

1. Introduction

1.1 Extensive beef cattle production

Beef cattle production plays an important role in the agricultural sector in Mozambique, contributing 14.8 % to agriculture GDP and 4.4% to the total GDP (FAO, 2005).

Extensive beef cattle provides farmers with the most efficient method of utilising forages grown from pasture, rangelands, forests and crop residues, which are converted into animal protein of high biologic value. In Mozambique, besides meat production, extensive beef cattle also contribute to the family livelihood through milk, ploughing, transport and family social standing. However, farming beef cattle is a complex activity consisting of various production factors that require appropriate and sustainable management interventions to ensure productivity and environmental sustainability.

The efficiency of a beef cattle production system depends on the reproductive rate of the cows, the growth rate of the calf to weaning, and the overall efficiency of feed utilisation (Duarte-Ortuno *et al.*, 1988; Pieris *et al.*, 1995; Naazie *et al.*, 1999; Morrison *et al.*, 1999; Kanuya *et al.*, 2006; Nqeno *et al.*, 2010). The age at which heifers calve for the first time and their lifetime production has an important effect on productivity (Nunez-Dominguez *et al.*, 1991; DeRouen *et al.*, 1994; Oliveira *et al.*, 2009). Both qualitative and quantitative aspects of animal nutrition influence the reproduction, growth and, therefore, the efficiency of beef cattle production systems.

Pastures are the main source of nutrition for extensive beef cattle, but the quantity or availability of pastures in the tropical and sub-tropical regions is influenced by the rainfall patterns, which results in seasonal variation in quantity and quality of nutrition throughout the year. Unfortunately, changes in nutritional requirements of extensive beef cattle during the reproduction and production cycle do not coincide with the seasonal changes in pasture availability. Consequently, when nutrient intake

is inadequate and body energy reserves are depleted, the interval from calving to first oestrus is extended (Rutter and Randel, 1984; DeRouen *et al.*, 1994; Grimard *et al.*, 1995; Morisson *et al.*, 1999, Aguilar-Pérez *et al.*, 2009). Since reproduction is a major component of production efficiency in a beef cattle production system, numerous studies have been performed to understand the factors that influence reproduction in post-partum beef cows.

Body condition score has been reported to be a good indicator of body energy reserves and re-breeding performance (Houghton *et al.*, 1990, Morrison *et al.*, 1999; Ayres *et al.*, 2009). It has been shown that cows with a greater BCS at parturition return early to oestrus and experience high conception rates (Laflamme and Connor, 1992; Osoro and Wright, 1992; DeRouen *et al.*, 1994; Morrison *et al.*, 1999; Ezanno *et al.*, 2005). The restriction of dietary energy intake during the peri-partum period demonstrates that luteinizing hormone (LH) pulse frequency and follicular growth in post-partum cows were influenced by negative energy balance (Beal *et al.*, 1978; Grimard *et al.*, 1995; Roche *et al.*, 2009). However, BCS has a low correlation with BW (Ayres *et al.*, 2009), indicating that the energy balance is probably a better predictor of reproduction in the post-partum period.

Research on the effects of energy balance on re-conception rates in extensive beef cows is limited. Leptin, a hormone secreted by adipose tissue, identified by Zhang *et al.* (1994), has been proposed to signal nutritional status in ruminants (Delavaud *et al.*, 2000; Tokuda *et al.*, 2000; Block *et al.*, 2001; Ludwik *et al.*, 2007). Whether leptin plays a central role in regulating reproduction in cattle has not been determined. However, plasma leptin concentration is related to adipose cell size and positively related to feeding level (Delavaud *et al.*, 2000). The decrease in plasma leptin concentration is associated with a reduction in the secretion of LH, Immunoglobulin F-I (IgF-I) and insulin in cattle (Amstalden *et al.*, 2000) and in sheep and goat (Morrison *et al.*, 1999; Azraqi, 2007). There is no information available on the effects of post-partum BCS, BW and their changes on leptin, follicle stimulating hormone (FSH), LH, ovarian steroids, their interactions and the related conception rates in extensive beef cattle.

Suckling is another important factor that extends post-partum anoestrus, affecting consequently the rebreeding performance of beef cows (Radford *et al.*, 1978; Williams, 1990; Stewart *et al.*, 1993; Lamb *et al.*, 1999; Marongiu *et al.*, 2002; Perea *et al.*, 2008; Pinheiro *et al.*, 2009). The mechanism by which this external stimulus impairs oestrus during the post-partum period is uncertain. Nevertheless, despite the fact that the LH concentrations in the anterior pituitary (Nett *et al.*, 1988) and in the plasma (Radford *et al.*, 1978) are similar after 30 days post-partum in suckling and non-suckling beef cows, the pulsatile LH pattern is low in suckling cows. Moreover, Murphy *et al.* (1990) and Crowe *et al.* (1998) report that the development of dominant follicles occurs in suckling and non-suckling cows, but no ovulation was observed in suckling cows.

Efforts to reduce the effects of suckling on the post-partum reproduction of beef cows have taken various forms, from understanding of suckling behaviour (Stewart *et al.*, 1993a; Paranhos da Costa *et al.*, 2006) to the effects of manipulation of different suckling times on the onset of post-partum oestrous (Reeves and Gaskins, 1981; Bell *et al.*, 1998; Lamb *et al.*, 1997; Lamb *et al.*, 1999; Alvarez-Rodriguez *et al.*, 2010) or on conceptions rates (Stewart *et al.*, 1993b; Gazal *et al.*, 1999; Escrivão *et al.*, 2009). The manipulations of suckling times and calf withdrawal have yielded different results – either on the interval to first oestrus, subsequent conception rates or on calf weaning weights. However, referring to the effects of calf withdrawal on post-partum rebreeding, the existing reports fail to consider the nutritional status, metabolic rate, stress and gonadotropic hormones, since it is believed that the yielded results are the combinations of these factors rather than calf withdrawal itself.

1.2 Motivation

In view of defining a strategy to improve reproductive efficiency in post-partum suckling beef cows an understanding of the complex nutrition-suckling-reproductive hormone interactions and the manipulation of related factors have to be considered. However, studies regarding this matter have been mostly performed under intensive management conditions, with breed types and climatic conditions that differ significantly from extensive beef cattle production in Mozambique. Therefore, a study on the effects of post-partum BW, BCS and calf removal on reproductive and productive characteristics of extensive beef cattle could make an important contribution to the productivity of extensive beef cattle and also the development of the beef cattle industry in Mozambique.

Mozambique has a total area of 778,000 km² of which it is estimated that 440,000 km² is potentially rich in pastures (FAO, 2005). The available natural pastures are of a relatively good quality, allowing a carrying capacity of approximately 8 ha per Large Stock Unit (LSU) (adopted from Timberlake and Reddy, 1986, 2006). If 50% of the estimated area could be used for cattle production, Mozambique would support a total of 3,142,857 LSU in a sustainable manner. The cattle population in Mozambique is 1.4 million (DNSV, 2010), that is approximately 935,200 LSU, which means that the country's potential for cattle production is used at 29.7%.

Approximately 80% of beef meat consumed in Maputo City (the major beef market in the country) is imported (DNSV, 2010). Considering the production characteristics of existing extensive beef cattle in the country (commercial and subsistence sectors), although the subsistence sector represents 70% of the cattle population, only the development of commercial farms could compete over the medium – or long term with imported beef. However, success will be attained if the management of commercial farms improves and emphasis is placed on reproduction and production management.

The calving rates in the commercial sector are still very low at <60% (Mandlate, 1985; Escrivão *et al.*, 1998; Escrivão *et al.*, 2009). A similar situation is evident in the

family livestock production sector where calving rates are below 50% (Rocha *et al.*, 1988). This poor calving rate represents one of the major constraints for the development of cattle production in Mozambique.

Previous studies in Mozambique have identified calving rate as the premium productivity indicator, but re-conception rates after calving lengthen the inter-calving period (Mandlate, 1985; Schwalback *et al.*, 1997; Escrivão *et al.*, 1999). None of the previous studies have focused on the factors that influence post-partum conception rates of suckling beef cattle under extensive production conditions in Mozambique. Small increases in productivity could be reasonably attained with lower cost through improvements in reproduction management and, more specifically, by increasing calving rates rather than by improvements in feeding management for slaughter animals (Burns *et al.*, 2010). In addition, financial resources are scarce for the majority of extensive beef cattle farmers in Mozambique, so reproduction management remains the most important approach to improving productivity.

For this reason, the present study consisted of a number of trials on the effects of BW, BCS and calf removal on reproductive and productive characteristics of extensive beef cattle in Mozambique. In order to ensure that these specific goals were achieved, the trials were conducted under extensive conditions. First, animals incorporated in the experiments were maintained in the herd without extra management but removed only for measurements or sample collections and returned afterwards. Second, the trials were designed in such a way that the results could be used to compile management strategies for similar extensive beef cattle production systems in Mozambique, including the communal farming sector.

1.3 General objectives

- To study the factors that influence post-partum reproduction of suckling beef cows in extensive production systems in Mozambique; and
- To develop new management strategies to improve reproductive efficiency of suckling *Bos indicus* beef cows in extensive production systems in Mozambique.

1.4 Specific objectives

To test the hypothesis in experiments 1, 2 and 3.

EXPERIMENT 1

Effects of post-partum body condition score, body weight, age and parity number and their interactions on ovarian steroids, cortisol, creatinine, urea and the related conception rates in *Bos indicus* cows in extensive production systems

Hypothesis 1

Ho. Post-partum BCS, BW, age and parity number do not affect ovarian steroids, cortisol, creatinine, urea and related conception rates of *Bos indicus* cows in extensive production system.

H1. Post-partum BCS, BW, age and parity number affect ovarian steroids, cortisol, creatinine, urea and related conception rates of *Bos indicus* cows in extensive production system.

EXPERIMENT 2

Effects of 12- hour calf removal on conception rates and calf weaning weights of *Bos indicus* cows in extensive production systems

Hypothesis 2

Ho. Restricting suckling at night from 45 days post-partum does not increase conception rates of *Bos indicus* cows in the subsequent breeding season in extensive production systems.

H1. Restricting suckling at night from 45 days post-partum increases conception rates of *Bos indicus* cows in the subsequent breeding season in extensive production systems.

Hypothesis 3

Ho. Calf weights at weaning are not affected by restricted suckling at night from 45 days post-partum in extensive production systems.

H1. Calf weights at weaning are affected by restricted suckling at night from 45 days post-partum in extensive production systems.

EXPERIMENT 3

Effects of 48-hour calf removal on conception rates and calf weaning weights of *Bos indicus* cows in extensive production systems

Hypothesis 4

Ho. Forty-eight-hour calf removal prior to breeding does not improve the conception rates of *Bos indicus* beef cows in extensive production system.

H1. Forty-eight-hour calf removal prior to breeding improves the conception rates of *Bos indicus* beef cows in extensive production system.

Hypothesis 5

Ho. Calf weights at weaning are not affected by 48-hour calf removal in extensive production systems.

H1. Calf weights at weaning are affected by 48-hour calf removal in extensive production systems.

In order to address all these aspects appropriately, the present thesis is divided into six chapters. A general introduction is provided in Chapter one, while the second chapter provides a detailed literature review on the relevant aspects related to extensive beef cattle production systems. Chapter two also incorporates the factors that influence post-partum reproduction of *Bos indicus* cows reared in extensive production systems. The effect of BCS, BW and suckling and the related effects on conception rates, as well as the influence of calf withdrawal on weaning weights are reviewed. The results of experiment one, two and three are presented and discussed in Chapters three, four and five, respectively. General discussion and conclusions are presented in chapter six, followed by a comprehensive bibliography.

2. Literature Review

Post-partum reproduction in suckling beef cows

2.1 Introduction

Post-partum rebreeding in suckling beef cows has been discussed (Hammond, 1927 cited by Short *et al.*, 1990; Wiltbank, 1991) and continues to be a vital subject for animal scientists (Goyache *et al.*, 2005; Satrapa *et al.*, 2010). Poor rebreeding is characterised by the non-appearance of oestrus (anoestrus) early in the post-partum period and extended interval to first service, which lengthens the calving interval above 365 days, reduces calf crop, and causes an economic loss to beef cattle producers (Short *et al.*, 1990; Yavas and Walton, 2000; Quintans *et al.* 2010).

After parturition, uterine involution is generally completed within four to six weeks (Gier and Marion, 1968; Dobson *et al.*, 2001; Zhang *et al.*, 2010). Thereafter, the duration of post-partum anoestrus is governed by the recommencement of the hypothalamic pituitary ovarian (HPO) axis activity. Due to this fact, much attention has been given to the nature of the signal that controls pituitary secretion of LH and FSH, the response of the ovary to LH and FSH (Bryner *et al.*, 1990; Martinez *et al.*, 2005) and to the other ovarian effects that are independent of gonadotropins (Paranhos da Costa *et al.*, 2006).

Several factors are implicated in the activation of the HPO axis activity during the post-partum period of suckling beef cows. These factors include suckling and nutrition (body energy reserves) as the major factors and many minor factors such as age, parity number, breed, individual genetic variation, presence of bull, diseases, twin births, dystocia, and retained placenta (Deutscher 1991; Grimard *et al.*, 1995; Marongiu *et al.*, 2002; Martinez *et al.*, 2005; Álvarez-Rodríguez *et al.*, 2010). The effects of body energy reserves, suckling and the related mechanisms that appear to influence post-partum reproduction of extensive beef cows are reviewed in sections 2.2 to 2.7.

2.2 Body condition score

Maintenance of body energy reserves in bovines has been considered to be the basis of any reproductive management strategy (Houghton *et al.*, 1990; Morrison *et al.*, 1999; Flores *et al.*, 2008). Body energy reserves were measured through weight loss, when energy reserves (fat) and protein reserves (muscle) are being depleted or, otherwise, through weight gain. Usually, weight gain or loss has been held as a good measure of well-being and productivity (Bishop *et al.*, 1994; Butler, 2003). However, weighing cattle is laborious and rarely done by veterinarians, animal nutritionists or farmers. A more useful method in assessing the energy reserves is based on assessing individual BCS, based on visual observation and more accurately by palpation of back, ribs and rear quarters. There are two main scoring systems: (1) the American scoring system on a nine-point scale (Herd and Spratt, 1986) and (2) the Scottish scoring system on a five-point scale (Edmundson *et al.*, 1989; Wiltbank, 1991). The Scottish body condition scoring system seems to have been adopted quite widely in the Southern African region, including Mozambique. Equivalence between these two scoring systems is presented in Table 2.1.

2.2.1 Other methods of assessing energy reserves in cattle

It is obvious that looking at the body weight of a cow does not give us an idea of existing energy reserves. Since an estimation of energy reserves represents an important tool for reproduction and production management, other techniques rather than BCS have been developed for cattle.

Subcutaneous fat thickness at the *longissimus dorsi* (UFAT; 12th rib fat thickness) and rump fat thickness (RFAT) (Schroder and Staufenbiel, 2006; Yokoo *et al.*, 2008) have been mostly used in dairy cattle to estimate the body energy reserves. Although the measurement of RFAT requires the use of ultrasonographic examinations that are non-invasive practices, skills are, however, needed for manipulation. Its use in beef cattle is limited and apparently not studied under extensive conditions. Nonetheless, a recent publication regarding RFAT showed its high correlation with BCS (Ayres *et al.*, 2009). These findings value the use of simple methods like BCS to estimate the body energy reserves. Due to this reason there is a probability that widespread use of RFAT in dairy and beef cattle may not take place.

Correlations between BCS and other direct methods of measuring energy reserves like energy balance, or indirect methods like circulating levels of hormones, leptin, were reported (Wathers *et al.*, 2007; Murrieta *et al.*, 2010). Recent results indicate that BCS remains the best indicator of nutritional status because of its high correlations with the related energy reserve indicators.

Table 2.1 Description of the Scottish Body condition score system and its American equivalent

Group	Score	Description
	system	
	Scottish (American)	
Thin condition	1 (1 and 2)	Extremely thin with severe muscle wasting may appear humped in the back with feet close together, usually weak; extremely prominent backbone, hooks, pins and ribs. <i>Similar to BCS 1 and 2 in 9-point system</i>
	2 (3)	Thin with little or no wasting of muscle structure; vigorous, little or no fat in ramp, rib or brisket; prominent backbone, hooks, pin and ribs normal appearing muscle structure. <i>Similar to BCS 3 in 9-point system.</i>
Moderate condition	3 (5)	Ideal Condition. Thrifty with normal muscle structure; some evidence of fat deposit in fore-rib, brisket and crops but limited around the tail-head. Some smoothness over the shoulder, ribs, backbone, hooks and pins. <i>Similar to BCS 5 in 9-point system.</i>
Fat condition	4 (7)	Fat but still firm; vigorous; considerable fat deposit over fore-rib; brisket protruding; tail-head full (bulging); very smooth over backbone with no skeleton visible except at hooks. <i>Similar to BCS 7 in 9-point system.</i>
	5 (8 and 9)	Very fat with considerable softness; very fat over the fore-rib and shoulder; large prominent brisket; broad flat top-line; large patchy fat deposit around the tail-head; body curvature become squares in appearance. <i>Similar to BCS 8 and 9 in 9-point system.</i>

Scores in italics ~ American equivalent

Source:

Edmundson *et al.*, 1989; Wiltbank, 1991 (Scottish BCS system)

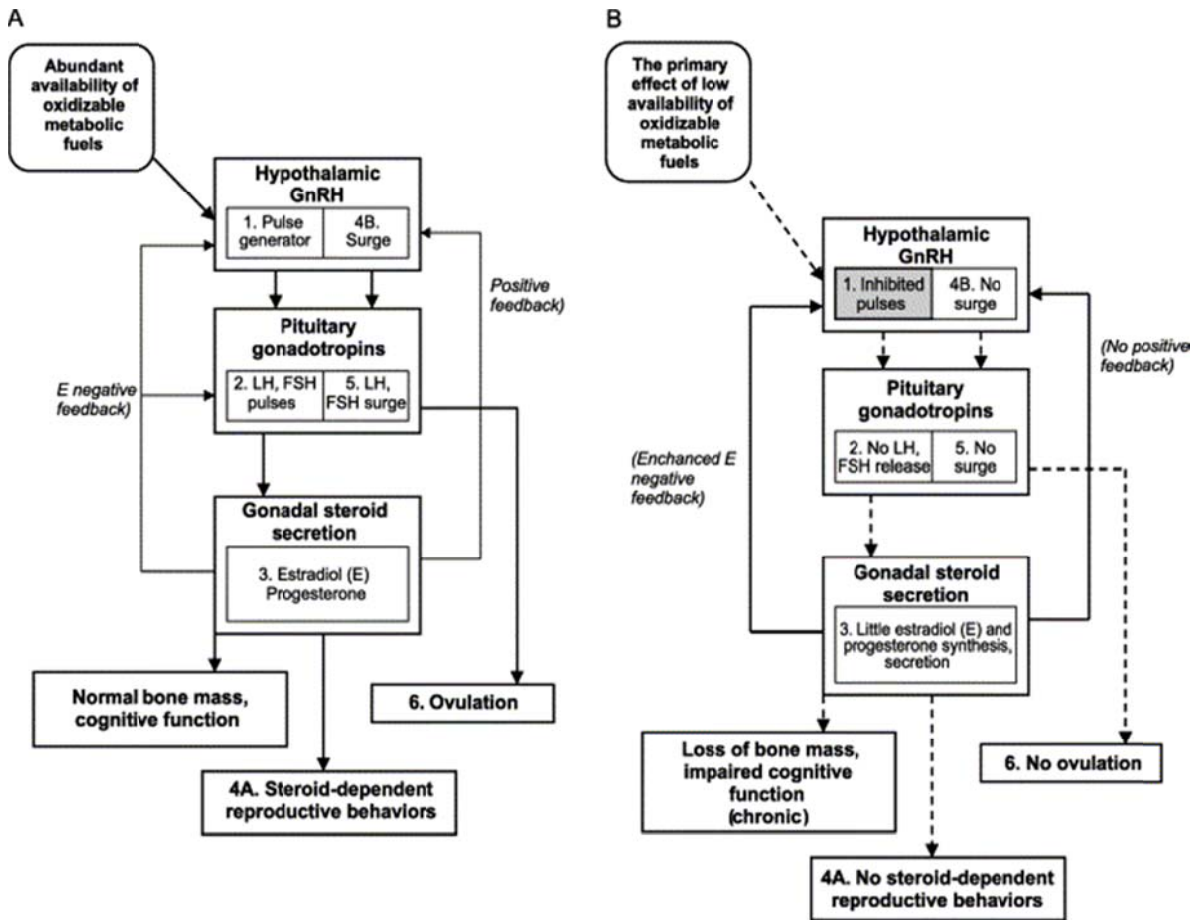
Herd and Spratt, 1986 (American BCS System)

2.3 Effect of changes in body condition score on post-partum reproduction

The effects of BCS on postpartum rebreeding of beef cows (Bishop *et al.*, 1994; Spitzer *et al.*, 1995; Renquist *et al.*, 2006; Flores *et al.*, 2008) and dairy cows (Roche *et al.*, 2009; Allbrahim *et al.*, 2010) have been discussed. Variation in BCS of beef cows in the post-partum period has a number of practical implications for bovine reproduction, such as the association with the length of the post-partum interval to oestrus and ovarian activity (Bishop and Pfeiffer, 2008), and conception rates (Renquist *et al.*, 2006; Roche *et al.*, 2009).

It is well known that the Gonadotropin releasing hormone (GnRH) pulse generator system and the secretion of GnRH are inhibited by under nutrition (Randel, 1990; Wade and Schneider, 1996; Nqeno *et al.*, 2010). Nevertheless, the physiology of nutrition illustrates that the oxidisable metabolic fuels are used for all physiological functions in the body and the excess is stored to be retrieved when a deficit occurs and, thus, to maintain production. Moreover, energy is partitioned by a priority to first maintain the life of the cow and then to propagate the species (Short *et al.*, 1990). The approximate order of priority has been indicated to be (1) basal metabolism; (2) activity; (3) growth; (4) basic energy reserves; (5) pregnancy; (6) lactation; (7) additional energy reserves; (8) oestrus cycle and initiation of pregnancy; and (9) excess reserves (Short *et al.*, 1990). Thus, reproduction takes place when basic physiological functions are satisfied in terms of energy.

The functioning of the hypothalamus-pituitary-ovarian axis when not energetically challenged is presented in Figure 2.1 (A), while when energetically challenged in Figure 2.1 (B). Figures 2.1 (A and B) illustrate that the prerequisite for the resumption of ovarian activity in the post-partum cows is an increased pulse frequency of episodic release of LH, which may occur in cows with moderate to good BCS (Bishop *et al.*, 1994).



Source: Schneider (2004)

Figure 2.1 Functioning of the hypothalamus-pituitary-ovarian axis when not energetically challenged in (A), while energetically challenged in (B).

2.4 Effect of suckling on post-partum reproduction

Suckling is important for calf survival and forms the basis of high and sustainable income in beef cattle production systems. However, there is a concern that this exteroceptive stimulus prolongs the post-partum anoestrus, probably through a neural-mediated inhibition of LHRH or an inhibitory effect of RH on gonadotrophins or action at the ovary (Acosta *et al.*, 1983; Convey *et al.*, 1983; Pérez-Hernández *et al.*, 2002). Notwithstanding the evidence that suckling might act in a chronic fashion to inhibit LH secretion through the post-partum period (Convey *et al.*, 1983; Garcia-Winder *et al.*, 1986; Crowe *et al.*, 1998; Pérez-Hernández *et al.*, 2002; Quintans *et al.*, 2009), the true mechanism by which suckling extends the post-partum anoestrus is uncertain.

Suckling may occur six to nine times a day, with young calves suckling more frequently than older calves (Shimada *et al.*, 1989; Stewart *et al.*, 1993; Gazal *et al.*, 1999; Das *et al.*, 2000; Paranhos da Costa *et al.*, 2006). Available reports indicate also that suckling frequency is high in first parity cows along with the short duration of the suckling meal (Stewart *et al.*, 1993; Paranhos da Costa *et al.*, 2006).

There is a breed-related difference in daily suckling frequency. *Bos indicus* cattle have a higher daily suckling frequency than *Bos taurus* and cross-breed cow-calf pairs (Das *et al.*, 2000).

Although the precise mechanism by which suckling extends the post-partum anoestrus is uncertain, evidence exists that suckling frequency is the characteristic that correlates best with the anticipated onset of oestrus in the post-partum period (Radford *et al.*, 1978; Shimada *et al.*, 1989; Williams, 1990; Stewart *et al.*, 1993; Lamb *et al.*, 1999; Gazal *et al.*, 1999; Marongiu *et al.*, 2002; Álvarez-Rodríguez *et al.*, 2010). In rodents, the inhibitory effect has been shown to be proportional to suckling intensity (Ford and Melampy, 1973; Hammons *et al.*, 1973) with comparable suggestion in ruminants (Quintans *et al.*, 2009).

2.5 Effects of suckling on post-partum LH and FSH concentrations

Around parturition the hypothalamus-pituitary axis responds to a negative feedback effect of the placental and ovarian steroids by suppressing FSH release and accumulating this hormone in the anterior pituitary and depleting LH stores (Yavas and Walton 2000). Severe increase in FSH is observed after parturition followed by the emergence of first follicular waves of which the dominant follicles do not ovulate, leading to the development of second follicular waves in both suckling- and non-suckling beef cows (Murphy *et al.*, 1990; Breuel *et al.*, 1993; Crowe *et al.*, 1998). There are similarities between suckling- and non-suckling beef cows in LH concentration in the anterior pituitary (Nett *et al.*, 1988) and in the plasma (Radford *et al.*, 1978, Walters *et al.*, 1982) after 30 days post-partum. For Garcia-Winder *et al.* (1986), the plasma LH concentration in suckling beef cows is low irrespective of post-partum period. On the other hand, there is an indication of low LH pulse frequency in suckling cows after 30 days post-partum (Walters *et al.*, 1982; Garcia-Winder, 1986; Quintans *et al.*; 2004) which is implicated in un-ovulation of dominant follicles emerged from second follicular waves (Williams *et al.*, 1983; Acosta *et al.*, 1983; Breuel *et al.*, 1993; Crowe *et al.*, 1998). Since reports suggest that the pattern of LH pulse frequency is crucial for oestrus to occur, the given data have reinforced the hypothesis that the suckling stimulus increases time to first ovulation by increasing the sensitivity of the hypothalamus to the negative feedback of estrogens during the post-partum period, resulting in decreased LH release.

The elimination of the suckling stimulus for 48 hr in *Bos taurus* beef cattle in intensive production systems increases serum LH concentration as well as pulse frequency and amplitude by 24 hr after calf removal, peaking by 48 hr, and then causes a decrease in LH concentration after the calf returns (Walters *et al.*, 1982; Whisnant *et al.*, 1985; Edwards; 1985). There is, however, a lack of information on the effects of temporary calf removal (12 hr or 48 hr) on *Bos indicus* cows in extensive production systems.

2.6 Effects of suckling on cortisol concentrations

Adrenocortical activity has been widely used as an indicator of social stress and, therefore, as an indicator of animal welfare (Milleder *et al.*, 2003). Koolhaas *et al.*, (1999) reported that the difference in adrenocortical activity might express basic differences in physiology rather than in stress level. In addition, measuring glucocorticoid concentration in plasma has two methodological problems: (1) blood sampling itself causes an increase in glucocorticoid concentration; and (2) frequent sampling is necessary due to considerable fluctuations. Because reproductive performance is altered in cattle subjected to physiological stress (Dobson and Smith 2000), circulating cortisol levels have been measured together with plasma gonadotropins to analyse their relationship and to understand to which extent stress could impair reproduction (Echternkamp, 1984; Lyimo *et al.*, 1999). Despite the fact that several studies on the correlation between cortisol and reproduction in cattle have been performed in dairy cattle and in *Bos taurus* beef cattle in intensive production systems, the influence of stress on gonadotrophin secretion and subsequent reproductive responses is dependent on the magnitude of the adrenal steroidogenic response and the animal's adaptability to the stress.

During the post-partum period of suckling beef cows, cortisol correlates negatively with LH (Dunlap *et al.*, 1981; Echternkamp, 1984). The increase in systemic cortisol of about 20-fold subsequent to intensive stress suppresses pulsatile LH release (Echternkamp, 1984). Unfortunately, very limited information is available on the effect of calf removal or restricted suckling on cortisol concentrations. Whisnant *et al.*, (1985) studying hormonal changes during 48-hour calf removal reported that serum cortisol concentration did not differ between cows with removed calves as opposed to cows with suckling calves, but a transient elevation was notable in the calf-removed group from 9 to 12 hours after calf removal. Because LH concentration was greater in cows that have weaned than in suckling cows and cortisol pattern followed the above described trend, it was concluded that cortisol may not be a physiological inhibitor of LH secretion in the post-partum period of suckled beef cows.

2.7 Strategies to reduce the suppressive effect of suckling on LH

The existing knowledge of mechanisms by which suckling seems to interfere in the post-partum rebreeding of beef cows was used to shorten the interval to first oestrus and to increase subsequent conception rates. The effects of restricted suckling, calf removal or complete weaning at different days post-partum ranging from 1 to 30 days (Convey *et al.*, 1983; Edwards, 1985) or after 30 days (Dunlap *et al.*, 1981; Walters *et al.*, 1982; Whisnant *et al.*, 1985; Dunn *et al.*, 1985) were reported, but the research was generally restricted to *Bos taurus* breeds and their crosses. Restricted suckling and partial calf removal make up the majority of the studies done in this field, probably because complete weaning would imply early weaning of calves, with subsequent negative effects on growth rate as well as the removal of the effects of suckling on re-conception rates.

The manipulation of suckling times was performed either to test the effect of suckling on development of dominant follicles or to analyse the responsiveness of the anterior pituitary on calf withdrawal. Salfen *et al.* (2001) reported that the development of dominant follicles was independent of suckling following a 48-hr calf removal on days two, four and eight during the post-partum period. The same authors observed an increase in oestrus rate of cows synchronised at 25 days post-partum following a 48-hr calf withdrawal. This observation supports the results reported by Walters *et al.* (1982) and Odde *et al.* (1986), in which 48-hr calf removal preceded the start of the breeding season.

There is no defined post-partum day on which calf withdrawal has to be implemented in order to achieve a desirable result from the anterior pituitary. The day of withdrawal may depend; however, on farmer's reproductive management and the cow's body condition score without neglecting the puerperal period.

At approximately 30 days post-partum, in cows with a moderate to good BCS, a 48-hr calf withdrawal may induce oestrus but the reestablishment of the oestrus cycle is uncertain (Salfen *et al.*, 2001).

Reeves and Gaskins (1981); Hoffman *et al.* (1996) and Lamb *et al.* (1999) found that when restricted suckling began before 30 days post-partum once or twice-daily-suckling did not shorten

the interval to first oestrus. But, when the same management strategy was carried out after 30 days post-partum or from about 30 days prior to the breeding season, the interval to first oestrus was shortened, with increased conception rates in the following breeding season (Reeves and Gaskins, 1981; Odde *et al.*, 1986; Bell *et al.*, 1998; Gazal *et al.*, 1999; Escrivão *et al.* 2009).

Bell *et al.* (1998) working with *Bos taurus* primiparous cows, reported that once daily suckling and early weaning 30 days before the onset of the breeding season decreased the post-partum interval to first oestrus. But early weaning had a negative effect on weaning weights at 205-days. Conversely, Randel (1981); Odde *et al.* (1986) report that once or twice daily suckling had no adverse effect on weaning weights.

Successful results for the interval to first oestrus and conception rates were related to restricted suckling combined with 48-hr calf removal. Similar results were also observed when 48-hr calf removal was implemented prior to the breeding season (Walters *et al.*, 1982a; Walters *et al.*, 1982b). A summary of existing reports on the effect of suckling management on the postpartum rebreeding performance of cattle is presented in Tables 2.2, 2.3 and 2.4.

Table 2.2 Effects of once-daily suckling on post-partum interval to oestrus and conceptions rates

Author (Year)	Breed	Days post Partum	PPI** to oestrus (days) (ad libidum suckling)	Conception rates (%) (ad libidum suckling)
Reeves and Gaskins (1981)	<i>Bos taurus</i>	21 days	41 ± 2.9 (61 ± 4)	Not recorded
Reeves and Gaskins (1981)	<i>Bos taurus</i>	> 30 days	38 ± 3 (47 ± 3)	Not recorded
Odde <i>et al.</i> , (1981)	<i>Bos taurus</i>	> 30 days	52.2 ± 2.6 (55.2 ± 2.7)	93 % (82.1%)
Randel (1981)*	Crossbred (Bt X Bi)	> 30 days	68.9 ± 6.2 (168.2 ± 13.8)	Not recorded
Bell <i>et al.</i> (1998)*	<i>Bos taurus</i>	> 30 days	Decreased 12 d compared to <i>ad libidum suckling</i>	Nor recorded

* First parity cows

** PPI – post-partum interval

Bt – *Bos Taurus*

Bi – *Bos indicus*

Table 2.3 Effects of 12-hour calf removal on post-partum interval to oestrus and conception rates

Author (Year)	Breed	Days post partum	PPI** to oestrus (days) (ad libidum suckling)	Conception rates (%) (ad libidum suckling)
Stewart <i>et al.</i> (1993)	<i>Bos taurus</i>	> 30 days*	Not recorded	86% (66%)
Gazal <i>et al.</i> (1999)	Crossbreed	From day 9*	36 ± 11 (40 ± 3.9)	100% (93%)
Escrivão <i>et al.</i> (2009)	<i>Bos indicus</i>	From 45* days to breeding	Not recorded	80% (59%)

* Day suckling cows

**PPI – post-partum interval

Table 2.4 Effects of 48-hr calf removal on post-partum days to oestrus and conception rates

Author (Year)	Breed	Days post partum	PPI* to oestrous (days) (ad libidum suckling)	Conception rates (%) (ad libidum suckling)
Odde et al., (1981)	<i>Bos taurus</i>	> 30 days	54.9 ± 2.6 (55.2 ± 2.7)	90.9 % (82.1%)
Meirelles et al (1994)	<i>Bos indicus</i>	Prior to breeding season	Not recorded	55% (20%)
Escrivão <i>et al.</i> (2011)	<i>Bos indicus</i>	Prior to breeding season	Not recorded	76% (55%)

* PPI – post-partum interval