 ± 0.4^{b}
2	1.0 ± 0.4^{NS}	1.9 ± 0.4^{NS}
4	3.6 ± 0.2^{x}	1.8 ± 0.2^{y}
6	2.4 ± 0.4^{NS}	2.4 ± 0.4^{NS}
8	1.8 ± 0.3^{NS}	1.9 ± 0.3^{NS}
10	3.1 ± 0.4^{NS}	2.8 ± 0.4^{NS}
12	3.2 ± 0.3^{NS}	2.6 ± 0.3^{NS}
14	3.0 ± 0.3^{NS}	3.4 ± 0.3^{NS}
16	2.9 ± 0.3^{NS}	3.3 ± 0.3^{NS}
18	3.0 ± 0.3^{NS}	2.9 ± 0.3^{NS}
20	3.3 ± 0.3^{NS}	3.2 ± 0.3^{NS}
22	3.2 ± 0.3^{NS}	4.0 ± 0.3^{NS}
24	3.3 ± 0.3^{NS}	3.2 ± 0.3^{NS}
26	3.9 ± 0.3^{a}	2.8 ± 0.3^{b}
28	2.8 ± 0.3^{NS}	3.2 ± 0.3^{NS}
30	3.2 ± 0.2^{a}	3.9 ± 0.2^{b}
32	4.1 ± 0.2^{a}	3.4 ± 0.2^{b}
34	3.9 ± 0.3^{NS}	3.8 ± 0.3^{NS}
36	3.9 ± 0.3^{NS}	4.1 ± 0.3^{NS}
38	3.4 ± 0.3^{NS}	3.8 ± 0.3^{NS}
40	4.2 ± 0.3^{NS}	4.3 ± 0.3^{NS}
42	3.8 ± 0.2^{NS}	4.4 ± 0.2^{NS}
44	3.6 ± 0.3^{NS}	4.2 ± 0.3^{NS}
46	3.9 ± 0.3^{NS}	4.6 ± 0.3^{NS}
48	3.3 ± 0.3^{NS}	3.9 ± 0.3^{NS}
50	4.1 ± 0.2^{NS}	3.9 ± 0.2^{NS}

NS = no significant difference
ab = means in the same row with different superscripts differ significantly ($P<0.05$)
cd = means in the same row with different superscripts differ significantly ($P<0.01$)

4.11.6 Sperm concentration and pH in Horro bulls

The time (weeks) when semen was collected did not have a significant effect on both semen concentration and pH (Table 4.20 and Table 4.21 and Figures 4.60 and 4.61 respectively). The sperm concentration in the bulls of the supplemented group tended to remain higher than the concentration of the bulls in the control group (Table 4.20) throughout the observation period - except for weeks 44 and 48 where the differences were significant ($P<0.05$). The time when semen was collected did not have a significant effect on semen pH. Semen pH remained relatively constant throughout the observation period for both groups (supplemented and non-supplemented) of bulls. A significant ($P<0.05$) correlation was recorded between rainfall ($r = 0.2$), minimum daily temperature ($r = 0.1$), maximum daily temperature ($r = -0.1$) and relative humidity ($r = 0.2$) on the day of collection.

4.12 LIBIDO IN HORRO BULLS

The libido scores are set out in Table 4.22. Supplementation had no evident effect on the libido recorded, but a seasonal trend was detected in both groups as is evident in Figure 4.62. Bull libido in this study was significantly ($P<0.01$) and positively correlated with scrotal circumference ($r = 0.1$). A significant ($P<0.01$) correlation was recorded between bull libido score and bull body weight ($r = 0.27$). The correlation between libido score and semen concentration was also significant ($P<0.01$) and positive ($r = 0.17$).

4.13 SCROTAL CIRCUMFERENCE IN HORRO BULLS

The corresponding least square mean (± SE) for scrotal circumferences is presented in Table 4.23 and illustrated in Figure 4.63. Time (week of collection) had no significant effect on scrotal circumference. The mean scrotal circumference of bulls in the supplemented group was generally higher, compared to that recorded in the non-supplemented group throughout most of the 50 week trial period. However these differences were statistically not significantly different. The mean scrotal circumference of the bulls in both treatment groups tended to increase during the latter part of the observation period (Figure 4.63).

Table 4.20 **Least square mean (± SE) semen concentration in Horro bulls over a 50 week period**

Week	Mean ($x10^6$/ml) ± SE supplemented bulls	Mean ($x10^6$/ml) ± SE non-supplemented bulls
0	387.1 ± 75.2^{NS}	393.1 ± 77.7^{NS}
2	366.2 ± 85.4^{NS}	433.3 ± 88.2^{NS}
4	522.3 ± 66.7^{a}	303.8 ± 68.9^{b}
6	623.22 ± 66.8^{NS}	564.2 ± 69.0^{NS}
8	346.6 ± 60.0^{NS}	366.4 ± 61.9^{NS}
10	400.1 ± 67.0^{NS}	440.9 ± 69.2^{NS}
12	451.6 ± 72.8^{NS}	483.9 ± 75.2^{NS}
14	505.7 ± 79.3^{NS}	501.7 ± 81.9^{NS}
16	593.5 ± 69.6^{NS}	534.2 ± 71.9^{NS}
18	582.3 ± 66.5^{NS}	489.8 ± 66.6^{NS}
20	517.6 ± 54.3^{NS}	537.7 ± 56.1^{NS}
22	514.4 ± 55.7^{NS}	545.6 ± 57.6^{NS}
24	562.4 ± 54.7^{NS}	499.1 ± 56.5^{NS}
26	504.7 ± 50.9^{NS}	542.2 ± 52.6^{NS}
28	330.4 ± 23.6^{NS}	368.6 ± 24.4^{NS}
30	451.1 ± 26.7^{NS}	338.4 ± 21.8^{NS}
32	401.8 ± 17.1^{c}	348.2 ± 17.7^{d}
34	491.4 ± 19.4^{NS}	359.1 ± 20.1^{NS}
36	465.2 ± 18.9^{NS}	360.8 ± 19.5^{NS}
38	541.1 ± 51.8^{NS}	475.1 ± 53.5^{NS}
40	457.9 ± 27.3^{NS}	397.3 ± 28.2^{NS}
42	420.2 ± 29.4^{NS}	431.1 ± 30.3^{NS}
44	493.3 ± 36.6^{a}	308.3 ± 37.8^{NS}
46	378.2 ± 22.9^{NS}	392.4 ± 23.6^{NS}
48	515.1 ± 19.2^{c}	304.1 ± 19.8^{d}
50	388.6 ± 22.9^{NS}	333.8 ± 23.6^{NS}

^{NS} = no significant difference

^{ab} = means in the same row with different superscripts differ significantly ($P<0.05$)

^{cd} = means in the same row with different superscripts differ significantly ($P<0.01$)

Table 4.21 **Least square mean (± SE) semen pH in supplemented and control Horro bulls**

Week	Mean semen pH (%) (±SE) supplemented bulls[NS]	Mean semen pH (%) (±SE) control[NS]
0	6.8 ± 0.0	6.8 ± 0.0
2	6.8 ± 0.0	6.8 ± 0.0
4	6.8 ± 0.0	6.8 ± 0.0
6	6.8 ± 0.0	6.8 ± 0.0
8	6.8 ± 0.0	6.8 ± 0.0
10	6.8 ± 0.0	6.8 ± 0.0
12	6.8 ± 0.0	6.8 ± 0.0
14	6.8 ± 0.0	6.8 ± 0.0
16	6.8 ± 0.0	6.8 ± 0.0
18	6.8 ± 0.0	6.8 ± 0.0
20	6.7 ± 0.0	6.8 ± 0.0
22	6.7 ± 0.0	6.8 ± 0.0
24	6.8 ± 0.0	6.8 ± 0.0
26	6.8 ± 0.0	6.8 ± 0.0
28	6.8 ± 0.0	6.8 ± 0.0
30	6.8 ± 0.0	6.8 ± 0.0
32	6.8 ± 0.0	6.8 ± 0.0
34	6.8 ± 0.0	6.8 ± 0.0
36	6.8 ± 0.0	6.8 ± 0.0
38	6.8 ± 0.0	6.8 ± 0.0
40	6.8 ± 0.0	6.8 ± 0.0
42	6.8 ± 0.0	6.8 ± 0.0
44	6.8 ± 0.0	6.8 ± 0.0
46	6.7 ± 0.0	6.8 ± 0.0
48	6.7 ± 0.0	6.8 ± 0.0
50	6.8 ± 0.0	6.8 ± 0.0

[NS] = no significant difference between means in the same row

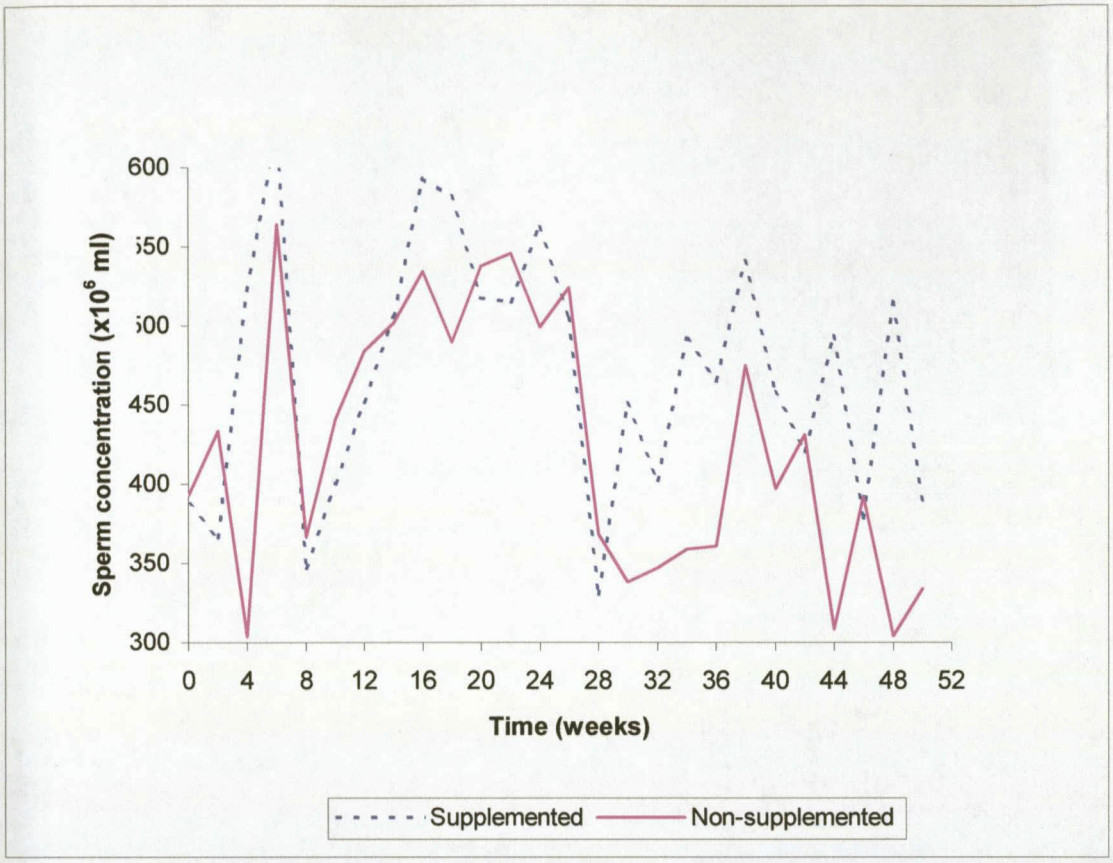

Figure 4.60 Least square mean sperm concentration as influenced by feed supplementation in Horro bulls over a 50 week period

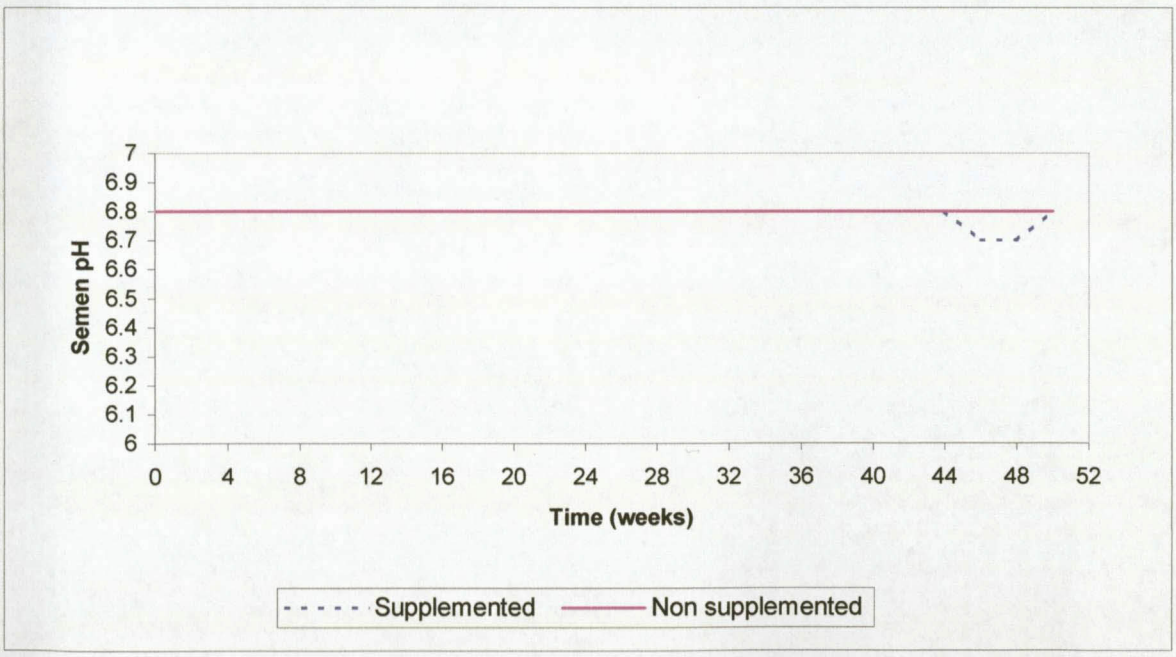

Figure 4.61 Semen pH in Horro bulls as influenced by feed supplementation over a period of 50 weeks

Table 4.22 **Least square mean (± SE) libido score in Horro bulls over a 50 week period**

Week	Mean ± SE supplemented bulls[NS]	Mean ± SE non-supplemented bulls[NS]
0	2.7 ± 0.3	2.0 ± 0.4
2	2.1 ± 0.5	2.2 ± 0.6
4	2.6 ± 0.5	2.4 ± 0.5
6	2.4 ± 0.5	1.42 ± 0.5
8	1.8 ± 0.4	1.7 ± 0.5
10	2.1 ± 0.4	1.8 ± 0,5
12	2.3 ± 0.3	2.9 ± 0.4
14	3.2 ± 0.3	3.6 ± 0.3
16	3.8 ± 0.2	3.6 ± 0.2
18	3.9 ± 0.1	3.8 ± 0.2
20	3.6 ± 0.2	3.7 ± 0.2
22	3.6 ± 0.2	3.9 ± 0.2
24	3.7 ± 0.2	3.7 ± 0.2
26	3.2 ± 0.2	2.7 ± 0.3
28	2.6 ± 0.2	1.6 ± 0.2
30	1.8 ± 0.2	1.4 ± 0.2
32	1.8 ± 0.2	1.7 ± 0.3
34	2.3 ± 0.3	2.1 ± 0.4
36	2.9 ± 0.2	2.5 ± 0.3
38	3.3 ± 0.2	2.9 ± 0.3
40	3.0 ± 0.3	2.9 ± 0.3
42	3.3 ± 0.3	3.3 ± 0.3
44	3.2 ± 0.3	3.0 ± 0.3
46	1.5 ± 0.3	2.0 ± 0.3
48	3.0 ± 0.3	2.2 ± 0.4
50	2.3 ± 0.3	1.7 ± 0.3

[NS] =. no significant difference between mean in the same row

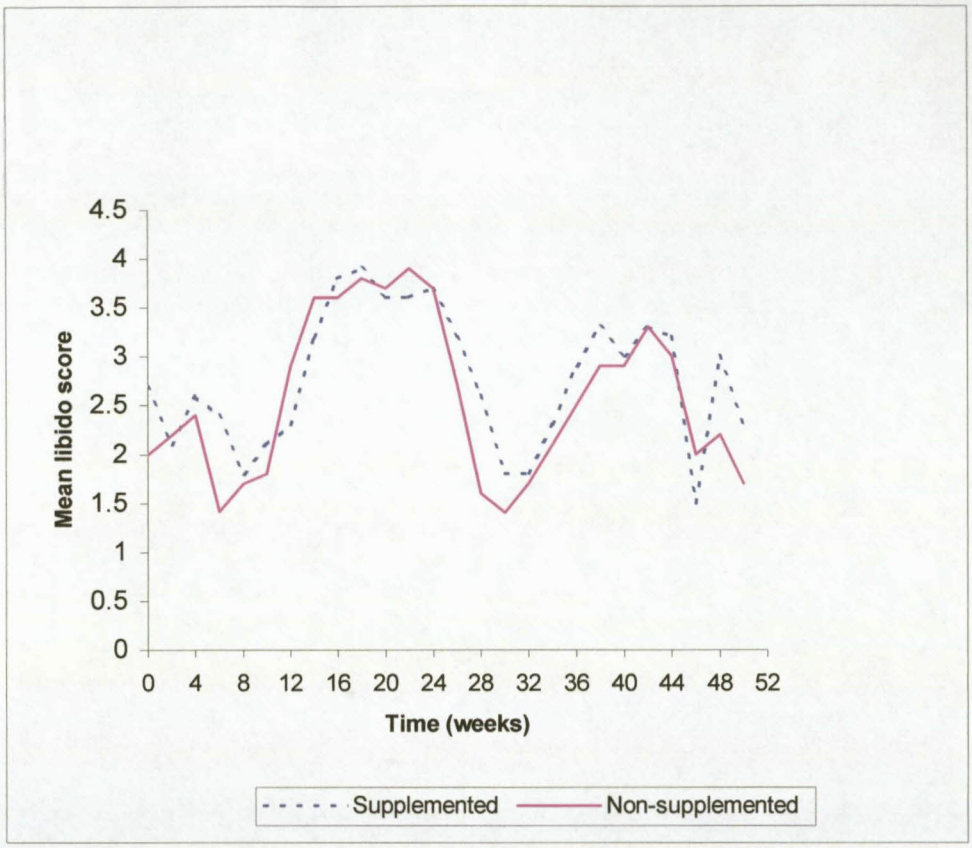

Figure 4.62 Mean libido score in supplemented and non-supplemented Horro bulls over a 50 week period

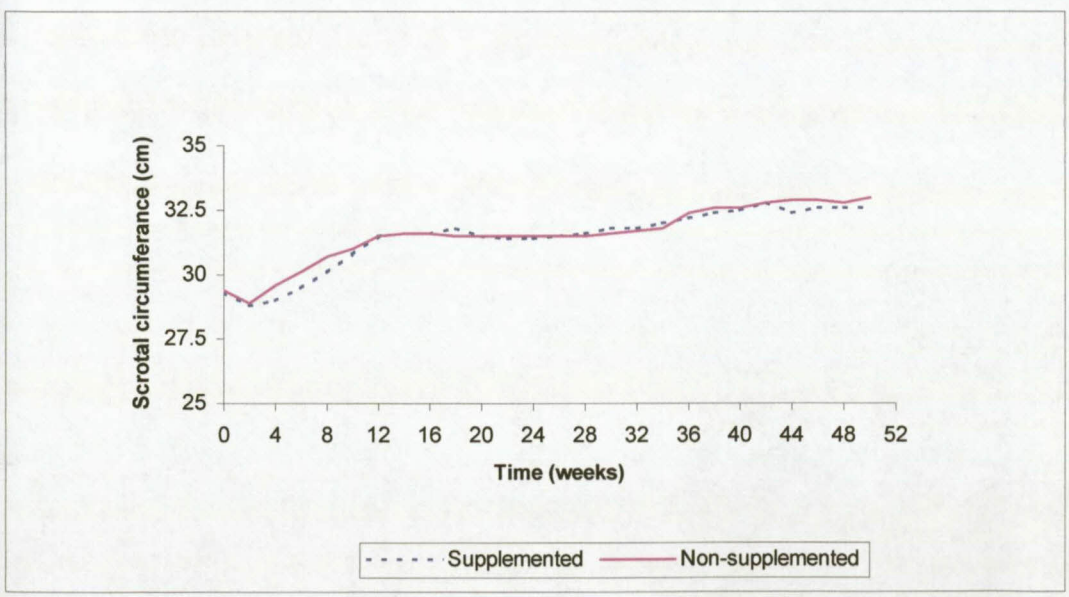

Figure 4.63 Mean scrotal circumference of supplemented and non-supplemented Horro bulls over a 50 week period

Table 4.23 **Mean (± SE) scrotal circumference (cm) of supplemented and control Horro bulls over a 50 week period**

Week	Mean (cm) ± SE supplemented bulls[NS]	Mean (cm) ± SE control bulls[NS]
0	29.3 ± 0.4	29.4 ± 0.4
2	28.8 ± 0.5	28.9 ± 0.5
4	29.0 ± 0.5	29.6 ± 0.5
6	29.5 ± 0.4	30.1 ± 0.4
8	30.1 ± 0.4	30.7 ± 0.4
10	30.8 ± 0.3	31.0 ± 0.3
12	31.5 ± 0.3	31.5 ± 0.3
14	31.6 ± 0.3	31.6 ± 0.3
16	31.6 ± 0.3	31.6 ± 0.3
18	31.8 ± 0.3	31.5 ± 0.3
20	31.5 ± 0.3	31.5 ± 0.3
22	31.4 ± 0.3	31.5 ± 0.3
24	31.4 ± 0.3	31.5 ± 0.3
26	31.5 ± 0.3	31.5 ± 0.3
28	31.6 ± 0.3	31.5 ± 0.3
30	31.8 ± 0.3	31.6 ± 0.3
32	31.8 ± 0.3	31.7 ± 0.3
34	32.0 ± 0.2	31.8 ± 0.2
36	32.2 ± 0.2	32.4 ± 0.2
38	32.4 ± 0.2	32.6 ± 0.2
40	32.5 ± 0.2	32.6 ± 0.2
42	32.8 ± 0.2	32.8 ± 0.2
44	32.4 ± 0.2	32.9 ± 0.2
46	32.6 ± 0.2	32.9 ± 0.2
48	32.6 ± 0.2	32.8 ± 0.2
50	32.6 ± 0.2	33.0 ± 0.2

[NS] = no significant difference between mean in the same row

Scrotal circumference was positively and significantly ($P<0.01$) correlated with scrotal skin thickness ($r = 0.5$), testis volume ($r = 0.7$), testis length ($r = 0.6$) and body weight ($r = 0.5$). No relationship was found between scrotal circumference and sperm motility, but a significant ($P<0.05$) low correlation was recorded between scrotal circumference and ejaculate volume ($r = 0.09$).

4.14 SCROTAL SKIN THICKNESS IN HORRO BULLS FOLLOWING NUTRITIONAL SUPPLEMENTATION

The least square mean scrotal skin thickness during the trial is set out in Table 4.24 and Figure 4.64. Scrotal skin thickness was measured as a possible indicator of fat deposition under the scrotal skin. The scrotal skin thickness was significantly ($P<0.01$) different between week 4 and 18 in both treatment groups, with the non-supplemented animals recording thicker scrotal skins. A time x treatment interaction was also recorded ($P<0.01$) regarding scrotal skin thickness. The mean scrotal skin thickness for both treatment groups increased steadily towards the end of the trial - when the mean scrotal skin thickness in both groups was recorded as 0.6 ± 0.0 cm. Scrotal skin thickness was positively ($P<0.01$) correlated to scrotal circumference ($r = 0.5$), testis volume ($r = 0.5$), testis length ($r = 0.4$) and body weight ($r = 0.5$). Scrotal skin thickness was however negatively ($P<0.05$) correlated with rectal temperature ($r = -0.11$), mean monthly rainfall ($r = -0.3$) and mean monthly minimum temperature ($r = -0.3$) on the day of semen collection.

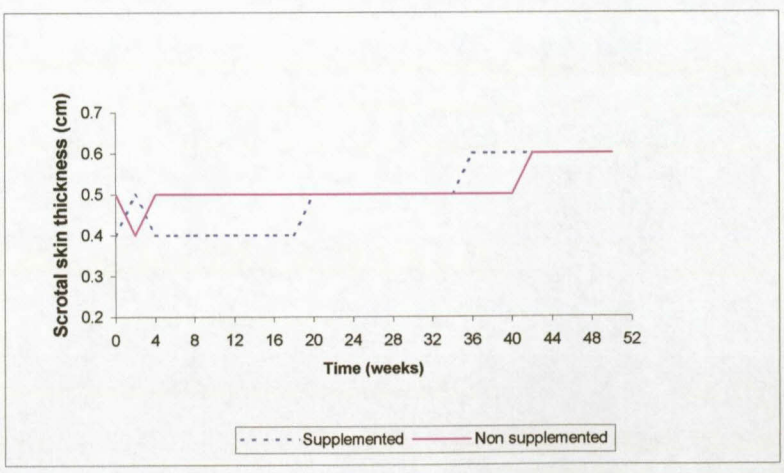

Figure 4.64 Mean scrotal skin thickness in supplemented and non-supplemented Horro bulls over a period of 50 weeks

Table 4.24 Least square mean (± SE) scrotal skin thickness following nutritional supplementation in Horro bulls

Weeks	Mean (cm) ± SE supplemented bulls	Mean (cm) ± SE non-supplemented bulls
0	0.4 ± 0.0^{NS}	0.5 ± 0.0^{NS}
2	0.5 ± 0.0^{NS}	0.4 ± 0.0^{NS}
4	0.4 ± 0.0^{a}	0.5 ± 0.0^{b}
6	0.4 ± 0.0^{a}	0.5 ± 0.0^{b}
8	0.4 ± 0.0^{a}	0.5 ± 0.0^{b}
10	0.4 ± 0.0^{a}	0.5 ± 0.0^{b}
12	0.4 ± 0.0^{a}	0.5 ± 0.0^{b}
14	0.4 ± 0.0^{a}	0.5 ± 0.0^{b}
16	0.4 ± 0.0^{a}	0.5 ± 0.0^{b}
18	0.4 ± 0.0^{a}	0.5 ± 0.0^{b}
20	0.5 ± 0.0^{a}	0.5 ± 0.0^{b}
22	0.5 ± 0.0^{NS}	0.5 ± 0.0^{NS}
24	0.5 ± 0.0^{NS}	0.5 ± 0.0^{NS}
26	0.5 ± 0.0^{NS}	0.5 ± 0.0^{NS}
28	0.5 ± 0.0^{NS}	0.5 ± 0.0^{NS}
30	0.5 ± 0.0^{NS}	0.5 ± 0.0^{NS}
32	0.5 ± 0.0^{NS}	0.5 ± 0.0^{NS}
34	0.5 ± 0.0^{NS}	0.5 ± 0.0^{NS}
36	0.6 ± 0.0^{NS}	0.5 ± 0.0^{NS}
38	0.6 ± 0.0^{NS}	0.5 ± 0.0^{NS}
40	0.6 ± 0.0^{NS}	0.5 ± 0.0^{NS}
42	0.6 ± 0.0^{NS}	0.5 ± 0.0^{NS}
44	0.6 ± 0.0^{NS}	0.6 ± 0.0^{NS}
46	0.6 ± 0.0^{NS}	0.6 ± 0.0^{NS}
48	0.6 ± 0.0^{NS}	0.6 ± 0.0^{NS}
50	0.6 ± 0.0^{NS}	0.6 ± 0.0^{NS}

^{NS} = no significant difference between means in the same row

^{ab} = means in the same row with different superscripts differ significantly ($P<0.05$)

4.15 TESTIS VOLUME IN HORRO BULLS FOLLOWING SUPPLEMENTATION

The mean testis volume over the observation period is presented in Table 4.25 and Figure 4.65. The time during the observation period when testis volume was measured showed significant ($P<0.05$) changes during certain stages (week 14 to 18). Testis volume in both the supplemented and non-supplemented groups gradually increased from the onset (week 0) to the end of the observation period (week 50) (475.1 ± 20.6 to 801.9 ± 4.8 ml for supplemented and from 449.4 ± 20.6 to 808.1 ± 4.8 ml in the non-supplemented group respectively). Testis volume was significantly ($P<0.01$) and positively correlated to scrotal skin thickness ($r = 0.53$), scrotal circumference ($r = 0.69$), testis length ($r = 0.77$), body weight ($r = 0.73$) and sperm motility ($r = 0.13$). Testis volume was also significantly ($P<0.01$) and negatively correlated with rectal temperature ($r = -0.21$), mean monthly rainfall ($r = -0.14$) and mean monthly minimum temperature ($r = -0.32$) at the day of collection.

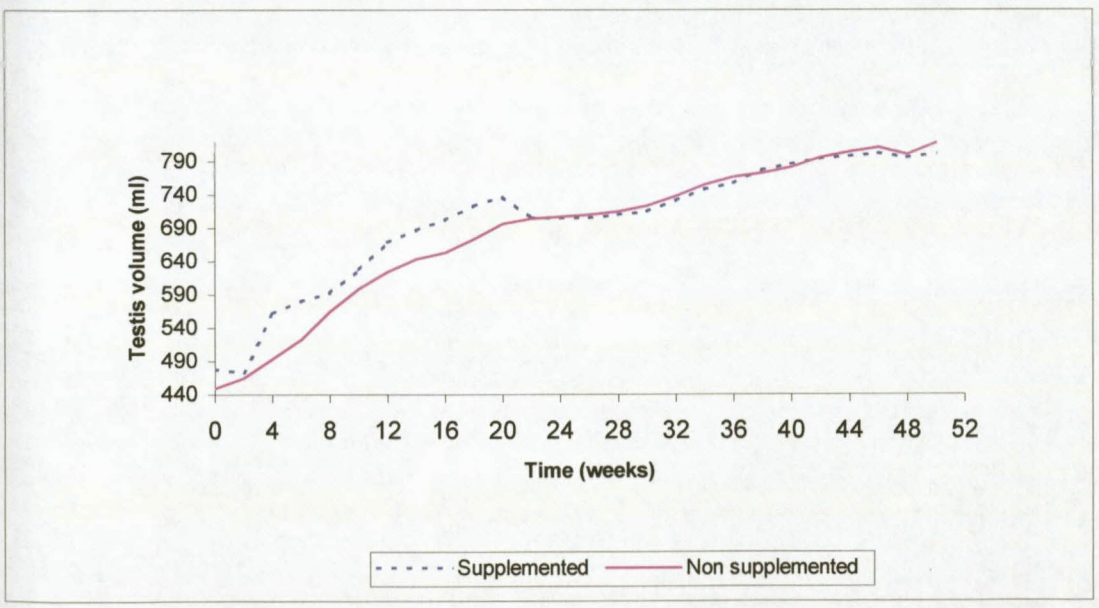

Figure 4.65 Mean testis volume in supplemented and non-supplemented Horro bulls over a 50 week period

Table 4.25 **Least square mean (± SE) testis volumes in supplemented and control Horro bulls over a 50 week period**

Week	Mean testis volume (ml) supplemented bulls	Mean testis volume (ml) control bulls
0	475.1 ± 20.6^{NS}	449.4 ± 20.6^{NS}
2	472.8 ± 16.4^{NS}	464.7 ± 16.4^{NS}
4	562.5 ± 16.6^{a}	493.8 ± 16.6^{b}
6	580.0 ± 16.1^{a}	523.1 ± 16.1^{b}
8	592.5 ± 16.6^{NS}	564.9 ± 16.6^{NS}
10	628.8 ± 15.1^{NS}	599.7 ± 15.1^{NS}
12	669.4 ± 15.5^{NS}	625.0 ± 15.5^{NS}
14	686.9 ± 13.4^{a}	643.8 ± 13.4^{b}
16	702.8 ± 13.0^{a}	653.8 ± 13.0^{b}
18	723.8 ± 11.2^{a}	673.8 ± 11.2^{b}
20	735.9 ± 9.4^{a}	656.9 ± 9.4^{b}
22	705.6 ± 7.6^{NS}	704.4 ± 7.6^{NS}
24	705.6 ± 7.5^{NS}	707.5 ± 7.5^{NS}
26	705.6 ± 7.5^{NS}	710.0 ± 7.5^{NS}
28	710.6 ± 7.6^{NS}	715.0 ± 7.6^{NS}
30	715.6 ± 8.0^{NS}	723.8 ± 8.0^{NS}
32	731.9 ± 7.4^{NS}	738.1 ± 7.4^{NS}
34	748.8 ± 5.6^{NS}	755.6 ± 5.6^{NS}
36	757.5 ± 5.0^{NS}	767.5 ± 5.0^{NS}
38	777.8 ± 4.3^{NS}	772.5 ± 4.3^{NS}
40	786.8 ± 4.1^{NS}	781.9 ± 4.1^{NS}
42	794.4 ± 4.5^{NS}	795.6 ± 4.5^{NS}
44	757.5 ± 5.7^{NS}	805.0 ± 5.7^{NS}
46	802.5 ± 9.5^{NS}	811.3 ± 9.5^{NS}
48	795.6 ± 6.0^{NS}	800.6 ± 6.0^{NS}
50	801.9 ± 4.8^{a}	808.1 ± 4.8^{b}

^{NS} = no significant difference between means in the same row

^{ab} = means in the same row with different superscripts differ significantly ($P<0.05$)

4.16 TESTIS LENGTH FOLLOWING SUPPLEMENTATION IN HORRO BULLS

The testis length (Table 4.26 and Figure 4.66) increased similarly in both treatment groups (supplemented and non-supplemented) from the onset of the experiment (15.8 ± 0.2 cm in the supplemented group to 18.0 ± 0.0 and from 15.0 ± 0.2 cm in the non-supplemented group to 18.0 ± 0.01 cm at the end of the trial respectively). A minimal increase in testis length was recorded over the 50 week observation period. Testis length was significantly ($P<0.01$) and positively correlated with testis volume ($r = 0.77$), body weight ($r = 0.55$), ejaculate volume ($r = 0.17$) and sperm motility ($r = 0.08$). Testis length was significantly ($P<0.01$) and negatively correlated with rectal temperature ($r = -0.16$), mean monthly rainfall ($r = -0.15$), mean monthly minimum temperature ($r = -0.35$) and relative humidity ($r = -0.01$) at the day of collection.

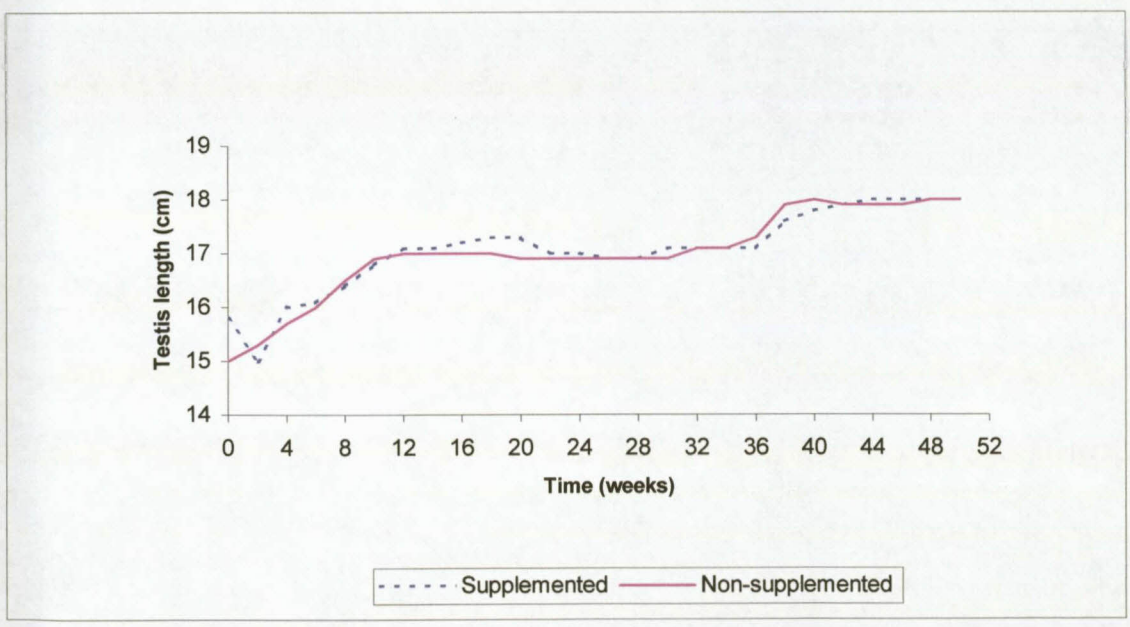

Figure 4.66 Least square mean testis length in supplemented and non-supplemented Horro bulls over a 50 week period

Table 4.26 **Least square mean (± SE) testis length (cm) in Horro bulls following nutritional supplementation**

Week	Mean ±SE (cm) supplemented bulls[NS]	Mean ±SE (cm) non-supplemented bulls[NS]
0	15.8 ± 0.2	15.0 ± 0.2
2	15.0 ± 0.2	15.3 ± 0.2
4	16.0 ± 0.3	15.7 ± 0.3
6	16.1 ± 0.2	16.0 ± 0.2
8	16.4 ± 0.2	16.5 ± 0.2
10	16.8 ± 0.2	16.9 ± 0.2
12	17.1 ± 0.2	17.0 ± 0.2
14	17.1 ± 0.2	17.0 ± 0.2
16	17.2 ± 0.2	17.0 ± 0.2
18	17.3 ± 0.2	17.0 ± 0.2
20	17.3 ± 0.2	16.9 ± 0.2
22	17.0 ± 0.2	16.9 ± 0.2
24	17.0 ± 0.2	16.9 ± 0.2
26	16.9 ± 0.2	16.9 ± 0.2
28	16.9 ± 0.2	16.9 ± 0.1
30	17.1 ± 0.2	16.9 ± 0.2
32	17.1 ± 0.1	17.1 ± 0.1
34	17.1 ± 0.1	17.1 ± 0.1
36	17.1 ± 0.1	17.3 ± 0.1
38	17.6 ± 0.1	17.9 ± 0.1
40	17.8 ± 0.1	18.0 ± 0.1
42	17.9 ± 0.1	17.9 ± 0.1
44	18.0 ± 0.0	17.9 ± 0.0
46	18.0 ± 0.0	17.9 ± 0.0
48	18.0 ± 0.0	18.0 ± 0.0
50	18.0 ± 0.0	18.0 ± 0.0

[NS] = no significant differences

4.17 BODY WEIGHT CHANGES FOLLOWING SUPPLEMENTATION IN HORRO BULLS

The least square mean body weights over the 50 week observation period are set out in Table 4.27 and Figure 4.67. Time had a significant ($P<0.01$) effect on the body weight of the bulls. A significant ($P<0.01$) time x treatment interaction was recorded for bull body weight. The overall body weight of both treatment groups increased from the start of the experiment (211.3 ± 4.0 kg in the supplemented group to 430.4 ± 3.5 kg at the end of the period - week 50). Similarly in the non-supplemented group the body weight increased from 211.3 ± 4.0 kg at the onset of the experiment to 329.3 ± 3.5 kg at the end. The bulls from the supplemented group gained 219.1 kg, compared to the 118 kg for the non-supplemented group during the observation period. During this treatment period the supplemented bulls gained significantly ($P<0.05$) more per day (600.3 g/day) than the control group (323.2 g/day). During the first 4 weeks of the observation period no significant differences were recorded in the ADG between the 2 groups.

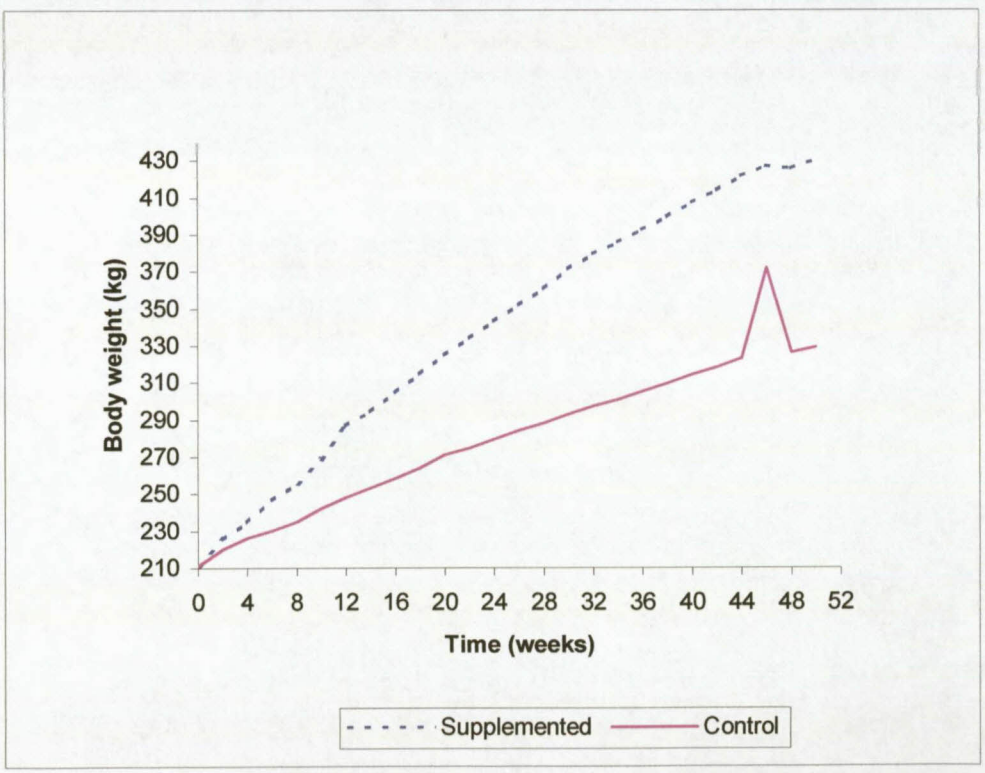

Figure 4.67 Least square mean body weight in supplemented and control Horro bulls for a 50 week period

Table 4.27 Least square mean (± SE) body weight in Horro bulls supplemented and non-supplemented over a 50 week period

Week	Mean ±SE (kg) supplemented bulls	Mean ±SE (kg) non-supplemented bulls
0	211.3 ± 4.0^{NS}	211.3 ± 4.0^{NS}
2	225.9 ± 3.8^{NS}	220.4 ± 3.8^{NS}
4	234.9 ± 4.1^{NS}	226.2 ± 4.1^{NS}
6	247.1 ± 4.1^{a}	230.4 ± 4.1^{b}
8	255.6 ± 4.2^{a}	235.2 ± 4.2^{b}
10	268.8 ± 4.1^{a}	242.1 ± 4.1^{b}
12	286.9 ± 4.2^{c}	248.2 ± 4.2^{d}
14	294.8 ± 4.3^{c}	253.3 ± 4.3^{d}
16	305.1 ± 4.2^{c}	258.4 ± 4.2^{d}
18	315.0 ± 4.1^{c}	264.1 ± 4.1^{d}
20	325.3 ± 4.4^{c}	271.3 ± 4.4^{d}
22	334.5 ± 4.1^{c}	274.9 ± 4.1^{d}
24	343.4 ± 4.1^{c}	279.6 ± 4.1^{d}
26	352.4 ± 4.0^{c}	284.3 ± 4.0^{d}
28	360.8 ± 3.9^{c}	288.4 ± 3.9^{d}
30	371.7 ± 3.8^{c}	292.9 ± 3.8^{d}
32	379.5 ± 3.8^{c}	297.3 ± 3.8^{d}
34	386.1 ± 3.7^{c}	300.8 ± 3.7^{d}
36	392.8 ± 3.7^{c}	305.4 ± 3.7^{d}
38	399.8 ± 3.7^{c}	309.8 ± 3.6^{d}
40	407.5 ± 3.5^{c}	314.6 ± 3.5^{d}
42	414.3 ± 3.5^{c}	318.4 ± 3.5^{d}
44	421.6 ± 3.5^{c}	323.1 ± 3.5^{d}
46	427.2 ± 8.1^{c}	327.1 ± 8.1^{d}
48	425.6 ± 3.6^{c}	326.3 ± 3.6^{d}
50	430.4 ± 3.5^{c}	329.3 ± 3.5^{d}

NS = no significant differences between means in the same row

ab = means in the same row with different superscripts differ significantly ($P<0.05$)

cd = means in the same row with different superscripts differ significantly ($P<0.01$)

4.18 SERUM TESTOSTERONE CONCENTRATION IN HORRO BULLS

The least square mean serum testosterone levels during the trial period are set out in Table 4.28 and Figure 4.68. Time (weeks) when serum was collected had a significant ($P<0.05$) effect on the serum testosterone concentration. The initial body weight of the bulls also had a significant ($P<0.05$) effect on the serum testosterone concentration. Serum testosterone levels obtained during the dry season were higher (911.6 ± 35.3 ng/dl), than those obtained during the wet season (768.6 ± 30.1 ng/dl) (Table 4.28). Although not significantly different, bulls from the supplemented group recorded the highest mean serum testosterone level (933.7 ± 37.4 ng/dl) compared to the non-supplemented group (746.4 ± 37.3 ng/dl) for the observation period.

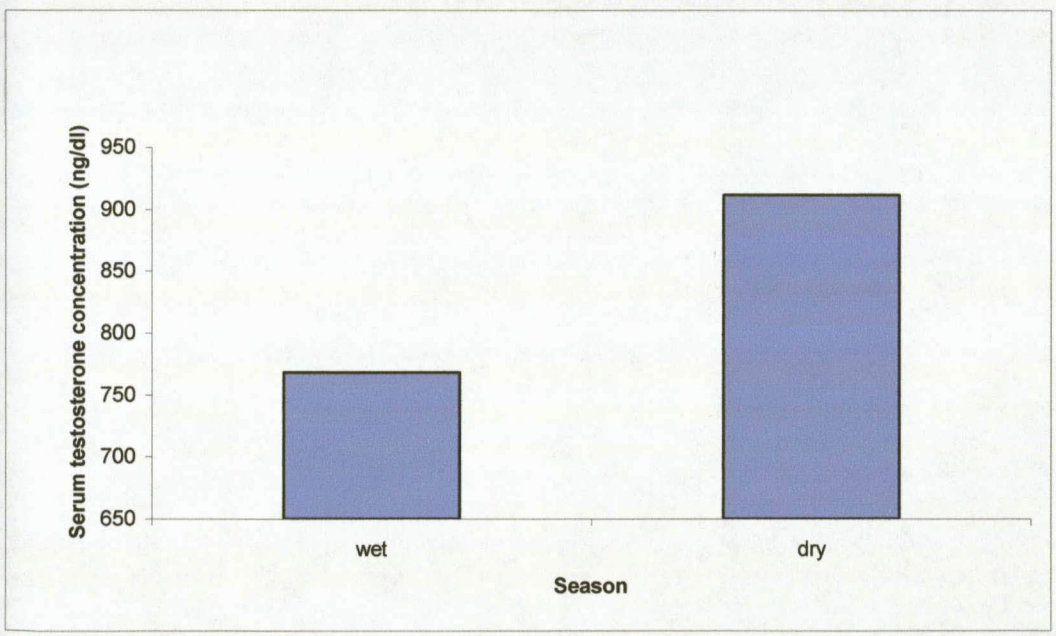

Figure 4.68 Effect of season on serum testosterone concentration in Horro bulls

Table 4.28 Least square mean (± SE) serum testosterone concentration in Horro bulls over a period of 42 weeks

Week	Mean ±SE (ng/dl) supplemented bulls[NS]	Mean ±SE (ng/dl) non-supplemented bulls[NS]
1	1226.4 ± 207.5	1073.7 ± 296.9
2	1088.4 ± 194.7	636.8 ± 278.6
3	1005.4 ± 330.5	484.2 ± 472.9
4	794.7 ± 302.7	843.06 ± 433.1
5	626.9 ± 258.7	363.6 ± 370.2
6	666.1 ± 256.2	842.3 ± 366.6
7	592.5 ± 208.2	958.5 ± 297.9
8	815.4 ± 334.7	936.2 ± 478.9
9	922.6 ± 361.9	1288.4 ± 517.8
10	892.2 ± 313.4	1228.6 ± 448.4
11	828.1 ± 176.3	424.2 ± 252.3
12	878.4 ± 305.1	925.7 ± 436.5
13	788.7 ± 397.3	957.1 ± 568.5
14	861.9 ± 275.7	1015.3 ± 394.6
15	703.6 ± 332.6	1344.8 ± 476.0
16	804.1 ± 190.4	866.2 ± 272.5
17	1348.9 ± 305.4	411.6 ± 437.0
18	1009.1 ± 614.1	1157.8 ± 878.7
19	672.2 ± 190.7	78.5 ± 272.8
20	492.0 ± 104.1	526.5 ± 149.0
21	1228.6 ± 243.5	176.3 ± 348.4
22	871.3 ± 160.5	738.4 ± 229.7
23	785.4 ± 146.9	231.8 ± 210.2
24	445.9 ± 89.2	493.1 ± 127.7
25	709.1 ± 90.1	610.3 ± 128.9
26	491.01 ± 155.5	686.5 ± 222.5
27	973.0 ± 244.9	291.9 ± 350.4
28	984.5 ± 234.4	451.5 ± 335.5
29	1008.6 ± 401.8	418.8 ± 575.0
30	1320.9 ± 508.3	570.1 ± 727.3
31	1222.5 ± 133.0	376.5 ± 190.3
32	656.5 ± 223.1	256.9 ± 319.3
33	1298.9 ± 369.0	960.2 ± 528.1
34	1463.2 ± 220.8	1206.03 ± 316.0
35	1127.7 ± 314.1	403.1 ± 449.4
36	1201.4 ± 248.7	653.2 ± 355.8
37	984.0 ± 384.0	808.9 ± 549.5
38	1184.9 ± 103.8	640.7 ± 148.5
39	1499.5 ± 486.0	233.5 ± 695.4
40	1453.1 ± 212.3	818.3 ± 303.7
41	1222.4 ± 175.5	285.2 ± 251.1
42	1025.3 ± 264.8	1579.4 ± 378.9

[NS] = no significant differences

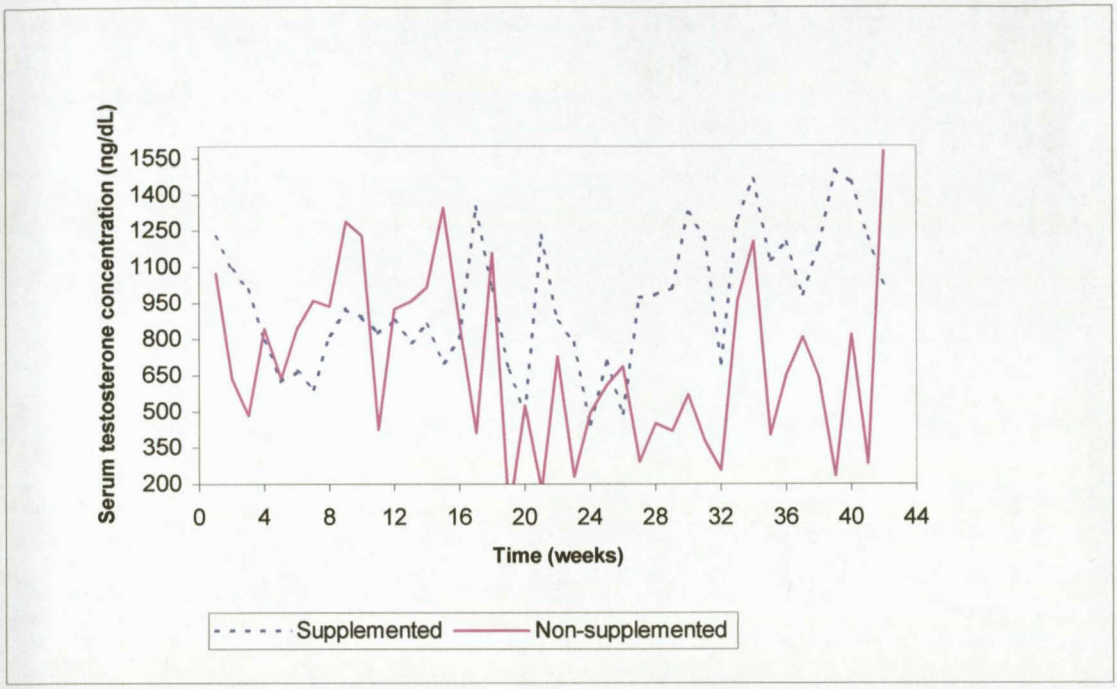

Figure 4.69 Mean serum testosterone concentration in supplemented and non-supplemented Horro bulls over a 50 week period

CHAPTER 5

DISCUSSION

5.1 AGE AND BODY WEIGHT AT PUBERTY IN HORRO HEIFERS

Age at puberty is primarily a function of the genetic make-up in heifers and the nutritional status or rate of weight gain during the post weaning and pre-breeding period (Cundiff *et al.*, 1986). In general dairy breeds reach puberty at a young age, while *Bos indicus* breeds reach it later and are thus generally later maturing. Age at puberty may be decreased by increasing the forage and feed intake (faster growth rate) and changing the genetic composition of the herd (Short & Bellows, 1971).

Luktuke and Subramanian (1961) reported a high incidence of anovulatory oestrus in Zebu heifers. The phenomenon of behavioral oestrus not followed by ovulation and formation of a corpus luteum, has been termed non-pubertal oestrus by Nelsen *et al.* (1985). Sexual maturation is a gradual process and puberty is only one stage in a series of maturational events that occur during the transition to adulthood. Byerley *et al.* (1987) reported fertility at the pubertal oestrus in heifers to be much lower than that at the third estrus following puberty - indicating sexual maturity follows puberty in the heifers.

Randal (1976) reported that heifers calving at 2 years of age demonstrate early maturation and see this as an important economic trait. In general Brahman and Brahman-cross heifers reach sexual maturity (puberty) at a later age than the European breeds (Reynolds, 1967). According to Short and Bellows (1971) the management decision of age at first breeding is complicated, as it involves many different factors. When both biological and economic outcomes are considered, decisions often produce results, which are in part advantageous and in part disadvantageous. These researchers reported factors involved in the decision on whether or not to breed heifers at a younger age to be based on both biological and economical considerations. Heifers should normally reach puberty 1 to 3 months prior to the time that they are bred. Thus in order for heifers to be bred as yearlings

and to calve at 2 years of age, Friesian heifers should reach puberty by 12 to 14 months of age. The earlier age at puberty in some breeds ensures that females achieve satisfactory potential fertility earlier in life or are ready to breed earlier in life (Byerley *et al.*, 1987). It has been known for many years that nutritional status and live weight gain are important determinants in the time to onset of puberty. In a study to evaluate the effect of different planes of nutrition, Ferrel (1982) showed a negative relationship between age at puberty and the rate of liveweight gain e.g. the faster growing heifers reached puberty at a younger age. Under normal nutritional management practices, the onset of puberty in heifers is unlikely to be a limiting factor in the achievement of calving at two years of age, as is commonly practiced in many countries (Ferrel, 1982).

The onset of puberty in heifers is more closely related to body weight than age. The age at which young females can normally be mated is dependant on the growth and development of individual animals. Dairy cattle reach puberty when the body weight is 30 to 40% that of the adult weight, whereas in beef cattle the percentage is higher (45 to 59%). The age at which puberty is attained, also varies between and within species. One of the main reasons for uneconomic production and dairying in the tropics is the late age at first calving. It is known to be influenced by the late age at first oestrus (puberty) and low conception rate (Moran *et al.*, 1989). In this study the mean age recorded for the age at puberty in Horro heifers was 39.4 months (ranging between 33.8 and 46.9 months). These results are in agreement with earlier studies in Horro heifers in which the average age at first oestrus was recorded as 38.4 months (Mulugeta, 1991). This however differs to the findings of Rahman *et al.* (1995) who recorded the age at first oestrus in Zebu heifers in Bangladesh to be 47.3 ± 0.6 months. Similarly Vashist and Katiha (1989) reported the age at first oestrus of Zebu heifers in India to be 44.0 months. Thus the results obtained in this study show that the mean age at puberty in Horro heifers is earlier than those reported by other authors for Zebu breeds elsewhere. The least square mean age at puberty over time (Table 4.1) showed variations over the years, but no clear trend for age at puberty could be noted. Season and year of birth played no significant role on the age at first oestrus (puberty). However heifers born in the wet season reached puberty slightly later

(41.0 ± 0.9 months) than the heifers born during the dry season (39.3 ± 1.4 months). Once again it can be emphasized that most breeds have the potential to reach puberty and breed satisfactorily at a younger age if provided with adequate nutrition and satisfactory management (Brinks, 1994).

Body weight has been shown to be the most critical criterium in determining when a heifer will reach puberty (Mukasa-Mugerwa, 1989). The mean body weight recorded at puberty in Horro heifers was 202.9 kg (180.8 ± 17.4 to 227.0 ± 13.7 kg). This was not significantly affected by the season of birth, year of birth or the birth weight. The results obtained in this study are in agreement with earlier findings of an average weight at puberty of 214 kg for Horro heifers (Mulugeta, 1991). From the least square means (Table 4.1) it is evident that weight at puberty of the heifers did not show a decreasing trend over the observation period from 1977 to 1996, except for the years 1994, 1995 and 1996. The season of birth did not affect the age and weight at puberty – this is contrary to Roy *et al.* (1980), who reported spring born Friesian heifers to reach puberty at an earlier age than autumn born heifers. Schillo *et al.* (1983) also observed the contrary.

The mean age at puberty in Horro heifers was not affected by the season of birth (wet or dry), year of birth or birth weight. Age and body weight are thus critical factors determining when a heifer will reach puberty with body weight probably being the more critical of the two factors. Thus to reduce age at puberty, sufficient nutrition to increase the growth rate is essential (Mukasa-Mugerwa, 1989).

5.2 AGE AND BODY WEIGHT AT CONCEPTION IN HORRO HEIFERS

The overall mean age at 1st conception recorded over the entire observation period was 50.1 months (40.9 ± 5.7 to 60.4 ± 5.7 months). This agrees with earlier findings of 55.3 months for Horro heifers (Mulugeta, 1991). In this study, the season of birth (wet or dry) did not seem to have any significant effect on the age at first conception. These results disagree with those of Schillo *et* al. (1992), who reported seasonal conditions in the post natal period to influence the time to onset of puberty and age at conception in beef heifers in the USA. Birth weight of the heifers also did not affect

the age at 1st conception. However, regarding the year of birth, here it was found that year had a significant (P<0.05) effect on the age at 1st conception. The year effect could be related to a variation in the availability of nutrition and the quality thereof. No clear trend regarding age at 1st conception was observed for the period from 1975 to 1995. This phenomenon was generally in line with the rainfall pattern and changes in management - with higher rainfall and certain managerial practices being more advantageous for earlier conception. Similarly, the overall least square mean weight at 1st conception (226.7 kg - ranging from 190.5 ± 24.4 to 254.2 ± 13.8 kg) was not influenced by the season of birth or birth weight. Year of birth however, once again significantly (P<0.05) affected weight at 1st conception – possibly for the same reasons as for age. The body weight at conception decreased over the years (1975-1995), but this was not accompanied by a corresponding decrease in age at conception. Regarding the age at 1st conception there is ample evidence to demonstrate the profound effect of nutrition on the age and weight at 1st conception in Horro heifers. In general it can be said that the effect of year of birth was related to variation in the availability of nutrition and quality of the pastures. Unfortunately the year of birth was also associated with changes in managerial practices of the heifers over the years and these were not registered - which complicates the interpretation of results.

5.3 AGE AND BODY WEIGHT AT 1ST CALVING IN HORRO HEIFERS

Most currently used beef cattle management systems require that heifers be bred at 14 to 16 months of age and calve at approximately 24 months of age. The reproductive efficiency of the cow is thus associated with her age at maturity. The earlier a cow matures, the more profitable she will be to the farmer over her productive life. A high post weaning nutritional plane will thus accelerate growth, reduce the age at puberty and conception and result in heifers calving at an earlier age (Singh & Singh, 1965).

The mean recorded age for Horro heifers at first calving in this study was 58.7 months (ranging between 51.5 ± 5.2 and 70.7 ± 3.0 months). This is higher than the 40 months reported for ranched cattle and 53 months for traditionally reared animals in

Ethiopia (Mukasa-Mugerwa & Matton, 1988). It is also much higher than the 32.8 months reported by Negussie *et al.* (1998) for Arsi (Zebu) cows, also in Ethiopia and higher than that reported for Zebu cattle (45.4 months) in Tanzania (Syrstad, 1990), East African Zebu cattle (40.5 months) (Rowlands *et al.*, 1994) - but comparable with the age at first calving for Bangladesh Zebu heifers (56.3 ± 0.5 months) (Rahman *et al.*, 1995).

Year of birth significantly ($P<0.05$) affected the age at 1st calving in this study, with heifers born in the drier years calving later for the 1st time. This is contradictory to the findings of Galal *et al.* (1981) who reported the year of birth not to have an affect on the age at 1st calving in F1 crosses (Horro x Jersey and Friesian x Simmental). The overall least square mean weight at 1st calving (259.2 kg) was not significantly affected by season of birth or birth weight. Similarly to age at 1st calving, the year of birth significantly ($P<0.05$) affected the weight of the heifer at 1st calving. It is assumed that in general the year of birth is related to the availability and the quality of the nutritional environment. However, it would seem that body weight at 1st calving decreased over the years and this was not accompanied by a corresponding decrease in the age at 1st calving. The average age could be reduced and weight improved at 1st calving in Horro heifers by improving the feeding and general management practices, but the feasibility thereof in Ethiopia is questionable. Management is an aspect that is very difficult to evaluate in this regard.

5.4 THE POST PARTUM ANOESTROUS INTERVAL AND THE POST PARTUM PERIOD IN HORRO COWS

A long post partum anoestrous interval can be seen as one of the most important factors limiting reproductive efficiency in Zebu cattle. Body weight at calving and weight changes during the post partum period affect the onset of reproduction activity in Zebu cattle, with a low body weight at calving and excess weight losses prolonging this period (Garcia *et al.*, 1990).

Mukasa-Mugerwa *et al.* (1991a) in an effort to evaluate the influence of suckling and continuous cow-calf association on the resumption of post partum ovarian function in

Bos indicus cows (monitored by plasma progesterone profiles), found continuous suckling or constant cow-calf interaction to extend the post partum anoestrous interval in Ethiopian Zebu cows. In a study on the effect of supplementary feeding and suckling intensity on post partum reproductive performance in small East African Zebu cows, it was reported that 65% of the supplemented and 53% of the control cows exhibited oestrus over the 8 month period. The post partum oestrous interval was shortened by 54 days in the supplemented, compared to control cows and by 13 days in restricted suckling versus continuously suckling cows (Tegegne *et al.*, 1992b). Studying the effect of urea and molasses on mineral supplementation on post partum ovarian activity in Zebu cows, Ghosh *et al.* (1993) reported that the number of days from calving to the onset of ovarian cyclicity averaged 25.5 ± 3.4 days (14 to 44 days) for the supplemented and 83.5 ± 7.5 days (60 to 175 days) for the non-supplemented group.

The overall mean post partum anoestrous period recorded was 77.2 days and this was not affected by calf birth weight. The season of calving significantly ($P<0.05$) affected the post partum anoestrous interval. Cows that calved during the wet season (May to September) had a shorter post partum anoestrous interval, compared to those that calved during the dry season. This finding was expected as cows that calve during the wet season (May to September) calve in a period of the year when the availability and quality (protein) of the natural pasture is much higher than in the dry season. These results are in agreement with the findings of Kanuya and Greve (2000) who reported that cows calving at the onset of the rainy season exhibit the shortest post partum anoestrous interval, while those calving in the dry season exhibited the longest. The year of calving significantly ($P<0.01$) affected the post partum interval. Season and year effects (climate, rainfall, vegetation, etc.) may be direct or indirect. Direct effects may be related to the effect of weather changes on the physiology of the cow, while indirect effects may be associated with the influence of climate on pasture and thus on the nutrient intake of the animal (Kaltenbatch & Dunn, 1980). A decreasing trend was observed in the post partum anoestrous interval from 1977 to 2001. A possible explanation for this may be better oestrous detection methods

employed at the center or a general improvement on husbandry practices over the years – an aspect difficult to evaluate.

The period from calving to conception is the most critical period in a cows' production cycle and minimizing this period is important for several reasons. One of the most important reasons is that cows that cycle earlier have a better chance of conceiving during a limited breeding season. Rocha *et al.* (2000) reported that in dairy cattle there is a period of negative energy balance during the first few weeks post partum, when feed consumption is not significant to meet the nutritional demands of lactation. The mean post partum anoestrous period of 117.5 days recorded in this study was not significantly affected by the season of calving, calf birth weight or sex of the calf. The year of calving, however, significantly ($P<0.01$) affected this period. It is well known that nutrition influences the reproductive efficiency in cattle and that the post partum period can be reduced by proper management and adequate nutrition of the pre- and post partum cows (Garcia *et al.*, 1990).

The level of nutrition during the last 50 to 60 days prior to calving have been shown to have a profound effect on the cyclicity after calving. This importance is further exaggerated by a low BCS of the cow. A cow with a moderate BCS (5 to 6 out of 10) that loses body weight pre-calving is more vulnerable to post partum lower nutrient levels than a cow in similar or even poorer condition that is gaining weight prior to calving. The nutrition level pre- and post calving is thus of utmost importance when it comes to the post partum anoestrous interval (Mudgal, 1985). Kaltenbatch and Dunn (1980) and Mukasa-Mugerwa and Azage (1991) reported the post partum interval (from parturition to first oestrus and ovulation) in cattle to depend primarily on the quality of nutrition offered during pregnancy. Bako Research Center in Ethiopia has a sub humid tropical climate. During the rainy season the availability of pasture is higher and as a result of this the cows gain weight during this period. During the dry season the availability (and quality) of pasture is limited and the cows loose weight and this may have a negative impact on the post partum period. This post partum period is thus the most important phase of the cow's reproductive cycle - both from a physiological and a management point of view. It directly affects the

subsequent intercalving period and the ability of a cow to calve every year (Gordon, 1996).

Peters and Ball (1987) have used body weight as an index of the nutritional status of the animal and found a significant negative correlation between body weight at calving and the length of the post partum anoestrous period in beef cows. It has been suggested that such seasonal effects are related purely to nutritional management. When comparing *Bos indicus* with *Bos taurus* it is suggested that prolonged anoestrus, often encountered when *Bos taurus* cattle are introduced into tropical environments, may occur mainly as a result of malnutrition rather than a direct result of high temperature. Randal (1990) has concluded that the BCS of the cow and whether the animal is gaining or losing weight are the major determinants of the interval between calving and the resumption of ovarian activity.

Based on the findings of the current trial it is recommended that the management of post partum anoestrus in Horro cows (*Bos indicus*) should focus on the conservation of BCS in cows. Cows that calved during the dry season exhibited the longest period to oestrous when compared to cows that calved during the wet season, so the introduction of a breeding season in order to synchronize a calving season in the wet season, seems to be warranted.

Sex of the calf recorded a significant difference in post partum interval to oestrus with cows giving birth to female calves recording the longest post partum oestrous interval, compared to male calves. The reason for this phenomenon is unclear – although the heavier calves (in this case the females) for the Horro breed would have a bigger energy drain on the dam.

5.5 THE INTERCALVING PERIOD (ICP) AND GESTATION LENGTH IN HORRO CATTLE

Zebu cattle are characterized by a low reproductive efficiency in the tropical regions (Oyedipe *et al.*, 1988; Mukasa-Mugerwa *et al.*, 1991a). Apart from the late attainment of puberty these cattle are also characterized by long intercalving intervals

(Turner, 1980; Mukasa-Mugerwa *et al.*, 1991a). Generally calving intervals of around 365 days are targeted in the cattle industry. To attain a 365 day calving interval, the calving to conception interval should be approximately 85 days. Cow fertility is markedly influenced by the nutritional level over the breeding period, as reflected by changes in the diet and fluctuation in body weight and condition. Loss in body weight during early lactation is often associated with a decline in a reproductive efficiency, stemming primarily from a delay in the resumption of ovarian activity. Cows losing weight around the time of mating are less likely to conceive than those gaining weight (Gaines, 1989). Having cows in a good BCS at calving, coupled with restricted suckling of the calf, is an effective way of reducing the intercalving interval.

In this trial an overall least square mean of 475.2 days (15.8 months) was recorded for the intercalving interval in Horro cows - which is in line with other findings under similar conditions for Horro cows: 498 ± 91 days (Galal et al., 1981), 24 months (extensive conditions) (Tesfaye, 1991), 14.5 ± 2.9 months (Mulugeta *et al.*, 1993) or 410.7 days (Negussie *et al.*, 1998). The absence of significant effects of season of calving on the length of the calving interval in Horro cattle is contrary to findings elsewhere (Galina & Arthur, 1989; Moyo, 1996). Mukasa-Mugerwa *et al.* (1991a) reported shorter calving intervals for Arsi (Bos indicus) cows calving during the rainy season in Ethiopia. Generally season is a complicated factor as it includes many variables with complex interactions between them. So to a certain degree this aspect and its effects on certain reproductive parameters are being over-simplified in this study. Another seasonal effect emphasized by Dawuda *et al.* (1989) states that heat stress alters the progesterone profile in post partum cows. Heat has always been considered as being responsible for increased secretion of the adrenocorticotrophins, which stimulates the secretion of progesterone from the adrenal glands. In this study cows that gave birth to male calves had a longer intercalving interval when compared to those with female calves, but these differences were not significant. Generally male calves are associated with a longer gestation period than females (Holland & Odde, 1992; Rege & Moyo, 1993). The absence of a significant effect of sex of the calf on the inter-calving period observed in this study is in agreement with Mukasa-Mugerwa *et al.* (1991b), also on Ethiopian Zebu cows.

Parity of the dam significantly affected the intercalving period in this study. This was also found by Kanuya and Greve (2000) and Rafique *et al.* (1999) who reported parity to have a highly significant effect on intercalving intervals. The longest intercalving period (503.7 ± 8.8 days) was recorded in cows in their 2nd parity, compared to the 3rd (469 ± 9.7 days), 4th (449.2 ± 11.2 days), 5th (468.6 ± 13.1 days) and 6th (456.8 days) parities, respectively. A decreasing trend with time was observed - as parity increased over time, the intercalving period decreased. The year of calving also had a significant ($P<0.01$) effect on the intercalving interval and is in agreement with Dionisio (1989) and De Souza *et al.* (1995). No clear trend was observed over time (1975 to 2001) regarding the intercalving period in this trial (Table 4.5). A general observation that can be made from the management at Bako Research Center was that no special attention was given to post partum cows. Further these cows were not nutritionally supplemented according to their needs and oestrous detection was done by visual observation (twice daily), but this was not reliable as it is conducted by poorly trained herdsmen. Extensive loss of dam weight during the lactational post partum period was not compensated for and this was most likely the main reason for the prolonged intercalving periods recorded.

The season of calving, sex of the calf and calf birth weight did not affect the inter-calving period during the observation period. This absence of any significant effect of calving season on the length of the intercalving interval was contrary to findings elsewhere. Calving season (wet/summer) was found to shorten the period between calving and conception (Galina & Arthur, 1989; Moyo, 1996). Year of calving however significantly affected ($P<0.01$) the intercalving period and could be related to variations in nutrition, climate and management. Parity also significantly ($P<0.05$) affected the intercalving period, with younger cows, recording the longest intercalving period.

Differences in the length of intercalving intervals from 1st to 3rd calvers and older dams have been associated with the physiological and nutritional stress on lactation and simultaneously growing younger animals (Dionisio, 1989; Mukasa-Mugerwa *et*

al., 1991a). Dawuda *et al.* (1988b) reported that ovarian activity increases with parity or age. Peak fertility in beef cows was reported to be in the age group of 6-7 years (Dionisio, 1989). The decreasing trend observed in the length of the intercalving period in this study, was in agreement with those of Dionisio (1989) and Mukasa-Mugerwa *et al.* (1991a, b). First calvers generally experience physiological stress accentuated by poor nutrition. Moreover, the 1st calvers have to complete their growth and simultaneously nurse a calf (Dionisio, 1989; Mukasa-Mugerwa *et al.*, 1991a).

The normal duration of pregnancy in the cow has been stipulated as being approximately 9 months and the existence of significant differences between breeds of cattle in the length of gestation is well documented (Jainudeen & Hafez, 1993). Some of the factors known to influence the duration of pregnancy are related to maternal, fetal, genetic and environmental factors. Differences in the gestation period in cattle are found, especially when European (*Bos taurus*) and Zebu (*Bos indicus*) species are compared. In the Afrikaner breed (Zebu), for example, the gestation length can be more than 296 days - which is 3 to 25 days longer than the periods usually recorded in breeds of European origin (e.g. the Friesian or Jersey). Sex of the fetus could also play a minor role in influencing the gestation length with bull calves being accommodated for a day or so longer than heifer calves (Jainudeen & Hafez, 1993). The overall mean of 283 days recorded in this study for gestation length in Horro cows was comparable to that reported by Azage *et al.* (1981) (280.7 ± 3 days) and Mulugeta *et al.* (1993) (282.2 ± 5.86). The year of calving with its many possible variables significantly ($P<0.01$) affected gestation length in this trial, but no clear trend was found. The sex of the calf sex also played a significant ($P<0.05$) role in determining gestation length. Males calves are associated with longer gestation periods than females (Holland & Odde, 1992; Rege & Moyo, 1993). Cows bearing male calves had a longer gestation length in this study. Mukasa-Mugerwa *et al.* (1991b) did not find any significant effect of sex of the calf on the length of the post partum interval in Ethiopian Zebu cows.

5.6 LIVE WEIGHT CHANGES IN POST PARTUM HORRO COWS

The year of mating with its variables has been reported to significantly affect the dam weight at mating, parturition and at weaning significantly (Hetzel *et al.*, 1989). Similarly, the year of calving also affects the dam weight at calving and weaning. Dionisio (1989) reported that season of calving significantly affects the dam weight at parturition and weaning in Afrikaner and Landim cows, respectively. Reproductive performance in extensive tropical breeding systems as experienced in Ethiopia is often very low and usually associated with deficiencies in forage quality and availability or lack of adequate managerial practices. A practical method of monitoring the herds' nutritional status is evaluating body weight changes of the animals. Such measurements are however dependant on the frame size of the animal and dam weight at mating, calving and weight changes during mating (Hetzel *et al.*, 1989; Schwalbach, 1997).

In this trial cows that calved during the dry (summer) season lost more weight, compared to cows that calved during the wet season. This was expected, as during the dry season the natural pastures are limited in quantitative and qualitative terms. Cows that calved in the wet season (May to September in the case of Bako Research Centre) thus lost less weight during the post partum period, compared to those that calved during the dry season. These findings could be explained by a higher nutritional content of the pastures during the rainy season. This effect of season of calving on post partum fertility is in agreement with Dionisio (1989). The dam weight at weaning was significantly ($P<0.01$) affected by the season of calving with cows that calved in the wet season being 10.2% heavier at weaning than those that calved in the dry season. It is also reported that in Friesian cows losing more than 35 kg weight during early lactation, the interval from calving to first oestrus was delayed by 72 to 104 days.

Of the total number of Horro cows calving in this trial during the dry season, only 20% became pregnant within 90 days post partum, compared to 60% for their counterparts calving during the wet season. This result was expected, as cows calving during the dry season generally loose more weight and take longer to recover

and resume oestrous activity. Although not monitored in this trial, Mudgal (1985) reported low nutrient intake to cause a decrease in body weight both before and after calving, resulting in infrequent manifestation of oestrus and low fertility during the subsequent breeding period. It is suggested that the post partum fertility of Horro cows can be drastically improved by post partum nutritional supplementation, particularly in cows calving during the dry season.

5.7 POST PARTUM SERUM PROGESTERONE CONCENTRATION IN HORRO COWS

Determination of the serum progesterone concentration has been found to have practical application as a method of improving reproduction efficiency in farm animals. So for example, serum progesterone levels have been measured for the purpose of pregnancy diagnosis in cattle (Robertson & Sarda, 1971; Heap *et al.*, 1973). Normally progesterone is a hormone produced in the cow following ovulation and fertilization and can be detected in milk or blood serum samples. As the serum progesterone profile follows a specific pattern it is possible to take blood/serum samples of a cow and predict when the next oestrous period is likely to occur - and thus determine the best time to inseminate the cow. A low progesterone level on the day of insemination gives a good indication whether the cow was in oestrus and subsequent levels should rise and remain high during pregnancy. Maternal heat stress conditions could also result in lower levels of serum progesterone, abnormal patterns of progesterone secretion, a shorter corpus luteum life span, higher oestrogen levels in the pre-ovulatory phase and a higher incidence of ovulation, without behavioural signs of oestrus (Berman, 1991).

In this study, an overall least square mean serum progesterone concentration of 6.1 ng/ml was recorded for the observation period and this was significantly ($P<0.01$) affected by the season when blood was sampled. Serum progesterone levels during the wet season were higher (8.5 ± 0.8 ng/ml) than those collected during the dry season (2.8 ng/ml). These values are in agreement with those reported by Dawuda *et al.* (1988a) who also found heat stress to alter serum progesterone patterns in post partum cows. Heat was also considered by Camothe-Zavaleta *et al.* (1991) to be

responsible for increased secretion of adreno cortocotropin which stimulates the secretion of progesterone form the adrenal glands. The initial body weight of cows at calving significantly ($P<0.01$) affected the serum progesterone concentration. The low serum progesterone levels recorded during the dry season are similar to those obtained by Berman (1991). Kaul and Prakash (1994) reported the accuracy of pregnancy diagnosis in Zebu and crossbred cattle by milk progesterone determinations (day 20 to 24) in positive pregnancy diagnosis to be 91%, and in negative pregnancy diagnosis to be 100%.

5.8 BODY WEIGHT IN HORRO CATTLE

5.8.1 Birth and 3 month of age weight in Horro calves

Birth weights of calves are affected by a variety of genetic and environmental factors. These include year and season of birth, age, lactational status and fertility of the dam, breed and sex of the calf (Lubout *et al.*, 1986; Newman & Deland, 1991; Schwalbach, 1997). Seasonal effects on birth weight may be attributed mainly to differences in dam nutrition, with emphasis on the critical last third of gestation (Rege & Moyo, 1993). Sex of the calf has been found to have a significant effect on birth weight (Dionisio, 1989), with male calves recording consistent higher birth weights – the advantage being approximately 5 to 8% over female calves (Holland & Odde, 1992).

The overall mean birth weight of calves recorded in the present study (18.4 kg) is comparable with earlier findings in Horro calves (18.6 ± 0.2 kg) (Mulugeta, 1991). From the results obtained it was evident that sex of the calf significantly ($P<0.01$) affected birth weight and the male calves were heavier than their female counterparts at birth. This finding is supported by Holland and Odde (1992), who also found male calves to be heavier, with the season of birth not having any significant effect on birth weight. This is however contrary to that of Lubout *et al.* (1986) who reported season to have a significant effect on birth weight. The birth weights recorded in this study are in agreement with those of Mabesa (1994) who reported no significant difference in birth weight in Bonsmara calves born during the dry and wet seasons. The year of

birth also had a significant ($P<0.05$) effect on the birth weight of calves in this study. The annual least square mean birth weight tended to increase over the period from 1997 to 2001. Significant year effects on birth weight have also been reported in other studies (Bothma, 1993; Rege & Moyo, 1993). The year effects may be due to variation in management during the years and also be related to better nutritional and climatic environments - mainly due to the difference in rainfall patterns and the direct effect on the availability and quality of nutrients.

The overall least square mean recorded for 3 month body weight was 48.9 kg in Horro calves (ranging from 33.8 ± 5.2 to 68.5 ± 1.9 kg) and this was not affected by the sex of the calf. No significant differences in body weight of male and female calves were recorded at this age. These results differ from that of Marques (1995) and Mabesa (1994), who reported sex to have a significant effect on body weight at 3 months of age. In the above-mentioned studies, males outweighted their female counterparts. Season of birth significantly ($P<0.05$) affected the body weight at 3 months of age, with calves born during the wet season being heavier than those born in the dry season (difference of 4.5%). Nesamvuni (1995) also found Bonsmara calves born during the wet season to be heavier than those born during the dry season. This however, disagrees with the findings of Oni *et al.* (1988) who studied the influence of certain environmental factors on the growth rate of two Nigerian cattle breeds and Charolais crosses and was found that season of birth did not affect bodyweight at 3 months of age. The 3 month weight of Horro calves was significantly ($P<0.01$) affected by the year of birth, with nutrition and ambient temperature presumably being the main contributors to this difference. A steadily decreasing trend was observed for the body weight at 3 months for the whole observation period from 1977 to 2001, an aspect that suggest that there is a problem. This may be due to improper management employed for the management of calves and poor quantity and quality feed offered during this period. The lowest 3 month weight was recorded in 2001.

5.8.2 The 6 and 12 month body weight in Horro calves

The average 6 month body weight was 68 kg. This weight was not affected by the sex of the calf or season of birth. Surprisingly, the sex of the Horro calves did not

have a significant effect on the 6 month of age weight. This is contrary to the reports by Dionisio (1989), Abessa *et al.* (1993) and Bothma (1993) who recorded a significant difference in the body weight at 6 months of age. In these studies the male calves of different tropical breeds grew significant faster than the heifer calves. There may be a few reasons for this unexpected phenomenon observed in the trial. Thorpe *et al.* (1980) and Lubout (1987) suggested a stressful environment may suppress the display of natural sexual differentiation (dimorphism) between male and female calves. In the case of the Bako Research Centre, with its subtropical climate, high humidity, high mean daily temperatures and poor pastures during the dry season may have contributed to stressful conditions at this age. Year of birth also significantly affected the weight at 6 months of age. Year effects are susceptible to changes in management during the years and also be related to varying nutritional and climatic environments - mainly due to the differences in rainfall patterns and the direct effect on the availability and quality of the natural pastures. Calf birth weight was significantly correlated ($P<0.05$; $r = 0.21$) with the weight at 6 months (weaning) of age. Six month body weight demonstrated a decreasing trend from 1977 to 2000. The possible explanation for this trend is once again poor management (nutrition) due to the over grazing of the pastures and no or irregular nutritional supplementation.

The 12 month body weight (mean of 87.5 kg) was significantly ($P<0.05$) affected by sex of the calf. At this stage female calves were found to be heavier (5.8%) than their male counterparts. These results differ from those obtained by Lubout *et al.* (1986) who reported no significant effect of sex of the calf on the 12 months body weight in Pedi cattle. This finding is, however, contrary to the reports of Bothma (1993) and Rege and Moyo (1993) for 12 months old body weights. Season of birth significantly ($P<0.05$) affected weight at 12 months of age with the calves born during the wet season being heavier (14.8%) than those born during the dry season. This result is contrary to the findings of Lubout *et al.* (1986) and Lubout (1987) who reported no significant difference between season of birth and weight at 12 months of age in Nguni and Pedi calves. Year of birth significantly ($P<0.05$) affected the weight at 12 months of age, similar to that obtained by Lubout *et al.* (1986). A gradual decrease in weight at 12 months of age from 1977 to 2000 was observed in Horro calves. The

year effect could be related to weather changes and the influence of climate on pasture and the feed intake of the animal. Calf birth weight was also significantly correlated ($P<0.05$; $r = 0.18$) with the weight at 12 months of age and calves with a heavier birth weight were found to be heavier at 12 months of age. The fact that female calves were heavier than the males could possibly attributed to the preferential management given to heifer calves at the Bako Research Center in Ethiopia. In times of shortage or deficiencies, heifers have priority with regard to supplementation.

5.8.3 The 18 and 24 month body weight in Horro cattle

The overall least square mean for 18 month weight in Horro cattle was 109.7 kg, ranging from 83.2 ± 14.6 kg to 142.8 ± 14.7 kg. Sex of the calf played a significant role ($P<0.05$) regarding the weight at 18 months of age. In this study at 18 months Horro female calves had outgrown their male counterparts. This once again, was contrary to Lubout *et al.* (1986) who reported no significant effect of sex of the calf in Nguni cattle. The lack of significant effects of season of birth on 18 month body weight is in agreement with Lubout (1987) in Pedi and Bothma (1993) in Nguni calves. This was however contrary to the findings of Dionisio (1989) who reported a significant effect of season of birth on 18 month weight of Afrikaner calves. The general lack of seasonal effects on 18 month weight in the present study could suggest compensatory growth of calves born during the dry season, when compared to those born during the wet season. The year of birth (and all its associated factors) significantly ($P<0.01$) affected the 18 month of age weight in Horro cattle. Once again birth weight significantly ($P<0.05$) affected the weight at 18 months of age, with the heavier calves recording a higher 18 month body weight. The year effect on body weight at 18 months is in agreement with the findings of Plasse *et al.* (1995) and Moyo (1996) and could possibly be related to weather changes, the effect of climate on pasture and the feed intake of the animal.

The overall average 24 month body weight recorded for the entire period was 140.9 kg (ranging from 109.2 ± 10.1 to 172.02 ± 18.9 kg). Sex of the calf had a significant ($P<0.05$) effect on the body weight at 24 months of age with contrary to the expected, the females being heavier than their male counterparts (3.2%). The unexpected

superiority of the females over the males could partially be explained by the preferential managerial practices of heifers at the center. Females after weaning, generally receive more strategic nutritonal management (supplementation) at the Bako Research Center as they are seen as long term investments (replacements) in the herd. Another factor that may have contributed to this is the stressful environment at the station (Bako Research Center's tropical climate), which could have suppressed the expression of the sexual superiority of the males over females. The season of birth significantly ($P<0.01$) affected the weight of the animals at 24 months of age in this study. Calves born during the wet season were heavier at 24 months than those born during the dry season. This is in agreement with the findings of Morris and Wilton (1976) and Bothma (1993) who reported the season and year of birth to have a significant effect on the growth rate in beef cattle. Season and year effects were related to year differences in climate and management. These seasonal effects result in better nutrition in the wet season when pastures are more abundant. The year of birth also significantly ($P<0.01$) affected the weight at 24 months of age. The year effect may reflect improvements in the management. Similarly calf birth weight significantly ($P<0.05$) affected the weight at 24 months of age with calves born with higher birth weights recording higher weights at 24 months of age.

5.8.4 The pre- and post weaning average daily gain (ADG) in Horro calves

The overall pre-weaning average daily gain (ADG) from birth to weaning at 6 months of age was 275 g/day (ranging between 225.5 and 443.4 g). This gain was not influenced by the season of birth. The results obtained are not in agreement with Rege and Moyo (1993) where it was reported that season of birth has a significant effect on the pre-weaning ADG and sex of the calf had no significant effect on the pre-weaning ADG. The absence of any sex effects on the pre-weaning daily gain is conflicting with the basic theories that explain the source of sexual differences between males and females and is probably management related (Nesamvuni, 1995). Another factor that may cause this lack of sexual dimorphism is inbreeding (Brinks & Knapp, 1975; Beffa, 1988). The year of birth significantly ($P<0.01$) affected pre-weaning ADG in this study, although these results are not in agreement with the findings of Nesamvuni (1995) and Moyo (1996) who reported the year of birth not to

have a significant effect on pre-weaning growth in Bonsmara, Indigenous and exotic beef cattle beef breeds. The year effects may be due to changes in management during some years and could also be related to nutrition of the calves. The calf birth weight also significantly ($P<0.01$) affected its pre-weaning ADG - with calves with a higher birth weight, recording the highest ADG.

The overall post weaning ADG was 130.9 g/day and this was not affected by the calf sex or calf birth weight. The fact that sex of the calf did not play a significant role in the growth differences between males and females does not agree with previous reports by Van Zyl (1990) and Moyo (1996). Environmental stress could have caused the lack of expression of sexual dimorphism in Horro calves regarding post weaning weight gain (Thorpe *et al.*, 1980; Lubout, 1987). Inbreeding also results in lack of expression of sexual dimorphism in beef cattle. Management practices could also have played a partial role in suppressing the expression of these expected sexual differences. Normally female Horro calves are given preferential treatment, as they are reared for replacement heifers in Ethiopia. The season of birth significantly affected the post weaning average daily gain. Similar findings have also been reported by Rege and Moyo (1993). In this study calves born in the wet season gained more body weight than the calves born in the dry season. Season/year of birth has been reported to significantly affect pre-weaning growth rates (Rege & Moyo, 1993; Moyo, 1996). Season/year effects may be associated with seasonal differences in quality and quantity of forages. The year of birth also significantly ($P<0.01$) influenced the post weaning ADG in this study. Speculatively the year and seasonal effects may also be explained by the change in management and be related to nutrition of the calf.

5.9 MORTALITY AGE IN HORRO CATTLE BETWEEN 1977 AND 2001

The mortality rate in Horro cattle have not previously been reported as no reliable records were available at the center. However, mortalities have been reported to be a major limiting factor in animal productivity and therefore alśo in herd efficiency in the tropics (Du Toit *et al.*, 1995). Calf survival rates reflect both breed and

management differences. Moyo (1996) showed pre-weaning calf mortality rates to be significantly affected by the year of birth and the previous calving status of the dam.

In the observation period, sex of the calf significantly ($P<0.01$) affected the mortality rate, with male Horro calves dying at a younger age than their female counterparts. This phenomenon could be due to several reasons. The most logical explanation may be the preferential treatment given to female Horro animals in terms of nutritional supplementation and health care.

Mortalities in the Horro breed at the Bako Research Center generally occur at a mean age of 1.1 ± 0.4 years in males and 2.4 ± 0.4 years in female animals. The season in which the animals die played no significant role in the mortality rate recorded. In certain drier years the animals may loose more weight and become more susceptible to various diseases. Nutritional status as such is important in the maintenance health of animals (Du Toit *et al.*, 1995). The highest mortality rates were recorded in 1985 and could be related to the drought experienced in Bako during 1984 - this could have effected the live weight changes in the animals and their susceptibility to diseases. The causes of mortalities were not recorded at the research center. For this reason, no further discussion on this topic is possible. This points to the fact that complete records must be kept, including the reason for mortalities - for future reference.

5.10 THE STAGE AND RATE OF ABORTION IN HORRO COWS

Abortion can be defined as the termination of pregnancy and the premature expulsion of a fetus of recognizable size before it is viable, before 260 days of gestation in cattle. Blowy (1985) claimed various causative factors to be involved in the occurrence of abortions. The season and year when abortions occurred did not seem to have any effect on the stage at which abortion occurred in this study. Of the total number of abortions recorded in this study 21.6% were stillbirths. It was interesting to note that abortions mostly occurred during late pregnancy (last trimester) in Horro cattle. This is consistent with the high incidence of brucellosis recorded in cattle at Bako center (Muktar, 1993). The incidence of abortion among indigenous (Zebu)

cattle in Ethiopia seems to be minimal, compared to that of crossbreeds. Generally, abortion has a direct effect on the income of the farmer through loss of calves and milk while it also reduces the life time production of the cow. Attention should be given to the health and nutritional management of the cows in order to minimize the occurrence of abortions.

5.11 EVALUATION OF SEMEN CHARACTERISTICS IN HORRO BULLS

5.11.1 Semen volume

The total volume of the ejaculate is influenced by the age of the bull, season of the year, elapsed time since the last ejaculation, breed and individuality of the bull (Swierstra, 1968; Amann, 1981). Some breeds produce less semen and there are also individual differences within breeds. Semen production, as reflected by semen volume or ejaculate volume in bulls is also influenced by the level of nutrition. Environmental and temperature fluctuations, hormonal abnormalities, seasonal changes, testicular degeneration and diseases all affect ejaculate volume in bulls (Foote, 1969; Amann, 1970a; Berndson, 1977).

The mean semen volumes recorded in this trial (2.8 ± 0.3 to 3.7 ± 0.1 ml for supplemented and 2.3 ± 0.3 to 2.8 ± 0.1 ml for non-supplemented bulls) was lower than that reported by Shelke and Dhami (2001) for Gir bulls (Bos indicus) (4.8 ± 0.2 ml) in India and Brahman and Nelore (Zebu) bulls (6.3 ± 1.2 and 5.9 ± 0.8 ml respectively) (Silva-Mena *et al.*, 2000). These differences could be attributed to the method of semen collection. The artificial vagina has been proven to be a more desirable semen collection technique when compared to electrical stimulation in bulls. When semen is collected by means of electrical stimulation the sample obtained is often of inferior quality. Deficiency of minerals, trace elements and vitamins have also been reported to effect semen production. In general, bulls from nutritionally supplemented bulls tend to record higher semen volumes compared to non-supplemented bulls. An increasing trend was observed for semen volume in both supplemented and non-supplemented groups with time. This is in agreement with Alvarez *et al.* (1995) who reported ejaculate volumes to increase with age. The high

ambient temperatures experienced during summer (October – April) did not seem to have any effect on the semen production in terms of volume. Except for the first weeks from the onset of the experiment, semen volume did not differed significantly between the two treatment groups. For the rest of the observation period, significant differences ($P<0.05$) could be observed between the two treatment groups, with the supplemented group recording significantly higher semen volumes than the non-supplemented group. The present result is not in agreement with the findings of Smith and Merilan (1991), who found supplementation not to show any significant effect on semen volume in Holstein bulls. It is however, in agreement with the findings of Tegene *et al.* (1992a) who studied gonadal and extra gonadal sperm reserves in Boran and Boran x Friesian bulls raised on 2 planes of nutrition in the highlands of Ethiopia.

5.11.2 Semen colour

Most bull semen samples collected in this trial were milky white to cream in colour. Herrick and Self (1962) reported that some bulls (up to 10%) produce semen, which is normally yellow in colour. This should not be confused with semen that is contaminated with urine. It has been further reported that this yellowish colour is due to riboflavin pigment that is characteristic in certain bulls. The 3 colour types observed during this trial were creamy, milky white and watery. The watery colour being due to probably excessive stimulation of the accessory sex glands. In general, colour is not affected by factors such as age, season, breed and management. Nutritional management and its interaction could have an effect on semen colour (Hafez & Hafez, 2000). In this trial semen from the nutritionally supplemented group tended to have a more creamy colour, an indication of a higher sperm concentration.

5.11.3 Sperm mass motility

Time (week of the year) during which semen was collected had a significant ($P<0.05$) effect on mass motility in all bulls collected. This indicates a weekly variation in the motility recorded and could presumably be attributed to the effect of season and/or the interaction between season and nutritional management on sperm motility. However,

no clear seasonal trend could be observed. Time x treatment interaction also showed a significant ($P<0.05$) effect on sperm mass motility. These results are in agreement with those reported by Belorkar *et al.* (1990), Osman *et al.* (1990) and Singh and Sharma (2001) who found time, ambient temperature, concentration and contamination to have a significant effect on sperm mass motility in bulls. In this trial on Horro bulls, there was a tendency for the supplemented group to have a higher sperm mass motility during most weeks of the observation period, particularly from the 8th week of the trial, compared to the non-supplemented bulls. In both groups (supplemented and non-supplemented) a decreasing trend in terms of mass motility was observed from the onset of the experiment in week 0 to the end of the experiment (week 50). The reason for this is unclear. These results are not fully in agreement with the findings of Alvarez *et al.* (1995) who reported that sperm motility increases with increasing age of the animals. Sperm motility is extremely susceptible to environmental conditions such as excessive heat or cold (Belorkar *et al.*, 1990; Osman *et al.*, 1990). Hafez and Hafez (2000) reported malnutrition, particularly low energy intake in males could reduce growth rate, delay puberty and permanently impair output. All these factors are associated with a reduction of *inter alia* sperm motility. The mass motility recorded in both groups (supplemented and non-supplemented bulls) decreased by the 50th week and this could possibly be attributed to season. This low motility score at the end of the experiment (summer) could be ascribed to the fact that the high ambient temperatures negatively affected sperm motility.

5.11.4 Percentage live sperm in Horro bulls

The percentage live spermatozoa in an ejaculate can be accurately determined by use of a stain that will not be absorbed by live sperm. At the end of the day, the total number of live sperm per insemination is more important than the percentage abnormal sperm. It has been stated that the percentage live sperm and the sperm motility are the main determinants of semen quality (Lincoln & Short, 1980; Hafez & Hafez, 2000). A significant difference in the percentage live sperm was recorded between months (seasons), with the lowest values being recorded in summer and the highest in winter (Jainudeen & Hafez, 1980).

In this study time (weeks) in which the semen collected did not have any significant effect on the percentage live sperm in both groups. A similar finding was observed in the percentage of abnormal sperm, both in the supplemented and control groups - from the onset of the trial to the end. A gradual increase in the percentage abnormal sperm was observed as the trial progressed, particularly towards the end, when the summer heat and humidity may have played a role. A time x treatment interaction recorded a significant ($P<0.05$) effect on percentage live sperm. These results obtained can possibly be attributed to the season of collection, a time by nutritional interaction and increased age of the animals. Lincoln and Short (1980) reported a significant difference in the percentage live sperm between summer and winter, with the lowest values being recorded in the summer and the highest in winter. In general the technique used to determine the percentage live sperm was consistent and repeatable and thus satisfactory.

5.11.5 Percentage abnormal sperm in Horro bulls

Sperm abnormalities may be described with respect to the part of the cell affected (e.g. the head, midpiece or tail) (Chacon *et al.*, 1999; Dragileva *et al.*, 1999). According to Hafez and Hafez (2000) heat stress is the cause of a large number of sperm abnormalities and periods of high ambient temperatures combined with high humidity that may render temporarily infertility in a male for a period of up to 6 weeks.

The mean sperm abnormalities in the non-supplemented (control) group remained slightly higher than the supplemented group throughout the observation period. These results are in agreement with studies done by Singh and Sharma (2001) who found nutritional supplementation to significantly decrease the percentage abnormal sperm. At the onset of the trial at Bako Research Center the supplemented group had higher (however not significant) percentages abnormalities, compared to the non-supplemented group, but this phenomenon reversed later in the trial. Johansson *et al.* (1998) in a study on the prevalence of morphological defects in spermatozoa from beef bulls, reported that most common defects to be proximal cytoplasmic droplets

(8.4%) distal mid piece reflexes (6.7%) spermatic heads (5.5%) and distal cytoplasmic droplets (3.8%). Chacon *et al.* (1999) in conducting breeding soundness tests in extensively managed bulls in Costa Rica, found that frequencies of sperm abnormalities were higher in bulls younger than 2 years of age than in older bulls.

Semen containing high numbers of abnormal morphologically shaped sperm are generally associated with a low conception rate. Bulls used in natural service usually display decreased fertility if more than 35% or 40% of the sperm are abnormal. Adverse environmental conditions and diseases can greatly affect sperm morphology in bulls while heat stress causes a transient increase in morphological abnormalities of sperm and a subsequent decrease in fertility (Elmore, 1985).

Soderquist *et al.* (1997) reported a significant difference between bulls regarding the occurrence of abnormal sperm heads and total sperm abnormalities. The percentage sperm head abnormalities recorded in this trial in the nutritionally supplemented group remained slightly (not significant) lower than in the control group for most of the trial period. In this study the time when semen was collected did not have any significant effect on sperm head abnormalities. The nutrition x time interaction showed a highly significant ($P<0.01$) effect on percentage of abnormal sperm. The overall percentage sperm abnormalities found in this study in supplemented and non-supplemented group were acceptably low at the onset of the experiment and increased slightly at the end of the trial at week 50.

It would seem that the season when the sperm was collected influences the sperm tail abnormalities. In this study, sperm tail abnormalities were also significantly ($P<0.05$) affected by nutritional and time (week) interactions. Sperm tail abnormalities were higher for the supplemented group at the onset of the trial. Thereafter the sperm tail abnormalities in both groups (supplemented and non-supplemented) increased steadily until the end of the experiment (week 50). The results obtained may indicate that sperm tail abnormalities may be affected more by the season of collection rather than supplementation. The sperm mid-piece abnormalities as such were not affected by the season when the sperm was collected.

In the present study, time (week) when semen was collected did not have any significant effect on specifically the sperm mid-piece abnormalities. The time x treatment interaction recorded a highly significant effect on sperm mid-piece abnormalities but it is difficult to assess the actual cause of the defects. The overall mean sperm mid-piece abnormality recorded in this study in both supplemented and control group is in an acceptable range. The results obtained may indicate that sperm mid-piece abnormalities may be affected more by season of collection rather than supplementation. Generally the sperm abnormalities recorded in this study are not high enough to prevent successful fertilization.

The lack of seasonal differences in sperm abnormalities (total sperm abnormalities, head, tail and midpiece abnormalities) observed in this trial is not in agreement with the findings of Soderquist *et al.* (1997) and Hafez and Hafez (2000) who reported season of the year to have an effect on sperm abnormalities. Seasonal changes in semen abnormalities have also been reported by Dhami *et al.* (1998) in India, in Friesian and Murrah bulls. It was found that the percentage of abnormal sperm was higher during the cold season. Van Camp and Van Camp (1997) and Johansson (1997) reported reduced fertility usually to occur when the number of primary sperm defects were greater than 20%. These semen evaluation results generally indicate satisfactory semen handling procedures used during the trial.

5.11.6 Sperm concentration and pH in Horro bulls

Sperm cell concentration is generally expressed as the number of cells per ml (Hafez & Hafez, 2000). The average concentration of semen ranges from 800 million to 1½ billion per ml in bulls. Differences in sperm cell concentration have been attributed to the feeding regime, season of year and for different geographic localities (Lodge & Salisbury, 1970).

In this study the mean sperm concentration for the two groups (supplemented and controls) followed the same trend – a slow increase in sperm concentration as the trial progressed (and the animals matured). The sperm concentration in the supplemented

group remained higher, ranging between 330.4 ± 23.6 and 623.2 ± 66.8 x 10^6/ml, while the sperm concentration for the control group ranged between 333.8 ± 23.6 and 564.2 ± 69.1 x 10^6/ml. These results differ from those of Shelke and Dhami (2001) who reported the sperm concentration to be 1219.4 ± 38.2 x 10^6/ml in Gir bulls, but it is comparable with those of Silva-Mena *et al.* (2000) who reported the sperm concentration for Brahman and Nelore to be 577.2 ± 83.4 x 10^6/ml and 621.7 ± 92.5 x 10^6/ml respectively. The lower sperm density in this study may be partly explained by the collection technique used. The electro-ejaculator, although not preferable, is more practical and therefore was the method used to collect the semen. The density or sperm concentration of the ejaculate collected by means of an artificial vagina has been found to be significantly higher compared to that of electro ejaculator (Amann, 1970).

Time of the year when semen is collected did not have any significant effect on semen concentration. Similarly a significant ($P<0.05$) time x nutrition interaction was not noted with semen concentration. Hafez and Hafez (2000) reported deficient nutrient intake to be associated with a reduction in secretory output of the accessory sex glands and hence sperm concentration. Differences in sperm cell concentration have been previously attributed to season of the year and different geographic localities where climate and humidity increase body temperature so that sperm concentration often declines (Lodge & Salisbury, 1970).

The pH of freshly ejaculated bull semen depends on several factors. Normally samples are more acidic, varying in a pH of 6.5 to 6.9 (mean 6.75) (Salisbury & Van Demark, 1961). The semen pH recorded in this trial in both the supplemented and the non-supplemented (control) group of bulls did not vary for most of the trial period. The pH remained fairly constant around 6.8. These results are comparable with that of Shelke and Dhami (2001) for Gir bulls (6.6 ± 0.1). The hydrogen ion concentration of semen is dependant on the metabolic activity of the spermatozoa. The month to month variation in pH of semen of Horro bulls was not significant. This result is also in agreement with those of Salisbury and Van Demark (1961). Lack of significant differences between weeks in semen pH was contrary to Tomar *et*

al. (1965), who reported a month to month variation in the semen pH of Zebu and buffalo bulls. More concentrated semen (of better quality) is usually more acidic (lower pH) than semen with lower sperm counts, that tends to be more alkaline (Shelke & Dhami, 2001). The method of semen collection may have contributed to the present results. Studies done on Hariana and Murrah bulls in India recorded a seasonal variation in the pH of semen (Tomar *et al.*, 1965).

5.12 LIBIDO IN HORRO BULLS

Libido is the sexual desire or the eagerness of a bull to breed a cow and the male hormone (testosterone) is responsible for this sex drive (Salizbury & Van Demark, 1961). Libido can be influenced by genetic, climate, season, level of nutrition, age, sexual experience, neural stimuli and other physical factors (Osborne *et al.*, 1971; Crichton *et al.*, 1987).

The reaction time recorded for the Horro bulls in this trial remained short (less than 5 minutes). The time (week) when the libido tests were performed had a significant effect on bull libido. This is in agreement with the findings of Crichton *et al.* (1987) who reported season of the year to influence libido in bulls. Weekly variation in libido score was also recorded, with no obvious effect of nutrition on libido being observed during this observation. This is in agreement with Mwansa and Makarechian (1991) who studied the effect of post weaning dietary energy level on sex drive of beef bulls and found that libido score was not affected by the feeding regime. Salisbury and Van Demark (1961) reported libido or sex drive to be mainly under hormonal control of testosterone secreted by the cells of Leydig in the testis. Chenoweth (1981) reviewed the use and value of libido tests and the environmental and genetic influence on libido. Field studies of Chenoweth (1981) as well as other studies (Farin *et* al., 1989) validate the predictive ability of the libido test for fertility. The test has also been used to demonstrate breed differences where *Bos indicus* bulls showed to have a lower libido than British bulls (Chenoweth & Osborne, 1975). A lack of significant differences in libido between the two (supplemented or control) is in agreement with the findings of Mwansa and Makarechian (1991) who reported that libido score was not affected by the feeding regime in young beef bulls. The libido

score in the present study (scale = 0 to 5) in 5 minute tests, is comparable with the findings of Nwakalor and Ezinma (1989) (scale = 0 to 10) in Muturu and N'Dama beef bulls and who reported the libido score to average 3.6 ± 1.0 and 6.7 ± 0.4, respectively.

In this study the low libido score recorded may be attributed to the hot and humid climatic conditions at the trial site. Price and Wallach (1990) reported the method of housing to have an effect on bull libido and individually housed bulls exhibited fewer mounts and spent less time with females, than group-housed bulls. In this study the bulls were housed individually and this could have contributed to the low libido score obtained in both the supplemented and non-supplemented groups.

5.13 SCROTAL CIRCUMFERENCE IN HORRO BULLS

Many factors such as breed, age, season and body mass influence testes size or scrotal circumference. Makarechian *et al.* (1984) reported testicular size in bulls to be an inherited trait and pre-weaning and feedlot growth rate and age may influence testes development. The most significant testicular growth in a bull occurs from the age of 6 to 36 months and can be monitored by measuring the scrotal circumference. Maximum testicular size usually occurs at 4 to 6 years of age (Meyer *et al.*, 1990; Mukasa-Mugerwa & Ezaz, 1992). The mean scrotal circumference of both groups (supplemented and non-supplemented) in this study was almost similar at the onset of the trial and at the end of the experiment. The scrotal circumference of bulls in the supplemented group ranged from 28.8 ± 0.5 to 32.8 ± 0.2 cm and in the control group from 28.9 ± 0.5 to 33.0 ± 0.2 cm. This is comparable with the scrotal circumference values quoted by Nwakalor and Obase in white Fulane (Bonagi) cattle (30.8 cm), but more than the scrotal circumference reported in N'Dama bulls (22.3 cm). Stage of the observation period when the scrotal circumference measurements were taken significantly ($P<0.05$) affected the scrotal circumference in both groups of bulls. This is an indication that scrotal circumference increases with age in bulls. Godfrey *et al.* (1990) reported marked seasonal fluctuations in testes size, increasing during the summer and decreasing during the winter. Lack of significant differences between the supplemented and control bulls in scrotal circumference is contrary to the findings

of Rekwot *et al.* (1988) and Venter *et al.* (1977), who reported a strong relationship between level of nutrition and scrotal development. Either the treatment was too short or the nutrition supplement not adequate to induce evident differences. Swanepoel and Heyns (1986) reported breed type differences in the rate of increase in scrotal circumference. *Bos taurus* breeds have been reported to have a relatively lower rate of increase in scrotal circumferences, when compared to *Bos indicus* and/or Zebu breeds. In this trial the scrotal circumference for both groups increased at a relative similar rate at the end of the experiment.

5.14 SCROTAL SKIN THICKNESS IN HORRO BULLS FOLLOWING NUTRITIONAL SUPPLEMENTATION

Scrotal skin thickness was measured as a possible indicator of fat deposition around the testes (Das & Tomer, 1995). No significant effect of supplementation was observed, indicating that the supplementation levels were not sufficient to induce subcutaneous fat accumulation in the scrotum. A highly significant ($P<0.01$) time (week of collection) effect was recorded regarding scrotal skin thickness (in both supplemented and non-supplemented groups). This parameter could give an indication of the effect of season and nutrition on the subcutaneous fat deposition in the scrotum. The time x nutrition interaction recorded was highly ($P<0.01$) significant – but the contribution of each factor is difficult to clarify. The overall mean scrotal skin thickness for both treatment groups increased towards the end of the trial, when the scrotal skin thickness in both groups recorded 0.6 ± 0.01 cm. This coincides with the season of better nutritional quality of the pastures.

5.15 TESTES VOLUME IN HORRO BULLS FOLLOWING SUPPLEMENTATION

Testes size (volume) is correlated to semen volume and acts as a good indicator of semen quality (Herrick & Self, 1962) and affects of season, breed and age on testes volume have also been reported (Patel *et al.*, 1988).

In this trial the testicular volume of the bulls increased significantly from the onset to the end of the trial - indicating testicular growth with age. Testicular volume was

related to an increase in body weight of the bulls with increased age. The significant ($P<0.05$) influence of time on the testicular volume recorded during the observation period suggests that as time progresses so body weight of the bulls has a subsequent effect on the testis volume. A significant ($P<0.01$) time x treatment interaction on testis volume was recorded in this trial. This could imply a specific influence of nutrition on body weight of the bulls and increased testes volume. The testes volume for the supplemented group of bulls increased from 478.1 ± 20.6 to 801.9 ± 4.8 ml, while that of the control group increased from 449.4 ± 20.6 to 808.1 ± 4.8 ml. No advantage of nutritional supplementation was observed regarding testes volume. This could indicate that the supplementation levels were not sufficient to affect testicular growth or the treatment period was too short. These results are not in agreement with the findings of Singh and Pangawkar (1989) who demonstrated a beneficial effect of nutrition on testicular growth in bulls.

5.16 TESTIS LENGTH FOLLOWING SUPPLEMENTATION IN HORRO BULLS

The total length of the testicles, including the epididymis, is of great importance. In order to function properly and at maximum efficiency, both testicles should be of a length that is within the given range of the optimal size, in accordance to the breed and age of the bull (Drayson, 1982).

The testis length in the bulls of both the supplemented and non-supplemented group increased steadily from the onset to the end of the trial at week 50. Time (weeks) when testis length measurements were recorded played a significant ($P<0.01$) role in testis length. Testis length was related to body weight and as the age increased so testis length increased. The testes length of the supplemented bulls increased from 15.8 ± 0.2 cm at the onset of the trial to 18.0 ± 0.0 cm at the end of the observation period, while in the control group it increased from 15.0 ± 0.2 cm to 18.0 ± 0.1 cm in the corresponding period. No significant differences in testes length were observed between the supplemented and non-supplemented groups and the results are consistent with those obtained for scrotal circumference and testes volume. It would

seem that the supplementation level was insufficient to induce testicular differences between the groups.

5.17 BODY WEIGHT CHANGES FOLLOWING SUPPLEMENTATION IN HORRO BULLS

Reports have shown the onset of puberty in bulls to be influenced more by body weight than age as such. Both weight and age are likely to be profoundly influenced by the level of nutrition and thus the post weaning rate of gain (Brown, 1994).

As can be expected the mean body weight for both groups of bulls (supplemented and non-supplemented) increased steadily from the onset of the observation period to the end of the experiment due to an increase in age. Time thus significantly ($P<0.01$) affected bull body weight, with the body weight in the supplemented group increasing and remaining higher than the control group. This difference could be attributed to a difference in plane of nutrition and thus growth rate. Similar results regarding supplementation have been reported by Tegegne *et al.* (1992a) for Boran and Boran x Friesian bulls in Ethiopia. The body weight of the supplemented group increased from 213.4 ± 4.0 kg at the onset of the trial to 430.4 ± 3.5 kg at the end of the trial at week 50. Similarly in the non-supplemented (control) group body weight increased from 211.3 ± 4.0 kg at the onset to 329.3 ± 3.5 kg at the end of the trial. The supplemented group gained significantly more weight (600.2 g/day), compared to the control group, which only gained on average 323.3 g/day. Body weight as a reflection of body condition of the bulls, is mainly affected by nutrition and the effect of nutrition on body weight was clearly evident in the treated group throughout the observation period.

5.18 SERUM TESTOSTERONE CONCENTRATIONS IN HORRO BULLS

Great variation in the serum testosterone concentration for both the supplemented and non-supplemented bulls were recorded. The pattern of serum testosterone fluctuation clearly indicates the influence of time (season) on testicular activity. In this study season significantly ($P<0.05$) affected the serum testosterone concentration. Serum testosterone levels of bulls collected during the dry season (October – April) were

higher (911.6 ± 35.3 ng/dl), compared to serum testosterone levels collected during the wet season (May – September) (768.6 ± 30.09 ng/dl). This is in agreement with Stumpf *et al.* (1993), who indicated season of the year to have an effect on the concentration and pattern of gonadotrophin and circulating testosterone secretion in beef bulls. This is contrary to Javed *et al.* (2000) who studied the influence of season on seminal plasma testosterone in buffalo bulls and found testosterone levels to have no significant difference between seasons. Nutritional treatment had no significant effect on serum testosterone concentration in this trial. The nutritionally supplemented group recorded the highest serum testosterone level (933.7 ± 37.4 ng/dl) compared to the non-supplemented group (747.4 ± 37.3 ng/dl) - indicating possible higher testicular activity. This would thus seem to demonstrate the effect of nutrition on serum testosterone production and testicular activity in bulls. The higher (better) the level of nutrition, the better the serum testosterone response. The pulsatile nature of testosterone however, complicates its use as an indicator of sexual activity in bulls.

CHAPTER 6

GENERAL CONCLUSIONS AND RECOMMENDATIONS

All the female reproductive and productive traits evaluated in this study such as age and weight at puberty (the time at which oestrus first occurs), at first conception, at first calving, the post partum anoestrous interval (from parturition to first oestrus and ovulation), post partum period (from calving to conception), intercalving period and calf growth traits such as birth weight, weight at 3, 6, 12, 18, and 24 months, and pre- and post weaning weight gains showed not much improvement over the years monitored at the Research Center. Environmental constraints (mainly nutrition) seem to be the major cause of poor reproductive and productive performance recorded in the Horro breed. Several factors were found to influence the traits studied. Among these, season of birth, season of calving, pre- and post nutritional management of the pregnant cows have the possible potential of improving the reproduction performance, if properly manipulated.

The wet season (May – September) demonstrated a shorter post partum anoestrous interval and shorter post partum period. Calf growth traits were better for animals that were born in this season. It demonstrated that if higher reproductive and production performance is to be attained, mating should be restricted to the dry season (October – April) and cows should give birth during the wet season when feed resources are readily available. Nutrition plays a crucial role in the initiation of post partum ovarian activity in the animals. If cows are poorly fed during the post partum period, as is often the case during the dry season under tropical extensive production systems, the major constraint will be post partum infertility, a prolonged rebreeding interval or a long post partum anoestrous period.

The mortality rate recorded in male and female Horro cattle during this study period at Bako Research Center show male animals to die at a younger age and

being more vulnerable to diseases than females. This could be due to less attention being generally given to male calves after weaning - as they are not used further in the herd (for replacement) and preferential treatment is given in the form of supplementary feed only to the heifers. Thus, a strategy should possibly be developed, in future sell the male calves at weaning (6 months of age). This would also reduce the grazing pressure on the pastures. The causes of the mortalities over the years were not recorded at the center and consequently, it is suggested that all causes of mortalities be recorded in future, so that it can assist in the proper planning of a health and nutritional management program.

The low rate of abortions recorded in Horro cows and heifers during this study was acceptable. This suggests that the incidence of abortion in animals (Zebu) indigenous to Ethiopia is minimal. This may be due to a satisfactory Brucellosis control through vaccination and due to the adaptation of the breed to the harsh environments prevailing in these tropical and subtropical regions (and their inherent resistance to diseases).

Growth is influenced by genetic and environmental factors, which exert their effects throughout the three phases of pre-natal, pre-weaning and post weaning growth. Most growth traits studied were influenced by season of birth in this study except for the body weight at 6, 18 months and pre-weaning ADG. Calves born during the wet season (May – September) were heavier compared to those in the dry season (October – April). Year of birth (with the respective environmental differences) influenced all growth traits. In some years the animal gained more weight than in others. This could be related to the rainfall pattern and availability of grazing. Bako Research Center also has a sub-humid tropical climate that can exert its effects on the growth performance of the animals. This effect can be avoided by proper planning e.g. planning the grazing time to avoid the hottest hours of the day. To improve the growth rate of replacement heifers, preferential treatment should be given so animals can reach puberty and start their productive life earlier.

Both from a reproductive and productive point of view, the establishment of a limited mating season to induce an early summer (wet) season calving, seems to be warranted.

Bull fertility indicators such as semen characteristics (semen volume, sperm mass motility, sperm concentration, percentage live sperm and percentage abnormal sperm), testicular characteristics (scrotal circumference, scrotal skin thickness, testes volume, and testis length), libido, body weight and serum testosterone concentration were markedly influenced by time of the year. This can be attributed to the effect of season (ambient temperature, rainfall and relative humidity). Bulls in the supplemented group recorded higher values for most characteristics evaluated. The effect of season was also markedly visible in other parameters recorded, e.g. scrotal circumference, testicular volume and scrotal skin thickness - serving as an indicator of sexual activity and fertility of the bulls. The serum testosterone level in both groups (supplemented and control) fluctuated considerably throughout the trial period. The effect of season was probably the reason for the fluctuation, with supplementation being advantageous.

In general, the supplemented bulls tended to record higher serum testosterone levels and showed better testicular and semen characteristics compared to the group receiving no supplementation. These differences were, however, only significant at certain times of the observation period and there was no strong evidence of seasonal trends or patterns for all parameters measured. Even within each nutritional group there was considerable variation between individuals regarding the parameters measured. This indicates the possibility to improve fertility in Horro bulls through selection. Another possible factor that could have affected the response of the animals in addition to season and nutritional status was the age of the bulls during the trial period. Younger bulls could have responded differently to the environmental and nutritional cues. The response to feed supplementation in terms of body weight gain measured

and semen and testicular characteristics indicates that this practice is advantageous. However, the results of the present trial indicate that the supplementation level adopted was probably too low.

Further research with regard to seasonal variation and supplementation of different age groups of animals is warranted to exploit the potential of this breed to the full.

Areas of further research at Bako Research Center should include:

- A re-evaluation of the carrying capacity of the pastures
- Establishment of feeding standards for calves to increase in the growth rate
- Establishment of an optimum age and weight at first breeding of heifers and to evaluate the effect of nutritional supplementation on this parameter
- Establishment of feeding supplementation programs for pre- and post partum cows to shorten the anoestrous interval
- Detailed study of the hormonal profiles of post partum Horro cows and heifers
- Further research with regard to seasonal variations in semen and testicular characteristics of bulls of different age groups
- Establishment of feeding supplementation regime for breeding bulls
- Study of hormonal aspects and libido evaluation in different age groups of Horro bulls.

ABSTRACT

AN EVALUATION OF REPRODUCTIVE PERFORMANCE OF HORRO CATTLE IN ETHIOPIA

by

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A study consisting of 2 phases was undertaken to evaluate the reproductive performance in female and male Horro (*Bos indicus*) cattle at the Bako Agricultural Research Center, Ethiopia. In the first part of the study the female reproductive indicators such as age and weight at puberty, age at first conception and first calving, post partum anoestrous interval, post partum period, intercalving period, growth from birth to 24 months of age, abortion rate as well as the herd mortality rate were evaluated using herd records collected between 1974 and 2001 at the Research Center. In the second part of the study, post partum live weight changes of cows, their serum progesterone profiles, the seasonal changes in bull semen, testicular characteristics and testosterone profiles were recorded in tests conducted between February 2001 and January 2002 at the same center. General linear model (GLM) procedures of SAS (SAS, 1994) were used to analyse the data. The least square means were separated using Duncan's multiple range test. The overall least square mean age and weight at puberty, 1st conception and 1st calving for heifers was 39.4 months, 202.9 kg, 50.1 months, 226.7 kg, 58.7 months and 259.2 kg respectively. The age at puberty, 1st conception and 1st calving was not affected by season of birth and birth weight. The age at 1st conception and 1st

calving significantly ($P<0.05$) affected the year of birth. Differences were recorded for age at 1st conception and 1st calving between the years monitored. The mean weight at puberty, conception and calving rates were not affected by the season of birth and birth weight. The year of birth did not affect the weight at puberty, but significantly ($P<0.05$) affected the weight at 1st conception and 1st calving. Differences were recorded for body weight between the observation years for weight at 1st conception and 1st calving. The overall least square means for the post partum anoestrous interval and post partum period were 77.2 and 117.5 days respectively. The season ($P<0.05$) and year of calving ($P<0.01$) significantly affected the post partum anoestrous interval. The shortest post partum anoestrous interval (72.5 ± 3.4 days) was recorded during the wet season (May to September), while the longest (81.7 ± 2.9 days) period was recorded in the dry season (October to April). Differences were recorded between years for the post partum anoestrous interval from 1977 to 2001. The season of calving, calf birth weight and sex of the calf did not affect the post partum period, but year of calving ($P<0.01$) played a significant role. Differences were recorded between years for the post partum period from 1977 to 2001. Sex of the calf significantly ($P<0.05$) affected the post partum anoestrous interval with dams bearing male calves demonstrating a longer period. The overall least square mean intercalving period and gestation length recorded, were 472 and 283 days respectively. Intercalving period was not affected by the season of calving, sex of the calf and calf birth weight. However the year of calving ($P<0.01$) and parity ($P<0.05$) significantly affected the intercalving period. Differences were recorded between years for intercalving period. The longest intercalving period (503.7 ± 8.8 days) was recorded during the second parity, compared to 3rd, 4th, 5th and 6th parities (469.0 ± 9.7, 449.2 ± 11.2, 468.6 ± 13.3 and 456.8 ± 16.4 days, respectively). Significant differences were recorded between years regarding gestation length, but no significant differences were observed between season (wet or dry) for gestation length. Sex of the calf significantly ($P<0.05$) affected gestation length with cows bearing bull calves having a longer gestation period.

Post partum live weight changes and serum progesterone concentrations in cows indicated that cows that calved during the dry season lost more weight. From

the total number of cows that calved during the dry season only 20% of them became pregnant within 90 days post partum, compared to 60% for cows that calved during the wet season. The overall least square mean serum progesterone (dry and wet season) concentration was 6.1 ng/ml and this was significantly ($P<0.01$) affected by season of calving and the cow body weight at calving. The mean progesterone level during the wet season (May to September) was higher (8.5 ± 0.8 ng/ml) and that during the dry season (October to April) was lower (2.8 ng/ml) .

For the progeny, the overall least square mean birth, 3, 6, 12, 18 and 24 month of age body weights, pre- and post weaning ADG for Horro cattle were 18.4, 48.9, 68, 87.5, 109.7 kg, 275 g/day and 130.9 g/day, respectively. The birth weight of the calves was not affected by season of birth, but sex of the calf ($P<0.01$) and year of birth ($P<0.05$) affected birth weight. Male calves were generally 11.6% heavier than their female counterparts at birth. Differences on birth weight were recorded between years. The 3 and 6 month weights were not affected by the sex of the calf, but season ($P<0.05$) and year of birth ($P<0.01$) significantly affected body weight at 3 months. Calves born in the wet season recorded the highest body weight at 3 months of age, compared to those born in the dry season. Differences were recorded between years from 1977 to 2001 regarding the weight at 3 months of age. The body weights at 12, 18 and 24 months were significantly ($P<0.05$) affected by the sex of the calf, season of birth and calf birth weight. Female calves were heavier at these ages compared to their male counterparts. Heavier calves at birth and those born in the wet season recorded the highest weights at 12, 18 and 24 months of age. Differences were recorded between the survey years in 12 and 18 months weight from 1977 to 2000.

The pre-weaning ADG was not influenced by the sex of the calf or the season of birth, but was influenced by the year of birth. Differences were recorded between years in pre-weaning ADG. Post weaning ADG was not affected by sex of the calf, but season of birth significantly ($p< 0.05$) affected post weaning ADG. Calves born in the wet season recording the highest post weaning ADG.

In the second part of this study the male reproductive performance and sexual characteristics of Horro (*Bos indicus*) (n=32) bulls, with an average initial body weight of 211 kg and age of approximately 6 years were evaluated. The bulls were divided into two treatment groups. One group was given a supplementary concentrate at a rate of 1.5 kg/day and the second group served as the control and received no supplementation. The observation period lasted for 50 weeks. Semen was collected every two weeks by means of electric stimulation with the aid of an electro-ejaculator. General linear model (GLM) procedures of SAS (SAS, 1994) were used to analyse the data. Semen and testicular characteristics, body weight and serum testosterone concentration were recorded during this period. The following semen parameters were evaluated: semen volume, semen color, mass motility, sperm concentration, percentage live sperm, percentage abnormal sperm and semen pH. Other male sexual characteristics evaluated were serum testosterone concentration, scrotal circumference, testis volume, scrotal skin thickness and libido as well as body weight every second week, concurrent with semen collection.

In general the bulls from the supplemented group tended to have higher quality semen characteristics. Three colour types of ejaculates were observed, namely, creamy, milky and watery. Semen from the supplemented group tended to have a more creamy colour, when compared to the non-supplemented group. There was a general tendency for the bulls from the supplemented group to maintain a higher sperm motility score during the trial period - ranging from 2.6 ± 0.2 to 3.6 ± 0.2, compared to the 1.7 ± 0.2 to 3.0 ± 0.3 of the control group. Sperm concentration in the supplemented group remained higher compared to that of the bulls in the non-supplemented group. The percentage of abnormal sperm (total abnormalities, head, mid-piece and tail) remained lower in the supplemented group than the non-supplemented group. Semen pH remained constant around 6.8 for most of the observation period. Libido score for both supplemented and control group remained constant (1.5 ± 0.3 to 3.8 ± 0.2 and 1.4 ± 0.2 to 3.8 ± 0.2, respectively). The scrotal circumference measured during the trial period for the supplemented and control group was 28.8 ± 0.5 to 32.8 ± 0.2 cm and 28.9 ± 0.5 to 32.9 ± 0.2 cm respectively. Scrotal circumferences were not influenced by nutritional supplementation. Scrotal

skin thickness was also not influenced by nutritional supplementation, but time (weeks) and the time x treatment interaction influenced scrotal skin thickness. As the trial progressed, the bulls increased in age and so the fat deposition in the scrotum increased. Testis length increased similarly in both treatment groups. A minimal increase in testis length was recorded over the 50 week period. The testis volume in both supplemented and control group increased gradually from the onset of the trial (week 0) to the end of the observation period (week 50). Significant differences were observed between the supplemented and control group regarding testis volume during certain weeks only. The mean body weight in both groups (supplemented and control) increased steadily from the onset of the trial to the end of the experiment. Bulls from the supplemented group gained on average more compared to the non-supplemented group. Serum testosterone levels of bulls collected during the dry season (October to April) were higher (911 ± 35.3 ng/dl) than during the wet season (May to September) (768.6 ± 30.9 ng/dl). Although not significant, bulls from the supplemented group recorded higher serum testosterone levels.

Overall, the productive and reproductive performance of Horro cattle (female reproductive and growth) at Bako Research Center has not improved much over the years. Inadequate nutrition and poor management in the herd have been implicated. It is suggested that efforts need to be made to improve the management. The introduction of a limited breeding season to induce early summer, calving is warranted. Calving during the summer (wet) season has advantages in both the reproductive and productive performance of the cows.

From the bull reproduction evaluation, it can be concluded that the semen and sexual characteristics observed during the trial are markedly influenced by the time (season) in which semen was collected. In general, the animals on the supplemented group tended to record higher serum testosterone levels and better semen and testicular characteristics compared to the control animals. It would seem that supplementation of breeding bulls is advantageous to their fertility.

Further studies on the reproductive and productive characteristics of the Horro breed were recommended.

OPSOMMING

'N EVALUERING VAN REPRODUKSIE PRESTASIE VAN HORRO BEESTE IN ETHIOPIË

deur

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'n Studie bestaande uit 2 fases, is onderneem om die reproduksie prestasie van vroulike en manlike Horro (*Bos indicus*) beeste te evalueer by die Bako Landbou Navorsingssentrum in Ethiopië. In die eerste deel van die studie is vroulike reproduksie parameters soos ouderdom en gewig tydens puberteit, ouderdom by 1ste konsepsie en 1ste kalwing, post partum anoestrus interval, post partum periode, interkalf periode, groei van geboorte tot 24 maande ouderdom, aborsie tempo asook die kuddemortaliteit geëvalueer deur van kudderekords gebruik te maak vanaf 1974 tot 2001 by die Navorsingssentrum. In die tweede deel van die studie is die post partum liggaamsgewig veranderinge van koeie, hul serum progesteroon profiele, die seisoensverandering in die bulsemen, testikulêre eienskappe en testosteroon profiele gegenereer uit studies tussen Februarie 2001 en Januarie 2002 by dieselfde sentrum. Die algemene liniëre model (GLM) prosedures van SAS (SAS, 1994) is gebruik om die data te analiseer. Die kleinste kwadraat gemiddelde is verdeel m.b.v. "Duncan's multiple range test". Die algehele kleinste kwadraat gemiddelde ouderdom en gewig tydens puberteit, 1ste konsepsie en 1ste kalwing in verse was 39.4 maande, 202.9 kg; 50.1 maande, 226.7 kg; 58.7 maande en 259.2 kg, respektiewelik. Die ouderdom tydens puberteit, 1ste konsepsie en 1ste kalwing is nie geaffekteer deur die geboorteseisoen of geboortegewig nie. Die ouderdom tydens 1ste konsepsie en 1ste kalwing het die jaar van geboorte betekenisvol ($P<0.05$) geaffekteer. Verskille in die

liggaamsgewig is gerapporteer gedurende die jare van observasie t.o.v. gewig met 1ste konsepsie en 1ste kalwing. Die algehele kleinste kwadraat gemiddeld in die post partum anoestrus interval en post partum periode was 77.2 en 117.5 dae, respektiewelik. Die seisoen ($P<0.05$) en jaar van kalwing ($P<0.01$) het die post partum anoestrus interval betekenisvol beinvloed. Die kortste post partum anoestrus interval (72.5 ± 3.4 dae) is gedurende die nat seisoen (Mei tot September) waargeneem en die langste (81.7 ± 2.9 dae) periode gedurende die droë seisoen (Oktober tot April). Verskille in die post partum anoestrus interval is waargeneem gedurende die periode van 1977 tot 2001. Die seisoen van kalwing, geboortegewig en geslag van die kalf het nie die post partum periode geaffekteer nie, maar die jaar van kalwing ($P<0.01$) het 'n betekenisvolle rol gespeel. Verskille in die post partum periode is waargeneem vanaf 1977 tot 2001. Die geslag van die kalf het die post partum anoestrus interval betekenisvol ($P<0.05$) geaffekteer met koeie dragtig met bulkalwers wat 'n langer periode gedemonstreer het. Die algehele kleinste kwadraat gemiddelde interkalf- en dragtigheidsperiode waargeneem, was 472 en 283 dae, respektiewelik. Die interkalf periode is nie geaffekteer deur die seisoen, geslag en geboortegewig van die kalf nie. Die jaar van kalwing ($P<0.01$) en hoeveelste dragtigheid ($P<0.05$) het die interkalf periode betekenisvol beinvloed. Verskille is deur die jare gerapporteer in die interkalfperiode. Die langste interkalfperiode (503.7 ± 8.8 dae) is waargeneem gedurende die 2de, vergeleke met die 3de, 4de, 5de en 6de dragtigheidsperiodes (469.0 ± 9.7, 449.2 ± 11.2, 468.6 ± 13.3 en 456.8 ± 16.4 dae, respektiewelik). Betekenisvolle verskille is waargeneem tydens die dragtigheidsperiode, maar geen betekenisvolle verskille is gedurende die dragtigheidseisoen (nat of droog) waargeneem nie. Die geslag van die kalf het die dragtigheidsduur betekenisvol ($P<0.05$) beinvloed - koeie dragtig met bulkalwers het 'n langer dragtigheidsperiode getoon.

Post partum liggaamsgewig veranderinge en serum progesteroon konsentrasies in koeie het aangetoon dat koeie in die droë kalfseisoen meer gewig verloor het. Uit die totale koeie wat gedurende die droë seisoen gekalf het, het slegs 20% beset geraak binne 90 dae post partum, vergeleke met 60% koeie wat gekalf het gedurende die nat seisoen. Die algehele kleinste kwadraat gemiddelde serum progesteroon (droë en nat seisoen) konsentraat was 6.1 ng/ml en is betekenisvol ($P<0.01$) geaffekteer deur die kalfseisoen en die koei se liggaamsgewig tydens kalwing. Die gemiddelde

progesteroonvlak was hoër (8.5 ± 0.8 ng/ml) tydens die nat seisoen (Mei tot September) en laer (2.8 ng/ml) gedurende die droë seisoen (Oktober tot April).

In die nageslag is gevind dat die algehele kleinste kwadraat gemiddelde vir voor- en naspeen GDT in Horro beeste tydens geboorte, 3, 6, 12, 18 en 24 maande 18.4, 48.9, 68, 87.5, 109.7 kg, 275 g/dag en 130.9 g/dag respektiewelik is. Die geboortegewig van die kalwers is nie geaffekteer deur die geboorteseisoen nie maar wel deur die geslag van die kalf ($P<0.01$) en die geboortejaar ($P<0.05$). Bulkalwers was oor die algemeen 11.6% swaarder as die verskalwers met geboorte. Verskille in geboortegewig is gedurende die jare gerapporteer. Die 3 en 6 maande liggaamsgewigte is nie deur die geslag van die kalf geaffekteer nie, maar die seisoen ($P<0.05$) en geboortejaar ($P<0.01$) het die 3 maande liggaamsgewig betekenisvol beinvloed. Hoër liggaamsgewigte is gerapporteer vir 3 maande oud kalwers wat tydens die nat seisoen gebore is vergeleke met 3 maande oud kalwers wat tydens die droë seisoen gebore is. Verskille is gerapporteer in die liggaamsgewig op 3 maande ouderdom van 1997 tot 2001. Die geslag van die kalf, geboorteseisoen en kalfgeboortegewig het die liggaamsgewigte op 12, 18 en 24 maande betekenisvol ($P<0.05$) beinvloed. Verskalwers was swaarder op die ouderdomme, vergeleke met bulkalwers. Swaarder kalwers tydens geboorte en kalwers gebore tydens die nat seisoen het die swaarste liggaamsgewigte gerealiseer tydens 12, 18 en 24 maande ouderdom. Verskille in 12 en 18 maande liggaamsgewigte is tydens die opnamejare vanaf 1977 tot 2000 gevind.

Die voorspeense GDT is nie deur die geslag van die kalf of the geboorteseisoen beinvloed nie, maar wel deur die geboortejaar. Verskille is gemonitor oor jare t.o.v. voorspeense GDT. Die geslag van die kalf het nie die naspeen GDT beinvloed nie, maar die geboorteseisoen het die naspeen gemiddelde daaglikse toename betekenisvol beinvloed. Die hoogste naspeen gemiddelde daaglikse toename is gerapporteer in kalwers gebore tydens die reënseisoen.

In die tweede deel van die studie is die manlike reproduksiepotensiaal en geslagseienskappe van Horro (*Bos indicus*) (n = 32) bulle met 'n gemiddelde inisiële liggaamsgewig van 211 kg en ± 6 jaar ouderdom geëvalueer. Die bulle is in 2 behandelingsgroepe ingedeel. Een groep is 'n aanvullingskonsentraat teen 'n tempo

van 1.5 kg/dag gevoer. Die tweede groep het as die kontrole gedien en het geen aanvulling ontvang nie. Die waarnemingsperiode het vir 50 weke geduur. Semen is elke 2 weke gekollekteer d.m.v. elektriese stimulasie m.b.v. 'n elektro-ejakulator. Die algemene liniêre model (ALM) prosedures van SAS (SAS, 1994) is gebruik om die data te analiseer. Semen en testikulêre eienskappe, liggaamsgewig en serum testosteroon konsentrasie is gemonitor gedurende die periode. Die volgende semen parameters is geëvalueer: semen volume, semenkleur, algehele motiliteit, sperm konsentrasie, persentasie lewende sperm, persentasie abnormale sperm en semen pH. Ander manlike geslagseienskappe soos serum testosteroon konsentrasie, skrotale omtrek, testes volume, skrotale veldikte, libido asook liggaamsgewig is elke tweede week tesame met semenkolleksie geëvalueer.

Oor die algemeen het bulle van die behandelde groep beter semeneienskappe getoon. Drie kleurtipes ejakulaat is waargeneem naamlik romerig, melkerig en waterig. Semen van die behandelde groep het geneig om meer romerige te wees as die onbehandelde groep. Die behandelde bulle het oor die algemeen 'n hoër sperm motiliteitstelling gehandhaaf tydens die waarnemingsperiode – variasie tussen 2.6 ± tot 3.6 ± 0.2, vergeleke met 1.7 ± 0.2 tot 3.0 ± 0.3 in die kontrole groep. Spermkonsentrasies in die behandelde groep was hoër, vergeleke met die van bulle van die onbehandelde groep. Die persentasie abnormale sperm (totale abnormaliteite, kop-, middelstuk- en stertabnormaliteite) het laer gebly in die behandelde groep as in die kontrole groep. Semen pH het konstant rondom 6.8 gebly vir 'n groot deel van die observasie periode. Die libido telling in beide die behandelde en kontrole groep het ook konstant gebly (1.5 ± 0.3 tot 3.8 ± 0.2 en 1.4 ± 0.2 tot 3.8 ± 0.2, respektiewelik). Die skrotale omtrek gemeet gedurende die waarnemingsperiode vir die behandelde en kontrole groep was 28.8 ± 0.5 tot 32.8 ± 0.2 cm en 28.9 ± 0.5 tot 32.9 ± 0.2 cm respektiewelik. Die skrotale omtrek asook die skrotale veldikte is nie beinvloed deur voedingaanvulling nie, maar tyd (weke) en 'n tyd x behandeling interaksie het wel die skrotale veldikte beinvloed. Namate die waarnemingsperiode gevorder het, het die bulle toegeneem in ouderdom en die vetlaag in die skrotum verhoog. Die testeslengte het dieselfde toegeneem in beide behandelingsgroepe. 'n Minimale groei in testeslengte is waargeneem tydens die 50 week periode. Die testesvolume in beide die behandelde en kontrole groep het geleidelik gegroei van die begin (week 0) tot die einde van die waarnemingsperiode (week 50). Betekenisvolle

verskille is tussen die behandelde en kontrole groepe t.o.v. testesvolume (slegs gedurende sekere weke), waargeneem. Die gemiddelde liggaamsgewig vir beide groepe (behandelde en kontrole) het stadig toegeneem van die begin van die waarnemingsperiode tot aan die einde van die eksperiment. Bulle van die behandelde groep het oor die algemeen meer in gewig toegeneem vergeleke met die onbehandelde groep. Serum testosteroonvlakke gekollekteer van bulle gedurende die droë seisoen (Oktober tot April) was hoër (911 ± 35.3 ng/dl) as gedurende die nat seisoen (Mei tot September) (768.6 ± 30.9 ng/dl). Alhoewel nie betekenisvol nie, is hoër serum testosteroonvlakke in die behandelde bulle waargeneem.

Oor die algemeen het die produksie en reproduksie prestasie in Horro beeste (vroulike reproduksie en groei) by die Bako Navorsingssentrum oor die jare nie verbeter nie. Dit is te wyte aan onvoldoende voeding en swak bestuur van die kudde. Daar word voorgestel dat pogings aangewend moet word om die bestuur te verbeter. Die instelling van 'n vasgestelde kalfseisoen ten einde die indusering van vroeë somerkalwings, is geregverdig. Kalwing gedurende somerseisoen (nat) is voordelig vir beide die reproduksie en produksieprestasie van die koeie.

Die gevolgtrekking uit die bul se reproduksie evaluasie, is dat die semen- en geslagseienskappe waargeneem tydens die periode, merkwaardig beinvloed word deur die tyd (seisoen) van semenkolleksie. Oor die algemeen was die diere in die behandelde groep geneig om hoër serum testosteroonvlakke te handhaaf en beter testikulêre eienskappe te toon, vergeleke met die kontrole diere en dit wil voorkom asof aanvullingsvoeding van teelbulle voordelig is vir fertiliteit.

Verdere studies oor die reproduksie- en produksie eienskappe in die Horro ras word egter aanbeveel.

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