

Effects of body condition score and parity on reproduction efficiency of Bonsmara cows in timed artificial insemination programmes

by

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PREFACE

The experimental work described in this dissertation was carried out in the school of Agricultural Sciences, University of Pretoria, Pretoria, from January 2020 to December 2021, under the supervision of Professor Edward C. Webb.

The studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any University. Where use has been made of the work of others it is duly acknowledged in the text.

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List of abbreviations

AI	Artificial Insemination
BCS	Body Condition Score
CIDR	Controlled Internal Drug Release
CL	Corpus Luteum
EB	Oestradiol benzoate
EBV	Estimated Breeding Value
eCG	Equine chorionic gonadotropin
ECP	Oestradiol cypionate
FSH	Follicle-Stimulating Hormone
GnRH	Gonadotropin-Releasing Hormone
IGF-1	Insulin-like Growth Factor one
LH	Luteinizing Hormone
MGA	Melengestrol Acetate
PGF2 α	Prostaglandin F2 α
PRID	Progesterone Releasing Intravaginal Device
SA	Survival Analysis
SD	Standard Deviation
TAI	Timed Artificial insemination
THI	Thermal-Humidity Index

Abstract

The objective of this study was to determine the effect of BCS and parity that affect the conception of the extensively farmed South African beef cows postpartum. The cows were synchronised using the 7-day Co-Sync + progesterone releasing device protocol. Body condition score (BCS) was recorded on the day of insemination. Recording information (cow identification numbers, previous calving records, cow age, inter-calving period, last calving date, cow mass and the number of calves. It also contained the Estimated Breeding Values (EBV) for Heifer fertility as well as Cow Fertility). Mixed model analyses were used to analyse the data that was obtained for the study. The cows ($n = 42$) that were included in the current study had a conception rate of 83,33%. The time of artificial insemination (AI) was shown to not have a significant effect ($p > 0.05$) on the conception rate of the cow. The weight change of the cow between weaning and calving for the second parity preceding the current one, showed to not have a significant effect ($p > 0.05$) on the current conception rate. The results show that there was a significant effect within the various parities for the major factors that were studied, e.g. Body condition score ($p = 0,021$), days to AI ($p = 0,031$) and the EBV for Fertility for the cow ($p = 0,006$) had significant effects on the conception rates in the cows.

The BCS within the weighted parity, has a significant effect on the conception rate in the cows. The cows that were found to be over conditioned ($>3,75$) were more likely not to conceive, and the cows that had a BCS of 3,00 had the best conception rates. The number of days that the cow is given for a recovery period was important to consider as the cows that were inseminated too early had a higher probability of not conceiving. The prime parity group was parity 6, which has the highest conception rate. The link between BCS and parity was important as cows that are not found in the correct BCS category and fall outside of the prime parity groups are the cows who struggle to conceive. The EBV of Fertility for the cow has a significant effect on the conception rate and can be an important tool for farmers to use when selecting replacement heifers for their herds. The time of day that AI takes place, may have an effect on the conception but more research needs to be done on this, this current study did not show any significant results and therefore no link can be made to what time of day would be optimal for maximised artificial insemination.

Chapter 1

Introduction

Fertility management in extensively farmed South African beef cattle (in this dissertation focusing specifically on Bonsmara cattle) is important due to the impact that it has on the economic and production factors on a production farm. In the beef industry, the offspring are raised and sold for income. Fertility and reproduction have generally been used interchangeably, but by definition; they are not the same. Fertility is the ability of a cow or a bull to reproduce. Reproduction is the offspring that are produced from mating. In specific environments the genetics, as well as the interaction of between environment and genetics, the production of offspring is a result of good fertility. Reproductive efficiency is the ability of a cow to produce offspring within a breeding season (Fontes *et al.*, 2020). While fertility has a low heritability, some components have a higher heritability than reproduction as a whole. Reproduction in cattle is the breeding of a bull and a cow to produce viable offspring. This is achieved through artificial insemination or natural service.

The most commonly used reproduction method in extensively farmed beef cattle is natural mating (Burrow & Prayaga, 2004). Artificial insemination (AI) is the introduction of semen into the female reproductive tract by the qualified technician by means of a pistolet. It is important that the introduction of semen to the female reproductive tract is done as precisely as possible, as transport and capacitation needs to occur before ovulation takes place (Hall & Dorsey, 2005). Approximately 92% of the artificial insemination that is used in South Africa is used in the dairy industry (Dean, 2019). While AI has been extensively studied and used in dairy cattle, the use in beef cattle is not as extensive and there has not been as much intensive research done in beef cattle as compared to dairy cattle (Washaya *et al.*, 2019). The use of artificial insemination in the beef industry is not popular due to the extensive nature of farming, the amount of labour that is required for the detection of oestrus as well as the skills required to perform the task of artificial insemination. The introduction of timed artificial insemination (TAI) was done to decrease the need for labourers to observe for oestrus. This was also used to improve conception rates of beef cows as it tends to be lower compared to dairy cows. This led to the development of different protocols, inserts, molecules, and treatments that are used in an attempt to maximise the conception rate.

BCS can be used by the farmer to assess the beef cow's nutrition needs and it can be used as one factor to assess the readiness for insemination (Rasby *et al.*, 2014). The number of days postpartum includes the anoestrus period and the uterine involution. The length of this period has been debated by many farmers and scientists. This is because the shorter it is the greater the income that will be made off those animals. The problem with it is that the number

of inseminations required, and the conception rate can be greatly affected by shortening the productive lifetime of the cow. The postpartum period, as well as the timing of the artificial insemination, will also be influenced by breed type, which is not always taken into consideration when the farmers are looking at what protocol should be used on their breed of cattle.

This dissertation focuses on the various factors that will possibly have an impact on the conception rate in the use of Artificial Insemination in beef cattle. The emphasis was placed on the external factors that could impact the success of the artificial insemination such as the nutrition and the Thermal-Humidity Index (THI) as well as other factors such as the inter-calving period, puberty, and the interaction if these factors.

Aim

The aim of this study was to determine if the conception rate in extensively raised Bonsmara beef cattle was influenced by the BCS at time of AI, the number of parities and the number of days to AI.

Motivation

A greater knowledge will refine the ability to predict response to various management techniques, which may lead to the improved use of artificial insemination and improve the conception rates due to the use of artificial insemination. This will lead to the improvement of profit margins as there will be a greater number of offspring born. The world population is expected to increase over the next 50 years (United Nations, 2019), and there will be an increase in demand for meat products. An improvement in the number of offspring that is produced will assist in the increase in demand in future. The improved techniques will also allow for easier management of cows and offspring. This study also aims to look at the interactions of various factors that affects the fertility management which will assist in improving management techniques as well.

Chapter 2 Literature review

External factors that affect the conception rate in cows, may influence some factors that will influence the reproductive efficiency in the cows. Understanding the effects of a variety of factors (e.g., BCS and parity) will allow for better management practises to be put in place and improve the reproduction efficiency within the breeding season.

1. The oestrous cycle of beef cows

Cows have a general monthly cycle that has changes in hormones, which result in a process of functions that would allow the cow to become pregnant once a month. The changes in the cycle will be different if the cow becomes pregnant or not. This section is to address what the normal oestrous cycle will be and what changes will occur if the cow becomes pregnant.

1.1. Normal oestrous cycle

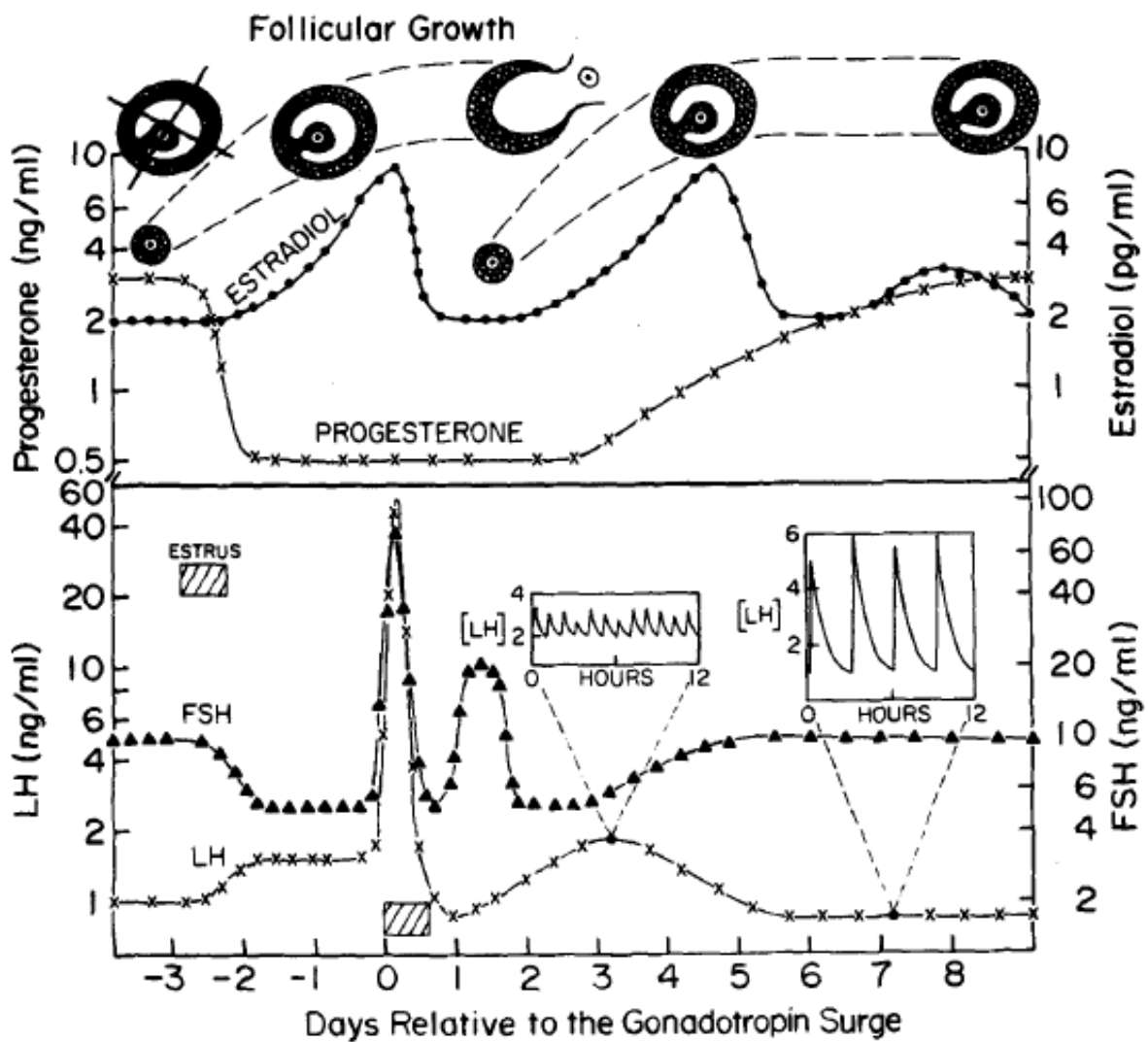


Figure 1 Hormone changes during the oestrous cycle (Hansel & Convey, 1983)

The oestrus cycle begins once puberty has been attained. The normal oestrus cycle in cows is on average 21 days (Forde *et al.*, 2011; Sartori & Barros, 2011). This is the period of time from one ovulation to the next ovulation within the same cow. The cow will follow a normal oestrus cycle for as long as there are no abnormalities such as hormonal changes (Forde *et al.*, 2011), nutritional deficits (Garcia-Garcia, 2012), or pregnancy (Chenoweth, 1994). Figure 1 shows the normal oestrus cycle of the cow. This shows the regular change in the reproductive hormones throughout the oestrus cycle. The most prominent reproductive hormones that will always be considered when looking at the oestrus cycle is Gonadotropin-Releasing Hormone (GnRH), Follicle-stimulating hormone (FSH), Luteinizing hormone (LH), oestrogen, and progesterone (Forde *et al.*, 2011). These are considered due to the control and effect that they have on ovulation. Figure 1 shows the changes in the concentration of these hormones (y-axis), which will influence when ovulation takes place in the oestrous cycle. The x-axis shows the concentration of hormones at a specific day in the oestrous cycle. Additional hormones that are considered are insulin-like growth factor one (IGF-1), insulin, leptin, and additionally the substrate glucose may also be considered (Garcia-Garcia, 2012). These additional hormones may have an influence on the possibility of ovulation.

1.2. The recovery period after calving

The recovery period is the interval from parturition to the point where re-conception can occur. As mentioned before, this is an important period, due to the need for involution to take place which has to occur before it is possible for the cow to be in calf again. The average gestation length for a cow is 282 days (Macmillan, 2002). The industry aims to have a cow calve every 365 days (Byerley *et al.*, 1987). This leaves on average 83 days for the postpartum recovery to occur before the stage where re-conception can take place (Macmillan, 2002). During the pregnancy period, the oestrus cycle and its hormones are affected and will play the role of maintaining pregnancy. The pregnancy will result in the stopping of the development of follicles and maintenance of the corpus luteum, resulting in the maintenance of high progesterone levels. This will assist in the maintenance of full-term pregnancy (Diskin & Kenny, 2016).

As can be seen in Figure 2, postpartum follicles will begin to grow and there will be a follicle that will become the dominant follicle (the follicle that will be ovulated) but during the first two

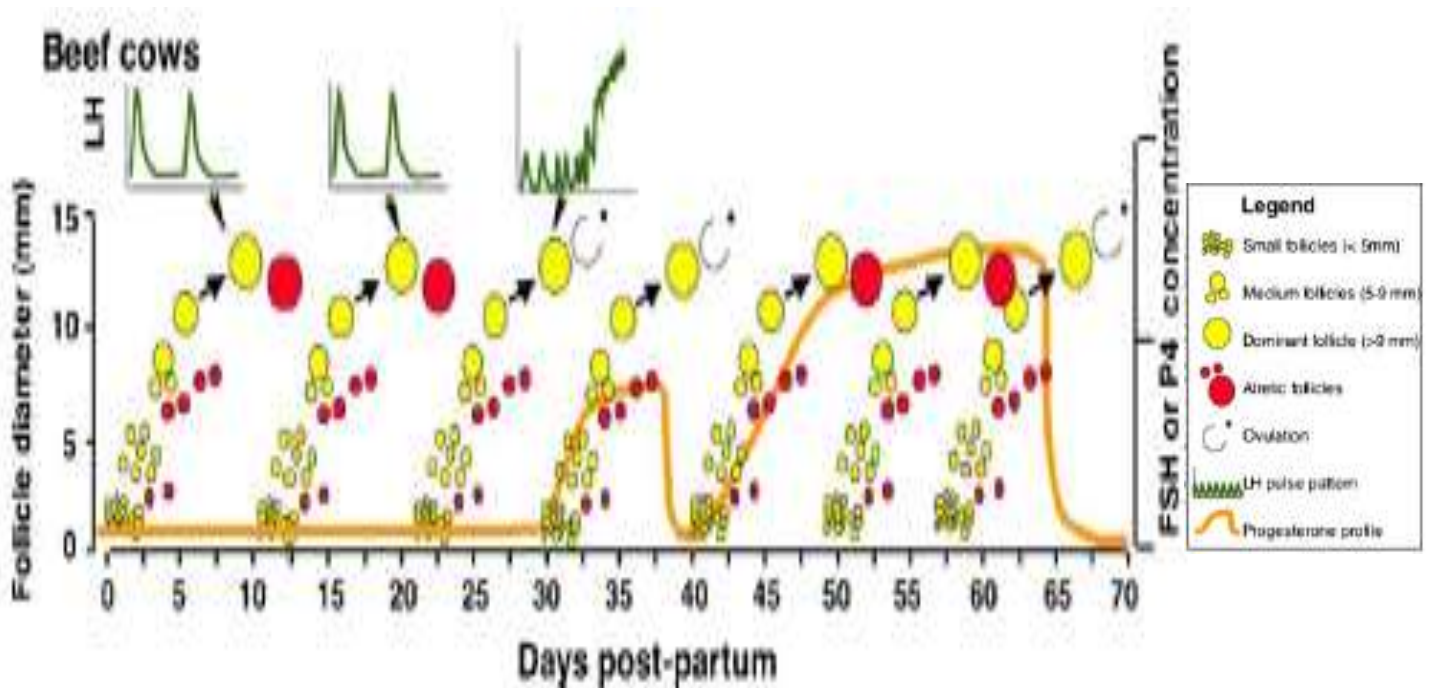


Figure 2 Changes in hormones and ovulation postpartum (Forde et al., 2011)

cycles no ovulation occurs and therefore no pregnancy can occur (Forde *et al.*, 2011). This is the recovery period, and it largely determines if the cow will become pregnant within the following breeding season (Short *et al.*, 1990b).

The recovery period length will be impacted by external factors as well as the internal hormonal factors (Macmillan, 2002). These are important to note as the length of the recovery period will also influence the length of the inter-calving period. **Suckling** will result in a delay in when the cow will be ready for re-conception because suckling results in a delay in the release of LH secretion, which is important for ovulation (Robinson, 1990; D'Occhio *et al.*, 2019).

Involution is the process of the uterine body returning to its normal state. When fertilisation occurs before involution is complete, the pregnancy rate is lowered. Beef cattle generally do not have this issue as they do not show oestrous cycles before involution has occurred (Short *et al.*, 1990b). Research into this aspect has significantly decreased over the years, and more emphasis has been placed on other aspects of reproduction (Short *et al.*, 1990b). A bacterial infection has the possibility of lengthening the involution period, which has been seen in Buffalo specifically (Usmani *et al.*, 2001). Parturition is a delicate time in maintaining the health of the cow. It is at parturition where the birth canal and uterine cavity may be invaded by bacteria due to their compromised state (Földi *et al.*, 2006; Sheldon & Dobson, 2004).

Bacterial infections will almost always interrupt the function of the uterus and the ovaries. This invasion of bacteria will result in an immune response which leads to subfertility and can cause infertility, as it hinders folliculogenesis in the cow (Sheldon *et al.*, 2002; Sheldon & Dobson, 2004).

The time that it takes for the cow to return to normal oestrus will also depend on its **BCS** (Body Condition Score) at calving and in the postpartum period. The BCS is a simple way to determine the energy reserves which influence the reproduction ability of a cow (Perry & Smith, 2018). Looking at the BCS at weaning is strategic because this is the time where there are the highest energy demands. The BCS at calving is one of the most important factors in determining the continuation of the oestrous cycle and re-conception (Perry & Smith, 2018; D'Occhio *et al.*, 2019). The energy requirements are elevated during the lactation stage. First and second calf cows will also require energy to be partitioned toward growth (Lishman, 1984). A prolonged negative energy balance will result in a significant loss of BCS. Following parturition there is generally a decrease in the feed intake by the cow, which is problematic due to the effect that it has on her BCS. A decrease in the BCS is expected due to the mobilisation of fat and sometimes protein to supply enough energy to sustain the physiological processes that are occurring at this point in the cow's life (Roche *et al.*, 2000). Cows that are fed high energy diets for a period before calving tend to conceive earlier in the breeding season

than those that were fed at half the energy levels for the same period (Perry & Smith, 2018). This is because the high energy assists with the maintenance of the body condition.

The study done by Lishman, (1984) was a study that was conducted on cows having only one calf and were going into their second breeding. This study was done in the tall grass veld of

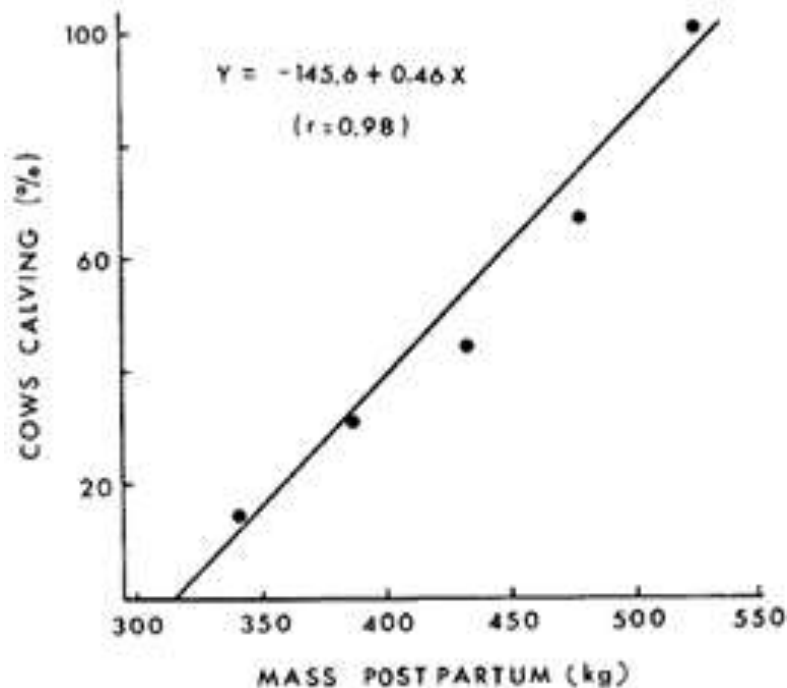


Figure 4 Changes in the calving percentage influenced by body mass at parturition (Lishman, 1984)

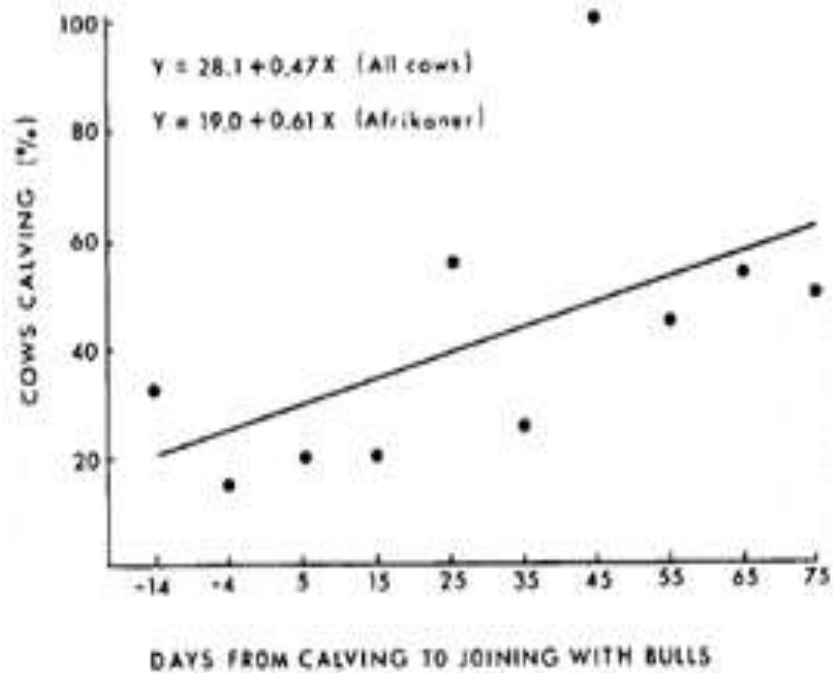


Figure 3 Calving rate as influenced by time of calving in relation to onset of subsequent mating period (Lishman, 1984)

Northern Natal. Figure 3 shows that the greater the postpartum mass is the higher the calving percentage will be. This is why it is important to note the BCS, as BCS is considered one of the most important if not the most important factor in a herd of cows that will be used for reproduction (Lishman, 1984; Azzaro *et al.*, 2011). The longer the cow takes to obtain a normal BCS the longer it will take to reach a state of re-conception and therefore the longer the recovery period would be (D'Occhio *et al.*, 2019)

Figure 4 shows the calving rate as influenced by the calving in relation to onset of subsequent mating period. It shows that the longer period that the cows are given to recover the higher the calving percentage will be (Lishman, 1984).

1.3. The change in hormones during pregnancy

If fertilization occurs the corpus luteum that forms on the ovary where the follicle was released, will remain functional throughout the pregnancy period. Progesterone will be produced, which will maintain the pregnancy (Hansel & Convey, 1983). In Figure 5, it shows the progesterone that is produced during the gestation period (Adelakoun *et al.*, 1978).

The pregnancy rate is a calculated percentage. It is the total females that are evaluated as pregnant divided by the total number of females that were inseminated (when using timed artificial insemination).

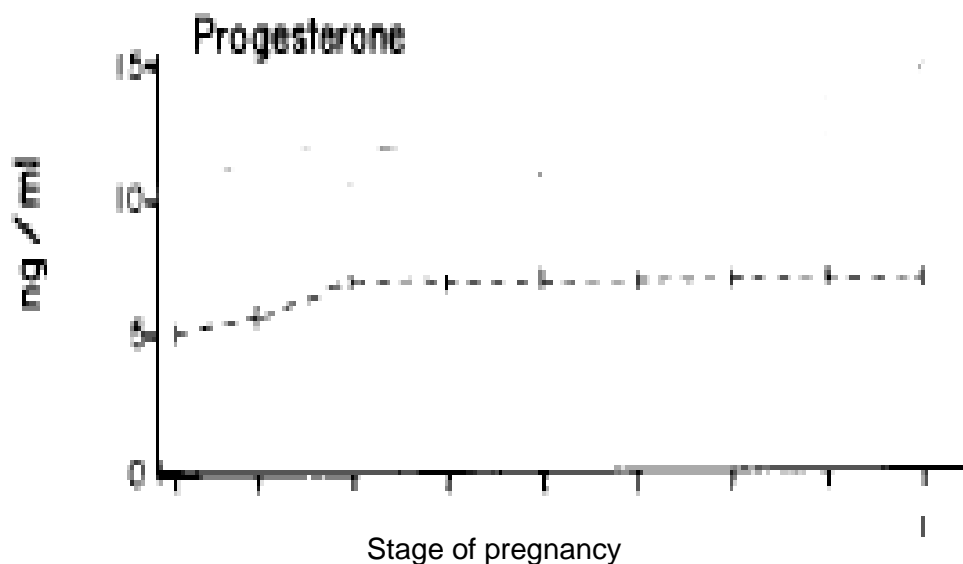


Figure 5 Level of progesterone throughout the 9-month pregnancy (Adapted from Adelakoun *et al.*, 1978)

A breeding season is a defined period that is used for strategic management in beef cattle. This helps with the calf management and calving. This allows for a set time of the year when calving will take place for most of the herd and the farmers focus may be on calving as they

can plan their duties around that period for the year. When it comes time for vaccination and weaning the herd will all be able to undergo the management at the same period in the year as the calves will all be approximately the same age. This will allow the farmer to plan for breeding and calving to occur in the optimum climatic conditions and forage availability.

2. Artificial insemination and protocols for timed artificial insemination

As stated previously, there has been a slow implementation of artificial insemination in beef cattle, due to the time and labour that is required for observation. This led to the development of timed artificial insemination to remove the time factor (Busch *et al.*, 2008). In tropical regions specifically, there is still a high reliance on natural service (Peralta-Torres *et al.*, 2010). A study done by Mugwabana *et al.*, (2018) showed that AI has a higher success rate in the rural communities of South Africa compared to natural mating (Mugwabana *et al.*, 2018).

Artificial insemination will also allow for the genetic diversification as well as the use of semen from superior bulls leading to economic gains for the farmer (Sá Filho *et al.*, 2013).

Insemination needs to occur at specific times because the spermatozoa and ova have a short survivability period. It will take approximately 6 hours for the first spermatozoa to reach the ova and following that there will be an increase in the number of spermatozoa from hours 8 to 18. Capacitation must also occur, which takes approximately 6 hours. The best time to inseminate is at the point where the sperm will travel and meet with the ova for fertilization to take place as early as possible and capacitation must take place, hence 12 to 14 hours after ovulation (Hall & Dorsey, 2005). The spermatozoa can survive in the female reproductive tract for anywhere between 28 and 50 hours. But after the 24-hour mark from ovulation, the embryo will be considered to be lower quality (Hall & Dorsey, 2005). This generally means that insemination takes place 12 hours after the onset of oestrus.

Synchronisation was developed to allow for the control of the occurrence of oestrus and therefore less time and labour would be required for the observation of the cattle as we would have the time frame for when oestrus would occur in control (Busch *et al.*, 2008). Different protocols and products have been developed in an attempt to maximise the effectiveness of the timed artificial insemination. Depending on the protocol that is used that will determine when artificial insemination is performed (Lamb *et al.*, 2010).

2.1 Body condition scoring of extensively farmed beef cattle

Body condition scoring is a subjective measurement that can be used by the farmer to assess the beef cow's nutrition needs and it can be used as one factor to assess the readiness for insemination. The tail head, loin, pins, hooks ribs, brisket and skin are good indicators of the BCS of a cow. Palpation of the loin and tail area to determine the protrusion of bones and the

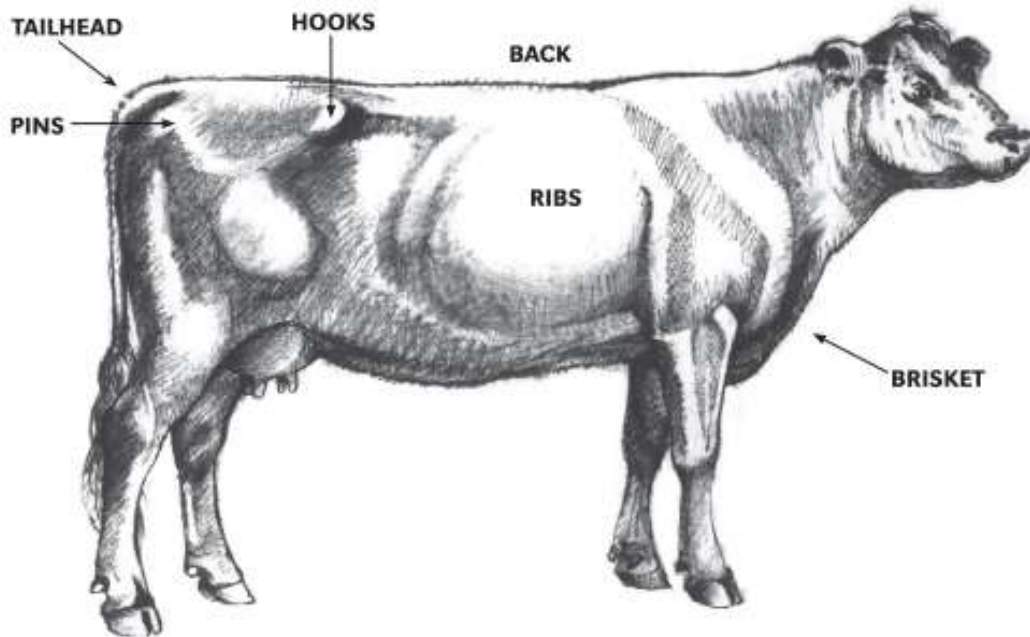




Figure 6 Key areas of evaluation for body condition scoring (Rasby *et al.*, 2014).

fat covering these areas (Scott, 2013; Rasby *et al.*, 2014). The use of the 1 – 5 scale allowed for cows to be categorised into stages ranging from emaciated (1) to obese (5). Table 1 shows the selection criterion for assigning a BCS to a cow as well as giving important aspects that should be considered when giving the cow a BCS.

Table 1 Body condition score criterion. Adapted from ('Body condition score for beef cattle - FutureBeef', 2012; Scott, 2013; Rasby *et al.*, 2014)

Photo of BCS	Selection criterion
<p>BCS 1</p> 	<ul style="list-style-type: none"> • Skeletal structure pronounced, sharp bone structure • Spinal processes feel sharp to the touch • Spine highly visible • No visible fat deposition • Muscle loss
<p>BCS 2</p> 	<ul style="list-style-type: none"> • Spine, pins and hooks, and shoulders are visible • Tail head is slightly recessed • Ribs are still slightly visible • Palpation of the spinal processes is slightly rounded not sharp to the touch

BCS 3



- Smooth outline
- Ribs are fully covered
- Firm pressure is required to feel the transverse processes.
- Hindquarters are full
- Brisket has some fat
- Tail is not recessed

BCS 4



- Ribs well covered and are not visible
- Tail shows fat deposition
- Rounded overall shape of the cow
- Fat present in the brisket

BCS 5



- Hooks and pins show fat deposition
- Tail head shows large amounts of fat deposition
- Bulging overall shape
- Difficult to see and feel bone structure
- Possibility that the movement of the animal may be impaired.

2.2 Reproductive tract scoring postpartum

Table 2 shows the criteria that are considered in the reproductive tract scoring in the postpartum cow. This is a subjective measure that is used to determine the likelihood that the cow is ready to be rebred. With some adjustments, reproductive tract scoring can also be used for heifers to determine their sexual maturity (Schwalbach *et al.*, 2000; Perry & Smith, 2018).

Table 2 Criteria for reproductive tract scoring (RTS) in postpartum cows (Adapted from Schwalbach *et al.*, 2000)

RTS	Vulva & Vagina	Cervix	Uterus	Ovaries
1	Purulent discharge, Recto-vaginal fistulae Pale mucosae	On the pelvic brim Not involuted Cervicitis Severe fibrosis	Not involuted, asymmetric Over the pelvic brim Irregular surface, with content	Not active Not palpable structures Flat and small
2	Vaginitis or severe Vulvae lesions with consequences to the shape and closure	Intrapelvic Not completely involuted Mild cervicitis Mild fibrosis	Not completely involuted At the brim. Distinct asymmetry (1:1.5) This wall, with no content No tone	Not active No palpable structures, but not flat
3	Vulva lesions with consequences to the shape but normal closure Dry pale/pink mucosae	Intrapelvic Involuted, but with a small area of fibrosis (scar tissue)	Not completely involuted Uterus intra-pelvic, nearly symmetrical (1:1.2) Thin wall, with no content No tone	Small developing follicles (<5mm) Rounded ovaries
4	Normal Moist pink mucosae	Intrapelvic Normal	Involuted. Intrapelvic Symmetrical (1:1.1) Thin wall, with no content Good tone	One ovary active, with follicles (>10mm) CL possible
5	Normal Moist pink mucosae	Intrapelvic Normal	Involuted. Intrapelvic Symmetrical (1:1.1) Thin wall. With no content Excellent tone	Both ovaries active with follicles (>10mm) CL present

Reproductive tract scoring has shown to be a good tool at accurately measuring the fertility of a heifer before the onset of the breeding season (Holm *et al.*, 2009). A study by Rosenkrans

& Hardin (2003) about the validity of using the reproductive tract scoring system to determine the pubertal status of heifers showed that reproductive tract scoring is a great tool to screen animals but not a stand-alone tool for the culling of prepubertal heifers (Rosenkrans & Hardin, 2003). Studies performed in South Africa and the United States have shown the results that have been stated. This shows that reproductive tract scoring used in tandem with other reproductive measures (e.g. BCS and body mass) will be a good reproduction selection tool (Schwalbach *et al.*, 2000; Rosenkrans & Hardin, 2003; Holm *et al.*, 2009, 2015).

2.3. Hormone treatments to synchronise oestrus

For the expression of oestrus to occur, there must be exposure to oestrogen. Postpartum oestrus will occur after uterine involution has taken place. Once involution has occurred there is generally a short cycle where there is no behavioural expression of oestrus as well as a short luteal phase and therefore it is generally an infertile stage. Cyclicity can be induced by various hormones (Lamb *et al.*, 2010).

2.3.1. PGF2 α

PGF2 α injections are used to cause the regression of the corpus luteum (Cooke & Marquezini, 2020). This causation of luteolysis will cause a return to oestrus when given in the luteal phase. This results in a decrease in the progesterone concentration allowing for the maturation of the follicle and ovulation (Bristol, 1987). This is also the most common hormone that is used for the synchronisation of the cattle in artificial insemination (Bó *et al.*, 2007).

2.3.2. GnRH

GnRH injections have two roles. The role of the first injection is used to cause ovulation or atresia of any dominant follicles that may be present. This occurs because an increase in GnRH will subsequently cause an LH surge stimulation the ovulation or atresia (Martinez *et al.*, 2001; Cooke & Marquezini, 2020). The second injection is used to stimulate an LH surge and ovulation, allowing all the cow ovulations to occur at the same time (Martinez *et al.*, 2001).

2.3.3. Oestradiol cypionate (ECP)

This is an oestrogen product, produced through the esterification of estradiol-17 β (Stevenson *et al.*, 2004) Its function is dependent on when in the synchronisation period it is administered. When administered at the beginning of the synchronisation, its role is to stop the dominant follicle growth. This will allow the next follicular wave to be more synchronised. The second administration intramuscularly (i/m) after the progesterone withdrawal it has a direct effect on the LH peak. In a study done by Stevenson *et al.* (2004) in Kansas State University, which compared the use of GnRH and ECP at the second injection in the Ovsynch protocol showed that the cows treated with ECP had a higher rate of oestrus and slightly fewer ovulations compared to the cows treated with GnRH (Stevenson *et al.*, 2004).

2.3.3. Oestradiol benzoate (EB)

This hormone acts in the same ECP in inducing ovulation (Stevenson *et al.*, 2004). EB is the most commonly used in synchronisation and heat induction (Peralta-Torres *et al.*, 2010). It is injected intramuscularly. The timing in which EB is used compared to ECP is slightly different. The use of EB will require more management time compared to ECP, as it is administered 24 hours after the withdrawal of progesterone, meaning the cows will have to go through the crush an additional time on an additional day (Peralta-Torres *et al.*, 2010).

2.3.4. Equine chorionic gonadotropin (eCG)

Equine chorionic gonadotropin is better known as PMSG. It is injected at the time of the device removal and is used to improve the synchronisation of beef cattle, generally increasing the occurrence of ovulation (Diskin; Lamb *et al.*, 2010). It can also influence the competency of the ovulatory follicle (Lamb *et al.*, 2010). It has also been shown to improve the follicle development and influence the pregnancy rates in TAI programmes (Sá Filho *et al.*, 2013).

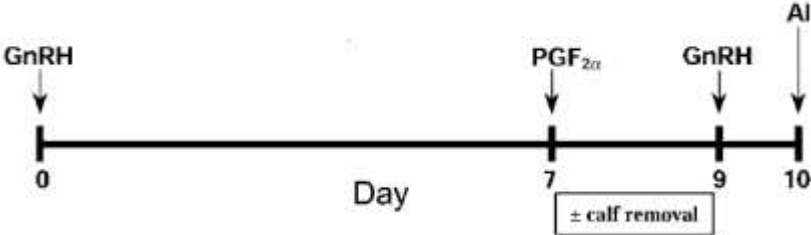

The use of Equine chorionic gonadotropin has been shown to have positive effects on the ovulation rate as well as the luteal function of the cow when injected at the point of the intravaginal device removal. These cattle tended to have larger corpus luteum as well as higher progesterone serum concentrations (Núñez-Olivera *et al.*, 2014). The eCG injection on day 7 has been shown to improve the pregnancy rates in primiparous cows when used concurrently with the PGF2 α injection (Small *et al.*, 2009).

2.4. Vaginal inserts used for oestrus synchronisation

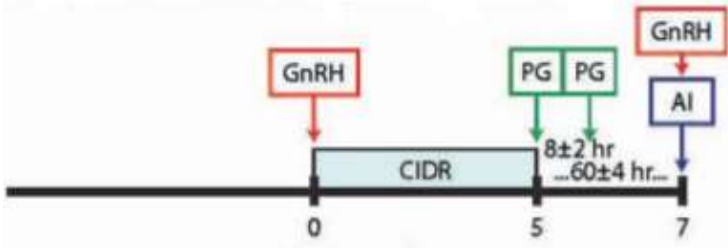
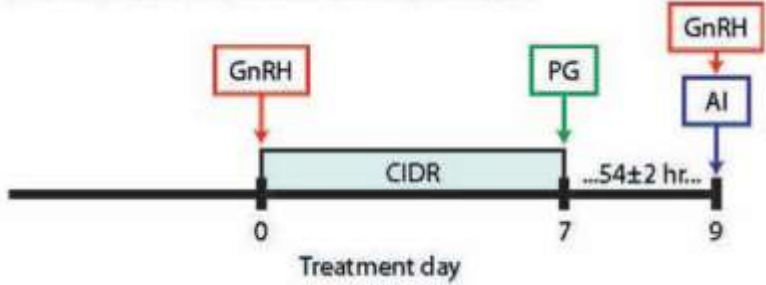
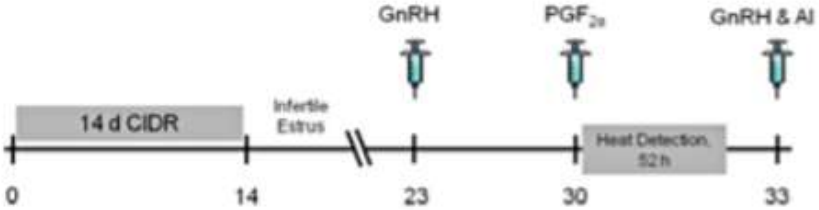
Intravaginal uterine inserts are progesterone releasing devices. They have proved useful in anovulatory cows. They also play a role in preventing or reducing cows showing premature oestrus during the AI period (van Werven *et al.*, 2013). The control of progesterone controls the LH surges and in turn ovulation (Abreu *et al.*, 2018). They have been inserted for up to 15 days, and there is a possibility of them being used more than once (Dadarwal *et al.*, 2013). The two most commonly used intravaginal progesterone releasing devices are PRID and CIDR. The shape of the different devices influences the surface area and how much contact surface area there is, which can also influence the progesterone levels in cattle as well as the functionality of the devices themselves. The rate that progesterone is released will also be influenced by the outer layer of material that is used (van Werven *et al.*, 2013). Another device known as a DIB is also a progesterone releasing device that has been used in the synchronisation protocols (Cipriano *et al.*, 2011).

2.5. Different timed artificial insemination protocols available for cows

Table 3 TAI protocols Adapted from Lamb et al., 2010

Name	Summary of steps
MGA Select + TAI 0,5mg/animal/day feeding rate	<ul style="list-style-type: none"> • MGA^a liquid feed additive consumed for 14 days. • MGA is withdrawn for a 12-day period. • A GnRH injection is administered at the end of the 12 days • PGF_{2α} 7 days after the GnRH injection • TAI performed 72Hrs after PGF_{2α}. GnRH injection at the time of AI.
Ovsynch	<ul style="list-style-type: none"> • GnRH injection is given on day 0. • PGF_{2α} injection 7 days later. • Admission of GnRH 48hrs after the PGF_{2α} • Timed artificial insemination takes place 16 hrs later.  <p>Figure 7 Ovsynch protocol (Geary <i>et al.</i>, 2001)</p>
CO-Synch	<ul style="list-style-type: none"> • GnRH injection is given on day 0. • PGF_{2α} 7 days after the GnRH is administered • GnRH is administered 48 to 66 hours after the PGF_{2α} injection, concurrent with TAI process.  <p>Figure 8 CO-synch protocol (Geary <i>et al.</i>, 2001)</p>
5 day-CO-Synch + CIDR	<ul style="list-style-type: none"> • GnRH injection and the insertion of CIDR takes place on day 0

^a Melengestrol acetate

	<ul style="list-style-type: none"> • CIDR removal takes place 5 days later. • PGF2α injection at removal. • PGF2α injection 12 hours after the first injection. • TAI takes place 72 hours after the first PGF2α and GnRH is administered.  <p>Figure 9 5-day-CO-Synch with CIDR protocol (Johnson <i>et al.</i>, 2015)</p>
<p>7-day-CO-Synch + CIDR</p>	<ul style="list-style-type: none"> • GnRH and insertion of CIDR takes place on day 0 • PGF2α injection 7 days later. • CIDR removal and GnRH injection and PGF2α takes place on day 7 TAI 60 to 66 hours after PGF2α injection.  <p>Figure 10 7-day-CO-Synch with CIDR (Johnson <i>et al.</i>, 2015)</p>
<p>CIDR select</p>	<ul style="list-style-type: none"> • CIDR is inserted for 14 days. • GnRH administration takes place 9 days after CIDR removal. A PGF2α administration is given 7 days after. • TAI takes place 72 hours after PGF2α and GnRH injection  <p>Figure 11 CIDR select protocol (Bridges <i>et al.</i>, 2009)</p>

2.6. Effective time to inseminate postpartum

The time interval postpartum before rebreeding is necessary for recovery. Cows are acyclic in this period meaning that they will not ovulate. Timed artificial insemination that occurs at the

Table 4 Pregnancy rates (%) after TAI of different parities and different intervals from calving (Taponen, 2009)

	Interval from calving			Total
	50-70	71-100	101-	
Parity				
0				43.8 (16)
1	83.3 (6)	56.0 (25)	16.7 (6)	54.1 (37)
2-5	100.0 (9)	49.0 (49)	55.6 (9)	56.7 (67)
6-	0.0 (3)	33.3 (6)	0.0 (1)	20.0 (10)
Total	77.7 (18)	50.0 (80)	37.5 (16)	

Numbers of artificial inseminations in different groups are shown in parentheses.

beginning of the breeding season has shown to increase the pregnancy rate (Sá Filho *et al.*, 2013). After involution has taken place cyclicity will resume (Macmillan, 2002). The cyclicity for a few cycles after involution tends to still be relatively unpredictable or silent, due to a low level of LH. This indicates that the LH pulse frequency has a major influence on the resumption of cyclic activity (Crowe, 2008). There are several factors that dictate how long this period will last, namely, suckling and the maternal bond, genetics, season, breed type, and nutrition (Williams, 2005). A study done by Stevenson *et al.*, (2004) looking at the differences in conception rate with different intervals from calving in Finnish field conditions, showed that a shorter period from calving to insemination resulted in pregnancy rates that were higher than those with a longer period from calving, as shown in Table 4 (Taponen, 2009). This study was conducted with a small sample size of Charolias cows, and therefore may not be effective in a general analysis but more applicable to a specific area analysis.

When performing TAI protocol, precise control of the hormones which are present and coordinate the processes within the oestrous cycle will need to be managed. The body

condition largely impacts the release of hormones in a cow throughout the inter-calving period and therefore when performing timed artificial insemination protocols the BCS will allow the farmer to improve the likelihood of conception and may result in the improved conception rate of the herd (Perry *et al.*, 2002). Figure 12 illustrates that the BCS at breeding is largely affected by the BCS at calving as shown in the study done by Hess *et al.*, (2005). The BCS is considered when evaluating animals for reproductive potential as it reflects the reserves that are available for all the basic activities that the cow or heifer will have to perform, such as metabolism, growth, lactation, and physical activity. This is important as there must be enough body reserves available to allow cows to successfully reproduce (Montiel & Ahuja, 2005).

The BCS has shown to have an influence on the concentration of the insulin-like growth factor 1 (IGF-1) in blood circulation (Samadi *et al.*, 2013). The concentration of IGF-1 has been shown to influence the resumption of ovulation (Ayres *et al.*, 2014). This is important to note as the metabolic hormones control the activity of GnRH neurons that are present in the hypothalamus and hence will influence the re-conception rate (D'Occhio *et al.*, 2019).

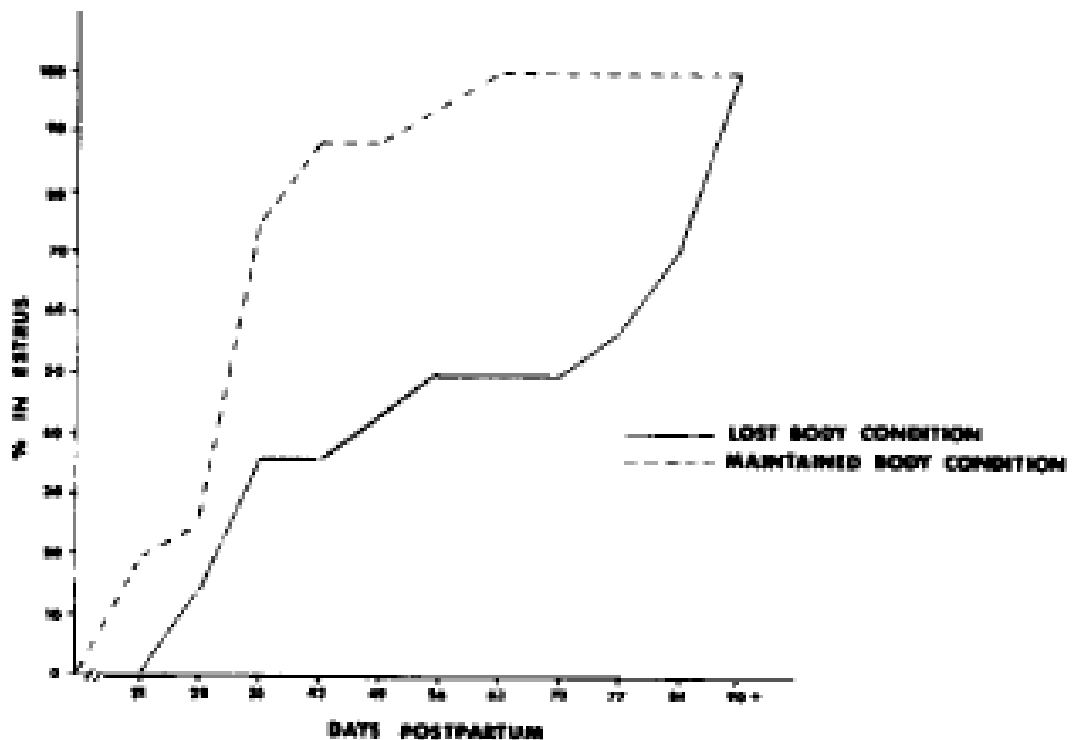


Figure 12 Effect of BCS on the postpartum interval to first oestrus (Rutter & Randel, 1984)

The main factor influencing the body condition will be the energy status, as previously mentioned (Montiel & Ahuja, 2005; D'Occhio *et al.*, 2019). This is due to the impact of body condition on the LH pulsatile releases which influences the growth of dominant follicles (Grimard & Thibier, 1995). The ovarian function that needs to be obtained after parturition is

also influenced by the BCS that the cow is in before and during insemination. The exact mechanism that influences the reproductive potential is not known but the energy balance has been shown to have a profound effect on the period of the postpartum anoestrus (Hess *et al.*, 2005). Beef cattle, the same as in dairy cattle, generally will suffer from a negative energy balance during the lactation period, as it is associated with metabolic changes effecting the reproductive potential of a cow (Humblot *et al.*, 2009). This energy deficit prolongs the time when oestrus will begin again as well as reducing the fertility in females (Montiel & Ahuja, 2005). In a study conducted by Grimard & Thibier, (1995) in France, showed that LH profiles were affected by the change in energy balance that a cow had undergone. The follicular growth at 50 days after parturition was shown to be greatly affected. A study conducted by Rutter and Randel (1984), in Texas, showed that the postpartum interval in the Brangus breed was shorted with increased dietary nutrient intake (which was changed by altering the energy balance), where the body condition was maintained as shown in Figure 12. A higher percentage of cows were found in oestrus when their body condition was maintained. This study also indicated that the loss of body condition resulted in the lowered nutrient supply to the reproductive tissues. This implies that there is not enough substrates for the reproductive tissues and hence the tissues will not be able to recover fully and reach a state that will allow for adequate conception rate (Rutter & Randel, 1984). Excessive body condition will also have a negative effect on the reproductive potential of cows (Montiel & Ahuja, 2005).

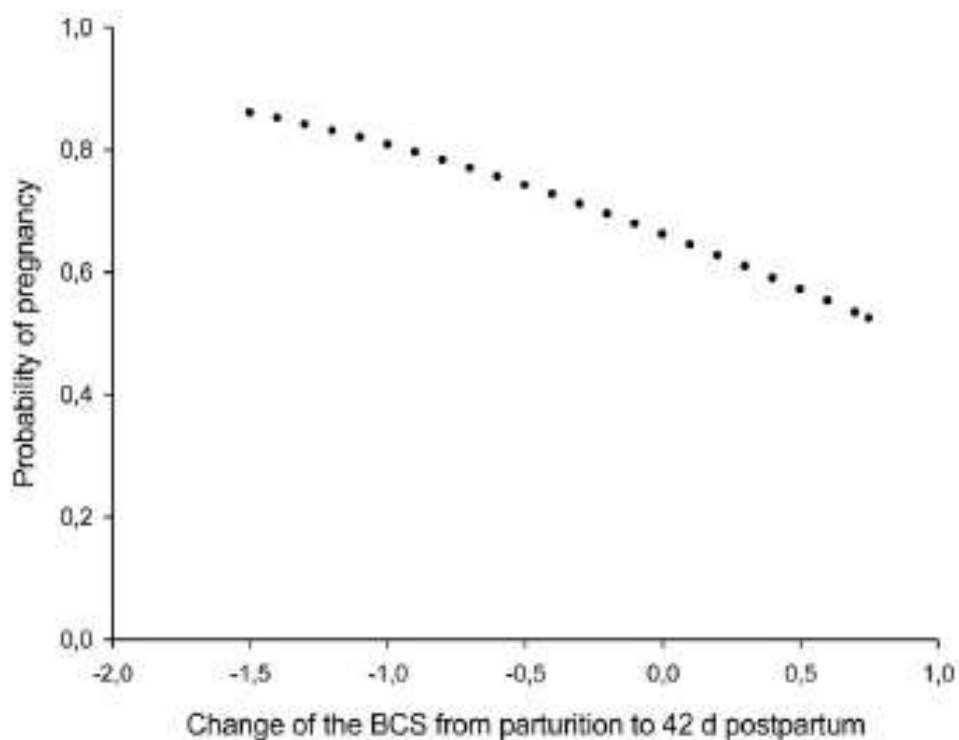


Figure 13 Probability of pregnancy and change in body condition score postpartum (Ayres et al., 2014)

There have been some studies that have shown that the pre-partum energy will assist in the management of the postpartum energy balance (da Silva *et al.*, 2017) but there are also other studies that do not corroborate this information (Sotelo *et al.*, 2018; De Lana Ferreira *et al.*, 2020). The information that is most constant in all research that is found is that the change in body condition has the most profound effect of the postpartum anoestrus period as is shown in Figure 13 (Ayres *et al.*, 2014), a study performed in Nelore cows. These factors affect the time as to when timed artificial insemination can occur. Once the anoestrous period has passed and the cow has begun cycling again, the synchronisation process can begin. This means that a protocol will be followed. While studies have been done on how long after the progesterone releasing device is removed, then insemination should occur, there is very limited research on the effective time of this and how practically this can be achieved on a farm. More research needs to be conducted in this area to note if there is an effect in the effective time of the removal and insemination.

2.7. Factors affecting TAI in Beef cattle

2.7.1. The effect of season on conception in TAI protocols

A study has shown that there is an advantage in artificially inseminated cattle in winter where they will calve in autumn, compared to doing it in summer and having the cows calve in winter (Azzam *et al.*, 1989). This breeding season will allow for a higher first-service conception, which will result in heavier weaning mass if weaning would take place on a fixed date (Azzam *et al.*, 1989).

2.7.2. The effect of the anoestrous period on conception in TAI protocols

For cows to calve once a year they need to conceive in the 75 to 85 days after calving occurred. Anoestrus is one of the most common postpartum conditions that delay re-conception. This is a common issue that has been seen in cattle that are found in the tropical environment (Baruselli *et al.*, 2004a). This anoestrous period results in a longer time that passes from calving to the time of rebreeding, which can lead to economic losses (Sá Filho *et al.*, 2013). This period is generally associated with static ovaries. The oestrus is silent and there is some follicle development, however, none develop enough for ovulation to occur (Montiel & Ahuja, 2005). Many factors can cause this anoestrus period such as prolonged suckling, nutritional deficiencies, time of year, and management (Miller & Ungerfeld, 2008).

2.7.3. The effect of suckling and calf/maternal bond on conception in TAI protocols

It has been shown that the maternal bond not only the presence of the calf is required for the suppression of the ovarian and sexual activity (Williams *et al.*, 2005). Suckling stimulus is one exteroceptive factor that has a major effect on the re-conception of the cow. The frequency, intensity, or duration will influence the length of the postpartum anoestrus. Suckling interferes

with the hormonal releases from the hypothalamus and/or the pituitary gland (Williams, 1990; Montiel & Ahuja, 2005).

Restricted suckling can result in a shortened postpartum interval. Suckling 2 to 3 times a day resulted in decreased cyclic activity, LH pulses, and sensitivity to the hypothalamic - hypophyseal axis (Montiel & Ahuja, 2005). In the *Bos indicus* breed type the anoestrus period length was reduced when suckling was restricted to once a day. This also allows for the BCS of the mother to be better for re-conception (Montiel & Ahuja, 2005).

2.7.4. The effect of bull exposure on conception in TAI protocols

The introduction of rams to ewes before the breeding season is used to stimulate the ewes and bring them into oestrus. It has also been used extensively in pigs, where the boars are required for stimulation. The introduction of the bull to the cow has been studied and some relevant information has been found, though it may not be substantial (Zalesky *et al.*, 1984). In the study done by Zalesky *et al.*, (1984) on Hereford and Hereford x Angus cows, showed that the presence of a bull shortened the time from parturition to the initiation of the oestrous cycles in mature cows. The postpartum period in this study was shown to be shortened by 30 days. Other studies have shown that exposing heifers to bulls will not stimulate the start of puberty as it does in gilts (Zalesky *et al.*, 1984; Custer *et al.*, 1990). The introduction of bulls to mature cows in the postpartum period caused the shortening of the postpartum period but the exposure of first-calf cows to bulls did not have an effect on the postpartum period (Custer *et al.*, 1990). There is limited research on the effect of the length of the postpartum period in correlation to when during the postpartum period the cow is exposed to the bull. The studies that have been conducted show that exposure to the bull between 20 and 30 days postpartum has the fastest effect on the cows, whereas exposure before and after this required a larger amount of exposure (Berardinelli & Joshi, 2005). The exposure of cows to different bulls every week also contributes to the shortening of the postpartum period (Miller & Ungerfeld, 2008). The bio-stimulation of cows does not seem to affect the pregnancy rate and synchronisation of oestrus in terms of using it for artificial insemination (Pfeiffer *et al.*, 2012).

2.7.5. The effect of breed type on conception in TAI protocols

Bos indicus breed types tend to have shorter and more intense cycles than *Bos taurus* breed types (Chenoweth, 1994; Sartori & Barros, 2011). Cattle that are raised in tropical areas such as the *Bos indicus* breed type tend to have a variable oestrus response after treatments that have PGF₂ α in them (Bó *et al.*, 2007). This may have implications on the protocols that are used for the different breed types (Meneghetti *et al.*, 2009). The *Bos indicus* breed type also tends to be more temperamental and handling will differentiate from the *Bos taurus* types, influencing how insemination can occur and hence the protocol (Bó *et al.*, 2007). A study

done by Meneghetti *et al.*, (2009) a variety of experiments were performed to determine a protocol for the *Bos indicus* breed type. Satisfactory pregnancy rates (45 – 55%) were found with a few different protocols that were tested in his experiments. The use of a CIDR was present in all experiments that produced satisfactory results, whether it was a new or used CIDR showed no difference in conception rate (Meneghetti *et al.*, 2009). *Bos indicus* breed types have been shown to have dominant follicles that have a smaller diameter, which results in a smaller CL. This affects the progesterone levels that the cow will have. Due to a smaller CL, the progesterone levels will be lower (Bó *et al.*, 2007). This can be linked to the study done by Meneghetti *et al.*, (2009) and the fact that the protocols with the satisfactory pregnancy rates are those that included CIDR, as this will have resulted in an increase in the progesterone that was found in circulation in the cow controlling the LH surges and ovulation better, improving the pregnancy rate (Bó *et al.*, 2007; Meneghetti *et al.*, 2009).

The inter-calving period is important in tropical conditions for the reproductive efficiency of *Bos indicus* cattle (Mukasa-Mugerwa *et al.*, 1991).

2.7.6. The effect of dam age on conception rates (heifer vs cow) in TAI protocols

Heifers that have reached 55 – 65% of their mature mass that will allow them to breed, will still have to partition energy more when used for reproduction as they have to partition energy into maintenance, reproduction as well as growth (Perry & Smith, 2018). The conception rate

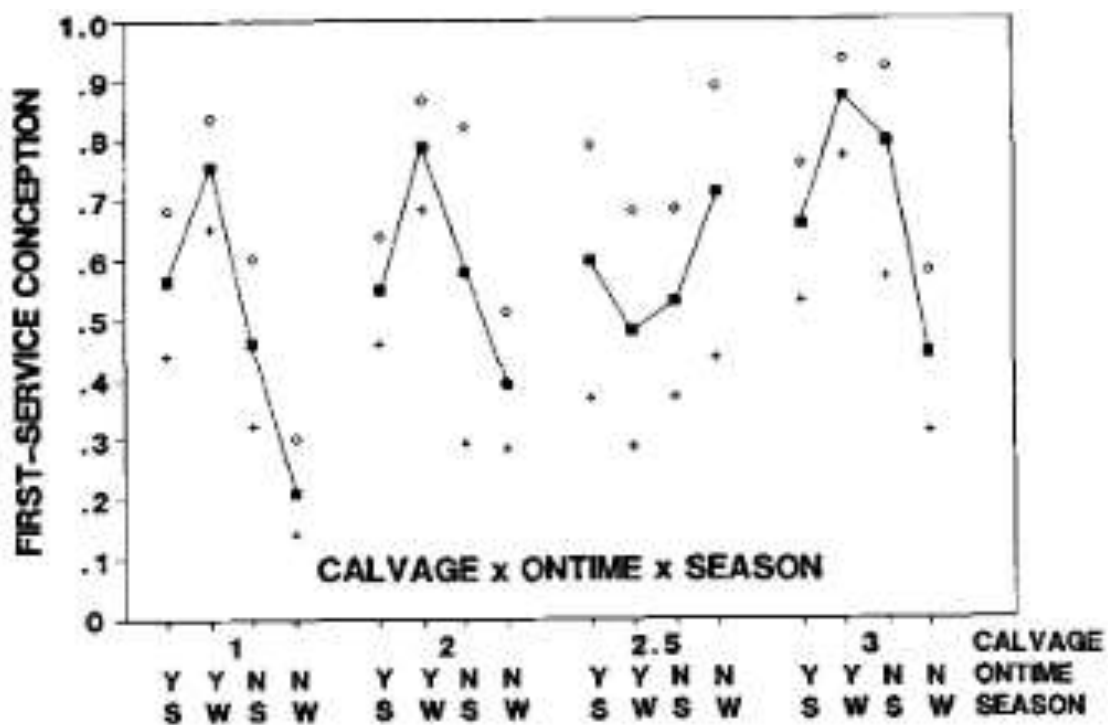


Figure 14 Graph showing the pattern on conception in cows in different parities (Azzam *et al.*, 1989)

in heifers that were artificially inseminated for the first time showed the same pattern of conception as cows who are in their second or third parity, as can be seen in Figure 13 (Azzam *et al.*, 1989).

2.8. The effect of rectal and vaginal temperature on conception rates

Rectal temperature is measured to obtain the normal temperature of the cow which is 38.5°C. Temperatures above this indicate a problem, for example, inflammation (Eley, 2011). A study done by Zakari *et al.*, (1981) conducted in Nigeria showed that when the rectal temperature increased from 38.2°C to 40°C there was a significant decrease in the pregnancy rate of Zebu type cows. They also showed that cows who had a rectal temperature above 39.7°C had a decrease in their fertility (Zakari *et al.*, 1981). While beef cows and dairy cows are not comparable, we can learn from the results obtained from studies that are done on dairy cattle. In the warm season, cows showed to have a greater rectal temperature due to the surrounding ambient temperature that the dairy cow lived in (Vasconcelos *et al.*, 2011).

The use of vaginal temperature measurement may also be a viable option in the detection of oestrous (Sakatani *et al.*, 2016). In a study conducted by Sakatani *et al.*, (2016) in Kyushu Okinawa Agricultural Research Centre, using Japanese Black cows. The use of vaginal temperatures showed higher detection rate (>90%) in all seasons compared to the use of pedometers. The temperature changes coincided with changes progesterone concentrations (Sakatani *et al.*, 2016).

3. Effect of the plane of nutrition on the re-conception rates in beef cows

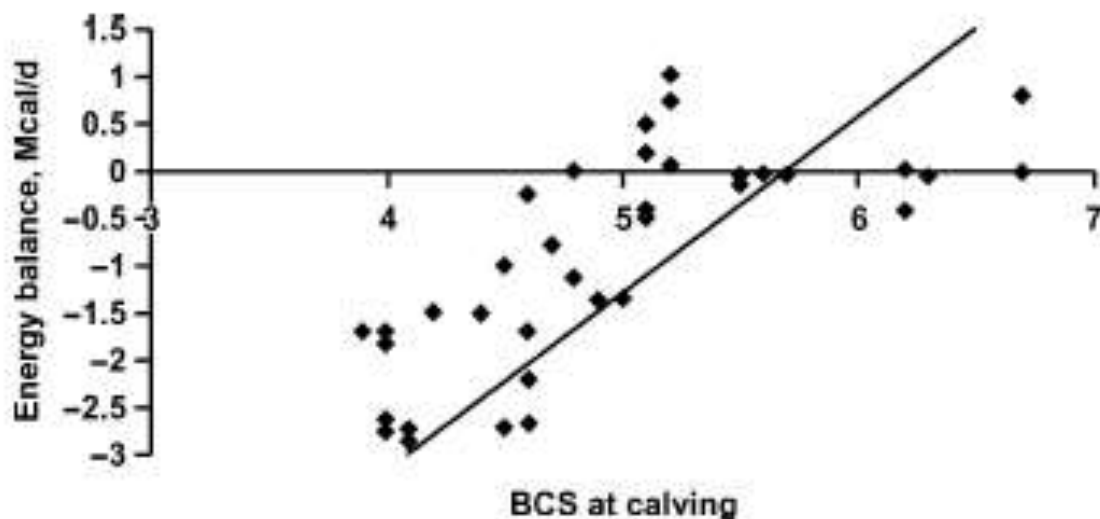


Figure 15 The relationship between prepartum energy balance estimated from prepartum BCS change and BCS at calving (Hess *et al.*, 2005)

The nutritional intake, energy intake levels, and the BCS are the main factors that are studied during the postpartum period, as these are considered the main factors that influence the point at which reproduction can commence again (Diskin *et al.*, 2003; Diskin & Kenny, 2014; D'Occhio *et al.*, 2019).

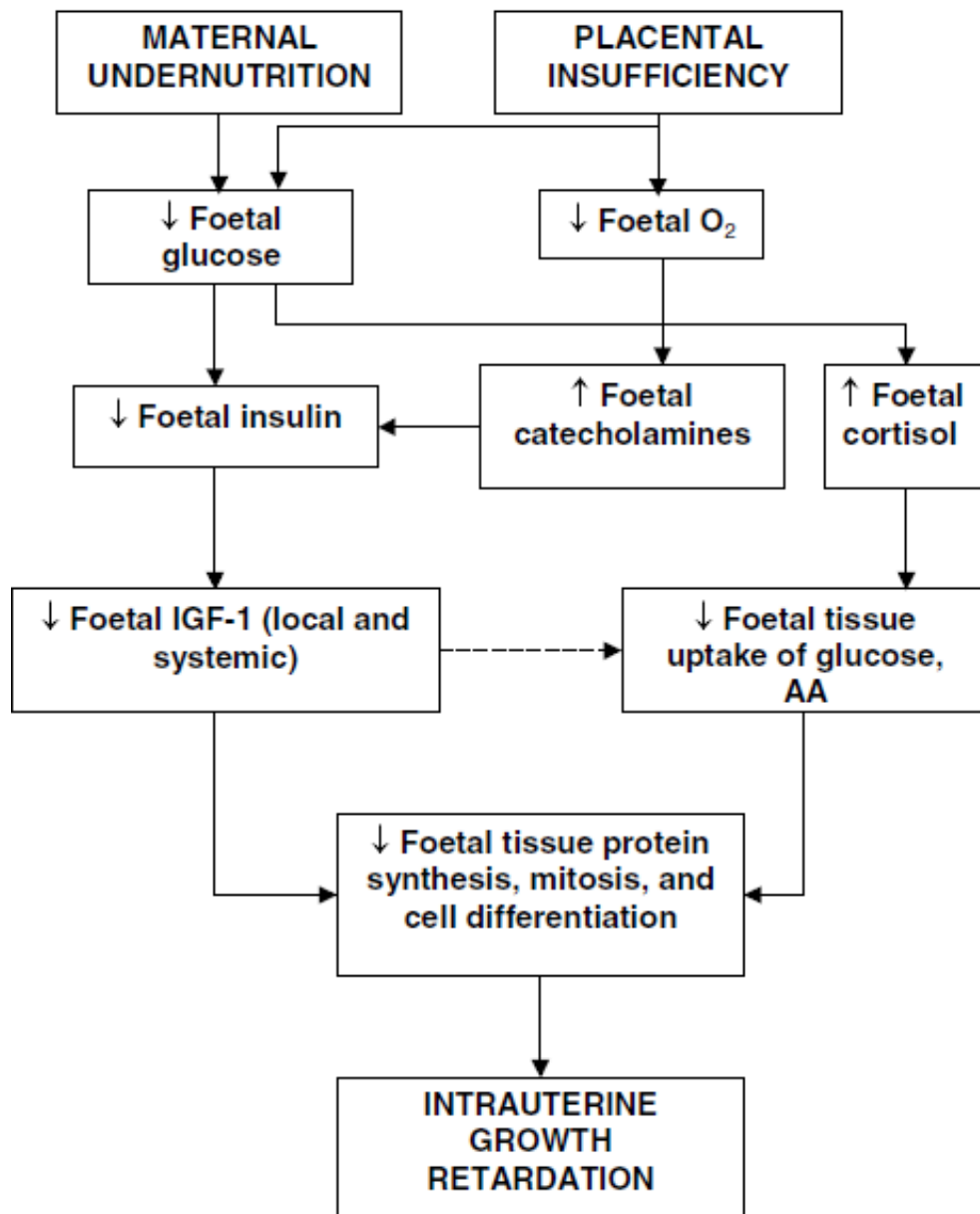


Figure 16 Schematic outline showing the effect of a small placenta and maternal undernutrition on the foetus (Greenwood & Bell, 2003)

The nutrition intake, in terms of supporting reproduction, is important both before and after calving. There will be different effects if there is acute or chronic deficiency in the feed intake, which can be due to a low plane of nutrition or just a general decreased intake of feed. A deficiency of a variety of different minerals or macronutrients can lead to anoestrous. A deficiency in minerals such as calcium, copper, phosphorus, and zinc can result in postpartum

anoestrus, but the macronutrients are more common factors that will result in extended postpartum anoestrus (Robinson, 1990). The energy balance is the main focus in most studies as it has been shown to have the greatest effect on reproduction, as it will have the greatest factor influencing the BCS (D'Occhio *et al.*, 2019). A negative energy balance will result in the use of the body fat reserves, decreasing the BCS which as shown earlier will result in anoestrus (or infertility period). The low-level plane of nutrition will affect the between animal variability, meaning that within the herd the feeding regime will not be optimal for all animals because they will always be in different stages with different requirements (Robinson, 1990). Postpartum is considered a period of infertility in cattle and the length if this infertility is highly influenced by the nutrition that the animal receives during this period. This is because the nutrition influences the change in hormones that occurs (Robinson, 1990). In thin primiparous cows, there tends to be an improved reproductive performance when the cows are given a higher nutrient intake (increase the plane of nutrition or increase the amount of feed that they are consuming). Some studies have shown that the increase in the nutrition for postpartum primiparous cows will decrease the time that it will take for the cow to cycle normally again (Diskin & Kenny, 2014).

Nutrition is important throughout the inter-calving period, and not only directly after calving, as it is the major influencer of BCS which is one of the most important factors affecting reproduction as stated earlier (Ndlovu *et al.*, 2007; D'Occhio *et al.*, 2019). Recording the BCS will allow the farmer to see what plane of nutrition the animal was exposed to over a long term period (Ndlovu *et al.*, 2007). As has been shown by much research the most important time to have the optimum BCS is at calving. On a scale of 1 to 5, this optimum condition would be between 2.5 and 3, for mature cows. This is the scale that is more commonly used in South Africa. There is evidence that the 9 point scale is more appropriate for tropical breeds as it will allow for a more accurate reading of those animals that are found in the rural areas (Ndlovu *et al.*, 2007). For heifers/cows that have not yet fully grown the optimum BCS will be relatively higher because they still need to grow and support a foetus/offspring (Rice, 1991; Diskin & Kenny, 2014). It has also been shown that mature cows will also benefit positively from an alteration in the diet (D'Occhio *et al.*, 2019). Studies have shown that changing the cow to a high energy diet postpartum improved the pregnancy rate in the herd (Rice, 1991).

After conception has occurred, the nutrition of the mother will affect the nutrition of the foetus. This is known as foetal programming (D'Occhio *et al.*, 2019). Foetal programming implies that a permanent effect will occur to the animal as it grows if there is a change during the critical time within the prenatal development period. Maternal malnutrition influences the growth and

development of the foetus and affects the placental size and hence how much nutrients reach the foetus (Greenwood & Bell, 2003). The way and nutrition that the foetus grows in will influence how the animal will survive for the rest of its life (Cronjé, 2003; D'Occhio *et al.*, 2019). Foetal programming will affect the survival of the offspring once it is born as it influences the immunity as it grows up. If there are fewer animals that survive there will be fewer cattle that survive and therefore there will be less available to reproduce in the next season (Cronjé, 2003). In cattle, the most severe effects on the foetus will occur when there is malnutrition during the second and third trimester (Greenwood & Bell, 2003). The amount of fat that the mother has to mobilise during this time will also influence the calf in terms of birth mass. This is more applicable to dairy cattle (where it has been studied more) (Lee, 1993; Greenwood & Bell, 2003). In dairy cattle specifically, it has become common knowledge that the higher the milk production the lower the fertility of the cow. This is because there is a decrease in the conception rate (Lee, 1993; Butler, 2000). Acute restriction of the diet will result in the lack of development of the dominant follicle and no ovulation will result due to the lack of an LH/FSH hormonal surge (Diskin *et al.*, 1999). Maternal malnutrition will result in calves that have a lower birth mass, which is negatively correlated to the vitality, resistance, and survivability of the calf (Hight, 1966; Tudor, 1972). The effects of malnutrition and underdeveloped placenta are depicted in Figure 16. Maternal malnutrition can result in thyroid dysfunction in adulthood of the offspring (Passos *et al.*, 2002).

The effect of nutrition can also affect the calving date (Angus cows) (Montgomery *et al.*, 1985). As discussed before, sucking has a major influence on the resumption of cyclic activity (Robinson, 1990; D'Occhio *et al.*, 2019). The lactation period will be the period when the cow is in the most negative energy-balanced state throughout the inter-calving period, and this is most critical in primiparous cows (0,25 Hereford, 0,25 Angus, 0,25 Red poll and 0,25 Pinzgauer) (Freetly *et al.*, 2006). Underfed beef cattle, that are in their lactation period will have a lower concentration of LH and FSH. This means that the frequency of the pulses of these hormones will be lower. This is not due to a decrease in sensitivity, it is due to a decrease in the release of gonadotropin hormone which is affected by the plane of nutrition. This will lead to a delay in the folliculogenesis process and therefore increasing the inter-calving period (Lee, 1993).

The nutritional composition of the diet will also influence the fertility of the cow. Anything that influences the fertility of the cow will influence the inter-calving period, as the longer the animal takes to exit the anoestrus period after calving/breed/ovulate the longer the inter-calving period will become (Butler, 2000).

All of this shows that the nutrition influences at all stages all the reproductive cycle that forms the inter-calving period, which will cause the inter-calving period to be extended or shortened, as well as produce fewer offspring that will lead to the reduction in the number of calves born. This also all affects the pregnancy rate and the likelihood of a heifer/cow becoming pregnant, hence increasing the inter-calving period, as they do not produce a calf in that season.

4. The effect of season on conception and re-conception rates in beef cows

Cattle are not known as seasonal breeders, but there are a variety of studies that have shown that there is a seasonal effect on their fertility (Montgomery *et al.*, 1985; Bastidas & Randel, 1987; Strahinger *et al.*, 1990; Schillo *et al.*, 1992; Zeitoun *et al.*, 1996; Tatman *et al.*, 2004). For this reason, there is a lot of systems that will consider the season, not only due to the interaction of season and nutrition but because of the effects of the season itself. Extensive farming systems are adopted by the majority of South African farmers, and therefore the calving season is correlated with the pasture growth and level of nutrition available (Diskin & Kenny, 2014). Variation in the postpartum period is affected by season. The longer postpartum interval results in a calving period that is more spread, and this will result in a lower fertility rate. This is due to the fact the breeding will occur at the same time for all cows in the herd. This means that the cows that calve last will have the shortest recovery period and may still be in a period of infertility when rebreeding occurs. The length of the interval is also different between calving, season, herd (spring and autumn) (Montgomery *et al.*, 1985). Studies have shown that even when beef cattle are fed a constant high plan of nutrition throughout the season they are still affected by the season, showing that nutrition is not the only variable that influences the cattle throughout the season (Montgomery *et al.*, 1985).

Season and nutrition interact to affect the calving interval of a single cow. The effects of the season are more likely to be seen with the effects of other factors that influence the inter-calving period of the cow (Montgomery *et al.*, 1985).

Many studies that have been done to see the influence of season on the reproduction of animals have been done on Brahman cows. The Brahman cow is categorised as a *Bos indicus* breed type. The studies that have been conducted have been done on cattle that are tropically adapted compared to the *Bos taurus* breed type. The experiment results cannot be extrapolated between the 2 breed types. These trials also took place in the United States and there may be some differences as compared to what the effects would be in a South African setting (Bastidas & Randel, 1987; Schillo *et al.*, 1992; Tatman *et al.*, 2004). The reproductive activity in the study by Strahinger *et al.*, (1990) done in Northeast Texas, measured the frequency of the corpora lutea and the uterine tone. In the study, it was shown that in spring these measurements increase, and they will peak in summer, and they decrease to a minimum

in winter. Periods of anoestrus showed to be greatest when the photoperiod was at its shortest. This study also showed that the LH surges were greatest in early spring (Bastidas & Randel, 1987; Stahringer *et al.*, 1990). The time in the calving season where the calves are born will influence when they reach puberty. A colder environment, which is produced in winter, causes a delay in the point at which puberty occurs (Schillo *et al.*, 1992). These effects may also be attributed to an interaction of season with several other factors and therefore it is stated that these effects may not be due to season alone, but that season does play a part in the effects on reproduction. As seen in other ruminants photoperiod does seem to be the main factor that is influencing the attainment of puberty (Schillo *et al.*, 1992). Brahman cattle have been shown to have decreased fertility as the day length decreases. This is shown through the increased concentration of progesterone in the spring and summer months compared to the winter months, as shown by a study conducted in Texas (Zeitoun *et al.*, 1996). This is specifically applicable to the *Bos indicus* breed types. The latitude that the animals are found at is important to consider, as the winter in the latitudes which are closer to the equator would fall into the thermal neutral zone whereas the summers they will experience heat stress, which will affect fertility more, whereas the areas that are further north or further south in latitude will have cold environments in winter which will negatively affect the fertility of the cattle in winter (Tucker, 1982).

4.1. Veld quality in South Africa

South Africa has 3 main types of veld (sweet- sour- and mixed-veld). The veld types are differentiated by when they are most palatable and nutritious. Nutrition has a large impact on reproductive efficiency of cattle (D'Occhio *et al.*, 2019). Sour veld will provide grazing for 6 to 8 months of the year, mixed veld for 9 to 11 months of the year, and sweet veld will fall in between the two (Tainton, 2013). The majority of South Africa has sourveld cover as can be seen in Figure 17 (Acocks, 1988). The characteristics of these different veld types are also influenced by the rainfall areas that they are found in which will influence their season of use (Tainton, 2013). Grass vigour has a direct effect on management. Any grazing will have a negative effect on veld vigour (especially with other species of animals that are selective grazers) and therefore there should always be a rest period included in the management system to allow for recovery (Nooitgedacht, 1995). The management system that is used on the veld will influence the quality of the veld that is available. The various macro and micronutrients influence the efficiency of cattle (D'Occhio *et al.*, 2019). South African veld is majorly sourveld. There are areas of sweetveld in South Africa which can be seen in Figure 16. This sweetveld area in winter the veld will maintain its high nutritive value, but this veld type occurs in low rainfall areas, and this results in forage shortages in South Africa. A lower

forage level will result in the need of a lower carrying capacity, the use of rotational grazing, or the supplementation of feed (KZN Department of Agriculture, 2019).

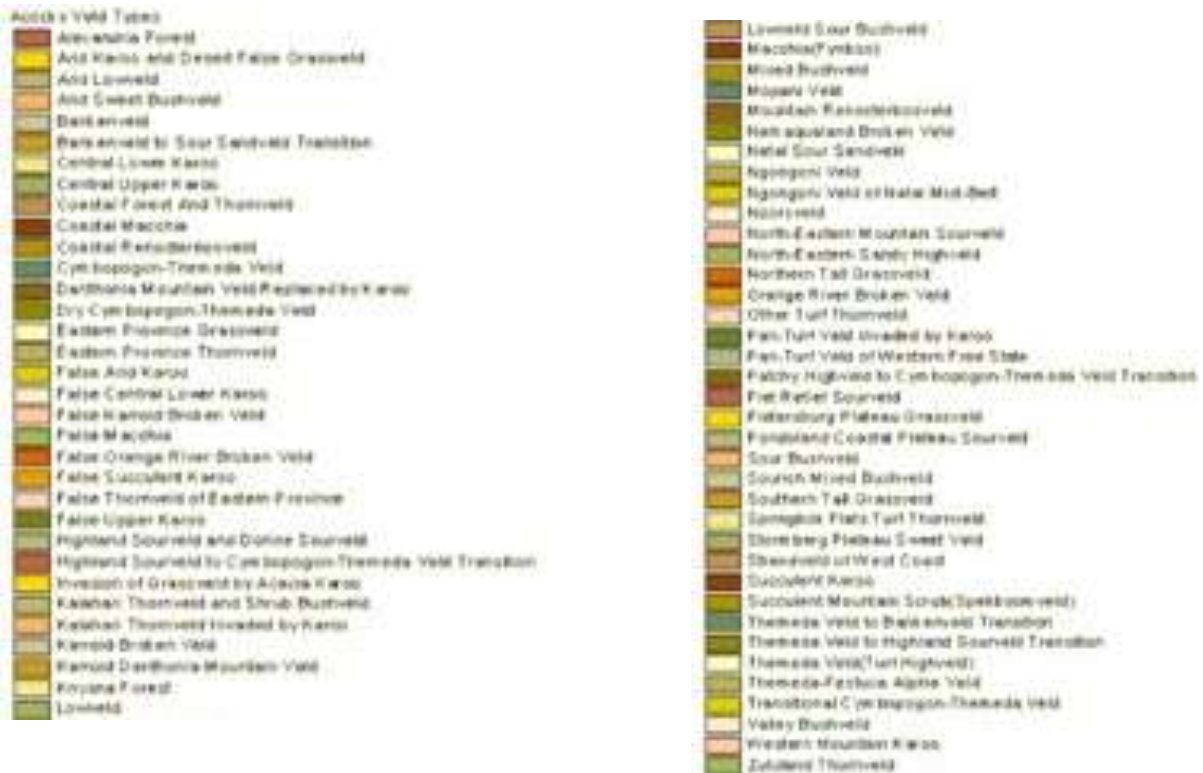
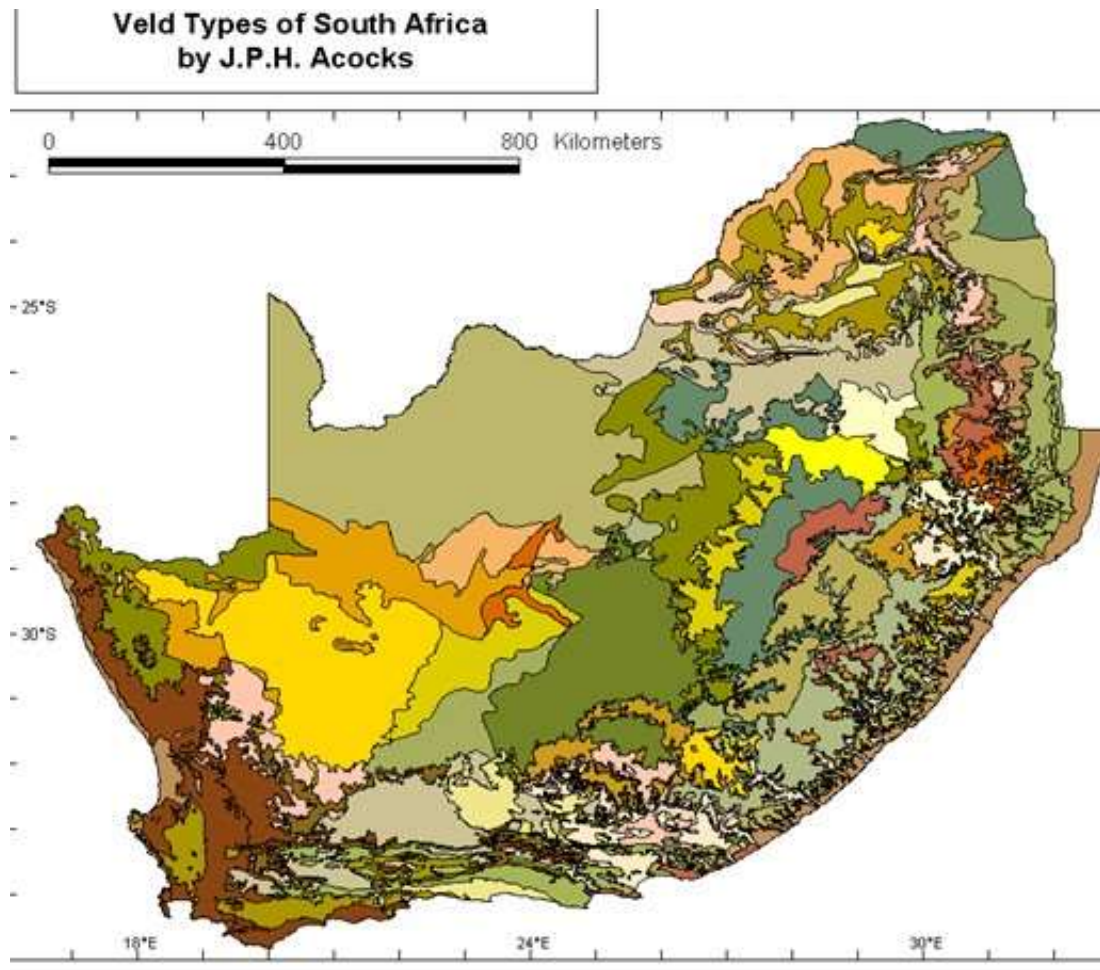


Figure 17 Veld types of South Africa (Acocks, 1988)

Veld that is low in quality has high fibre and low crude protein, as shown in Table 5. The veld that has decreased protein will result in decreased feed intake. Protein deficiencies can impact the expression of oestrus, resulting in silent oestrus leading to lower conception rates (Nqeno, 2008). It is important for ruminants that the crude protein percentage is above 13% so that the ruminant can maintain their body mass. The fibre content should be 30% and lower for the veld to be palatable and mass to be maintained (Dannhauser, 2020).

Table 5 Veld quality (Dannhauser, 2020)

Quality	Crude Protein (CP) (%)	Fiber (%)
Good quality	Above 18%	30% and lower
Medium quality	11 – 18%	30 – 35%
Poor quality	10% and lower	Above 35%

Energy deficiencies tend to be the most commonly occurring deficiency. This has a negative impact on the BCS resulting in a lower occurrence of ovulation as well as a lower likelihood of conception on the first service (Rae, 1990; Nqeno, 2008). Mineral deficiencies also affect reproduction. Phosphorus, copper, zinc, and iodine have been shown to influence the occurrence of retained placenta (Molefe & Mwanza, 2020).

The BCS influences reproduction. In a state of a low BCS, a cow will not be able to reproduce and generally, the oestrous cycle will be stopped or silent (D’Occhio *et al.*, 2019).

Other metabolic factors that influence the likelihood of pregnancy is the type of fatty acids that are present in the diet and that are therefore absorbed into the blood stream. Saturated fatty acids have been shown to have a large negative effect on the oocytes and embryos. While unsaturated fatty acids have shown to have a positive effect (D’Occhio *et al.*, 2018).

4.2. The effect of environmental stress on the physiological factors in the cow

Environmental stress on the animal is any external factors that make it more difficult for the animal to survive. The animal will become weak and is more likely to fall sick (Lee, 1993). This results in the need for animals to be adapted to the environments that they are present in and that can be done through phenotypic or physiological factors (Lee, 1993). Stress caused by

the environmental temperature is commonly known as heat stress. There is also cold stress, where there is a lot less information on how it affects reproduction (Lee, 1993), but this dissertation will be focused on heat stress. Cattle have thermoregulation systems that allow for the core body temperature to be maintained. When cattle are in a thermal neutral zone, there is no use of energy to maintain body temperature. This is when the animal will have optimal production because all the energy will go into other bodily functions, and none will be used to manage the body temperature. The upper critical temperature of their comfort zone is between 72 and 75 on the thermal-humidity index (THI). When cattle are put into a heat stress situation, it results in an increased respiration rate, increases heart rate, and an increase in panting (Dahlen & Stoltenow, 2012). These actions all require additional energy that will take away from the energy required for production. The conception rate also largely decreases when the cattle are in a THI above 72 (Lee, 1993). In terms of reproduction, heat stress is detrimental, because it results in hormonal imbalances (Lee, 1993; Farooq *et al.*, 2010). Due to the hormonal imbalances, there is a decrease in the intensity and prevalence of oestrus activity (Lee, 1993). The influence on fertility can also be due to an alteration in the expression of oestrus (Sakatani *et al.*, 2016) which will result in an inaccurate observation of oestrus if being artificially inseminated, or it will not be detected by a bull. It can also affect the health of the oocyte (Amundson *et al.*, 2006).

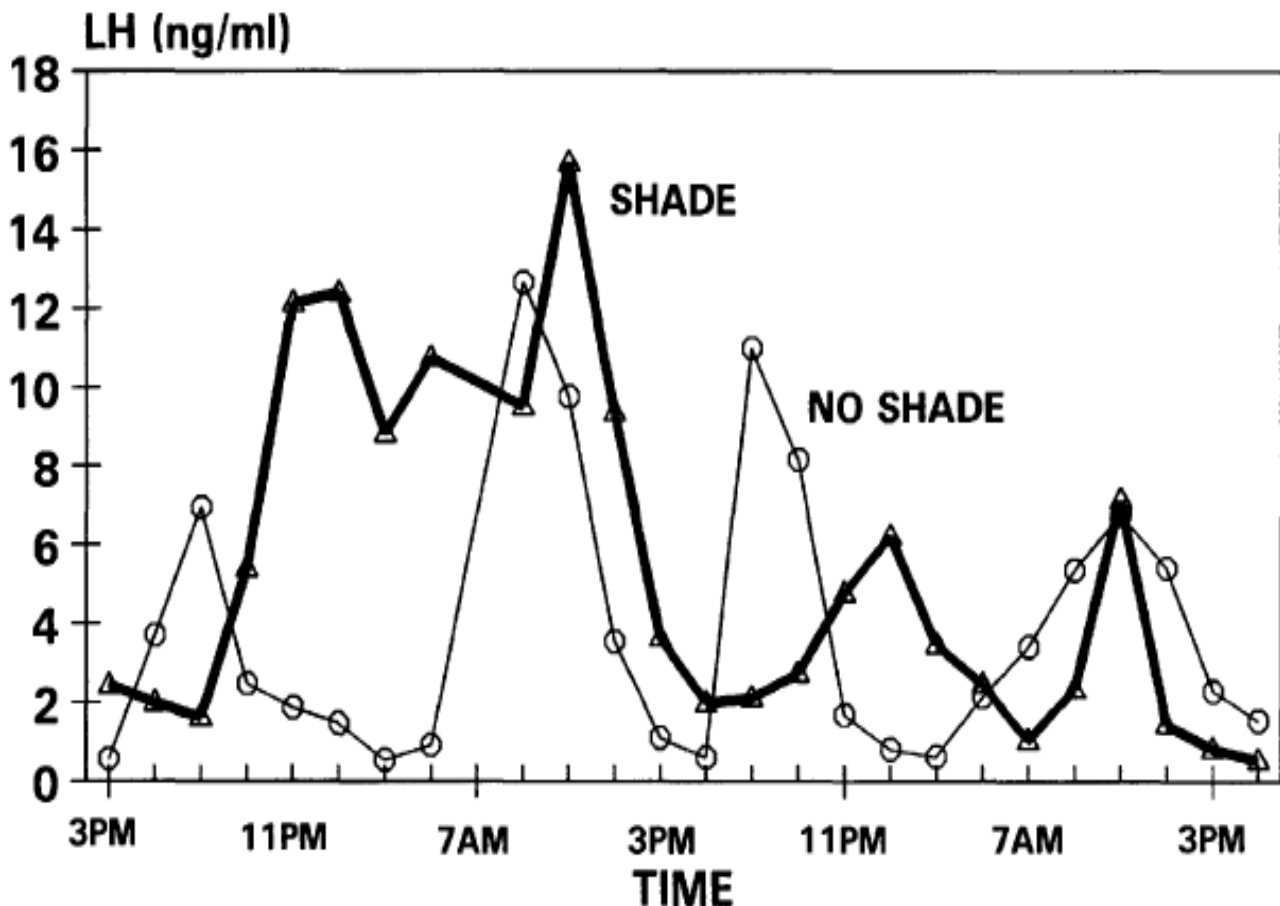


Figure 18 The difference in LH surge throughout the day, with and without shade (Lee, 1993)

In Figure 18, it can be seen that the LH surges are not as frequent and not as intense when the cattle are not provided shade and start entering a state of heat stress (Lee, 1993). This can be caused by high levels of progesterone, but the progesterone levels fluctuate depending on if the heat stress is acute or chronic hence there will be other factors that influence the LH surge in frequency (Lee, 1993; Aggarwal & Upadhyay, 2012).

Other hormones that affect dairy cattle when it is in a state of heat stress are growth hormone, cortisol, prolactin, and thyroxine (Lee, 1993; Farooq *et al.*, 2010). The concentration of growth hormone decreases in cattle that are in a heat stressful situation. This is because growth hormone is known as a calorogenic hormone, therefore in a heat stress situation, the body will decrease the production of this hormone, as it will cause an increase in heat production within the body. (Farooq *et al.*, 2010). This is then linked to thyroid hormone production which is also decreased. This has a synergistic effect on the growth hormone outcomes (Farooq *et al.*, 2010).

Temperature and humidity are often cited as issues that affect cattle and are therefore accumulatively important. Heat stress is an important factor to consider in both pasture and feedlot-based systems. Cattle that go through a heat stress situation, are stressed physiologically and need to have time to recover otherwise there is a higher risk of death if they are exposed to another heat stress situation (Dahlen & Stoltenow, 2012). This means that the management is important so that the cattle will be able to reproduce efficiently when needed. This can be done by ensuring that the cattle have enough access to water, that there is sufficient shade provided, and most importantly to not work cattle during the extreme temperatures of the day (Dahlen & Stoltenow, 2012). As stated earlier, heat stress affects breed types differently and their thermal neutral zones will be different this means that these animals need to be managed and treated differently, which must be taken into consideration (Farooq *et al.*, 2010). The main focus of this differentiation would be that everything is less pronounced in *Bos indicus* breed types making them better adapted to heat stress (Farooq *et al.*, 2010).

5. The onset and changes that occur at the onset of puberty

Puberty is the stage in the heifer's life whereby the heifer becomes reproductively active and is capable of reproducing. This involves many physiological changes that will result in the

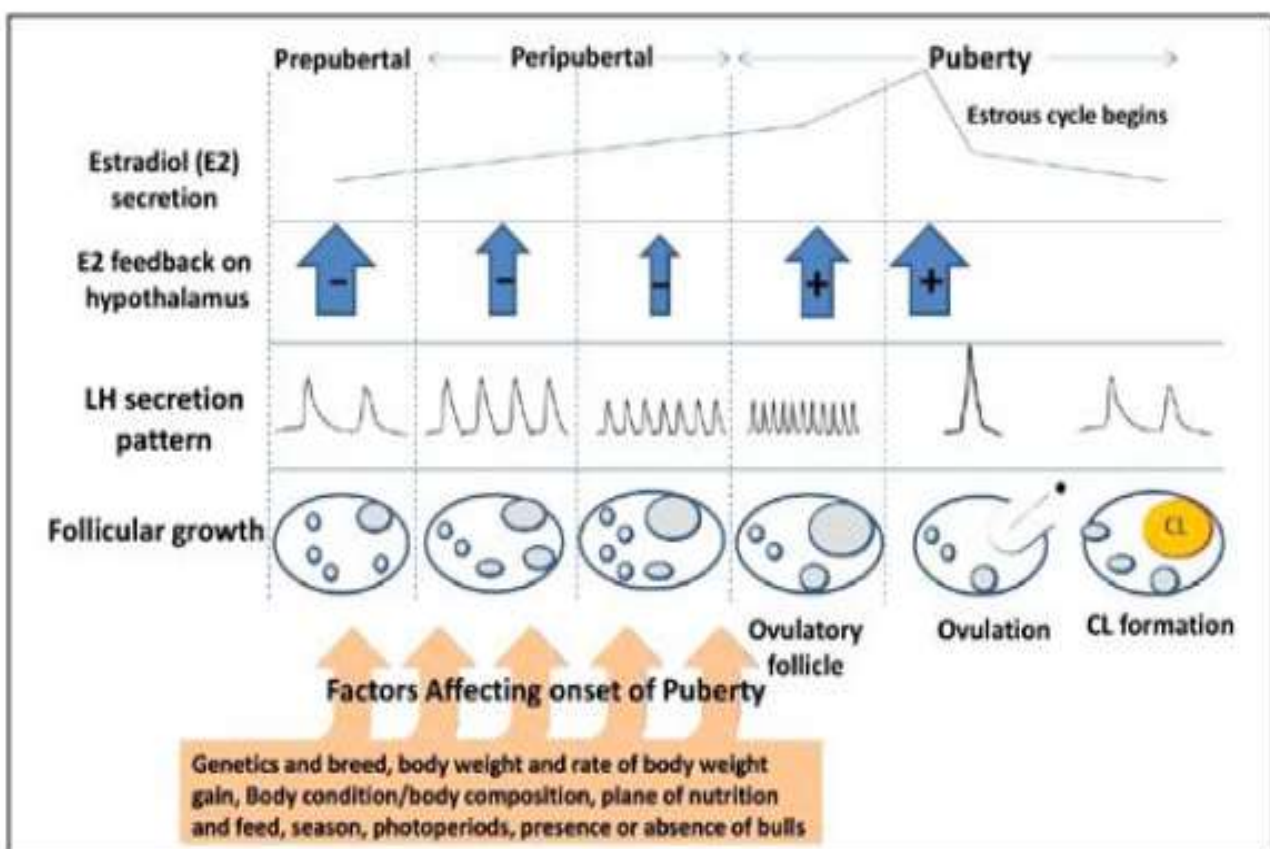


Figure 19 Changes in hormones indicating puberty (Gupta *et al.*, 2016)

specific hormonal patterns that allow the oestrus cycle to take place approximately every 21 days (Moran *et al.*, 1989). These changes can be seen in Figure 19, where the change of the oestradiol, and LH, as well as follicular growth, is shown from pre-pubertal to puberty (Gupta *et al.*, 2016). Heifers should have 2 to 3 oestrous cycles before they are bred with as the fertility of the first oestrus is lower than that of the following cycles (Schillo *et al.*, 1992). Many factors will influence the age at which puberty is achieved. These are factors that will have an influence on the time at which hormones are released, the quantity as well as the frequency. This can be seen in Figure 20. It is important to determine what the age will be when puberty takes place as this will have an influence on when the cow will be ready to be used for breeding

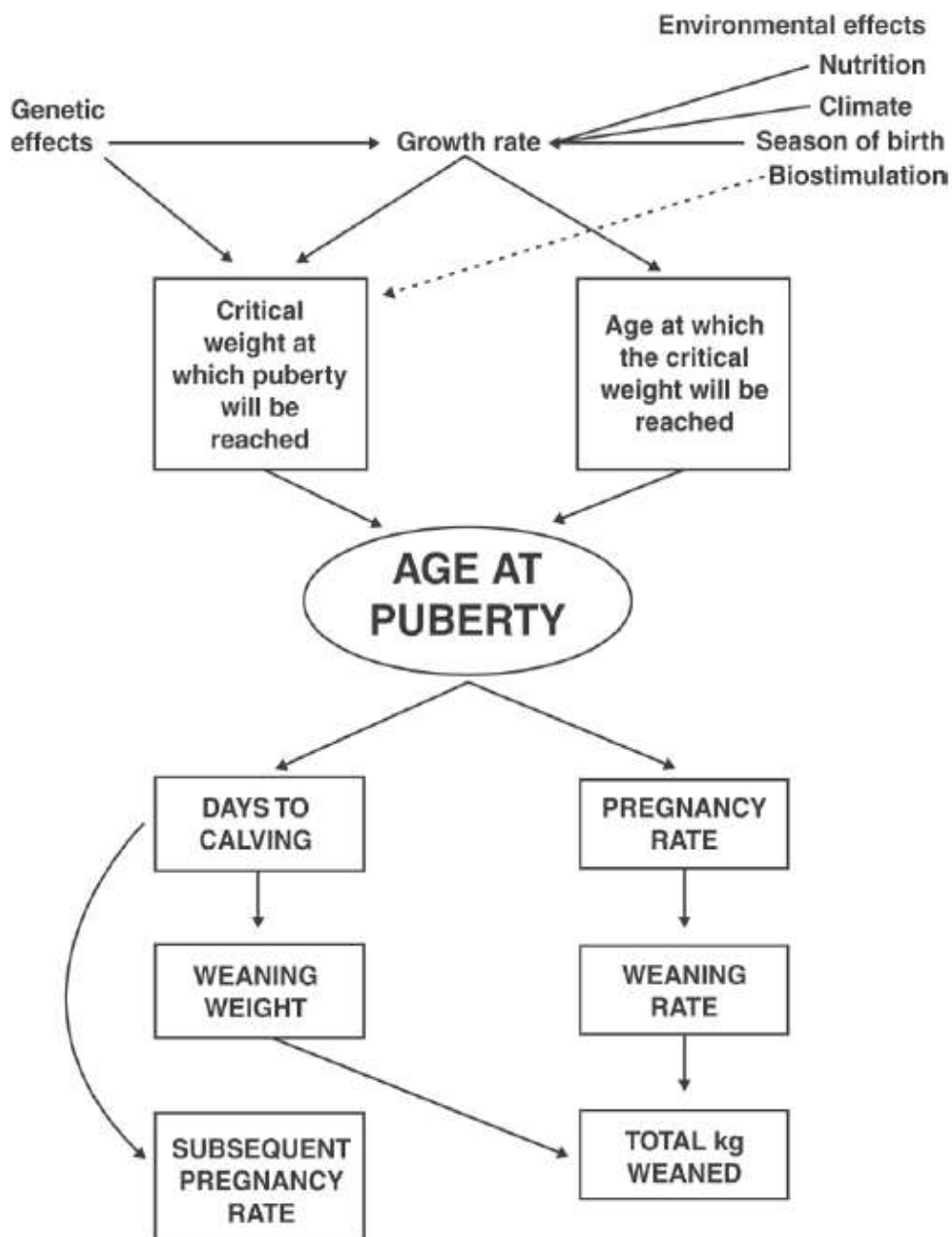


Figure 20 Factors affecting the age at which puberty occurs (Holm *et al.*, 2009)

(Moran *et al.*, 1989). The age at which puberty occurs can occur at any time between 6 and 24 months (Moran *et al.*, 1989). The age that puberty occurs will influence the subsequent rebreeding ability (Day & Nogueira, 2013). Most beef production systems aim to have heifers conceive at 14 to 16 months of age and this will result in them calving at 2 years old (Schillo *et al.*, 1992). Puberty is delayed in heifers exposed to the photoperiod and the seasonal temperature changes of autumn-winter-spring as opposed to spring-summer-autumn. Beef cattle production is seasonally orientated, to align the breeding and times of highest nutritional requirement with the highest nutritional growth of pastures (Day & Nogueira, 2013). Spring born heifers will go through less maturation in the winter season, allowing them to reach puberty earlier, based on season alone. The season will interact with the nutrition to have a largely effect the onset of puberty as previously discussed (Schillo *et al.*, 1992).

Another environmental factor that will affect the stage at which puberty is achieved is exposure to males (Gupta *et al.*, 2016). This will be due to the exposure of pheromones and stimulation (Moran *et al.*, 1989). The environmental factors that affect the age at which puberty occurs are illustrated in Figure 20.

Mass is one of the most important factors that determine when puberty will occur. Economically the age at which puberty will occur is important. This is because the earlier in chronological age the heifer breeds the more that the animals will breed in their lifetime and therefore the greater the income will be of one heifer (Dow *et al.*, 1982; Moran *et al.*, 1989; Day & Nogueira, 2013). This results in a large focus being place on attaining the correct mass for puberty to occur as fast as possible so that the animal is as young as possible to rebreed. The mass is more important for puberty than chronological age (Gupta *et al.*, 2016). The mass at which puberty is generally achieved is 55 – 65% of the mature body mass, which is dependent on the breed (Perry, 2016). Mass and nutrition are related which causes different effects on puberty. Looking at the interaction of the two which cause an effect of the point at which puberty takes place is different from the effects of nutrition alone (Gupta *et al.*, 2016). Underfeeding will result in lower body mass and therefore it will take longer for that heifer to achieve the correct mass at which puberty will take place. A heifer that is receiving the correct amount of nutrition but the incorrect balance of nutrition will also take longer to achieve the correct body mass that needs to be attained for puberty to occur (Gupta *et al.*, 2016). This means that nutritional management should be highly focused on, but it is not the only factor that will influence puberty, but it does have a major impact. A sudden increase in the plane of nutrition can stimulate the change in hormones (Figure 19), causing puberty to occur (Moran *et al.*, 1989). The type of nutrition is also important, as the leptin that is produced by the adipose tissue influences the hypothalamic-pituitary axis. This stimulation is required in a high

enough concentration to result in the cascade leading to the change in oestradiol and LH surges (Perry, 2016).

As has been stated before there are differences in the breed types in when puberty is attained (Sartori *et al.*, 2010). *Bos indicus* breed types have been less selected for in general. The range for selection is much greater in them as there will be a wider range of genetics to select from (Sartori *et al.*, 2010).

6. The age of first breeding

Many factors affect the point at which puberty occurs, but that age will have an effect on the cow for the rest of her reproductive life. There has been a correlation shown between the age at which puberty/ first breeding occurs and the subsequent breeding's (Byerley *et al.*, 1987). There are no conclusive results about the correct body mass at which the heifers should be bred or the correct time that heifers should be introduced to males. It is generally accepted, that the correct mass to breed at is 55-65% of their mature body mass, and that they should be bred at the third oestrus (Funston & Deutscher, 2004; Perry, 2016). A study done by Funston & Detscher, 2004, in Gudmundsen Sandhills Laboratory near Whitman, they considered the seasons in which the heifers were born. They also considered the first breeding and the rebreeding of these heifers when they reached puberty and were ready to be bred with. The spring-born heifers were placed into 2 groups where one group was on a high-gain diet, and the second was on a low-gain diet. There was a 24kg difference in mass between the two groups at first breeding. This difference in mass did not influence the pregnancy rate. The rebreeding rate did not differ between the groups. In the summer-born group, here the animals were again split into 2 groups, and they were exposed to bulls at different times. Group 1 had early exposure, whereas group 2 was only exposed a few months later. The body mass of both groups was similar, however calving difficulties were greater for the animals with earlier exposure, but the calf mass gain was greater. These animals were also exposed to a longer postpartum recovery. The rebreeding of the summer born group was lower than the spring-born group, and was considered unsatisfactory (Funston & Deutscher, 2004).

No conclusive conclusion has been made regarding this nutritive aspect and still requires research. From what is shown in this study, however, is that we need to look at both when our heifers are calving and when they will be rebred, to correlate it to the correct season, as well as looking at the plane of nutrition, and bull exposure. The mass at breeding may still effect on the age at which first breeding can take place, but from the limited research that there is, it may not have as large an impact as previously thought.

7. Difference in breeds in environment and reproduction

7.1. The effect of adaption and climate on different breeds of cows

Different cattle do better in different environments. This is because they are physiologically different in various aspects. Adaption is explained as the specific differences, whether they be biochemical, physiological, morphological, or anatomical, as the ability of the animal to survive and thrive in a specific environment (Chaidanya *et al.*, 2015). In a tropical setting, it can also be defined as the ability to reproduce under harsh environments (Regitano *et al.*, 2006). This is important to consider because if the animal is not adapted to its environment it will experience more stress, which will have a negative impact on reproduction (Chaidanya *et al.*, 2015). Many stressors influence the productivity of cattle and all should be considered, but the thermal stress that animals experiences will have the greatest impact on the productivity of the animal (Chaidanya *et al.*, 2015).

Bos indicus breeds are more tropically adapted, while the *Bos taurus* breeds are more temperate adapted breeds (Beatty *et al.*, 2004). This means that the *Bos taurus* breed will have better productivity in a cooler thermal temperature compared to *Bos indicus*, and the *Bos indicus* breeds will have better productivity compared to the *Bos taurus* breed in a higher thermal environment (Chaidanya *et al.*, 2015). Some *Bos taurus* breeds have been bred in such a way to allow them to be more heat tolerant and these breeds will have better productivity in a higher thermal environment compared to *Bos indicus* (Hammond *et al.*, 1996). With climate change being a significant issue at the moment, it is important to note all these differences between these breed types to allow for the best breeds that will be suited for optimal productivity in the coming years for food security (Porto-Neto *et al.*, 2014).

Bos taurus animals have gone through more selection than *Bos indicus* breeds and for this reason, they are considered as the animals that produce more or better meat and milk (Porto-Neto *et al.*, 2014). But because these are also the breeds that survive in more temperate environments, they are breeds that are going to be more susceptible to heat stress in tropical environments. (Porto-Neto *et al.*, 2014). *Bos indicus* cattle show a more subtle decrease in reproductive performance compared to *Bos taurus* cattle genetically (Porto-Neto *et al.*, 2014). *Bos indicus* calves are also generally more likely to suffer from cold stress directly after birth as they are less adapted to the cold environment, this will result in a larger number of losses of the *Bos indicus* breed type in temperate environments as there will be a lower calving success rate (Godfrey *et al.*, 1962).

The physiological responses to heat stress in the different breed types are prolonged and substantial in the *Bos taurus* types, while in the *Bos indicus* types it is not, therefore the milk and beef production of the *Bos indicus* types are less affected (Farooq *et al.*, 2010).

7.2. The differences in reproduction between the *Bos indicus* and *Bos taurus* breed types

As has been stated before the type of animal and the environment it is in, will determine its reproductive success (Godfrey *et al.*, 1962; Porto-Neto *et al.*, 2014). When looking at the *Bos indicus* and the *Bos taurus* breed types they are also different physiologically, which is why they are adapted to different environments (Sartori *et al.*, 2010; Chaidanya *et al.*, 2015). Physiologically these breed types differ in puberty, oestrus cycle and follicular dynamics, acquisition of ovulatory capacity, the maximum size of the ovulatory follicle, and circulating hormones (Sartori *et al.*, 2010; Forde *et al.*, 2011; Sartori & Barros, 2011).

The oestrous cycle starts after puberty has occurred and the state of the first oestrous cycle is what indicates puberty. Cows usually only reach maximum fertility on their third oestrous (Sartori *et al.*, 2010). In the *Bos taurus* breed types this occurs between 6 – 12 months of age, where the mass of the cow will be between 200 and 250kg (Forde *et al.*, 2011). In *Bos indicus* animals, puberty is more likely to be achieved at a later age of 2 years old. This is due to the environment and the nutrition levels that they receive because in the tropical environment it is usually of lower quality (Sartori *et al.*, 2010). But it has also been shown that there is a genetic difference in puberty (Nogueira, 2004; Sartori *et al.*, 2010). During the winter months where the days are shorter in length, *Bos indicus* heifers that are post-pubertal will have a higher incidence of anoestrous (Nogueira, 2004). *Bos indicus* animals tend to reach puberty at a heavier mass and an older age than *Bos taurus* heifers (Sartori *et al.*, 2010). As has been stated before the *Bos taurus* breed types have gone through more selection pressures than the *Bos indicus* breed types (Sartori *et al.*, 2010; Porto-Neto *et al.*, 2014) and this still holds for reproductive traits. There have been many studies on the relationship between sire scrotal circumference and the age at which their daughter offspring reach puberty (Coulter & Foote, 1979; Moser *et al.*, 1996; Eler *et al.*, 2002; Menegassi *et al.*, 2019) and there has been less selection pressure on this in the *Bos indicus* breed types and therefore this could also be a major factor in the results of differences in the age at which puberty is reached and the *Bos indicus* age can potentially be improved (Sartori *et al.*, 2010). As can be seen, the differences in the breed types can be due to human and natural selection pressures. Many of the differences are attributed to genotype-environment interactions (Chenoweth, 1994).

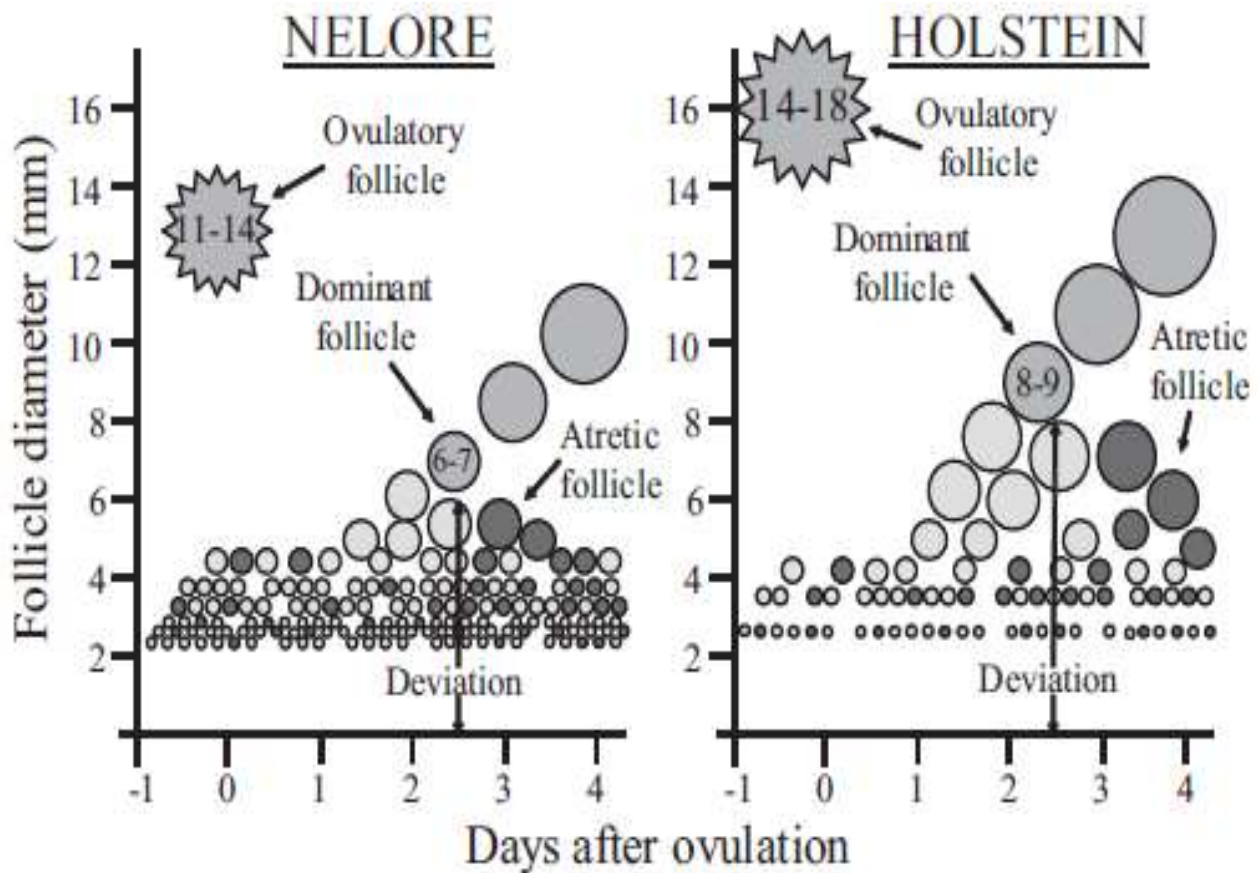


Figure 21 Difference in follicle diameter between Nelore (*Bos indicus*) and Holstein (*Bos taurus*) cattle (Sartori *et al.*, 2010)

The breed types also differ in their oestrous cycles and follicular dynamics (Sartori *et al.*, 2010). Referring back to Figure 2, looking at the follicular waves, *Bos indicus* breed types on average have two waves for ovulation to occur, which in the *Bos taurus* breed types the average number of waves is different for heifers (average three) and cows (average two) (Sartori *et al.*, 2010).

Figure 20 shows that the follicular dynamics in the different breed types vary in the number of primary follicles where the *Bos indicus* breed types have a larger number and the *Bos taurus* breed types have a much smaller number of primary follicles (Sartori *et al.*, 2010). *Bos taurus* cattle generally have roughly 24 primary follicles, while the *Bos indicus* are found to generally have a higher number of roughly 50 primary follicles (Sartori & Barros, 2011). The oestrous cycle has been compared between the *Bos indicus* and *Bos taurus* breed types, where the length is similar in length and no significant differences were seen (Sartori *et al.*, 2010). A difference has been seen in the size of the ovulatory follicle itself, but there is contradicting

research results on this. In Figure 21 (Sartori *et al.*, 2010) it is shown that the *Bos indicus* breed types are found to have a smaller ovulating follicle than the *Bos taurus* breed types. Similar results were found in the study by Alvarez *et al.*, (2000) while in a study by Sartori & Barros, (2011) it was shown that the *Bos indicus* cattle had the larger ovulating follicle.

Bos taurus breed types tend to have a gestation length that is shorter than that of most *Bos indicus* breed types with the exclusion of the East African Zebu breed types that tend to have a gestation length that is closer to that of *Bos taurus* breed types (Chenoweth, 1994; Sá Filho *et al.*, 2013).

Before ovulation occurs there is abundant changes in the reproductive hormones as described earlier in Figure 1 (Hansel & Convey, 1983). There are insufficient studies to show if the level of circulating hormone is different in the breed types. Alvarez *et al.* (2000) reported that there was no difference in the circulating oestradiol concentration between the different breed types. There have also been a few other studies that have reported differences in the reproductive hormones in the different breed types (Sartori & Barros, 2011). Segerson *et al.*, (1984) reported that there was a difference in the serum progesterone concentrations between the breed types from day 7 to day 17.

The length of time that the different breed types are sexually receptive has also been differentiated. It has been shown to last for a longer period in the *Bos taurus* breed types and shorter in the *Bos indicus* breed types and may also be more intense (Chenoweth, 1994; Sartori & Barros, 2011). Some studies have shown that the *Bos taurus* breed types calve earlier in the breeding season than the *Bos indicus* breed types (Navorsingstasie, 1994).

7.3. Differences in consumption of nutrition between *Bos indicus* and *Bos taurus* cows
Beef cattle turn low-quality roughage into high-quality protein for human consumption. The study of their nutrition is important to maintain and improve growth, to optimise the protein that is being received for human consumption (Diskin & Kenny, 2014). It is well studied that the nutrition cattle receive will influence their reproduction status. Nutrition influences the BCS which is one of the most important factors in successful reproduction (D'Occhio *et al.*, 2019). Metabolic hormones are those that influence and are related to the diet that is provided to the animal and studies have shown that these will have an impact on the reproduction of cattle, whether it influences the hormones or the BCS that the cow is in (Sartori *et al.*, 2013; D'Occhio *et al.*, 2019). *Bos indicus* bulls and steers have been shown to have a lower voluntary feed intake than that of their *Bos taurus* counterparts (Siebert & Hunter, 1985). In calves, there have been differences in these two breed types, one of which being that *Bos indicus* breed type calves have shown to retain more magnesium from the diets than *Bos taurus* calves do (Black, 1976).

7.4. Management difference in *Bos indicus* and *Bos taurus* cows

Bos indicus breeds have been said to be more timid than *Bos taurus* breeds, and therefore management with those breed types can require more time and patience to allow the animals to adjust to people who are managing them. Calves that are removed from their mothers and are reared using an artificial system will take time to adjust to the new environment. *Bos indicus* cattle have been seen to have lower whole milk or milk supplement intake compared to that of *Bos taurus* breed types (Black, 1976).

There are a variety of factors that can affect the conception rate in cows. The literature reviewed showed that there are areas such as puberty, nutrition and management can have an effect on the conception rate of cows. Most research has been done in dairy cows and very limited research has been done in beef cows. Further research needs to be conducted in beef cows to know if the effects will be similar to those in dairy cows and to be able to implement proper management practices in extensive beef cow herds.

Chapter 3 Materials and methods

3.1 Material and Methods

A protocol was established and from this ethical approval was applied for at the University of Pretoria. The ethical application (NAS313/2020) was approved, and permission was obtained from various farm owners to record data from their cattle as well as access data as recorded on the Logix Data Base of SA Studbook.

3.1.1 Location

Data was obtained from nine farms, as well data from the Logix Data Base of SA Studbook. The selection of farms was randomised throughout different areas within various South African Limpopo, Gauteng and North-West provinces.

In this study, all the cows in this area fed on natural pastures, with no or minimal supplementation, and the natural grazing in this area was sourveld. Modimolle was found to be the most central town for the majority of the farms, and therefore was used as the central location for average rainfall and climate readings. Cleaned of data resulted in all selected farms being located in the Limpopo province. The weather data was taken from the nearest weather station, which is located in Pietersburg, 140km away from the area. The average rainfall for this area is 478mm. The graphs below show the average climate in the Modimolle area.

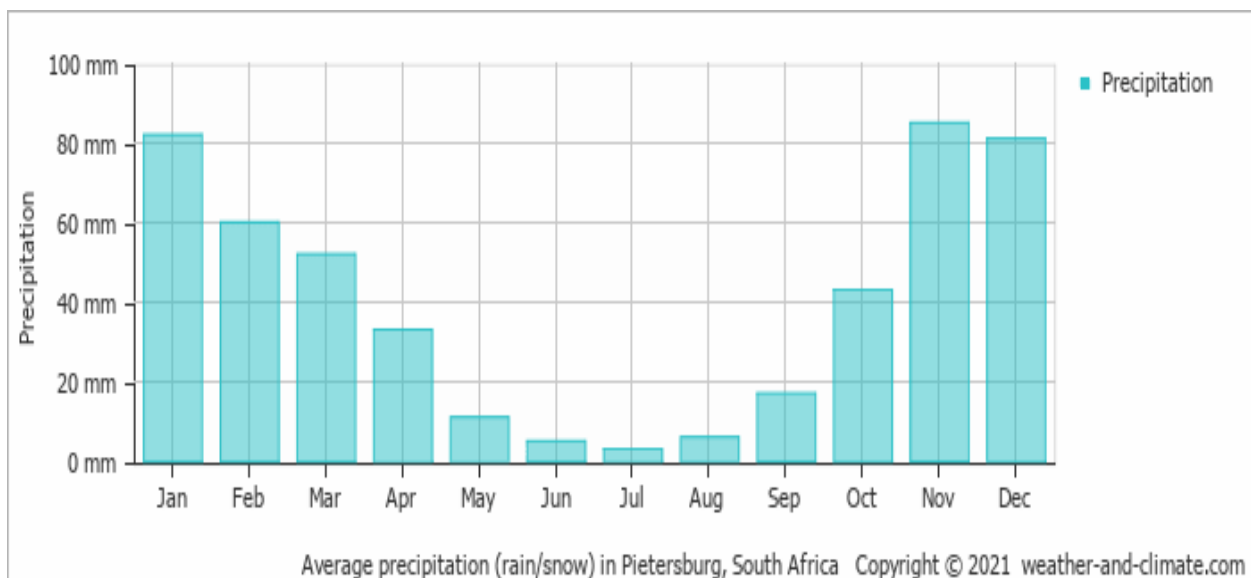


Figure 22 Average annual rainfall in Modimolle during the time of this study

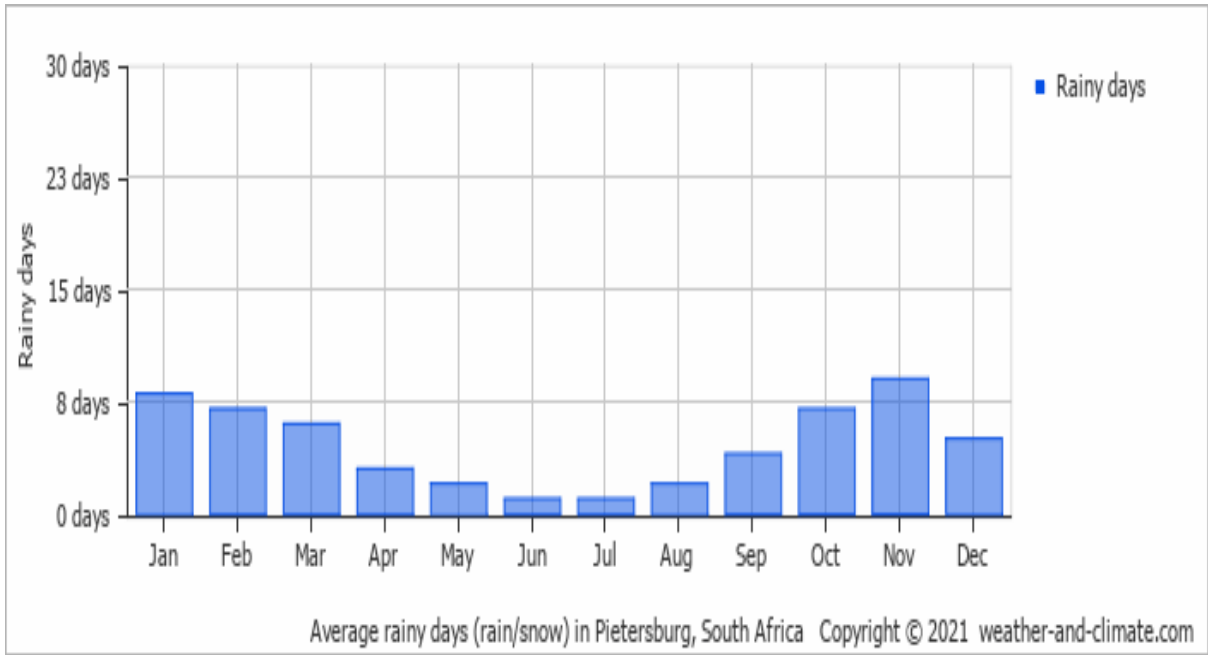


Figure 23 Average number of rainy days in Modimolle during the time of this study

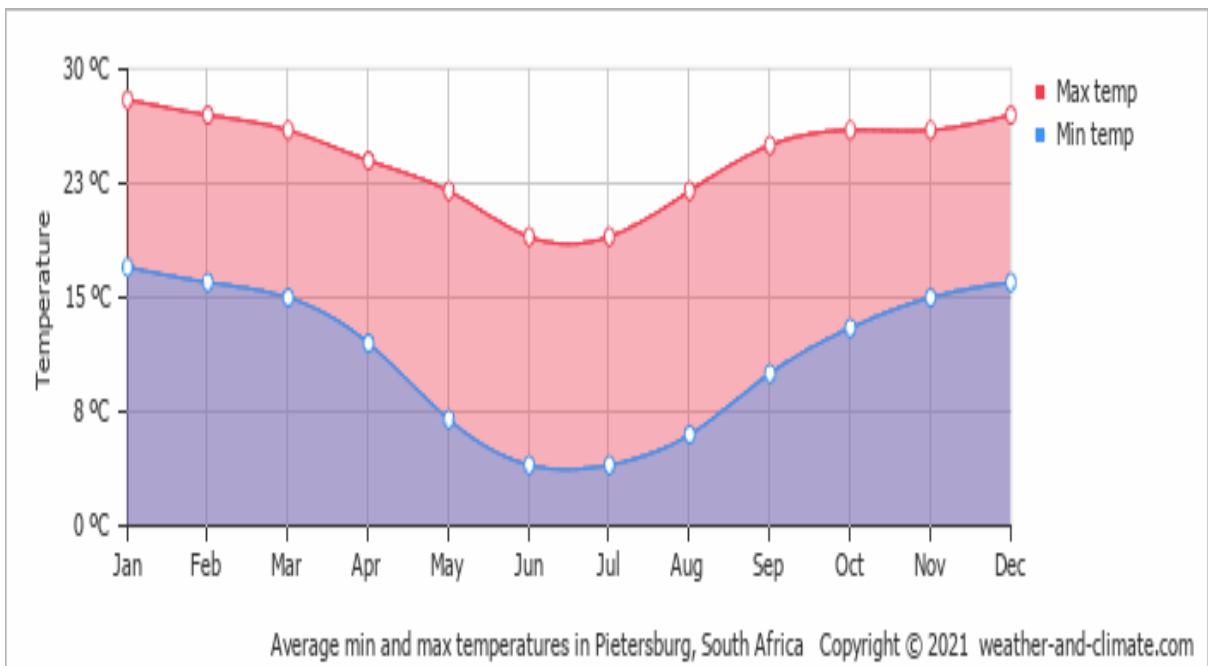


Figure 24 Average maximum and minimum temperature for Modimolle during the time of this study

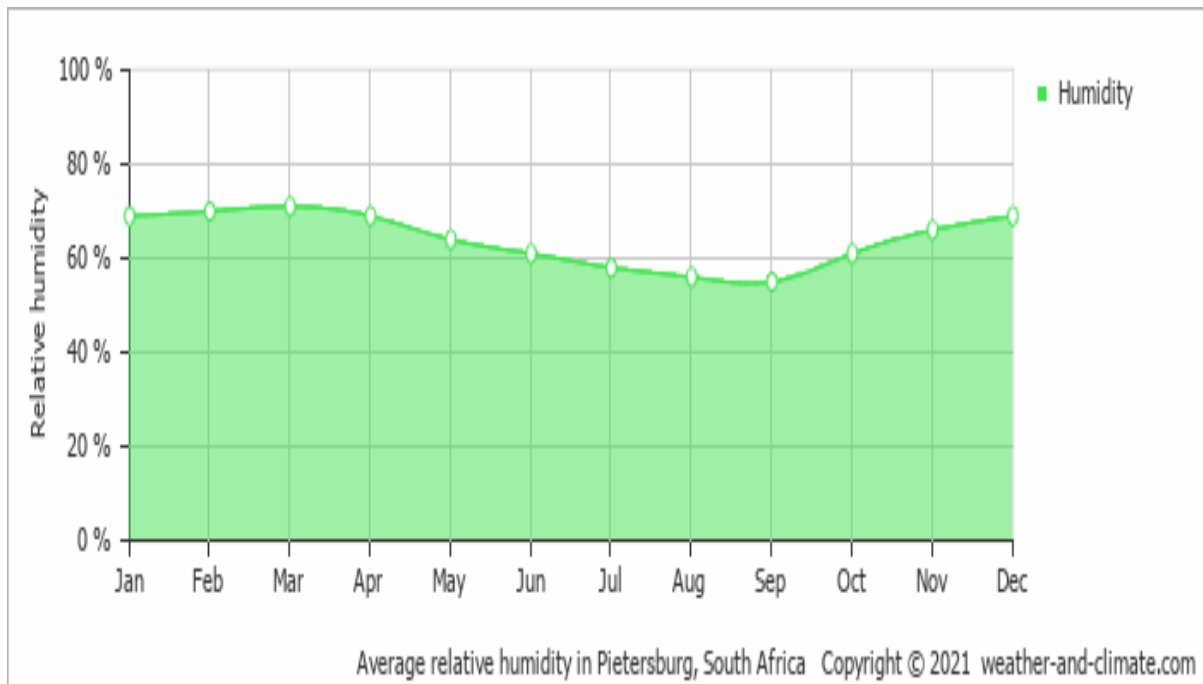


Figure 25 Average humidity in Modimolle during the time of this study

The wettest season is on average November, with the rainy season stretching from November to February (Figure 22). The rainy days fell into the same pattern as the precipitation (Figure 23). This influences the biomass that will be available for grazing. A lower biomass would be available in spring (August to September) and a higher biomass will be available in autumn (March to May). The temperature was lowest in June and July, and the highest in December and January (Figure 24). The humidity levels drop to the lowest in September and are highest in March (Figure 25) (World Weather & Climate Information, 2021).

The dominant grass species found in the area that are most selected for by cattle are Common finger grass (*Digitaria eriantha*), Bushveld signal grass (*Urochloa trichopus*), Kalahari sand quick (*Schmidtia pappophoroides*), Lehmann love grass (*Eragrostis lehmanniana*), Silky bushman grass (*Stipagrostis uniplumis*) and Curly leaf (broad) grass (*Eragrostis rigidior*) and woody species included Brandy bush (*Grewia flava*), Cork bush (*Mundulea sericea*), Shepherd tree (*Boscia albitrunca*), Grey hair acacia (*Acacia gerrardii*), Bergboegoe (*Croton gratissimus*), and Kalahari bauhinia (*Bauhinia petersiana*) (Mphinyane *et al.*, 2015).

The artificial inseminations specifically took place in December, but it is important to know the climate for the year as this will influence the quality and quantity of sourveld grazing that was available to the cows. The temperature influences the level of hormones that are produced and can have an effect on the environmental stress levels that are experienced by the cow and therefore need to be noted as these factors will have an influence on the fertility of the cow.

3.1.2 Animal Selection

Nonpregnant females were selected, and BCS was also taken into consideration. The cows that were chosen were within the range of 2,0 to 4,00, and cows that were 3,5 to 4,0 were assessed continuously within their positive energy balance. No cows with body condition below 2,0 was artificially inseminated, as it would not be economically viable to artificially inseminate cattle who are in a poor condition, the energy reserves will be too low. The days postpartum was also considered for all the cows that were selected, as they must have had enough time to allow for involution and recovery before they will return to oestrous and leave the anoestrus period.

The data received from SA Studbook contained the following information, cow identification numbers, previous calving records, cow age, inter-calving period, last calving date, cow mass and the number of calves. It also contained the Estimated Breeding Values (EBV) for Heifer fertility as well as Cow Fertility. As consulted with Dr H Theron from SA Studbook, Heifer Fertility EBVs are estimated by using Age of First calving measurements of the cow as well as her family, and for Cow Fertility EBVs the first three ICP's of the cow and her family were used. These EBVs were obtained to use along with the statistical analysis to check for any genetic influences on the cow. When a cow was seen as an outlier it's genetic EBV was taken into consideration. This allowed us to see if the cow was considered to be of exceptional genetic value. The EBV of such a cow would have a EBV value of above 120, and if the cow was of poor genetic quality, it would have an EBV of below 90.

The data that was collected from various farms included, the cow identification number, body condition score, date of progesterone releasing device insert and the date of removal, the AI date was also recorded, as well as the order the AI took place in, the bull identification number was recorded for tracking, and the semen was recorded as fresh or frozen. The farmer was also asked if the cows only had natural grazing or if they were supplemented. The cows that were supplemented and the supplementation that was given was also recorded (Table 7 and Table 8). The AI technician was also recorded as human error can result in inconsistencies in the results. When the farmer did the pregnancy diagnosis of their cattle, the result of this test was recorded for each cow.

The animals that were considered to be outliers, were removed from the data group before analysis took place.

Table 6 Number of cows that are found within each parity

Parity	Number of animals within the parity
1	0

2	8
3	2
4	8
5	9
6	6
7	4
8	3
9	2

Table 7 Composition of summer mineral lick supplemented to extensively farmed Bonsmara cattle

Raw materials	Mineral lick	
	MCP	DCP
Grain meal / Hominy chop		
Monocalcium phosphate	300	
Dicalcium phosphate		350
Salt	450	450
Feed lime	50	
Green grazer premix	200	200
Total (kg)	1000	1000
Composition (%)		
Calcium	11,68	13,38
Phosphorus	6,30	6,30
Magnesium	3,35	3,35
Sulphur	3,00	3,00
TDN (Energy)		
Intake (g/day)	100 - 200	

Table 8 Composition of the winter protein lick supplemented to extensively farmed Bonsmara cattle

Ingredients	
Grain meal / Hominy chop	400
Salt	350
Veld grazer 128	250

Total (kg)	1000
Composition (%)	
Protein	35,3
Protein ex NPN (% of total)	90,9
Energy (MJ ME / kg)	5,0
Calcium	3,29
Phosphorus	1,30
Intake – Cattle (g / day)	500 – 700
Application of the licks	Pregnancy

3.1.3 Data collection

Data was the main consideration within this paper, it is important to understand the synchronisation protocol that was used on the cows as this is one of the main factors that is being considered throughout the research. The data that was collected from the various farms was recorded in the same manner. Missing information was recorded.

The synchronisation protocol that was used to allow for insemination at the same time began 7 days before the decided AI date.



Figure 26 Injection of hormones



Figure 27 Progesterone releasing device insertions

The cows were packed tightly into the crush where they were first checked for pregnancy to confirm that they are all empty. The progesterone releasing device was inserted on Day 0 by qualified personnel. On Day 0, there were also hormones that were injected (Figure 26) in conjunction with the insertion of the progesterone releasing device (Figure 27). These were estrumate (1 ml i/m) and estradiol benzoate (2 ml i/m), which were injected intra muscularly.

On day 7 the progesterone devices were removed, and all the cows were injected with estradiol cypionate. The progesterone device was all removed at approximately the same time (48 hours before artificial insemination occurred).

The artificial insemination process took place on day 9, in the morning or the afternoon depending on the farm that the sampling was taking place on. Various farms were travelled to in one day and the time of day that was spent on one farm was dependent on the order that the farms were visited in the one day. Therefore, some farms were sampled in the morning, while others were sampled in the afternoon, and this was recorded. The frozen semen was thawed using the conventional textbook method by qualified personnel. The artificial inseminations were performed by qualified personnel. Data was recorded on the day included the unique animal identification number and the cow breed (all Bonsmara), the day and time that that the progesterone releasing device was removed, the date that the artificial insemination occurred, the BCS of every individual cow that was inseminated, the bull semen that was used, as well as if the semen that was used was fresh or frozen. These were all handwritten and then transferred to electronic copies later that day. The BCS was recorded on a 1 to 5 scale (1 being emaciated and 5 being obese). A bull was introduced to the herd after insemination took place.

With the use of data from various farms, the pregnancy diagnosis was done when the farm owner made the decision to do it. This was not all at the same time for the various farms. When the pregnancy diagnosis was conducted it was done by a qualified technician and recorded. It was performed by doing a rectal palpation, and the cow was recorded as either pregnant (ic) or not pregnant (nic) on the day of diagnosis. Some farmers recorded the foetal age (months) which was also included in the data set.

The cows were grouped into parities, first parity, second parity, and third parity and above. This is done because the animals that are found in the first and second parity, will have to partition energy into growth which is an influencing factor in the conception rate. Cows that were older than 39 months and had not had their first calf were removed. The statistical analysis was used to determine the impact of the season, number of days postpartum and body condition on the conception rate of the cows that are considered in this study.

3.1.4 Statistical Analysis

The data was all placed in the same format and all data points were considered. Once the data had been filtered and unusable data was all removed, the data was statistically analysed using the Statistical Package for the Social Sciences (IBM SPSS) version 27 program.

Animals with missing information were excluded from the data set. Frequencies and descriptive statistics were first obtained to understand the initial data that was obtained. This included obtaining means and standard deviations (SD) for all variables

When using a mixed model analysis, it is important to define factors as fixed or random effects. This will affect the power at which the study can be tested (Bennington *et al.*, 1994; Van Dongen *et al.*, 2004). In this study the fixed effects were BCS, time of AI, days to AI, latest change in dam weight and the EBV of the cow, are considered the fixed effects, as they are levels that were specifically chosen for this study. The fixed effects are used to determine the mean value or estimated mean value of the population. As with the fixed effects the random effects were listed as a whole for the study as they can be drawn from different studies depending on the factors that were used to get the different results. The farm where the cows were and the AI technician if there was a difference in the technician who performed the AI and the bull semen that was used, were fitted as random effects in this study, as they may influence the results (Bennington *et al.*, 1994; Van Dongen *et al.*, 2004). The results were expressed as least squared means \pm standard deviation.

A significance level of 95% ($P \leq 0.05$) was used for all critical values or F-statistics, to assess all the procedures.

The survival analysis (SA) is a method of analysis that is used to determine the effectiveness of a specific factor in relation to one specific outcome over a period of time. (Pereira *et al.*, 2006). In this study the survival analysis will be used to look at the effect of the BCS and the parity on the days to conception in the cows that did conceive.

Chapter 4 Results

4.1. Descriptive statistics

The sample size that was used for the results was animals that had all the relevant measurements for the variable being analysed. There are some differences between farms as PD information was dependant on the information received from the farmer. The cows were all artificially inseminated on the seventeenth of December 2020. Some of the cows ($n = 28$) were given supplementation of the 42 animals. They are supplied with both a winter and a summer lick. The licks are described in Table 7 and 8.

The conception rate of the cows that were used in the study was 83,33% of the sample ($n = 42$). A total of 7 cows were found to be not pregnant and 35 were found to be pregnant. The days to conception could only be measured for the cows that did conceive and the 7 cows that were found to be not pregnant, did not have a measurement for the days to conception.

The average body condition for this study is $2,9 \pm 0,22$. The skewness value (-0,040) shows that the BCS are almost normally distributed, with only a very slight deviation to the left and a standard error of skewness of 0,365. The kurtosis value (-0,794) indicated that the values are slightly platykurtic (having less kurtosis than a normal distribution, producing a flatter graph), and a standard deviation of 0,717. The slight differences off centre of these values is likely due to some cows being bred in a low body condition and are in calf. When consulting with Professor Webb about the BCS given to the animals, it was determined that the cows were scored with a score of 0,5 too low. An adjusted BCS was given to each cow, increasing the BCS by 0,5.

The second and third parities, respectively, have 7 and 9 missing values respectively for the ICP 2 and ICP 3 values, because those cows are young and have only had the ability to have 1 or 2 parities. The average number of parities in this study is $4,8 \pm 2,027$. The slight skewness value (0,207) shows that the values are very slightly towards the right, this can be due to the selection process, as cows age the likelihood of pregnancy tends to decrease (Khan et al., 2015).

The average ICP for the 4 stages of the cow's life that was recorded decreased as the cows became older, where ICP 1 was $411,1 \pm 82,192$ and the average ICP for the current parity is $382,6 \pm 79,733$. The skewness values for the different ICP's (1,664, 2,567, 0,006 and 2,787) all show that the curve is shifted towards the right. This will also be due to the selection process, as cows that do not go back into calve in a set period of time (determined by the farmer) are then culled and hence this data would not be included in this study.

The EBV for Heifer Fertility is a measure that was estimated by SA Stud Book, which determines the genetic potential for the age at which the heifer could calve for the first time. The EBV for Cow Fertility was also estimated by SA Stud Book, indicating the genetic potential of the cow to calve with shorter inter-calving periods. When consulting with SA Stud Book it was explained that a normal EBV for fertility is between 90 and 110, and with an average, of 105,6 for Cow Fertility, the cows that were used in this study are on average in a good genetic range for fertility.

Table 9 Summary statistics of body condition score (BCS), artificial insemination (AI) date, time of artificial insemination (AI), parities, change in mass, age at first calving (AFC), Inter-calving period (ICP) 1, 2, 3, ICP before the last calf, estimated breeding values (EBV) for Heifer Fertility and Cow fertility

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
		Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
BCS	42	2,50	3,25	2,9	0,22	-0,04	0,37	-0,79	0,72
Adjusted BCS	42	3,00	3,75	3,4	0,22	-0,04	0,37	-0,79	0,72
Time of AI ^b	42	8,30	14:00	12:19	2:32	-0,87	0,37	-1,30	0,72
Days to AI (days) ^c	42	48	93,0	74,6	11,4	-0,31	0,37	-0,45	0,72
Number of months pregnant ^d	42	0,0	7,0	3,6	2,0	-0,60	0,37	-0,37	0,72
Days to conception (days) ^e	42	56,0	219,0	126,3	48,8	0,21	0,37	-1,33	0,72
Number of Parities	42	2,0	9,0	4,9	2,0	0,21	0,37	-0,67	0,72
Latest change in weight (kg) ^f	42	-125,0	87,0	-16,9	50,6	-0,05	0,37	-0,62	0,72
Dam age of last calf (months)	42	35,0	126,0	80,4	23,5	0,06	0,37	-0,85	0,72
AFC (days) ^g	42	692,0	1143,0	931,7	143,6	-0,08	0,37	-1,21	0,72
ICP 1 (days) ^h	42	337,0	702,0	411,1	82,2	1,66	0,37	2,64	0,72
ICP 2 (days) ⁱ	35	324,0	772,0	402,2	102,3	2,57	0,40	6,52	0,78
ICP 3 (days) ^j	33	326,0	409,0	368,2	20,1	0,01	0,41	-0,55	0,80

^b The time of day at which the AI took place

^c Number of days from calving to the day of AI

^d The number of months that the cow was found to be pregnant when PD test was done

^e Number of days that it took for the cows to conceive

^f The change in weight from calving to weaning of the dam

^g Dam age at first calving

^h The number of days from calving in parity 1 to the calving in parity 2

ⁱ The number of days from calving in parity 2 to the calving in parity 3

^j The number of days from calving in parity 3 to the calving in parity 4

ICP before last calf (days) ^k	42	308,0	729,0	382,5	79,7	2,79	0,37	8,50	0,72
EB Heifer Fertility	42	67,0	127,0	99,1	13,7	-0,39	0,37	-0,12	0,72
EBV Cow Fertility	42	110,0	134,0	105,6	17,2	-4,07	0,37	22,82	0,72

^k The number of days from calving in the previous parity to the calving in the current parity

4.2 Mixed model analysis results for the effect of various factors on the conception rate in beef cows

Table 10 Statistics of factors that have an effect on the conception rate in Bonsmara cattle

Model Term	Coefficient	Std. Error	t	Sig.
Intercept	-104,79	61,87	-1,69	0,10
BCS	-0,02	3,30	-0,01	0,99
Time of AI	0,00	0,00	0,11	0,91
Days to AI	0,08	0,10	0,79	0,44
Latest change in mass	0,00	0,02	0,25	0,80
Dam age of last calf	0,58	0,33	1,76	0,09
EBV Cow	0,22	0,11	1,97	0,06
Number of Parities=2	46,03	24,99	1,84	0,08
Number of Parities=3	40,28	22,29	1,81	0,08
Number of Parities=4	63,45	537,96	0,12	0,91
Number of Parities=5	36,59	19,11	1,91	0,07
Number of Parities=6	22,07	11,30	1,95	0,06
Number of Parities=7	9,07	5,04	1,80	0,08
Number of Parities=8	34,09	1083,73	0,03	0,98
Number of Parities=9	0 ^b	.	.	.

Probability distribution: Multinomial

Link function: Generalized logit

a. Target: Pregnancy diagnosis

b. This coefficient is set to zero because it is redundant.

The mixed model analysis information criterion (210,395) was more suited to the data type compared to the Generalised Linear models (214,782 and 217,447) that were available for analysis.

Mixed model analysis showed that the parities had an influence on the conception rate (Table 9). The mixed model analysis was run again, setting the parity as a weighted factor. This will allow SPSS to adjust for the parity and see the difference in the fixed factors (Table 11). This shows that some of the factors do significantly influence the conception rate in terms of the parity that the cow is found in. The model is significant ($p < 0,05$) for the mixed model analysis with the number of parities being adjusted for.

The seven factors that were analysed as main effects are, the intercept, BCS, time of AI, days to AI, latest change in dam mass, dam age at last calf and the EBV for Cow Fertility. There was one random effect that was included in the study. The random effect was the farm owner, was found to be redundant, and therefore left out in the analysis. The BCS and days to AI showed to be significant ($p < 0,05$) when run through the mixed model analysis, adjusted for parity. The latest change in dam mass and the dam age of last calf showed a tendency to influence the conception rate but did not have a significant influence ($p > 0,05$) (Table 11). The time of AI had the smallest effect on the conception rate ($p > 0,05$). The latest change in dam mass and the dam age at last calf have a negative relationship with the conception rate, while the time of AI had a negative relationship with conception rate.

The mixed model analysis showed that the BCS had a positive effect on the conception in cows. The increase in BCS resulted in an increase in the conception rate. This category was further looked at in a survival analysis later in the study. The days to AI was found to have a positive effect on the conception in cows. While the time of AI did not have a significant effect on the conception, it did have a positive influence on the conception rate.

This study shows that the genetics of the cow has a significant effect ($p < 0,05$) on the conception of the cow.

Table 11 Mixed models analysis of factors weighted by parity, that may influence conception rates of Bonsmara cows

Model Term	Coefficient	Std. Error	t	Sig.	95% Confidence Interval		Exp(Coefficient)	95% Confidence Interval for Exp(Coefficient)	
					Lower	Upper		Lower	Upper
Intercept	-11,60	3,48	-3,34	0,00	-18,66	-4,54	$9,176 \times 10^{-6}$	$7,89 \times 10^{-9}$	0,011
BCS	2,26	0,93	2,42	0,02	0,37	4,15	9,56	1,44	63,39
Time of AI	$2,87 \times 10^{-5}$	$2,58 \times 10^{-5}$	1,11	0,27	$-2,36 \times 10^{-5}$	$8,10 \times 10^{-5}$	1,00	1,00	1,00
Days to AI	0,05	0,02	2,62	0,01	0,01	0,09	1,06	1,01	1,10
Latest change in mass	-0,01	0,01	-1,79	0,08	-0,02	0,00	0,99	0,98	1,00
Dam age of last calf	-0,02	0,01	-1,76	0,09	-0,05	0,00	0,98	0,95	1,00
EBV Cow Fertility	0,03	0,01	2,92	0,01	0,01	0,06	1,03	1,01	1,06

Table 12 Analysis of factors that may affect the number of months pregnant of Bonsmara cows

Source	F	df1	df2	Sig.
Corrected Model	0,90	6	35	0,51
BCS	0,13	1	35	0,72
Time of AI	0,56	1	35	0,46
Days to AI	2,75	1	35	0,11
Latest change in mass	0,22	1	35	0,65
Dam age of last calf	0,49	1	35	0,49
EBV Cow Fertility	2,56	1	35	0,12

Probability distribution: Normal

Target: Months

The mixed model analysis adjusted for parity with the target of months was run to show the effect of natural insemination vs artificial insemination. It was assumed that cows that were found to be less than 5 months pregnant, were impregnated by the bull that was placed with the cows after the AI took place. The cows that were found to be 5 months pregnant or more were in calf due to the AI process. The mixed model analysis showed that there were no factors that had a significant effect ($p > 0,05$) on the number of months pregnant of the cow (Table 12). The factors that were studied did not play a role in which insemination strategy caused the cows to conceive.

4.3. Survival analyses and pairwise analysis results

Figure 28 shows the linear relationship between the observed days to conception against the predicted value for days to conception for the study.

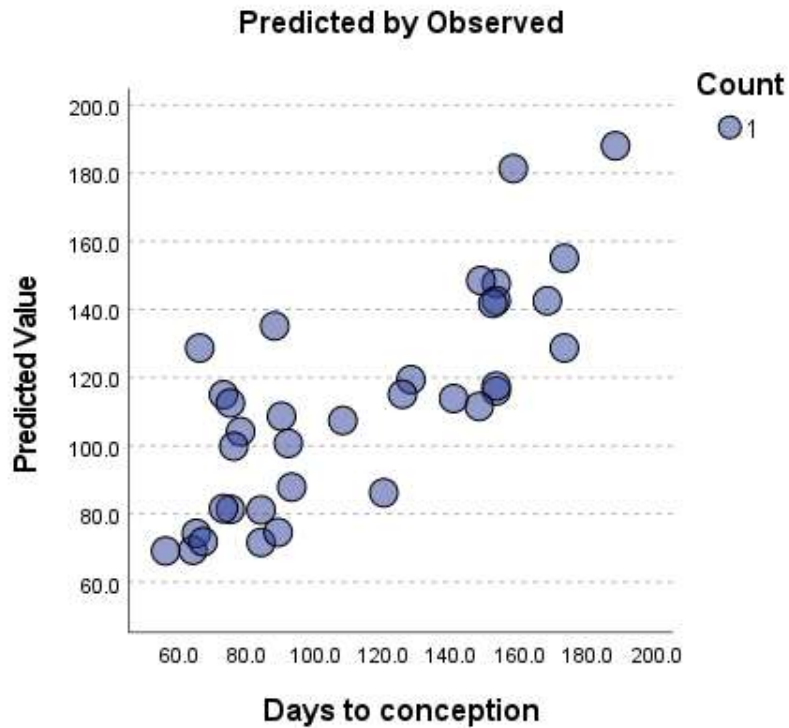


Figure 29 Relationship between predicted and observed days to conception

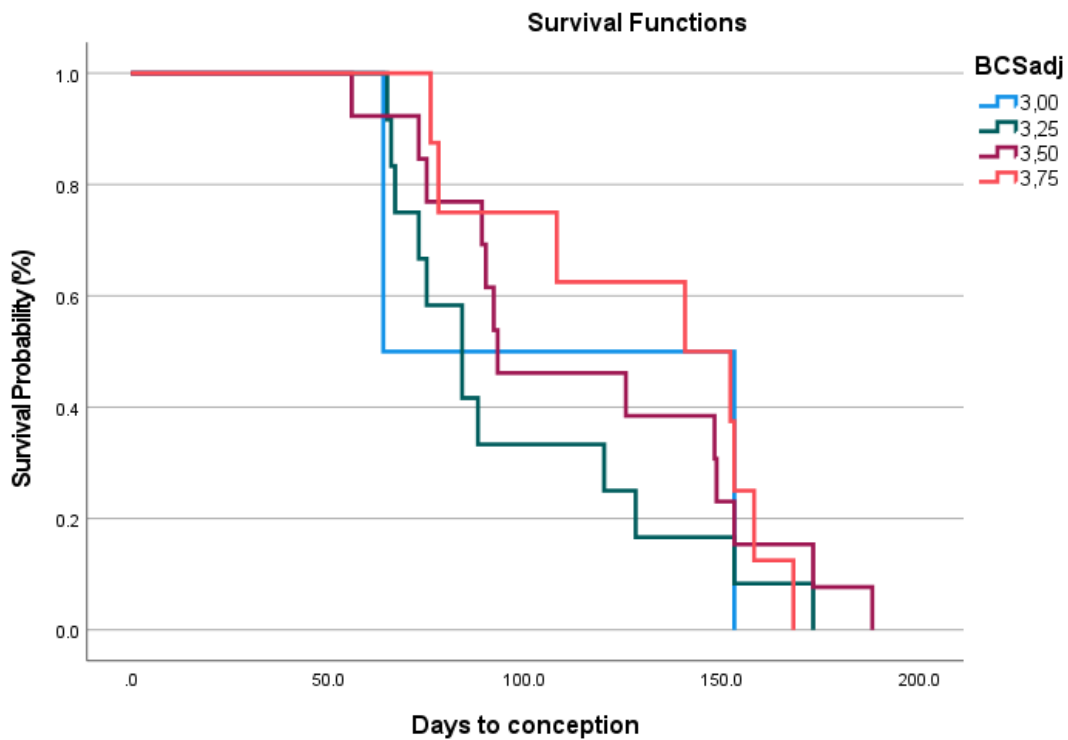


Figure 28 Survival analysis for days to conception according to various BCS

A survival analysis was run for the cows that were found to be in calf, according to the different BCS categories. The cows that were found to have a BCS of 3,25 were shown to have the lowest average number of days to conception ($98 \pm 10,57$ days). The BCS of 3,0 had the second lowest average number of days to conception ($108,5 \pm 44,50$ days). Cows found to have a BCS of 3,5 had the second highest average number of days ($115,70 \pm 11,77$ days), while those found to have a BCS of 3,75 were found to have the longest average number of days ($129,19 \pm 12,90$ days). The survival analysis showed that the cows in the BCS grouping

Table 13 Mean survival times for days to conception for different body condition scores

BCS	Mean	Standard error	Confidence interval	
			Lower bound	Upper bound
3.00	108,50	44,50	21,28	195,72
3.25	98,00	10,57	77,29	118,72
3.50	115,69	11,77	92,62	138,76
3.75	129,19	12,99	103,73	154,65
Overall	112,30	6,78	99,01	125,59

of score 3,00 to 3,50 is beneficial for the early conception of the cow, which would have been the cows that took to the insemination due to AI and the ones that took place later were the ones that conceived due to the bull. A BCS of 2,5 did allow for early conception and is seen as the lower limit.

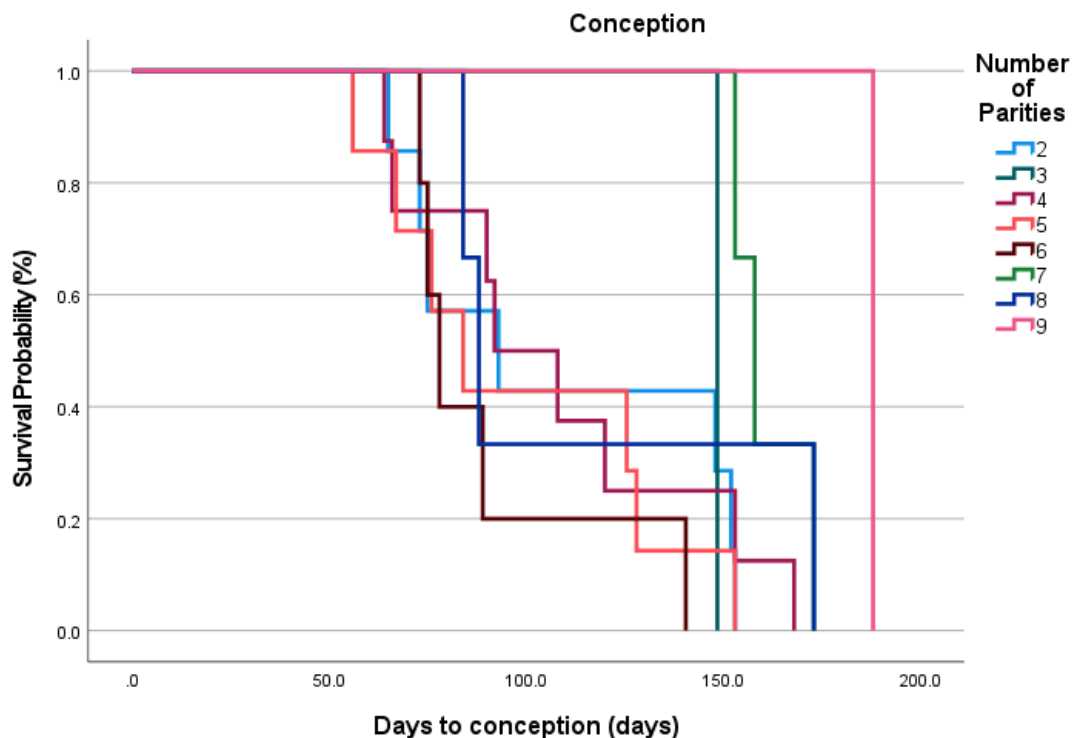


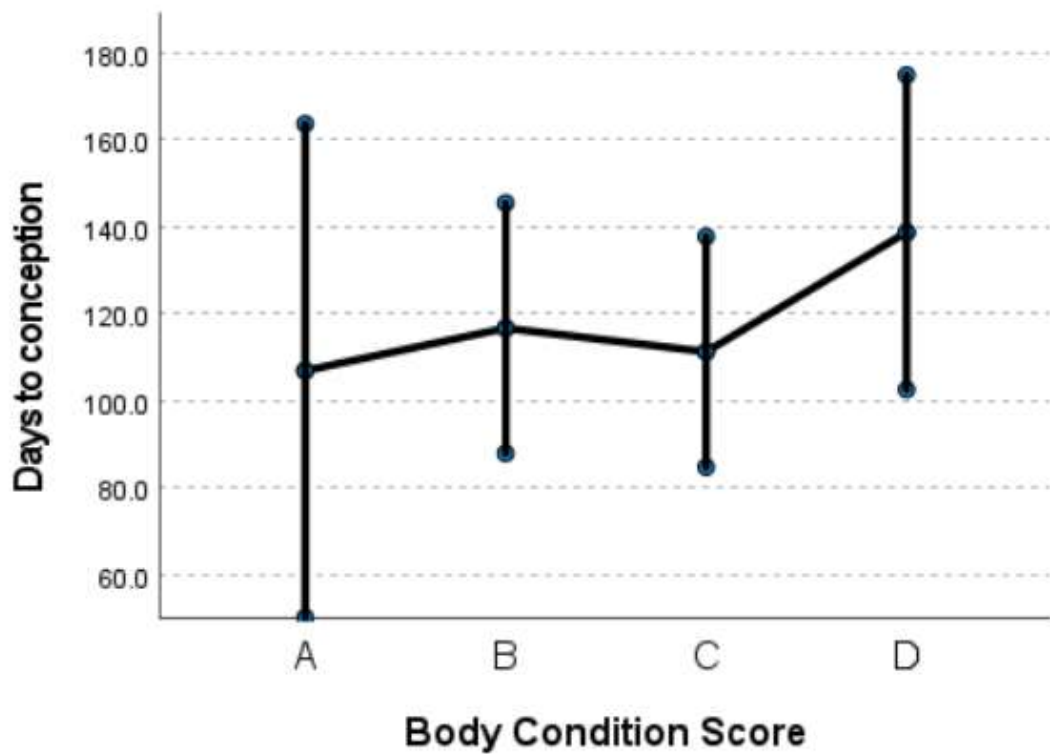
Figure 30 Survival analysis for conception according to parity

The survival analysis according to the parity of the cows, showed that the cows that had three or six parities had the shortest days to conception rate. Parity six is shown to have the shortest average number of days to conception ($91,10 \pm 12,66$ days). Parity five had the second lowest average number of days to conception ($98,50 \pm 13,87$). This was followed by parity four with an average of $107,63 \pm 13,40$ days. The cows who had seven or more parities took longer to conceive than those who had a lower number of parities, excluding parity three. Cows that were found to be in the third parity, had the second longest average number of days to conception ($148,5 \pm 0,00$). Parity seven had an average number of days to conception of $161,33 \pm 6,01$ days. Parity eight was found to have an average number of days to conception of $115,00 \pm 29,02$ days, and parity nine was found to have an average number of $115 \pm 0,00$ days to conception.

Table 14 Mean survival times for days to conception for different parity groupings

Number of parities	Mean	Standard error	Confidence interval	
			lower bound	Upper bound
2	108,43	15,39	78,26	138,59
3	148,50	0,00	148,50	148,50
4	107,63	13,40	81,37	133,88
5	98,50	13,87	71,31	125,69
6	91,10	12,66	66,30	115,91
7	161,33	6,01	149,56	173,11
8	115,00	29,02	58,12	171,89
9	188,00	0,00	188,00	188,00
Overall	112,30	6,78	99,01	125,59

Cows that were rated with a BCS of 3,75 (D) (Figure 28) were found on average to take longer to conceive. The cows found in this category are be considered over conditioned. The cows rated a BCS of 3,00 (A) were shown to on average have the shortest days to conception. Cows that had a BCS of 3,50 (C) had the second shortest number of days to conception. Cows that had a BCS of 3,25 (B) had days to conception fell on average between category 3,50 and 3,00 and were the cows that had a BCS of 3,25. The pairwise analysis can be linked to the survival analysis that the over conditioned cows take longer to conceive compared to those having a BCS falling between 3,00 and 3,50. None of the pairwise contrasts showed any significant differences within the difference BCS categories (Table 13). The values showed tendencies toward categories A ($p = 0,286$), B ($p = 0,285$) and C ($p = 0,132$) being different to that of category D. These differences are important to note as they will still make a difference on the farm, and it will be discussed further in the discussion section.



Continuous predictors are fixed at the following values:
 TimeofAI = 12:27:25,7143, Latestchangeinweight = -18,29,
 Damageoflastcalf = 79,60, EBVCow = 105,97

Figure 31 The days to conception within the various BCS categories

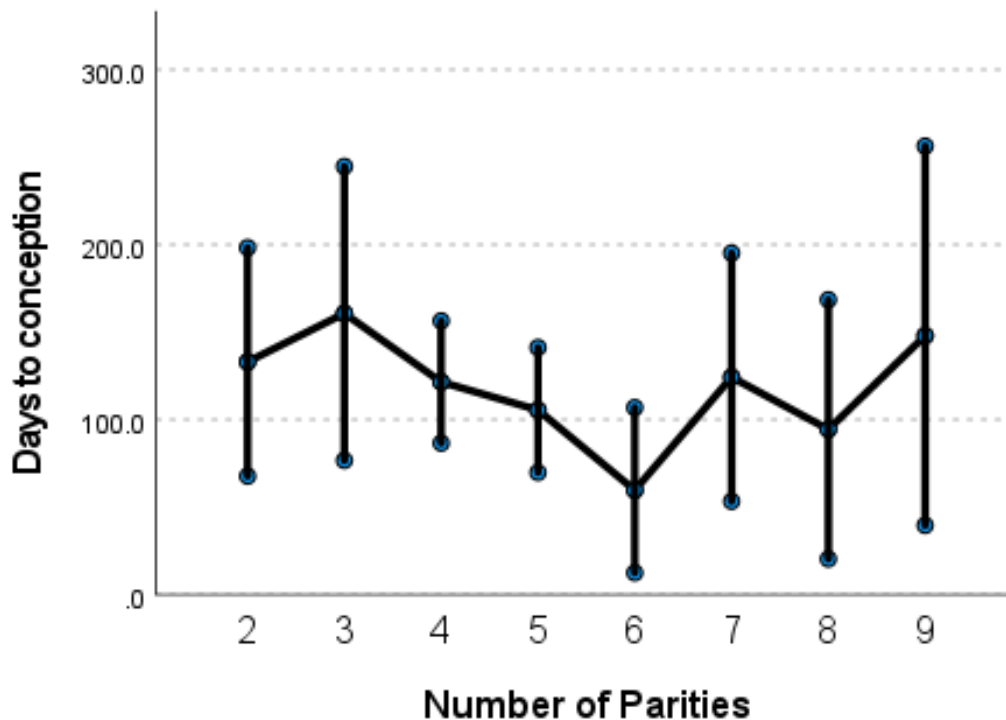
Table 15 Pairwise analysis for the difference BCS categories

BCS categorical Pairwise Contrasts	Contrast Estimate	Std. Error	t	df	Adj. Sig.	95% Confidence Interval	
						Lower	Upper
A - B	-9,76	29,45	-0,33	20	0,74	-71,19	51,66
A - C	-4,35	28,97	-0,15	20	0,88	-64,79	56,08
A - D	-31,80	28,98	-1,10	20	0,29	-92,25	28,65
B - A	9,76	29,45	0,33	20	0,74	-51,66	71,19
B - C	5,41	15,83	0,34	20	0,74	-27,61	38,43
B - D	-22,04	17,23	-1,28	20	0,22	-57,97	13,89
C - A	4,35	28,97	0,15	20	0,88	-56,08	64,79
C - B	-5,41	15,83	-0,34	20	0,74	-38,43	27,61
C - D	-27,45	17,46	-1,57	20	0,13	-63,86	8,97
D - A	31,80	28,98	1,10	20	0,29	-28,65	92,25

D - B	22,04	17,23	1,28	20	0,22	-13,89	57,97
D - C	27,45	17,46	1,57	20	0,13	-8,97	63,86

The least significant difference adjusted significance level is .05.

A pairwise analysis was also performed for the various parties (Figure 32) that the cows were found to be in. This showed the effect that the parity had on the number of days that it took the cows to conceive. As with BCS the pairwise analysis for the number of parties could be linked to the survival analysis that was performed with the number of parties as a factor.



Continuous predictors are fixed at the following values: TimeofAI = 12:27:25,7143, Latestchangeinweight = -18,29, Damageoflastcalf = 79,60, EBVCow = 105,97

Figure 32 The average days to conception depending within the various parities

In the pairwise analysis parity two and parity three showed to have two of the longest days to conception (the only other being parity nine), showing that these are two of the less productive parties within the cow, which can be understood by previous studies that showed that these cows may still have to divert their energy into other factors (such as growth) and will not be able to provide enough energy that will be needed for reproduction. There was a significant difference found between the sixth and seventh parity (Table 16). In this study from parity four they have shown to store up enough energy reserves to have a more productive parity (Figure

Table 16 Pairwise analysis for the different parities

Number of Parities	Contrast	Std.				95% Confidence Interval	
Pairwise Contrasts	Estimate	Error	t	df	Adj. Sig.	Lower	Upper
2 - 3	-27,70	37,45	-0,74	20	0,47	-105,83	50,42
2 - 4	11,49	25,45	0,45	20	0,66	-41,53	64,51
2 - 5	27,50	34,77	0,79	20	0,44	-45,02	100,03
2 - 6	73,32	47,72	1,54	20	0,14	-26,23	172,87
2 - 7	8,74	60,52	0,14	20	0,89	-117,51	134,98
2 - 8	38,56	60,27	0,64	20	0,53	-87,17	164,29
2 - 9	-14,96	74,00	-0,20	20	0,84	-169,33	139,41
3 - 2	27,70	37,45	0,74	20	0,47	-50,42	105,83
3 - 4	39,20	38,11	1,03	20	0,32	-40,30	118,69
3 - 5	55,20	44,66	1,24	20	0,23	-37,95	148,36
3 - 6	101,02	51,75	1,95	20	0,07	-6,93	208,97
3 - 7	36,44	60,98	0,60	20	0,56	-90,77	163,64
3 - 8	66,26	62,01	1,07	20	0,30	-63,10	195,62
3 - 9	12,74	72,82	0,18	20	0,86	-139,17	164,65
4 - 2	-11,49	25,42	-0,45	20	0,66	-64,51	41,53
4 - 3	-39,20	38,11	-1,03	20	0,32	-118,69	40,30
4 - 5	16,01	23,70	0,68	20	0,51	-33,42	65,44
4 - 6	61,82	33,02	1,87	20	0,08	-7,05	130,70
4 - 7	-2,76	45,25	-0,06	20	0,95	-97,14	91,62
4 - 8	27,07	45,81	0,59	20	0,56	-68,50	122,63
4 - 9	-26,46	61,46	-0,43	20	0,67	-154,66	101,75
5 - 2	-27,50	34,77	-0,79	20	0,44	-100,03	45,02
5 - 3	-55,20	44,66	-1,24	20	0,23	-148,36	37,95
5 - 4	-16,01	23,70	-0,68	20	0,51	-65,44	33,42
5 - 6	45,82	26,52	1,73	20	0,10	-9,51	101,15
5 - 7	-18,77	39,34	-0,48	20	0,64	-100,82	63,29
5 - 8	11,06	37,28	0,30	20	0,77	-66,71	88,83
5 - 9	-42,46	53,88	-0,79	20	0,44	-154,86	69,93
6 - 2	-73,32	47,72	-1,54	20	0,14	-172,87	26,23
6 - 3	-101,02	51,75	-1,95	20	0,07	-208,97	6,93
6 - 4	-61,82	33,02	-1,87	20	0,08	-130,700	7,05
6 - 5	-45,82	26,52	-1,73	20	0,10	-101,15	9,51
6 - 7	-64,58	29,25	-2,21	20	0,04	-125,59	-3,57
6 - 8	-34,76	28,77	-1,21	20	0,24	-94,77	25,26
6 - 9	-88,28	45,34	-1,95	20	0,07	-182,87	6,31
7 - 2	-8,74	60,52	-0,14	20	0,89	-134,98	117,51
7 - 3	-36,44	60,98	-0,60	20	0,56	-163,64	90,77

7 - 4	2,76	45,25	0,06	20	0,95	-91,62	97,14
7 - 5	18,77	39,34	0,48	20	0,64	-63,29	100,82
7 - 6	64,58	29,25	2,21	20	0,04	3,57	125,59
7 - 8	29,82	31,51	0,95	20	0,36	-35,90	95,55
7 - 9	-23,70	42,05	-0,56	20	0,58	-111,40	64,01
8 - 2	-38,56	60,27	-0,64	20	0,53	-164,29	87,17
8 - 3	-66,26	62,01	-1,07	20	0,30	-195,62	63,10
8 - 4	-27,07	45,81	-0,59	20	0,56	-122,63	68,50
8 - 5	-11,06	37,28	-0,30	20	0,77	-88,83	66,71
8 - 6	34,76	28,77	1,21	20	0,24	-25,26	94,77
8 - 7	-29,82	31,51	-0,95	20	0,36	-95,55	35,90
8 - 9	-53,52	42,92	-1,25	20	0,23	-143,05	36,01
9 - 2	14,96	74,00	0,20	20	0,84	-139,41	169,33
9 - 3	-12,740	72,82	-0,18	20	0,86	-164,65	139,17
9 - 4	26,47	61,46	0,43	20	0,67	-101,75	154,66
9 - 5	42,47	53,88	0,79	20	0,44	-69,93	154,86
9 - 6	88,28	45,34	1,95	20	0,07	-6,31	182,87
9 - 7	23,70	42,05	0,56	20	0,58	-64,01	111,40
9 - 8	53,52	42,92	1,25	20	0,23	-36,01	143,05

The least significant difference adjusted significance level is .05.

26). The significant difference ($p = 0,039$) between parity six and seven is expected as this is the transition from the most productive phase in the cow's lifetime and following into the seventh parity the cows start to become less productive. At approximately parity seven the cows that are continued to be used for breeding are those that are selected for and therefore there will be an improvement in the days to conception in the following parities, where only the best cows are breeding (Figure 30). Parity nine is also shown to have a longer number of days to conception. This is considered old for a cow, and the cows that are kept for this long are those that show to continually rebreed without missing a breeding season, even though they may take longer within the breeding season. The cows that were found to be in this parity group within the correct BCS category were the cows that conceived, the others that were not in the correct BCS category did not conceive.

Chapter 5 Discussion

5.1 The effect of body condition score on conception rate

In the current study where the BCS is found to have a significant effect ($P < 0,05$) when adjusted from the parity with the use of the mixed model, the higher the BCS the greater the probability of conception up until a BCS of 3,50. Above this the conception rate decreased and the cows were considered over conditioned. The pre-partum energy reserve levels therefore have a significant effect on the conception rates in the cattle. Nutrition has been shown to have an effect on the reproduction potential of a cow. Nutrient partitioning is important in the resumption of the normal oestrous cycle, and reproduction will generally be the last priority that energy is used in, assuming there is still energy remaining (Short *et al.*, 1990a). In an article by Baruselli *et al.* it stated that the BCS has an effect on the ovarian cyclic activity in beef cows, and that a BCS of 2.5 was the lowest score that could be given for a successful synchronisation (Baruselli *et al.*, 2004b). In the current study the score of 2,5 was the minimum that was used for synchronisation, but cows were shown to have this BCS.

Differences in the current study and the study done by Baruselli *et al.*, (2004) and other studies can also be due to investigator observational differences in BCS. The BCS is based on the investigators perception and is subject to their observation.

Cows in good condition, have been shown to have fewer waves before ovulation occurs while those in a poor body condition could have up to 10 waves before ovulation occurs. These ovulations are usually silent (Crowe, 2008), and with no observation of oestrous detection the farmer would usually not synchronise or inseminate their cows. In this study, a cow having a BCS less than 3,0 (thus being in a state of nutritional deficiency) will struggle to conceive. These cows would have most likely taken longer to respond to an increase in postpartum nutrients (Rice, 1991). The body condition of the cow can be improved in a period as short as two months when adjusted feeding is done pre-partum (Short *et al.*, 1990a). This can be linked to studies showing the effect of BCS at calving on ovarian cyclic activity, where it has been shown that a nutrient restriction resulted in a low concentration of LH and therefore a follicle will develop due to FSH but will be atretic due to the lack of LH (Baruselli *et al.*, 2004b; Crowe, 2008). In a study done by Ayres *et al.* showed that cows that had an improvement in BCS in their dry period improved the probability of first conception (Ayres *et al.*, 2014). The cows that were excluded from the study, may be able to be improved in terms of BCS in a period of 2 months allowing for the improvement of the number of cows that calve.

Lipid reserves are linked to the production of the metabolic hormone leptin. Leptin has a regulatory effect on the level of body fatness. Cows that have excessive amounts of body fat will cause leptin to reduce the feed intake (Humblot *et al.*, 2009). This will be problematic for the cows that have a BCS of higher than 3,50 as their feed intake will decrease and will most

likely enter a negative energy balance in the future. These cows still conceive even though it is later in the breeding season, and therefore if they are found in a negative energy balance, this will impact the energy available during pregnancy and lactation. A negative energy balance will result in a longer anoestrus period, in the current study therefore the BCS of above 3 had longer days to conception. This is due to the effect the negative energy balance has on the LH pulses and the follicular development (Filho *et al.*, 2009). Cows that are over conditioned tend to have a decrease in the IGF-1 levels, which is involved in the ovary for follicular development (Samadi *et al.*, 2013). These effects are shown in Figure 32.

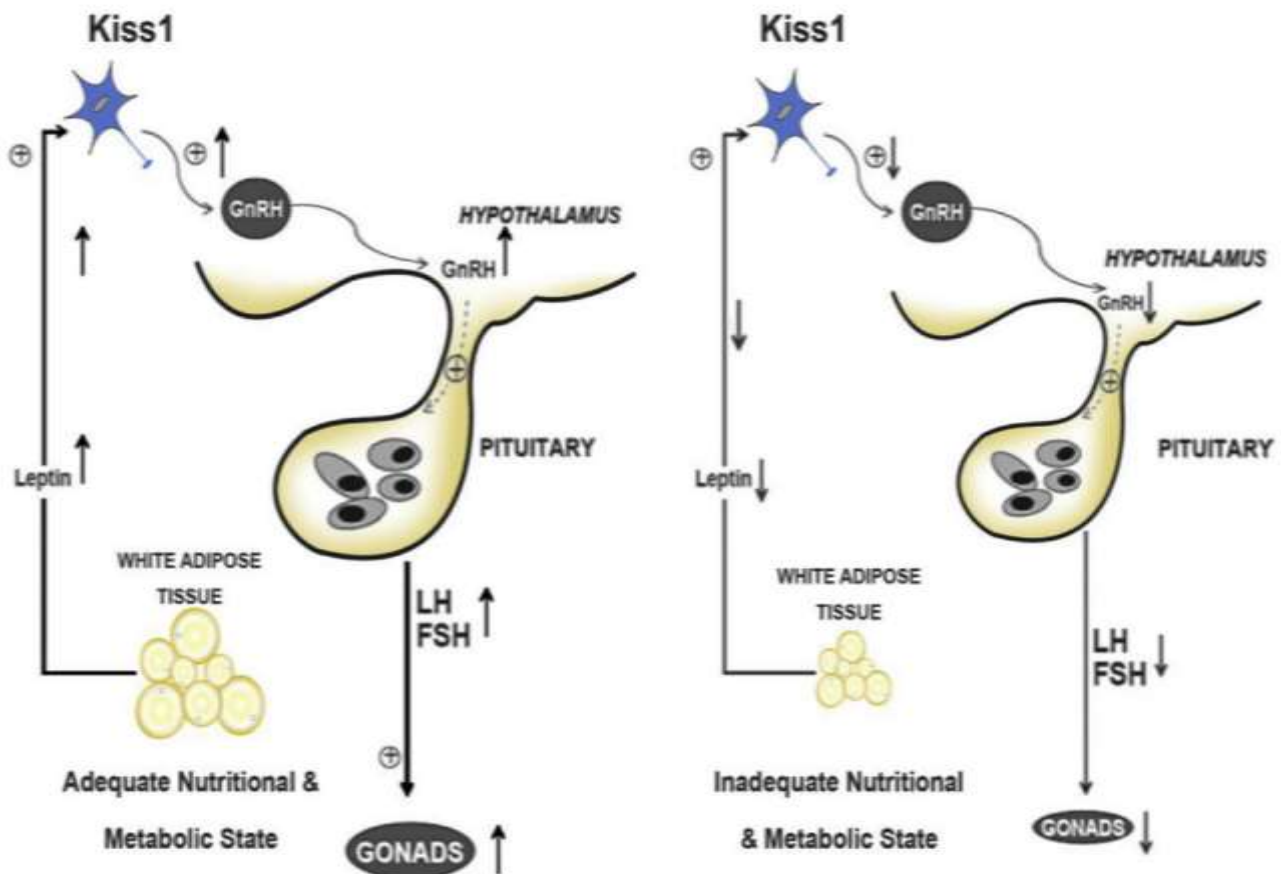


Figure 33 Influence of Leptin (D'Occhio *et al.*, 2019)

The influence of BCS on the days to conception is important to consider. The survival analysis (Figure 33) shows that the best BCS to AI cows in will be a score between 2,75 and 3,00, a score below or above this lower the number of days that it takes the cows to conceive. In this study that means that the cows that fall out the 3,25 to 3,50 range were fertilised by the bull and did not take to the AI insemination as they were not in the right condition for it at the time of insemination.

The BCS did have a significant effect within the parity that the cows were found to be in. this is important to know as the BCS alone did not show significant effect. Within the parity

however, the conception was dependant on the BCS category that the cow was found to be in. This shows that there is an interaction between parity and BCS. The cows that were found to be older and to be in the wrong BCS category, that were given enough days for the recovery period (< 60 days) are the cows that did not conceive.

5.2. The effect of days to artificial insemination on conception rate

The days to AI was considered in this study to determine if the conventional 60 days recovery period is a long enough period for the cow to recover fully. In a study done by Murphy *et al.*, it was shown that the first follicles that approach ovulation after calving do develop into a dominant follicle but undergo atresia and ovulation does not occur (Murphy *et al.*, 1990). In the current study the days to AI was calculated from the previous calving date to the date of AI. The days to AI did play a significant role ($p < 0,05$) on the conception of a cow.

In the current study, the majority of the cows that were found to be in the correct body condition category but still did not conceive were the cows that had an insufficient amount of time to recover (>60 days). The cows that did have more than 60 days recovery and did not conceive were the cows that were over conditioned in terms of BCS. This shows that the 60 days to AI is a sufficient period for cows to conceive as long as they are found in the correct BCS at the point of AI. In a study done by Taponen, (2009), the days to AI and the effect of parity was tested. The study showed that the best fertility was the group of cows that had the shortest interval in that study (50 to 70 days) (Taponen, 2009). The current study shows the same results in terms of the number of that's the cow is given to AI.

This is important for a farmer because of the economic implications that this will have. The sooner the cow can conceive again the more calves she will have in her lifetime and the more profitable she would be. But if she is artificially inseminated too soon after the calving date and fails to conceive, leading to the need to be inseminated again, makes the cow cost ineffective. If the cow takes too long to conceive, she will not be worth keeping, as she will be costing money (feed and care) but not be producing any income (calves).

5.3. The effect of dam age at last calf and parity on conception rate

The dam age at last calf did not significantly affect the conception in the cow. It did have a very strong tendency to affect the conception in the cow. One study conducted only look at the difference between parity two and three and the rest of the cows lifetime, and not all the parities within the cow's lifetime which was conducted in dairy cows (Khan *et al.*, 2015). In a study done by Renquist *et al.*, (2006) showed that cows that were older than 3 years, had shortened calving intervals and these cows also had calves who were found to be lighter. In the current study, the current cows had not calved down, and the calf weight was not the focus

of the study. In this current study the parity was the focus, which can be linked to the age of the cow.

The survival analysis (Figure 29) shows that parities four, five and six are associated with the shortest days to conception. This can be linked to the study Renquist *et al.*, (2006) where the cows under 5 years of age, which would be between two and four parities, if the cows were bred every year (Renquist *et al.*, 2006). These are the more productive parities in the beef cow's life, where she produces calves in the shortest period of time.

Dystocia can also be associated with the age of the cow and the parity that she is in (Short *et al.*, 1990a). Heifers generally have a higher incident of dystocia (Perry & Smith, 2018). This was not recorded in the present study and therefore will not be expanded on further.

5.4. The effect of EBV for Cow Fertility on the conception rate

The EBV for Cow Fertility indicates the cow's genetic potential. The study shows that the EBV for Cow Fertility has a significant effect on the conception on the cow. This can be associated with the offspring and the probability of conception in them. The heritability of fertility traits is low (VanRaden *et al.*, 2004) and the EBV value allows for the farmer to potentially select better cows and calves to be kept as replacement heifers. Improvement of the conception chances in the herd, by increasing the replacement heifers' chances for conception. The skewness value shows that the animals that are being selected for are genetically superior as it is a negatively skewed value (-4,072).

5.5. The effect of the latest change in dam mass on the conception rate

Wiltbank and associates were some of the first to report on the effect of nutrition in the reproduction of cattle, showing that a high energy diet before calving improved the re-conception rates in cows (Wiltbank *et al.*, 1962). This led to the research in this study on the positive and negative energy balance that the cow was in before breeding and its influence on conception. The mass change that was calculated was the mass of the dam at weaning minus the mass of the dam at birth. The information that was obtained was the mass for the second last calf that the cow had, meaning it was for two breeding seasons prior to the current one. This factor was studied to show if a cow was in a positive or negative energy balance in that season of breeding. This was found to possibly have an effect on the current breeding season. The effect was not significant but showed a tendency to affect the conception rate in the current breeding season.

The change in weight for the previous breeding season would be a more direct effect on the AI of the cows, a period that is closer to the current breeding season. There are studies that

have shown the change in weight from the last calving to the current breeding season have an effect on the chances of conception in cows (Agyemang *et al.*, 1991).

5.6. The effect of the time of artificial insemination on conception

The AI's all took place 48 hours after the progesterone releasing device removal, meaning that the time that the AI took place was dependant on the time that the progesterone device was removed. Some farmers planned to have the AI technician go to their farm in the morning, and therefore the AI took place in the morning, while the AI technician was available in the afternoon for different farmers. While there was a slight trend in the effect in the time of day that the AI took place, the time of AI showed no significant effect on the conception of cows. The trend did show that a higher chance of conception occurred when the later in the day that the AI occurred. This could be due to a difference in handling and care by the farmer, as well as stress levels. A low variation in the data may also influence the results that have been shown. No other study on the time of day that the AI occurred has been done to my knowledge at the time of this study.

Chapter 6

6.1 Conclusion

The BCS within the parity has a significant effect on the conception rate in the cows, those that are over conditioned are cows that are more likely not to conceive, and selection of cows to inseminate that have a BCS of 3,00 will allow for the best conception rates. The number of days that the cow is given for a recovery time is important to consider as those that are inseminated too early have a high probability of not conceiving. The prime parity group was parity 6, which has the highest conception rate. The link between BCS and parity is important as cows that are not found in the correct BCS category and fall outside of the prime parity groups are the cows who struggle to conceive. The EBV for Cow Fertility has a significant effect on the conception rate and can be an important tool for farmers to use when selecting replacement heifers for their herds. The time of day that AI takes place, may have an effect on the conception but more research needs to be done on this, this current study did not show any significant results and therefore no link can be made to what time of day would be optimal for maximised artificial insemination.

6.2 Recommendations

Focus needs to be placed on nutrition for extensively farmed beef cattle, as BCS plays a significant role in the conception rate in the extensively farmed beef cattle. It is especially important to focus on parity four, five and six as in this study it is shown to be the most productive parities in the cow's life. The EBV for Cow Fertility should be considered when selecting beef cattle.

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