FACTORS AFFECTING COW EFFICIENCY IN A BONSMARA HERD AT KOOPMANSFONTEIN RESEARCH STATION

by

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DECLARATION OF INDEPENDENT WORK

I declare that the thesis hereby submitted by Siphokazi Diamond for the degree of Master of Agriculture at Central University of Technology, Free State, is my own independent work, and has not been submitted by me at another University/Faculty. It complies with the code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology, Free State.

S. Diamond

DEDICATION

I dedicate this study to my late supervisor, Mrs Annette Theunissen. I am grateful for her existence because without her love, support, and constant prodding to strive for the best, I would not be where I am. May her beautiful soul rest in peace.

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ABBREVIATIONS

ADG	average daily gain
BCS	body condition score
BW	birth weight
CBW	calf birth weight
CWW	cow weight at weaning
DG	digestible energy
g	grams
ICP	inter-calving period
kg	kilograms
LSU	large stock unit
ME	metabolizable energy
N	number
PA	pelvic area
PH	pelvic height
PW	pelvic width
Yr	year

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ABSTRACT

This study investigated the factors affecting cow efficiency in a Bonsmara herd at the Koopmansfontein Research Station. Twenty-four pure-bred two-year-old Bonsmara heifers were stratified according to their age and divided into two experimental groups. All heifers used for the study were in good body condition, with an average body condition score (BCS) of 3. The control group only received summer lick (October to March) and winter lick (April to September), while the treatment group received a summer lick during the summer months, but production lick instead of a winter lick during the winter months. The recommended intake of winter lick for cattle is 400–650 g per day, and the recommended intake of summer lick is 100 g (minimum) – 200 g (maximum) per day. A ratio of 2:1, which is two bags of winter lick and one bag of yellow maize, was used as the production lick. There was a significant difference (P = 0.034) in pelvic measurements between the pelvic area of the two heifer groups. Supplementing heifers with production lick resulted in a larger pelvic area (214.9 ± 21.63 cm^2) and higher calving rate, with heavier calves at birth. The findings of the study demonstrated that heifers supplemented with production lick weighed significantly more (426.3 ± 39.5 kg), than those supplemented with winter lick (361.8 ± 41.6 kg) in 2020, and the production lick group had more calves which is 11(91.67%) calves in their first calving season. The PL group had a higher calving percentage (P < 0.05) than the WL group. Understanding cow efficiency factors allows producers to implement strategies that improve cow efficiency, thereby increasing productivity and sustainability within the livestock industry.

Nutritional supplementation played a vital role in the reproductive performance and achieving appropriate target weights prior to first breeding which had a positive effect on re-breeding after the first calf. Proper supplementation can also positively influence calf weights during weaning, aligning with previous research that heavier calves at birth have higher weaning weights and improved cow efficiency.

CHAPTER ONE: BACKGROUND

1.1 THE SOUTH AFRICAN BEEF PRODUCTION INDUSTRY

1.1.1 Farmland Background

In South Africa, livestock constitutes the largest agricultural sector, contributing approximately 40% of the agricultural income. Livestock production is the only viable agricultural activity in a large part of the country due to approximately 80% of South African agricultural land not being suitable for crop production (DAFF, 2019). According to the latest Census of Commercial Agriculture conducted by Statistics South Africa in 2017 and announced in 2020, the total number of farms or farming units involved in the country's commercial agriculture sector in 2017 was approximately 40 122, of which the largest proportion – 13 639 farms – farm with livestock, followed by 12 458 farms that practice mixed farming and 8 559 farms that grow cereals and other crops (Statssa.gov.za).

1.1.2 Livestock Background

South Africa is endowed with a rich biodiversity of livestock that contributes to food security, the livelihoods of people, as well as the growth of the economy (DAFF, 2019). Livestock are produced throughout the country, with species, breeds, and numbers varying according to the environment, type of grazing, and production system (Meissner *et al.*, 2013). Cattle production in South Africa is more concentrated in the Eastern Cape, KwaZulu-Natal, the Free State, and the North West. Approximately 60% of the beef cattle in South Africa are owned by commercial farmers and 40% by the emerging sector (DAFF, 2019). According to Booysen (2007), a large part of the emerging sector can still commercialise from a subsistence farming baseline.

1.1.3 Meat Market Background

Meat consumption in South Africa has expanded rapidly over the past decade. South Africans consume about 3.9 million tons of poultry, beef, lamb, and pork meat per annum (USDA FAS, 2019). In 2018, the South African consumer spent approximately R225 billion on meat products, which represented 35% of total expenditure on food (USDA FAS, 2019). Poultry is the most consumed meat in South Africa, the per capita consumption has been estimated to be around 35 - 40 kg per person per year. Chicken is particularly consumed due to its affordability and versatility. The beef consumption in South Africa ranges from 10 – 12 kg per person per. South Africa has a strong beef industry, but beef is more expensive than poultry, influencing consumption levels. However, pork consumption is lower than that of beef and poultry, which is 5 – 7 kg per person per year. Pork is not consumed as chicken or beef, due to cultural and dietary preferences. Lamb consumption is relatively low, ranging from 3 – 5 kg per person per year (DAFF, 2022).

According to the USDA FAS (2019), poultry meat represents more than 60% of total meat consumption in South Africa. As poultry meat is relatively inexpensive and globally available, it has grown to be the most important protein source in the diet of the majority of South Africans. It has been found that the chicken industry is the beef industry's main competitor, given the 47% predicted growth in average annual chicken consumption (BFAP, 2013).

1.1.4 Beef Market Background

The gross value of beef production depends on the number of cattle slaughtered and the price received by producers from buyers. Currently, South African beef prices are determined according to the different meat classes. The average Class A price in 2023 was R53.20/kg, while Class C was priced around R47.50/kg (ABSA, 2023).

The average gross value of beef produced amounts to approximately R21 billion per annum (DAFF, 2018). Schutte (2006) emphasises that meat is the fastest growing agricultural commodity worldwide, thus South African meat producers will have to remain competitive in the global meat market. The price of beef has recently been unpredictable on global scale for both live cattle and feeder cattle, and this trend may continue for some time.

The economy of South Africa is expected to shrink over the short term. The effects of the COVID-19 pandemic have included lower commodity prices, labour unrest, and a weak exchange rate (National Treasury, 2020). The prospect of a weaker global economy will impact the economy negatively. The driving factors behind swings are the extreme uncertainty surrounding long-term impacts of the COVID-19 event and future expectations of macro factors. For the foreseeable future, local beef prices are expected to trade sideways, and uncertainty has been dominating views (National Treasury, 2020).

Large numbers of weaner calves are imported annually from neighbouring countries due to demand exceeding supply in the domestic market (DAFF, 2011; DAFF, 2012). This implies that South Africa is still a net importer of beef. However, it is a net exporter of pork (DAFF, 2011).

Due to several factors, including low productivity and environmental concerns, the national beef herd cannot realistically be increased; therefore, it is of utmost importance to improve the existing production efficiency (De Jong & Phillips, 2013). By increasing the offtake in the beef sector, South Africa could move towards self-sufficiency (Scholtz *et al.*, 2008). This also presents an opportunity for emerging and communal farmers to contribute significantly to the South African beef value chain.

1.1.5 Production System Background

A full description of a beef production system includes age, weight, and carcass class at which animals are marketed, as well as the breeding, management, and feeding practices followed. These systems can differ significantly based on geographic location, climate and market demands. Understanding the beef production system may help farmers to navigate the difficulties of the farming industry and adopt practices that can lead to improved efficiency, sustainability and animal welfare. Buying-in systems are also commonly used, in which animals are bought, kept for a time during which they are usually fed to gain mass or condition, and then sold (Beef production system, 2020).

1.1.6 Extensive beef production system in South Africa

The most common beef production system in South Africa is a weaner production, followed by a steer production (tolly and ox), and buying–in/speculative systems. (Beef Production System., 2020). As a rule of thumb, in weaner systems the cow herd constitutes approximately 60% of the total animal units, and in steer systems, the cow herd constitutes approximately 40–50% of the total animal units (KwaZulu-Natal DARD, no date).

1.1.7 Reproduction

The main objective of the beef cow herd is calf production. In a commercial beef cattle farming enterprise, cow fertility and cow longevity are among the key traits that are of economic importance (Saxton *et al*., 2014). Therefore, in beef production systems, the reproductive rate of the cows and survival rates of their calves play a significant role in overall productivity (Saxton *et al*., 2014).

1.1.8 Feed

Farmers usually focus on cost management, which is an important factor in profitability. In the cattle industry, managing feeding conditions is the main responsibility of management. Herd *et al*. (2003) and Lamb and Maddock (2009) indicate that the provision of feed to animals is the major cost input in almost any production feed system. The cow-calf production cycle represents approximately 72% of the energy consumed from conception to slaughter (Ferrell & Jenkins, 1982; Farmer's Weekly, 2020). If cow maintenance requirements can be reduced, the feed energy requirements will be lowered, the input cost of the cow is reduced, and thus overall cow efficiency is improved.

1.1.9 Cow Weight and Calf Growth

Calf growth rate also plays an important role in cow production efficiency; however, its effect is only significant when reproductive performance is at high levels of adaptation (Grobler *et al*., 2013). Scasta *et al*. (2015) indicate that cow weight is a significant trait to consider when selecting animals to match their environment, primarily in terms of effectively matching animal demand with forage supply in order to optimise genetic growth relative to nutritional requirements. On a farm, the goal is to have the highest percentage of calf crop at the heaviest weight without dystocia, resulting in maximum total weight/kg of calves with minimum investment and costs. Improvement of fertility and growth through selection of beef cattle is becoming increasingly important (Taylor, 2006).

1.1.10 Cow Efficiency

Efficiency must be associated with the biological type of the cow and not just cow size, as higher producing cows have higher maintenance requirements, even when the cows are not in lactation (Ferrell & Jenkins, 1982). Vargas *et al*. (1999) investigated production efficiency in three calving periods of small, medium, and large Brahman cattle. The small- and medium-framed females were more efficient during the first two calving periods, but by the third, when the large-framed cows had reached their full growth potential, the large cows were more biologically efficient (Taylor, 2006).

Research has proven that there are numerous factors affecting cow efficiency, including age-at-first calving, longevity, maintenance, gestation and lactation feed requirements, calf maintenance and growth requirements, and calf weight. The most important factor is reproductive performance (Jenkins & Ferrell, 2002; Greiner, 2009). Efficient cows are those that produce calves regularly, and reproduction is the constant variable defining cow efficiency (Notter, 2002). Cow efficiency is a complex, multi-trait measure that is variable depending on differences in production environments and management systems (Greiner, 2009). Hence, the most efficient cow may not be the same in different production environments – for example, in the northern hemisphere (temperate environments) versus the southern hemisphere (tropical and subtropical environments). However, environmentally sustainable beef production can only be achieved through the adoption of systems and practices that make the most efficient use of available resources and reduce environmental impact per unit of food (Capper *et al*., 2011).

This research is based on beef cow efficiency because farmers are continually looking for ways to increase the production and profitability of their livestock enterprises. The focus is usually on production measures and means to increase production, as production is the component of the profit equation that directly affects the income of the farming enterprise.

1.2 PROBLEM STATEMENT

Livestock farming under extensive conditions has certain limitations – specifically the grazing (quantity) and variation in quality (nutritive value) (Taylor, 2006). Veld quality and quantity in

South Africa are often negatively impacted by low seasonal rainfall, which is experienced on a regular basis. Livestock farming under these circumstances often necessitates the use of supplementary feed to improve cow efficiency in beef production.

1.3 RATIONALE/MOTIVATION

Beef cattle production in Southern Africa is predominantly an extensive system, being based mainly on the utilisation of natural rangeland. According to Snyman (1998) and Smit (1999), approximately 65% of South Africa's grasslands are classified as arid to semi-arid, as they receive less than 500 mm of rain per annum. In these drier areas, grassland is often subjected to seasonal droughts, high ambient temperatures, and low soil fertility, causing the greater part of the beef producing areas in the country to have marginal agricultural potential (Van Niekerk, 1996). This has resulted in a beef industry that is heavily dependent on natural pastures and, therefore, the most practical method of production in these areas is the extensive grazing of beef cattle. Smit (1999) argues that natural pasture remains the cheapest source of forage for cattle production and that the economic viability of cattle farming is placed under pressure by increases in input costs such as those associated with additional feeding.

Beef producers need fertile cows that deliver vigorous calves that wean heavy at a reasonable input cost to maximise profitability. A focus on production measures and means to increase production is important, as production is the profit equation component that directly affects income from the enterprise. This focus translates into an emphasis on the profitability of the cow-calf operation (Ramsey *et al*., 2005). It is widely agreed that reproduction in cattle reflects the level of management to which animals are exposed (Lishman *et al*., 1984). Therefore, fertility is the main component influencing total herd productivity (Lopes *et al*., 2013). According to Patterson *et al.* (2000), most components of fertility that influence calving and subsequent reproductive performance are not highly heritable, thus it can be deduced that the majority of factors related to reproductive performance in cattle are influenced entirely by management.

The primary component of herd management is the operation feeding conditions, as body condition score (BCS) at parturition has been identified as the single most important factor affecting postpartum interval to oestrus and pregnancy (Paisley & Chichester, 2005; Walker & Perry, 2007). In the commercial beef sector in South Africa, calving percentage is estimated at 62%, and in the emerging sector, it is estimated at 48%, which indicates opportunity for improvement in almost all beef cattle herds (Grobler *et al.*, 2013).

Long-term improvement in reproduction results from selecting animals that are adapted to a particular environment and improving the management system. Longer calving seasons that coincide with the seasonal peaks in feed production, combined with an increase in calving rates, mean that more and possibly heavier calves of a uniform age can be weaned (Grobler *et al*., 2013). This could be explained by the fact that cows calving earlier in the season have a longer recovery period to the next mating season and have the opportunity to calve in a better body condition during the next season than those cows calving late in the season (Holm, 2006; Odhiambo *et al.*, 2009). This will promote cow efficiency.

1.4 AIM AND OBJECTIVES OF THE STUDY

The aim of the study was to investigate factors such as supplementary feeding, growth, rate of development and body condition score on cow efficiency in a Bonsmara herd at Koopmansfontein Research Station. The first objective of the study at Koopmansfontein Research Station was to determine the effects of supplementary feeding on the reproductive performance of Bonsamara Cattle.

The secondary objectives were to identify:

- Factors that affect the age at first calving. These include growth and development rates of heifers, condition score at start of breeding season, and condition score at calving.
- Factors that affect the inter-calving period (ICP) of cows. Mating and calving records from 2015 to 2020 (females born at Koopmansfontein since 2013) were used to generate an average ICP for each cow, bearing in mind that cows could have been culled. These factors, amongst others, may include cow weight at start of breeding season, condition score of cows at start of breeding season, and age of cow at start of breeding season.
- Factors that affect longevity of cow fertility. These include the functionality of cows, such as their teeth and teats.
- Factors that affect cow efficiency. These include weaning weight, cow large stock units (LSU), and kg calf weaned / LSU.

1.5 HYPOTHESIS OF THE STUDY

Improved supplementary feeding, growth development and BSC will improve cow efficiency in a Bonsmara herd at Koopmansfontein Research Station.

CHAPTER TWO: LITERATURE REVIEW

2.1. HISTORICAL DEFINITIONS OF COW EFFICIENCY

The most important contributing factor to cow efficiency is frequency of calving (Grobler, 2016). This is thus the main consideration to take into account when breeding/selecting for cow efficiency, and it is measured either as calving percentage (%), ICP, or days-to-calving. Dickerson already stated in 1970 that an efficient cowherd also exhibits early sexual maturity, a high rate of reproduction, low rates of dystocia, cow longevity, and minimum maintenance requirements. Dickerson (1970) further argues that to maximise efficiency in the cow-calf context, the objective is lean growth and earlier sexual maturity with a minimum increase in mature weight. For a beef cow, annual efficiency may be defined by the relationship between the weight of the calf produced and the feed inputs required by the cow-calf unit (MacNeil *et al*., 2017). It can also be quantified by the ratio of calf weight at weaning to cow weight (Davis *et al*., 1983; Frahm & Marshall, 1985; Scholtz *et al*., 2015).

Cow-calf production efficiency can be expressed as the ratio of kg of calf weaned per unit of forage consumed. It should be noted, however, that measures of efficiency can differ from one production system to the another. Traditionally, there were only two measures of cow efficiency, namely calf weaning weight/cow weight ratio (MacNeil, 2007) and calf weaning weight/cow weight X 0.75 (for metabolic weight) ratio, as metabolic weight accounts for significant variation in dry matter intake among animals of different size (Rasby, 2010). However, MacNeil (2007) argues that the use of these ratios as selection criteria has theoretical flaws, as they place inconsistent emphasis on the component traits. This will result in variable responses to selection. A solution is to develop an index that includes all the components of cow-calf efficiency.

2.2 COW EFFICIENCY

Efficient reproductive performance is vital for high productivity (production and reproduction) and economic efficiency in cattle farming. Optimal reproductive performance is important in producing replacement animals for the herd and milk production for the calf. Thus, evaluation of the reproductive performance is a good starting point in any programme aiming to improve productivity in cattle farming (Kanuya *et al*., 2006).

Following Mokolobate's (2015) proposed use of kg calf weaned per large stock unit (kgC/LSU) as a measure of cow efficiency or cow productivity, it was realised that improving cow efficiency by increasing the weaning weight of a calf in relation to cow weight, but expressed in LSU, simultaneously gives an expression of the output-input costs of beef production. Another alternative could be to use the relationship between weight of calf produced and estimated feed inputs (by using LSU) required to sustain the cow and allow her to provide for the calf.

LSU is the equivalent of a bovine with a weight of 450 kg and a weight gain of 500 grams per day on grass pasture with a mean digestible energy (DE) concentration of 55% (Meissner *et al.*,1983). To maintain this, 75 MJ metabolizable energy (ME) per day is required (Meissner *et al.*, 1983). This implies that any other class, type, or species of animal may be equated to an LSU by calculating their expected intake of ME (Hardy, 1996). The differences in LSU units between animals of the same body weight but with different frame sizes is based on the principle that there are differences in the voluntary feed intake between such animals, although they have the same body weight (Meissner *et al*., 1983).

Utilisation of feed has been recognised as one of the most essential factors in determining profitability in the beef cattle production enterprise (Kenny *et al*., 2018). Efficiency is calculated based on the inputs needed to create a desired output. However, measuring efficiency can be complicated due to the numerous variables that contribute to the efficiency and effectiveness of the breeding herd (Maddock & Lamb, 2010). Measures of efficiency can also differ from one production system to another.

It can be argued that previous formulae for calculating efficiency favoured smaller cows. Mokolobate (2015) emphasises that it is important to note that cows with the same body weight, but different frame size, do not have the same LSU. She further explains that a medium-frame cow of 500 kg with calf at foot equates to 1.5 LSUs, with a voluntary feed intake of 13.6 kg of dry matter per day, while a large-frame cow of 500 kg with calf at foot equals 1.78 LSUs, with a voluntary feed intake of 15 kg/day.

Mokolobate (2015) and Jordaan (2015) suggest measuring cow efficiency, while taking feed requirements into account, as the ratio between kg calf weaned and cow LSU. Furthermore, Mokolobate (2015) states that it is important to take frame size into consideration. Depending on the formula used to accurately calculate cow productivity, certain parameters are critical. These include the number of cows exposed to bulls, the number of calves weaned, birth weight, date of birth and sex of the calf, weaning weight and date, as well as the body weight and condition score of the cow (Lancaster & Arthington, 2014).

To calculate the LSU, a frame-size-specific equation should be used (Mokolobate *et al*., 2015). The formulae are as follows:

Small-framed animals:

$$Y = 0.2871428571 + 0.0025542857{*}x - 0.0000005714{*}x^2$$

Medium-framed animals:

$$Y = 0.220714286 + 0.0030978571*x - 0.0000010714*x^2$$

Large-framed animals:

$$Y = 0.3239285714 + 0.0036535717*x - 0.0000015*x^2$$

where Y = LSU and x = cow weight.

The following equation can be used to get an indication of cow efficiency (kg calf weaned per LSU (kg calf/LSU):

Cow productivity = calf weaning weight (corrected 205 day/LSU) * estimated calving %.

An improvement in kg calf weaned/LSU mated (KgC/LSU) is thought to reflect an improvement in cow productivity. Scholtz *et al*. (2016) define cow productivity as the kg calf weaned (output)/cow LSU (indicative of feed intake – input) x weaning rate (how frequently a calf is produced).

2.3 COW LONGEVITY

According to Szabo and Dakay (2009), cow longevity is defined as length of productive life, calculated as the number of years from the first date of calving to culling or death date. Although Vukasinovic *et al*. (2001), Pachova *et al*. (2005), Sewalem *et a*l. (2005), and Bielfeldt *et al*. (2006) stated that the age at first calving does not have much effect on the length of a cow's productive life, Patterson *et al.* (1992) report that heifers that calve before 24 months have an increased productive life in a herd in relation to heifers that calve later than 24 months of age. According to Rogers *et al*. (2004) and Forabosco (2005), longevity of a breeding cow has a major impact on economic efficiency in the beef production systems. Rendel and Robertson (1950) outline an economic measure of productive herd life importance and report that prolonged productive herd life may boost profits by reducing annual replacement cow expenses, extending herd production through an increase in number of cows in the high-producing age groups, reducing the number of replacement cows to be reared, and allowing an increase in productive herd size. Weaning weight of calves produced by each cow acquired over her lifetime is a complete measure of fertility, maternal ability, milking capacity, and cow survival (Tanida *et al*., 1988). This can be taken as an essential measurement of lifetime production.

Cow longevity is a convenient trait that is highly variable. Yet, small changes in longevity can greatly impact herd profitability (Parish, 2010). Many traits influence cow longevity, including age at puberty, direct and maternal calving ease, milk production, mature size, ability to store body fat (fleshing ability), and udder soundness (Parish, 2010). Physical soundness limits the productive life of a cow as she ages. For example, as cows age, teeth deterioration affects their ability to graze and maintain body condition conducive to an optimum level of production (Thrift & Thrift, 2003).

In some commercial herds, all cows are culled at a certain age. Cows that are too old have higher chances of losing their next calf, weaning a lighter calf, dying, or being too thin to have adequate value as a culled cow. However, there are genetic differences that affect all these factors. For example, cows with badly worn teeth and mouths cannot graze effectively and become less productive than those with mouths and teeth in better condition. Most of the eye problems which cause cows to leave the breeding herd are associated with cancer eye, which is known to be more prevalent in cows with white pigment around their eyes, although there are probably genetic differences in susceptibility to cancer eye that are independent of pigmentation (Thrift & Thrift., 2003).

According to Riley *et al.* (2001), producers attempt to improve herd production by culling cows based on factors such reproductive failure, structural issues, progeny performance, and diseases. Riley *et al.* (2001) further stated that udder conformation has been identified as an important factor in cow-calf profitability. Poor udder conformation and associated low milk yield led to management challenges and reduced calf performance because of the negative impact on pre-weaning average daily gain (ADG). Beef cows with poor udder conformation produce calves with lower weaning body weight and increase labour costs, leading producers to cull productive cows with mammary problems.

2.4 AGE AT FIRST CALVING AND INTER-CALVING PERIOD

Age at first calving and ICP are two important reproductive efficiency measurements that are recorded in beef-breeding enterprises. These two traits can decrease production costs through genetic improvement of cow fertility (Abe *et al*., 2009). Age at first calving and ICP is an indication of the level of reproduction and fertility of the cow, which is the most important trait to be measured in a herd.

In many beef operations heifers are bred to calve at 24 months of age. However, with proper management and nutrition, some producers breed heifers as early as 12 to 15 months of age, but this requires careful attention to the heifer's growth and development. In beef cattle, an ideal inter – calving period is normally around 12 months. However, a range of 12 to 18 months influenced by factors such as reproductive management, nutrition, and herd welfare. Farmers aim to achieve a calving interval that maximizes reproductive efficiency and overall productivity (NCBA, 2019).

2.4.1 Age at First Calving

A heifer's growth rate and age at maturity is directly linked with productive and reproductive performance. When a heifer calves for the first time, it marks the beginning of her productive life; thus, reducing age at first calving is one way to improve lifetime productivity (van der Merwe & Schoeman, 1995). Heifers must reach puberty by 15 months of age if they are to conceive and calve by 24 months, but as much as 35% of all beef heifers fail to reach puberty by this time (Patterson *et al*., 1992). Morris (1980) reports lifetime production to be neither greater nor significantly different when heifers first calved at 2 years compared to the age of 3 years. Overall, heifers first calving at 2 years of age produces 0.7 more calves in their lifetime than the ones calving at 3 years. Age and weight at puberty are moderately to highly heritable traits. This means producers can use selection to improve these traits within a given a herd. In addition, it is best to select daughters of bulls with large scrotal circumference, as these daughters tend to reach puberty earlier (Deutscher, 1980; Menegassi *et al*., 2019).

Most published reports indicate that heifer growth plays an important role in milk production. Increasing calving weight has a positive effect on first lactation milk yield (Harville & Henderson, 1966; Keown & Everett, 1986). Higher growth rate assists in early achievement of the target weight that is essential for early maturity. Target growth rates or optimum body weight are needed to maintain economically efficient growth of individual animals so that breeding and first calving occur at the ideal age and weight. Therefore, the most efficient way to increase heifer growth potential is to improve nutrition and feeding in the pre-puberty phase (Gabler & Heinrichs, 2003).

In heifers, age at first calving reduces the cost of rearing replacements in cattle herds (Ettema & Santos, 2004). However, younger, smaller heifers and older, over-conditioned heifers have a higher risk of dystocia (Ettema & Santos, 2004). Hence, age at first calving is a benchmark that should be properly managed in order to achieve longer productive cow life and the highest economic return. For example, Grobler (2016) indicates that it might be more viable to breed Bonsmara heifers in an extensive production system in the Sourish Mixed Bushveld region at 26 months of age to calve for the first time at 35 months of age instead of calving these heifers earlier.

2.4.2 Inter-Calving Period

The ICP, which is defined as the time period from one calving to the next, is one of the factors related to cow productivity. It has been described as a measure that involves three phases, namely the gestation period, postpartum anoestrus, and the subsequent breeding period. Apart from their age at first calving, calving date for first-calf females can also affect cow longevity and productivity (Endecott *et al*., 2013). Selecting heifers that had calves early in the calving season might be the easiest approach to enhance the length of a cow's herd life and her profitability (Mousel *et al*., 2012). Cows of the same age may be given a chance to produce additional calves to verify which cows can remain productive to advanced ages if a breeder wishes to improve the genetic standard for longevity. On the contrary, calving late in the mating season may increase the number of cows that either calve later or do not conceive at all in the next calving season (Cushman *et al*., 2013), thus decreasing cow efficiency.

With fewer calves, the calving interval indicates low reproductive performance. Prolonged intercalving periods increase the risk of culling cows and the cost of their replacement (Pryce *et al*., 2000; Kadarmideen *et al*., 2003; Ettema & Santos, 2004; Mostert *et al*., 2006; Sewalem *et al*., 2008). A shorter ICP during a relatively long-life span can partially be attributed to the fact that cows are tolerant of their environment and are not subjected to death or being culled for subpar reproductive performance or other maladies (Thrift & Thrift, 2003). Decreased ICP in cows contributes to higher cow efficiency in a beef herd (Parish, 2010).

2.5 PELVIC MEASUREMENT

Pelvimetry is the measurement of the capacity and diameter of the pelvis, either internally or externally or both, with hand measurement, or with a pelvic meter (Kolkman *et al*., 2009). Murray *et al.* (2002) stated that pelvic area (PA) is a reliable measurement influencing calving difficulty; a larger PA is associated with reduced calving difficulty. Micke *et al*. (2010) further stated that PA is used to identify heifers with small or abnormally shaped pelvis that may be at risk for dystocia at calving. Pelvic area is calculated by multiplying the pelvic height (PH) with the pelvic width (PW), which results in a rectangular area (Kolkman *et al*., 2009). A Rice pelvimeter is used to take internal measurements of the height and width of the pelvic area (Kolkman *et al*., 2009).

Differences in pelvic area are generally due to pelvic height, with discrepancies between the dam and foetus more likely to occur for pelvic height and depth of calf chest than for width measures (Micke *et al*., 2010). Pelvic size, independent of cow weight, affects calving difficulty. Heifers of increased skeletal size usually have larger pelvic openings, but also tend to have heavier calves at birth. Hence, selection for cow size alone is ineffective (David *et al*., 2022). Heifer weight and age generally have a positive relationship to pelvic area, but weight is not always a good indicator. Pelvic measurements should be used in addition to, rather than in place of, selection for size, weight, and, above all, fertility (Bullock & Patterson, 1995). Beef producers should be aware that selection for pelvic area will likely not result in increased pelvic dimensions alone but may result in increased size of the entire skeleton and animal.

Calving difficulty, or dystocia, mostly occurs in two-year-old or first-calf heifers. Research indicates that disproportion between calf size (birth weight) and size of the female birth canal, which is pelvic area, is a major contributor to calving difficulty (Patterson *et al*., 1992). Producers are advised to use yearling pelvic measurements as a culling tool to reduce the potential incidence and severity of calving difficulty among first-calf heifers in their herds (Patterson *et al*., 1992).

External pelvimetry is done to correlate internal pelvic measurements with measurements taken outside of the animal, like the distance between the two tuber ischia (pin width), the two tuber coxae (hip or hook width), the anterior surface of the ilial wing and the posterior surface of the ischium (rump length), ilial wing to hip joint, and iliac crest to ischial tuberosity (Coopman *et al*., 2003; Johanson & Berger, 2003; Le Gal *et al.*, 2010).

2.6 NUTRITIONAL SUPPLEMENTATION FOR HEIFER GROWTH AND DEVELOPMENT

Nutrition is one of the most important factors for cow fertility. Beef heifers with a diet that is deficient in energy and that have a low BCS and/or lose condition after calving are much less likely to be pregnant in the subsequent calving season than heifers in a better condition (Livestock247, 2021). The main goal of supplementary feeding should be to identify the nutrient that is limiting production in any given circumstances and only supplement that nutrient. Season has a significant impact on the most limiting nutrients in any given area, but the quantity required will depend on the kind and productive state of the animals involved. Feeding more than the first limiting nutrient is often precluded by economic realities (Van Niekerk, 1996). The nutrients that heifers require are as follows:

- **Energy**. This is essential for maintenance feed digestion, core body functions, and to support growth, lactation, and reproduction. Energy accounts for the largest proportion of feed costs and is the nutrient required by animals in the largest quantity (Hamilton, 2015).
- **Protein**. Heifers, cows, as well as those in late pregnancy or lactation require more protein for growth development and reproduction (Hamilton, 2015).
- **Water**. This is an essential nutrient for cattle, accounting for 50–80% of an animal's live weight. For livestock to maximise feed intake and production, they require daily access to potable water of adequate quality and quantity. Insufficient water intake may reduce the animal's performance faster and more than any other nutrient deficiency (Alberta Agriculture, Food and Rural Development, 2005). A 364 kg heifer at an environmental temperature of 4.4°C can be expected to consume 23 litres per day; at 21°C, this will increase to 34.8 litres. At the same 4.4°C temperature, a 182 kg heifer will consume 15.1 litres. Water consumption and body weight are not correlated by a straight-line relationship. A 409 kg lactating cow at the 4.4°C temperature will consume 43.1 litres per day.
- **Vitamins**. These support many vital metabolic processes in cattle. They are inorganic compounds that are normally required in small amounts. Vitamin requirements are

influenced by age and production status of the animal. Vitamins such as A, D, E, and K are fat soluble and are stored in the animal's fat tissue and liver (Rabsy *et al*., 2011).

- **Minerals**. Seventeen minerals are required by beef cattle, and these are divided into two groups: macro minerals and micro minerals. Macro minerals are those required in large amounts for bodily functions, while micro or trace minerals are required in much smaller amounts. Beef cattle require 10 micro minerals, which are expressed in parts per million, (ppm) or mg/kg, rather than as a percentage of the diet. They are chromium (Cr), cobalt (Co), copper (Cu), iodine (I), iron (Fe), manganese (Mn), selenium (Se), and zinc (Zn) (Rabsy *et al*., 2011).

The requirements for these nutrients vary depending upon the class, age, condition, and stage of production of the animal. Environmental factors will also influence animal nutrition and nutrient levels in both the feed and water sources (Hamilton, 2015).

Van Pletzen (2009), Ferreira (2015), and Yara International (formerly KK Animal Nutrition; 2013) recommend a three-phase supplementation programme for a cow-calf production system to ensure that the cow herd's condition and nutritional status is adequate during critical stages of the production year. The three-phase supplementation programme is meant to ensure high weaning percentages and acceptable weaning weights for any particular region. The programme is recommended by Van Pletzen (2009), Ferreira (2015), and Yara International (2013) entails the following:

- **A wet season or summer supplementation period**. This period starts after good rain, when there is abundant green veld that is high in protein, highly digestible, and palatable. Phosphate and trace elements are the most limited nutrients on green natural veld. Phosphate is essential to maximise reproduction and growth.
- **Early dry season or winter supplementation period**. This period starts in autumn, when temperatures start dropping and frost sets in. Protein is the most important limiting nutrient in the early dry season/winter. Protein supplementation is important to maintain body mass and condition during the dry season by increasing roughage intake and digestibility.
- **Late dry season supplementation period**. During this season, the veld is characterised by low protein and energy content. Cows start calving in this period, and to maintain the condition of lactating cows and ensure good conception rates, protein and energy are supplemented during this period.

2.7 BODY CONDITION SCORE

The BCS describes the relative fatness or body condition of a cowherd. This score is most applicable to mature cattle and may be of very little use for cattle under one year of age. The purpose of body condition scoring is to achieve a balance between economic feeding, good production, and good welfare (Thomas & Bailey, 2021). Body condition score can be done using only visual indicators or a combination of visual indicators and palpation of key bone structures for fat cover. A BCS of between 1 and 5 can be determined by assessing the degree of muscle and fat cover at specific places on the animal's body over the spinous and transverse processes of the short ribs and, in fatter cattle, the tail head and ribs. Research shows that cows in moderate body condition will have a shorter interval from calving to first oestrus than cows with thin body condition.

2.7.1 Description of body condition score (BCS 1–5)

BCS 1: The bone structure of shoulder, ribs, back, hooks, and pins is sharp to the touch and easily visible. There is little evidence of fat deposits or muscling.

BCS 2: Little evidence of fat deposition but some muscling in the hindquarters. The spinous processes (vertebrae) feel sharp to the touch and are easily seen, with space between them.

BCS 3: Beginning of fat cover over the loin, back, and fore ribs. The backbone is still highly visible. Processes of the spine can be identified individually by touch and may still be visible. Spaces between are less pronounced.

BCS 4: Fore ribs are not noticeable, but the 12th and 13th ribs are still noticeable to the eye, particularly cattle with a big spring of rib and width between ribs. The transverse spinous processes can be identified only by palpation (with slight pressure) and feel rounded rather than sharp. Full, but straight muscling in the hindquarters.

BCS 5: The 12th and 13th ribs are not visible to the eye unless the animal has been shrunk. The transverse spinous processes can only be felt with firm pressure and feel rounded but are not noticeable to the eye. Spaces between the processes are not visible and are only distinguishable with firm pressure. Areas on each side of the tail head are well filled but not mounded.

The optimal BCS for a cow at mating is 3–3.5. At this stage, the animal has a good level of muscle development on the skeleton structure, and there are visible signs of fat on the body. If the animal does not reach the ideal BCS, it will experience a delayed puberty stage, which in turn affects the productivity of a female calf throughout her life.

Condition score 1

Backbone prominent
Hips and shoulder bones prominent
Ribs clearly visible
Tail-head area recessed
Skeletal body outline

Condition score 2

Backbone visible
Hips and shoulder bones visible
Ribs visible faintly
Tail-head area slightly recessed
Body outline bony

Condition score 3

Hip bones visible faintly
Ribs generally not visible
Tail-head area not recessed
Body outline almost smooth

Condition score 4

Hip bones not visible
Ribs well covered
Tail-head area slightly lumpy
Body outline rounded

Condition score 5

Hip bones showing fat deposit
Ribs very well covered
Tail-head area very lumpy
Body outline bulging due to fat

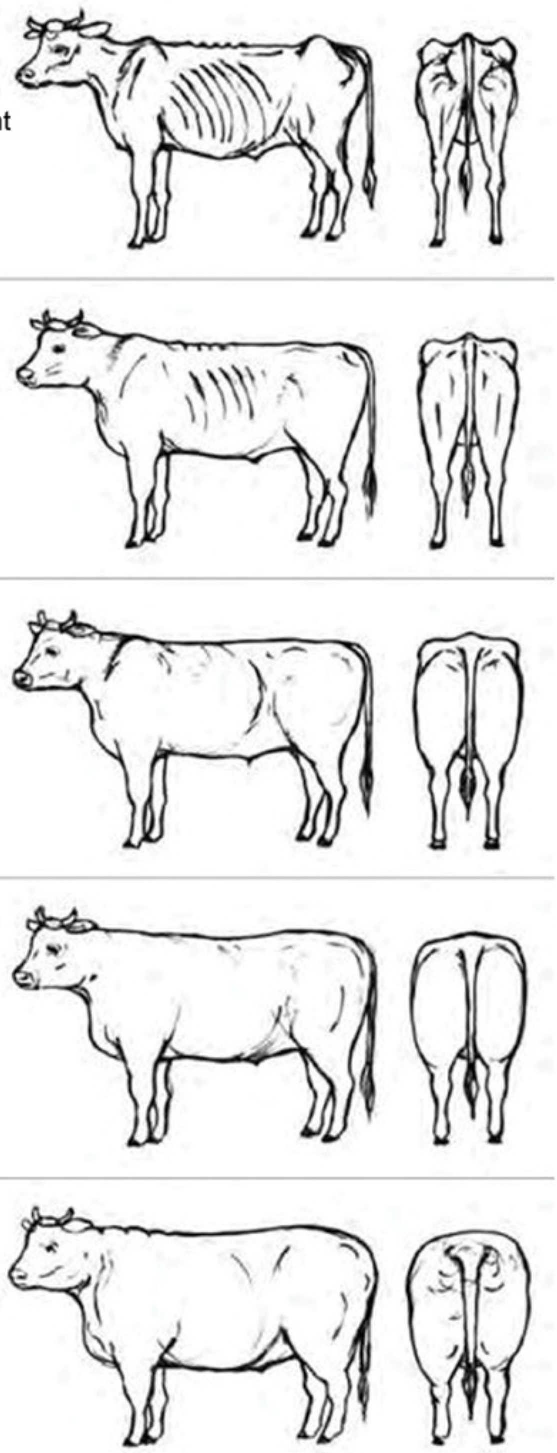

Figure 2.1 Criteria for visually determining BCS in beef cows

Source: Howel (2015)

CHAPTER THREE: GENERAL MATERIALS AND METHODS

3.1 STUDY SITE

This study was conducted at the Koopmansfontein Research Station, which is 3222 ha in size and situated 61 km north-west of the towns of Barkly West, 115 km east of Postmasburg, between Kimberley and Hotazel in the Northern Cape Province. The GPS coordinates are 28.241°S 24.037°E. The summers are hot, and winters are very cold and frosty, with average temperatures ranging from 6–40ºC. The rainfall distribution in the area is very erratic, with average precipitation around 450mm per annum, of which 88% is experienced during the summer months from October to April in the form of thunderstorms. The most dominant grass growing in the area is *Themeda triandra* (Red grass) (Raper, 1987).

3.2 ORIGIN AND DISTRIBUTION OF BONSMARA BREED

The Bonsmara is a breed of cattle known for its high-quality beef. It originated in South Africa as a scientific experiment conducted by Professor Jan Bonsma at the Mara and Messina Research Stations from 1937 to 1963. The Bonsmara is the most prominent beef breed in South Africa. Furthermore, Bonsmaras are bred and selected through a system that mostly promotes cow efficiency. The Bonsmara is functionally efficient and well adapted to extensive production as well as the harsh climatic conditions in Southern Africa. They are very fertile, with small- to medium-sized calves for easy calving, and they produce a calf that is sought after by the feedlot industry (Scholtz, 2010). The breed was recognised in 1964, and its breed improvement programme has been operating since then (Bonsmara SA, 2019).

3.3 EXPERIMENTAL ANIMALS AND MANAGEMENT

3.3.1 Management Practices at Koopmansfontein Research Station

Breeding bulls

Three Bonsmara bulls were used for mating. Fertility tests were done on the bulls before mating season, which involves semen examination and sheath washes to detect venereal diseases. The bulls grazed on natural pastures and were given VOERMOL SB100 (SB 200 supplement is an economical and easy-to-feed concentrate for cattle) with maize before the mating season to reach the ideal condition score. Their BCS was determined prior to mating, and all bulls were in a good condition, with the ideal score being 3 out of 5.

Figure 3.1 Veterinarian measuring and examining the scrotum for any defects

Figure 3.2 Sheath wash was done prior to mating to test for trichomoniasis

Heifers

The Bonsmara herd that was established in 2013 by the Department of Agriculture, Land Reform, and Rural Development was used for the study. Normal management practices for the area for extensive beef production were followed.

In order to study the growth rates for heifer development at Koopmansfontein Research Station, 24 pure-bred Bonsmara female weaners were used in this study. The two-year-old heifers were divided into two experimental groups of 12 heifers each with similar weights. All heifers used for the study were in good body condition, with an average BCS of 3. The control group only received summer lick (October to March) and winter lick (April to September), while the treatment group received a summer lick during the summer months, but production lick instead of a winter lick during the winter months. The recommended intake of winter lick for cattle is 400–650 g per day, and the recommended intake of summer lick is 100 g (minimum) to 200 g (maximum) per day.

Table 3.1 and Table 3.2 show the nutritional composition of the licks that were fed to the heifers in the study group.

Table 3.1 Winter lick composition

Nutrient composition	Nutrient levels
Moisture (max)	120 g/kg
Protein (min)	400 g/kg
Urea (total feed)	135 g/kg
Calcium (max)	21 g/kg
Urea protein of protein	80%
NPN of total protein (max)	96%

Table 3.2 Summer lick composition

Nutrition composition	Nutrient levels
Moisture (max)	150 g/kg
Phosphorus (min)	60 g/kg
Calcium (max)	120 g/kg
Iron (min)	750 mg/kg
Copper (min)	150 mg/kg
Zinc	600 mg/kg

A ratio of 2:1, which is two bags of winter lick and one bag of yellow maize, was used as the production lick.

All animals were treated for internal and external parasites with Ivomec and were further treated quarterly with Ivomac and MultiMin + Se Cattle for the prevention and treatment of zinc deficiency from one year of age until they were mated with the bulls. The animals were weighed on an electronic scale on a monthly basis from weaning to the end of the first cow calving season.

A breeding period of three months for the two-year-old heifers (heifers started on 15 November 2019 and the cows on 1 December 2019 up to end of February 2020) was employed, and four experienced Bonsmara bulls were allowed to mate all heifers, which were stratified into two mating groups to calve at the age of three. The BCS was evaluated at the start and end of the breeding season. At the Koopmansfontein Research Station, an optimal BCS of 3 was used for mating, as this score means the animal has a good level of muscle development on the skeleton structure and there are visible signs of fat on the body. Pregnancy diagnoses were conducted by a veterinarian four months after the start of the breeding season. Out of the 24 heifers, only 20 were pregnant (11 heifers in the treatment group and 9 heifers in the control group).

Pelvic measurement done on heifers

The pelvic measurement of the heifers was done using the Rice pelvimeter instrument, which consists of two cast aluminium arms and a stainless steel scale graduated in centimetres. The measurements were read on the inside (vertical and horizontal) of the measuring arms. All measurements were taken in centimetres.

The general procedure in taking pelvic measurements is to restrain the animal in a chute using a light squeeze. The best procedure is a comfortable, normal standing position (Van Zyl, 2008). Faeces were removed from the rectum and a lubricate oil was applied on the instrument and on the animal. Using the method of Van Zyl (2008), the instrument was carefully placed into the rectum and thereafter gradually opened by guiding it with the handle. It was then twisted from left to right to feel the ossified joint on the pubic symphysis as a reference point, for purposes of measuring the height between the dorsa pubic tubercle on the floor of the pelvis and the sacrum (spinal column). The instrument was turned 90° sideways to measure the width of the pelvis at widest points between the right and left shafts of the ilium bones. Thereafter, the instrument was pulled out in the same twisted position to measure the width between the left tuber ischia and the right tuber ischia. The instrument was then removed from the animal. After each use, the instrument was cleaned with water and disinfected with a disinfectant before using it on the next animal.

The pelvises of all the heifers were measured once before breeding, using a method adapted from several researchers (Walker *et al*., 1992; Kilgour & Haughey, 1993; Patterson & Herring, 1997; Van Rooyen *et al*., 2012).

The following formula was used to calculate pelvic area (Morrison *et al*., 1986; Van Rooyen *et al*., 2012):

$$PA \quad = \pi(\frac{PH}{2} \times \frac{PW}{2})$$

Recording of birth weights and weaning weights

Birth weights on live calves were recorded within three days after birth to determine calving percentage and the growth rate of the calves.

Corrected data from the Integrated Registration and Genetic Information System (INTERGIS) for birth weight, weaning weight, 12-month weight, and 18-month weight were used to compile average growth curves for the two groups of heifers. These growth curves could then be used to determine the economic feasibility of the winter supplementary feeding regime.

Breeding cows

Sixty Bonsmara cows were stratified according to their ages into three breeding groups of 20 cows each. Two bulls were allocated to each of the three breeding groups.

The animal health management and supplementation implemented were similar to that of the control group of heifers. All cows were weighed and their condition scored at the beginning and end of the mating season and at calving and weaning.

Cow age is a measurement of longevity and productivity, thus the age records of 114 Bonsmara cows between the age of 5 and 20 years at the Koopmansfontein Research Station for the period 2013 to 2020 were extracted from INTERGIS. Cows were only culled from the herd due to worn teeth and poor udders. The ICP of all cows that formed part of the study were also extracted from INTERGIS for further analysis to determine the trait's relationship with other traits that affect cow efficiency.

In the study, we used the medium-frame LSU equation (cow with calf at foot) to calculate the LSU (Mokolobate *et al*., 2015):

$$Y = 0.220714286 + 0.0030978571*x - 0.0000010714*x^2$$

Data analysis

The analysis is discussed in Chapter Four and Chapter Five**.** The collected data were captured in Microsoft Office Excel, and SAS and GenStat were used to analyse the data.

CHAPTER FOUR: HEIFER REPRODUCTION

4.1 INTRODUCTION

The raising of good quality replacement heifers is an important component of any beef production system. In addition to selecting good breeding stock, nutrition and environment play a vital role in the growth and reproductive performance of these heifers. Growing animals on a low-nutrient diet can result in an increase in dystocia. This is primarily due to abnormal skeletal growth and therefore smaller PA (Anderson, 1992; Wilson & Rossi, 2006). In an extensive beef production system in the Eastern Kalahari Bushveld, overfeeding is seldom a major contributing factor to dystocia. However, beef producers must maintain a balance between achieving maximum frame growth without allowing excessive fat deposits. Basically, fat animals will have a high incidence of dystocia, similar to that found in underdeveloped/undernourished animals (Wilson & Rossi, 2006).

In an extensive production system, lick supplementation is commonly used to strategically supply additional nutrition to the animals. In the current study, the two heifer groups received mineral lick during summer (October to March), while the two groups received either production lick or winter lick (see Chapter Three) during winter (April to September).

Beef heifers usually achieve puberty when they reach 55–60% of their mature body weight (Funston & Deutscher, 2004) but are usually mated for the first time when they reach between 60–65% of their mature weight (Kasimanickam *et al*., 2021). Another tool to evaluate heifers before mating is to take pelvic measurements prior to mating to calculate the pelvic area. Heifers with small pelvic size or abnormally shaped pelvis normally have a higher-than-average incidence of calving difficulty.

4.2 AIM OF CHAPTER 4

The aim of the study was firstly to determine the effect of two different lick supplementation strategies between weaning and first conception on the subsequent calving percentage and cow and calf weights, as well as calving percentage and weight over the second and third calving seasons. Secondly, the study aimed to measure the PA of the heifers at the start of the breeding season to confirm their suitability for mating.

4.3 MATERIALS AND METHODS

Twenty-four Bonsmara heifers were divided into two groups of 12 animals each after weaning at the Koopmansfontein Research Station in the Eastern Kalahari Bushveld of South Africa. The two heifer groups received the same mineral lick (60g/kg Phosphorus and 120g/kg Calcium) during summer (October to March). During the winter months (April to September), Group One received a protein-rich winter lick (400g/kg protein), while Group Two received a production lick which consisted of the same winter lick supplemented with yellow maize in a ratio of 2:1 to supply additional protein and energy. Lick specification is discussed in detail in Chapter Three. Animals were subjected to normal herd management practices (see Chapter Three).

Pelvic area measurement with pelvimetry is a useful tool according to studies done by Gundelach *et al*. (2009), Johanson and Berger (2003), and Holm *et al*. (2014), who all concluded that pelvimetry is an accurate and repeatable procedure. Pelvic measurements taken prior to breeding allow for the culling of heifers with small pelvic sizes.

The pelvic width and height of all the heifers were measured once before breeding, using a method adapted from several researchers (Walker *et al*., 1992; Kilgour & Haughey, 1993; Van Rooyen *et al*., 2012; David *et al*., 2022). The formula of Morrison *et al*. (1986) was used to calculate the pelvic area, which is discussed in detail in Chapter Three.

Pelvic measurements were analysed using the statistical program GenStat (2022). The "Student" t-test was used to test whether the mean measurements for the control and treated groups were significantly different. A significant probability ($p \leq 0.05$) indicated that the treatment and control group means differed significantly at the 5% level.

4.4 RESULTS AND DISCUSSION

4.4.1 Pelvic Measurements of Heifers

The measurements of the heifers' pelvic region taken one month prior to breeding are shown in Table 4.1. The results indicated that there was a significant difference ($P = 0.034$) in pelvic measurements between the pelvic area of the heifers that were supplemented with production lick and those that were supplemented with winter lick. The PW of the heifers that received production lick and those that received winter lick differed significantly ($P = 0.031$).

Table 4.1 Pelvic height, width, and area ± standard deviation (SD) of Bonsmara heifers who received either production lick or winter lick before commencement of the first mating season

	Pelvic Height (cm) ± SD	Pelvic Width (cm) ± SD	Pelvic Area (cm^2) ± SD
Production Lick	18.33 ± 1.07	14.92 ± 1.08^a	214.9 ± 21.63^a
Winter Lick	17.27 ± 2.28	14.00 ± 0.77^b	190.4 ± 29.86^b
p-value	0.182	0.031	0.034

^{a,b} Means with different superscripts in the same row differ significantly at $P \leq 0.05$

The mean PA of the animals that received production lick was bigger (214.9 ± 21.63 cm^2) than those animals that received winter lick (190.4 ± 29.86 cm^2). Additionally, the treatment group (production lick) had a higher calving rate during their first year of calving and gave birth to heavier calves. These results show that there was a significant difference (at $P \leq 0.05$) in the PA of the two group,(see table 4.1). In a similar study by Bila (2019), the mean PA of one group of Sussex heifers was measured at 171.95 ± 19.12cm^2, which is significantly different from this study's results. This could be because the heifers are of different breeds (Bonsmara and Sussex) and the animals were managed using different management techniques, although the heifers used in both studies were the same age (24 months). Micke et al. (2010), stated that in beef heifers calving at three years of age, when the incidence of dystocia was only 14%, found that PA was related to dystocia. Additionally, they found that this association had no effect when increasing the amount of nutrition during the first or second trimester of pregnancy. In the current study, no dystocia cases has been observed. The absence of dystocia problems in heifers supplemented with production lick and winter lick at 3 years of age shows a positive relationship between nutritional management and calving ease. According to Bila (2019), the reduction of dystocia in the beef cattle industry may be greatly impacted by the PA of both sires and dams when replacing heifers in the herd.

In 2020, the mean PA of the control group in this study was smaller, and there was only one heifer in the group that experienced dystocia during her first calving.

4.4.2 Heifer Weight at Breeding

According to Kasimanickam *et al.* (2021), heifers should be fed to reach 60–65% of their estimated mature body weight before the start of breeding season. However, Endecott *et al.* (2013) state that raising heifers to be 50–57% of mature body weight may present an economic advantage over developing heifers to 60–65% of mature body weight. For this study, the heifers had to reach 55% of their mature body weight at first mating.

The weight data were subjected to a factorial analysis of variance (ANOVA) to test for significant main effects and interactions using SAS version 9.4 statistical software (SAS, 2016). The residuals were examined for deviations from normality, and outliers causing skewness were removed. Fisher's protected t-LSD (Least Significant Difference) was calculated to compare treatment means of significant effects (Ott, 1998).

The heifers were fed according to Table 4.2 in order to achieve their ideal weight prior to their first mating. It appears that there were no significant differences in body weight gain between the treatment group (production lick) and the control group (winter lick) in 2019. However, in the following year (2020), the animals that were supplemented with production lick weighed significantly heavier ($P < 0.05$, 426.3 ± 39.5 kg) than those that were supplemented with winter lick (361.8 ± 41.6 kg).

Although the heifers that were fed with production lick weighed less (414.5 ± 39.7 kg) in 2021 compared to 2020, while the control group heifers that were fed with winter lick gained weight (404.8 ± 32.2 kg) in 2021, there was no significant difference between the two groups in 2021.

Table 4.2 Mean heifer weight (kg) ± standard deviation at the beginning of the mating season for heifers who received either production lick or winter lick before commencement of the first mating season

Year	Production Lick	Winter Lick	Groups combined
2019	288.7 ± 33.2^{c}	286.3 ± 39.1^{c}	287.5 ± 35.5^{B}
2020	426.3 ± 39.5^{a}	361.8 ± 41.6^{b}	394.1 ± 51.6^{A}
2021	414.5 ± 39.7^{a}	404.8 ± 32.2^{a}	409.7 ± 35.7^{A}
Mean	376.5 ± 73.0^{1}	351.0 ± 61.8^{2}	

^{a,b,c} Means with different superscripts in the same row differ significantly at $P \leq 0.05$

^{1,2} Means with different superscripts in the bottom row differ significantly at $P \leq 0.05$

The treatment group had more calves in their first calving season in 2020, as shown in Table 4.3. The fact that they were still nursing their first calves may have contributed to their slight loss of weight in 2021, while the control group gained weight since the majority of the animals did not calve. Lishman *et al*. (1984) state that the nutritional requirements for growth of the young cow in addition to those for lactation are not usually met by the natural grazing available, and the provision of supplements thus plays a vital role in their reproductive performance. These results are also in agreement with Kroker *et al*. (2000), who report that when heifers are fed to achieve appropriate weights prior to their first breeding, a positive effect on re-breeding after the first calf can be seen. When heifers are bred for the first time with inadequate live weights, conception rates and calving percentages are poor, calving problems increase, and their chances of being rebred while nursing their first calves are very low. The results show that production lick supplementation had a positive influence on the growth and development of heifers.

Table 4.3 Calving percentage of Bonsmara heifers during their first three breeding seasons

Cycle x Treatment	Heifers that did not calve	Heifers that calved
2020×production lick	1 (8.33%)	11 (91.67%)
2020×winter lick	4 (33.33%)	8 (66.67%)
2021×production lick	6 (50%)	6 (50%)
2021×winter lick	7 (58.33%)	5 (41.67%)
2022×production lick	5 (41.67%)	7 (58.33%)
2022×winter lick	8 (66.67%)	4 (33.33%)

4.4.3 Calving Percentage of the Heifers

Calving percentage is the number of calves born per number of female cattle exposed to a bull, expressed as a percentage (Chenoweth, 1994). Calving percentage does not relate to the dates of birth or when calves were born during the calving season. All calves were included in the number of calves born, even if they were dead at birth. Calving percentage, which is influenced by pregnancy rate and pregnancy loss percentage, is a good indicator of breeding performance and herd fertility (Taylor, 2006 & Nkadimeng, 2022). A low calving percentage indicates that a problem exists in a herd, but does not indicate the cause of the problem and where it occurs.

Experimental data involving frequencies may be subjected to analysis by the contingency table method – that is, the Chi-square test for an R x C contingency table. In this study, the Chi-square test was applied on the proportion of calves born in the different years for the control and treatment group. The Chi-square test for the R x C (6 x 2) contingency table (Figure 4.1) was done to test whether the proportion of calves born varied over the different classifications. A significant (P = 0.0627) Chi-square test indicated that the proportions did vary at the 10% level of significance. In other words, the proportion of calves born was dependent on the treatment and year (Rayner, 1969). These tests were performed with SAS version 9.4 statistical software (SAS Institute, 2016).

The calving percentages of the group which received production lick in the winter before the first breeding season were 91.67%, 50%, and 58.33% for the first, second, and third calving seasons, respectively. The production lick treatment group had a higher calving percentage ($P < 0.05$) than the winter lick treatment group, where calving percentages of 66.67%, 41.67%, and 33.33% were recorded from 2019–2021 (Figure 4.1). The Chi-square test indicated that the proportion that calved depended on the treatment and year. These results also indicate that it may be worthwhile for farmers to provide good nutrition and supplementation before the first breeding season and thereafter for the incentive of a better calving percentage and higher calf weaning weights up to the third calving season.

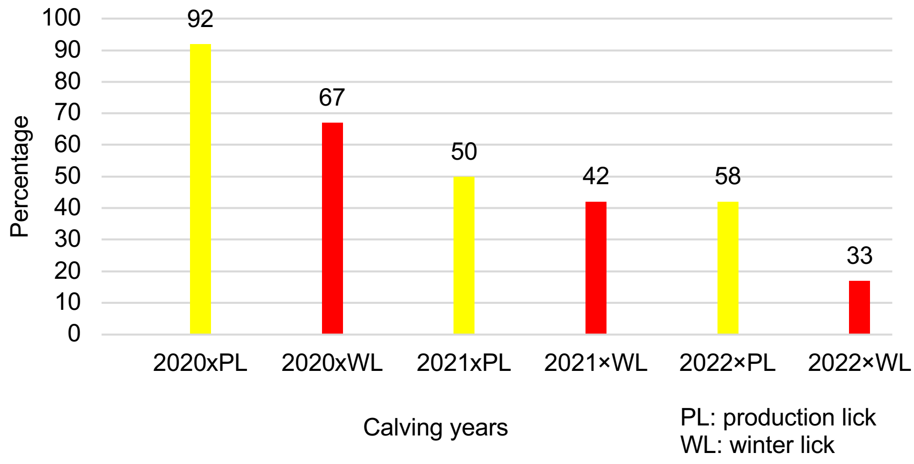

Figure 4.1 Calving percentage of Bonsmara heifers during the first three consecutive breeding seasons

These results are in agreement with the study of Foster (2015), which showed that beef heifers commonly conceive at a higher rate during their first breeding season, provided they have grown sufficiently. The calving rate is one of the measures of cow efficiency, because it is linked to body condition of the cow, which is achieved mainly through good feeding (Foster *et al*., 2014). Furthermore, Endecott *et al.* (2013) state that the choice of supplements offered to first-calf heifers is very important, as nutritional stress could affect their fall-out rate, longevity, and mature cow size. Supplements thus play a vital role in heifers' reproductive performance. When heifers are fed to achieve appropriate weights prior to first breeding, a positive effect on re-breeding after the first calf can be seen.

4.4.4 Heifer Weight at Calving

Weight at calving is an important factor that can affect heifer performance in general as well as milk production. Farmers have to consider weight at calving in cattle breeding as it can have implications for the health and productivity of both the dam and the calf (Kathambi *et al*., 2018). Although body weight at calving can impact milk yield and herd life, it is not the sole determinant. The long-term productivity and survival of heifers are also influenced by other factors, such as maturity rate (Han *et al*., 2021). Body weight at first calving can also be influenced by factors such as genetics, nutrition, management practices, and growth rate during rearing period.

In 2019/2020, there were no significant differences in body weight at first calving between the two experimental groups. However, there was a significant difference the following year in 2020/2021, when animals that were fed with production lick weighed more (372.5 ± 40.7 kg) than those that were fed with winter lick (329.4 ± 25.6 kg). The results further showed the two experimental groups gained weight in the last year but there was no significant difference between them. Han *et al*. (2021) report that faster growth rates may result in higher body weights at calving, while slower growth rates may lead to lower body weights.

Table 4.4 Heifer weight (kg) at calving ± standard deviation for heifers who received either production lick or winter lick before commencement of the first mating season

Year	Production Lick	Winter Lick	Groups combined
2019/2020	337.9 ± 33.7^{b,c}	311.1 ± 22.0^{c}	326.6 ± 31.7^{B}
2020/2021	372.5 ± 40.7^{b}	329.4 ± 25.6^{c}	352.9 ± 40.0^{B}
2021/2022	428.3 ± 30.1^{a}	420.5 ± 34.6^{a}	415.6 ± 29.1^{A}
Mean	370.0 ± 47.9^{1}	340.0 ± 47.6^{2}	

^{a,b,c} Means with different superscripts in the same row differ significantly at $P \leq 0.05$

^{1,2} Means with different superscripts in the bottom row differ significantly at $P \leq 0.05$

4.4.5 Calf Birth Weight

The weight of a newly born calf is of great importance to the breeder, producer, and livestock owner in judging its health as well as those of its dam, and it also gives a good indication of the calf's subsequent development (Wakchaure & Meena, 2010). Calf birth weight is one of the key factors defining calf morbidity and survival at calving time but also calf growth and health in later life. For example, dystocia can be linked with high calf birth weight and could increase calf mortality at calving and up to 30 days following birth, and it can compromise long-term health. Therefore, calf-birth-weight predictions could be used to maximise cow and calf welfare at birth while avoiding losses associated with low and high calf birth weight. However, calf birth weight can be a complex trait influenced by environmental and genetic components. In this regard, fulfilling nutrition requirements is essential for the growth and development of calves (Hickson *et al*., 2015).

The calf birth weights are presented in Table 4.5. There was no significant difference in the birth weights between the two groups during 2019/2020. At birth, the calves were almost the same size for the production lick (36.7 ± 4.4) and winter lick (34.1 ± 5.5) groups, but in the year 2020/2021, there was a significant difference ($P < 0.05$) in calves born from the group that received production lick, which had significantly higher birth weights (38.5 ± 5.3 kg) than those whose mothers received winter licks (34.2 ± 4.4 kg). The calves from the animals that were fed winter licks, however, had significantly higher BW than the calves from the animals that received production licks the following year, in 2021/2022. The results align with those of Sejrsen *et al*. (2000), who found that the positive relationship between birth weight at calving and milk yield is mainly due to a positive relationship between growth-rate capacity and milk yield.

Table 4.5 Corrected calf birth weights (kg) ± standard deviation for heifers who received either production lick or winter lick before commencement of the first mating season

Year	Production Lick	Winter Lick	Groups combined
2019/2020	36.7 ± 4.4	34.1 ± 5.5	35.6 ± 4.9
2020/2021	38.5 ± 5.3	34.2 ± 4.4	36.5 ± 5.2
2021/2022	34.0 ± 2.6	37.5 ± 2.1	35.3 ± 2.9
Mean	36.4 ± 4.4	34.9 ± 4.6	

4.4.6 Cow Weight at Weaning

Cow weight at weaning is a crucial indicator of the cost of maintaining a cow. It provides valuable information regarding the cow's ability to conceive and nurture a healthy calf. The productivity and efficiency of the cattle population can be increased through selective breeding based on cow weight at weaning (Crook *et al*., 2010).

According to the results in Table 4.6, there was a significant difference in CWW in 2020, and the heifers that were supplemented with production lick (324.1 kg) were significantly ($P<0.05$) heavier than those that received winter lick (293.3 kg). The results show that supplementing growing heifers with production licks had a positive effect on cow weaning weights. Dickerson (1970) states that increased feed conversion efficiency is correlated with a higher weaning weight in cows. However, there are no apparent differences between the two groups in 2021 and 2022. The animals weighed almost the same at weaning.

Table 4.6 Cow weights at weaning (kg) ± standard deviation for heifers who received either production lick or winter lick

Year	Production Lick	Winter Lick	Groups combined
2021	324.1 ± 25.0	293.3 ± 25.5	312.1 ± 28.9
2022	335.7 ± 31.9	330.2 ± 19.5	333.5 ± 26.4
2023	358.6 ± 73.4	316.2 ± 45.9	343.2 ± 65.7
Mean	337.0 ± 46.1	309.3 ± 32.8	

The weight of a cow at weaning and weight of a cow before mating are related. Numerous research studies that investigated the relationship have found that the ratio of mature equivalent cow weight at weaning to calf weaning weight can be used as a measure of cow efficiency (McNeil ,2005., Scholtz *et al*., 2016 & William *et al*., 2018). From Table 4.2, it is evident that the animals weighted nearly the same at the beginning of the first mating season; however, at weaning, the production-lick group weighed significantly heavier than the winter-lick treatment group.

4.4.7 Calf Weaning Weight

Calf weaning weights can be influenced by various factors. One study found that calves managed in confinement and fed concentrate-based diets had greater ADG during a feeding trial. To attain a high weaning weight, calves have to get enough feed.

From Table 4.7, it can be seen that the calves born from the heifers who were fed production lick weighed heavier (186.4 kg) at weaning than the calves born from the heifers that were fed winter lick (139.6 kg) in 2021. Weaning weights differed significantly ($P < 0.05$) between the two groups receiving either production lick or winter lick over the three-year project period. The highest weaning weight for the production lick group was 186.4 kg (2021), while the highest weaning weight for the winter lick group was 144.7 kg (2022). The average weaning weight of the two groups combined did not differ significantly between years over the three-year project period.

Table 4.7 Calf weight (kg) at weaning ± standard deviation of calves in the treatment and control group

Year	Production Lick	Winter Lick	Groups combined
2021	186.4 ± 13.9^{a}	$139.6 \pm 44.5^{b,c}$	166.7 ± 38.0
2022	$153.2 \pm 12.8^{a,b,c}$	$144.7 \pm 38.8^{b,c}$	149.8 ± 24.7
2023	$172.6 \pm 37.6^{a,b}$	$132.2 \pm 36.1^{b,c}$	157.9 ± 40.7
Mean	$174. \pm 26^{1}$	139.1 ± 38.8^{2}	

^{a,b,c} Means with different superscripts in the table differ significantly at $P \leq 0.05$

^{1,2} Means with different superscripts in the bottom row differ significantly at $P \leq 0.05$

4.4.8 Body Condition Score of Heifers Before Mating

The BCS is an effective hands-on management tool that is used to evaluate the nutritional status of beef cattle. In order to manage a beef herd in the most cost-efficient way, producers must, at all times, be aware of the body condition of their herd. Research has found that the body condition of beef cows is related to at least 16 critical aspects of production – including days to oestrus, conception rate, milk production, and calving interval (NFACC, 2013).

The Koopmansfontein Research Station used the optimal BCS of 3 for mating, which was determined by assessing the degree of muscle and fat cover at specific places on the mature animal's body – specifically over the spinous and transverse processes of the short ribs.

4.4.9 The Economics of Supplementation Feeding for Heifers

The calf-feeding economics analysis report aimed to assess the financial implications of different feeding strategies for the two heifer groups who received either winter lick (n = 12) or production lick (n = 12) during the dry season (April to September). Due to the heifer groups' age, weight, and management being similar at the beginning of the study, the analysis only focused on winter lick supplementary costs, lick intake levels, calving percentage, calf weaning weight, and market prices to determine the most cost-effective approach to feeding heifers.

The calves were weaned in June and, therefore, the estimated average weaner price of R34.94 in the first week of July 2023 (RPO, 2023) was used for the calculations. Winter lick bags cost R280 per 50 kg, while yellow maize cost R295 per 50 kg bag. The production lick consisted of a 2:1 ratio made by mixing two bags of winter lick with one bag of yellow maize. The production lick thus cost R285 per 50 kg or R5.70/kg. The group receiving winter lick had an average lick intake of 0.45 kg per day, while the group receiving production lick had an intake of 1.5 kg per day.

The cost per kg for the control group of heifers that were fed winter lick was R5.60, and the intake was 0.45 kg per day. The feeding cost for the animals receiving winter lick was thus R2.52 per animal day. This amounts to a winter lick feeding cost per animal for the dry season (183 days) of R461.16. The cost per kilogram for the production lick was R5.70, and the intake was 1.5 kg/day. Feeding cost per animal per day was thus R8.55. This amounts to a production lick feeding cost per animal for the 183 days of the dry season of R1 564.65. The above calculations show that significantly more money was spend on the treatment group animals that received production lick than those that received winter lick. From Table 4.6 it can be seen that the mean 205-day corrected weaning weight of calves born from heifers receiving production lick was 174.0 kg, while the calves born from heifers that received winter lick had a mean weight of 139.1 kg.

In order to determine the approximate profit a farmer would receive when feeding production lick, one must multiply the weaning weight of the calf (i.e. 174.0 kg) by the average weaner calf price of R34.94 (RPO, 2023), which amounts to an average weaner price of R6 079.56. The average weaner calf price (R6 079.56) minus the cost of production lick per season (R1 564.65) gives a profit of R4 514.91 per animal. The profit per year for calves born to heifers (n = 12) that received production lick was R36 119.28, with an average of 8 calves per year (average calving percentage 67%).

The average weaner calf price of R34.94 (RPO, 2023) multiplied by the average 205-day corrected weaning weight (139.1 kg) of the calves born to heifers that received winter lick amounts to an average weaner price of R4 860.15. The average weaner price (R4 860.15) minus the cost of winter lick per season (R461.16) gives a profit of R4 398.99 per animal. With an average of 5.7 calves born (average calving percentage 48%) from the group receiving winter lick (n = 12) over the three-year project period, the profit per year for calves born from heifers that received winter lick was R25 074.24.

Based on these results, it can be seen that a farmer who feeds his animals production lick pays more money to purchase lick per year but makes more money on average per year from calves born to heifers that received production lick. Farmers should thus make yearly calculations to determine their yearly profit, with the aim that the output should be more than the input for current circumstances. Moreover, it is essential to consider the age at which the calves are weaned when analysing the feeding economics. This is especially important as different management practices and feeding strategies can have long-term implications for the health, welfare, and performance of the calves (Scoley *et al*., 2019). However, herd management and environmental conditions may also affect growth and therefore profit margin.

The goal of this report is to provide farmers with valuable insights into the economics of feeding heifers, allowing them to make informed decisions that optimise their profitability and ensure the sustainability of their operations.

4.5 CONCLUSION

Supplementing heifers with production lick resulted in a larger PA and higher calving rate with heavier calves at birth. The findings of this study demonstrate that heifers supplemented with production lick weighed significantly more than those supplemented with winter lick in 2020, and the production lick group had more calves in their first calving season. Nutritional supplementation is important for reproductive performance and achieving appropriate weights prior to first breeding. Adequate nutrition can help the animals to reach the target weight before mating by providing energy and nutrients for growth. The study shows that faster growth rates may result from higher body weights at calving. Providing good nutrition and supplementation to heifers before their first breeding season and afterwards can significantly improve calving percentage and calf weaning weights up to the third calving season, as supported by previous studies. This highlights the importance of proper feeding and supplementation in enhancing heifer reproductive performance and overall cow efficiency. The absence of dystocia in calves that were supplemented with production lick and winter lick indicates that proper nutritional supplementation plays a crucial role in ensuring calving ease processes.

CHAPTER FIVE: HERD PRODUCTION AND EFFICIENCY

5.1 INTER-CALVING PERIOD OF COWS CORRELATED WITH AGE

5.1.1 Introduction

The ICP is an important factor in a herd as it affects reproductive efficiency and herd productivity. The ICP of cows is influenced by their age (Mkhize, 2019). Furthermore, Nalecz-Tarwacka *et al.* (2011) state that the age of first calving has an effect on the ICP. Cows that calve for the first time at a younger age tend to have a shorter ICP. A shorter ICP indicates that cows are cycling and calving at regular intervals, allowing for a consistent production cycle. On the other hand, a longer ICP can lead to decreased milk production and economic losses due to extended non-productive periods.

Materials and methods

Cow records for the Bonsmara herd at Koopmansfontein Research Station for the period between 2014 and 2021 was extracted from the INTERGIS database. Data of cows that were culled from the herd due to worn teeth and poor udders were excluded in the analysis. This is to determine the relationship between ICP and cow age in the Bonsmara herd at Koopmansfontein. The correlation between the ICP and cow age was calculated in Microsoft Excel 2016.

Results and Discussion

Cow fertility at Koopmansfontein is considered to be low. The ICP of cows is considered to be a trait of cow-fertility. Cow age is a measurement of cow longevity and efficiency. However, it is believed that there is antagonism between ICP and cow age.

The results showed that the average ICP for cows at different ages at Koopmansfontein varied from 424 days for 9-year-old cows to 747 days for 6-year-old cows, with an average of 529 days. A negative correlation (r = -0.47) between ICP and cow age was found. This suggests that approximately 22% of the variation in ICP could be explained by cow age and that cows with higher longevity are also more fertile. This outcome should, however, be interpreted with caution since the number of records in certain cow age groups was low, and environmental and animal effects were not removed with statistical analysis.

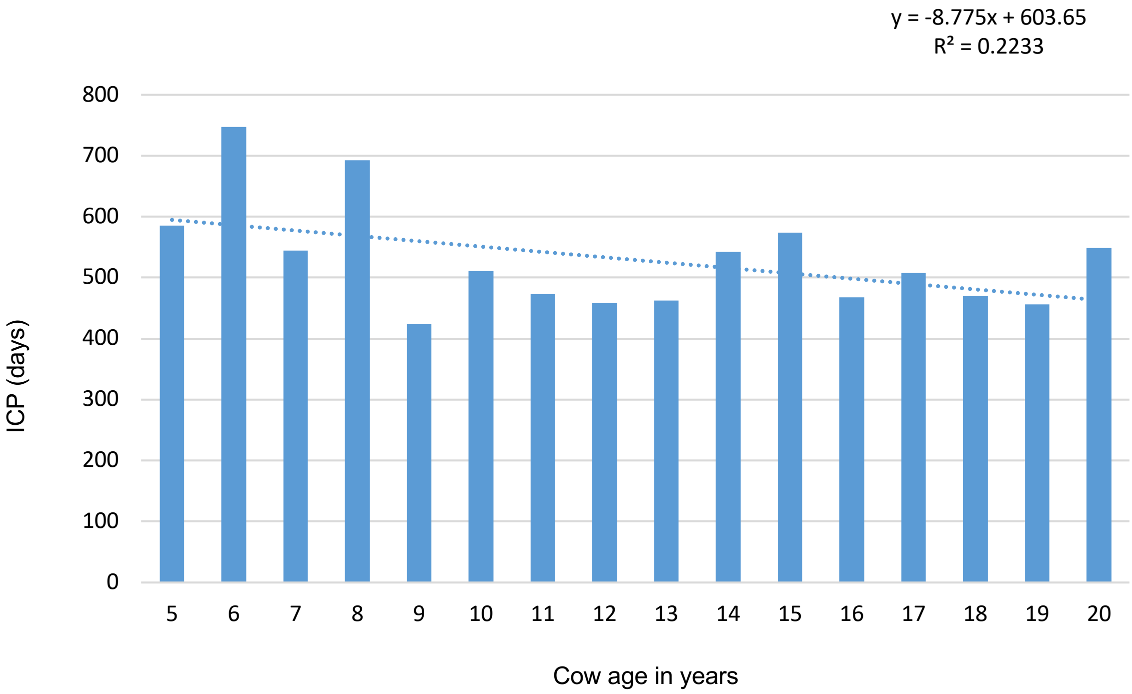

Figure 5.1 Histogram showing the relationship between cow age and ICP in the Koopmansfontein Bonsmara

The fact that the study found a negative correlation between ICP and cow age implies that the older cows in the Koopmansfontein Bonsmara herd are more fertile. The high ICP of the herd could be mediated by using a variety of resources and available tools. While breed resources and genetic variation for adaptability may be a long-term solution, management interventions such as economically supplementary feeding, spring or extended mating seasons, and genetic approaches for improved adaptation will also be required. More research is needed for the development of new production systems and adapted genotypes that may be more productive.

5.2 REASONS FOR CULLING WHICH INFLUENCE COW LONGEVITY

Longevity and culling of cows are very important to the sustainability and profitability of any beef operation. Culling of cows from the herd eliminates poorly performing cows, inferior genetics, and quality defects in cows that would limit short- and long-term productivity.

At the Koopmansfontein Research Station, the cows were mainly culled for worn teeth, age, poor teats, and infertility. Culling cows from a productive herd has a significant impact on cow efficiency. Twenty-five animals had to be culled from the herd between 2014 and 2021 due to worn teeth and bad udders, which may lead to long-term concerns regarding cow nutrition, BCS, and reproductive performance. Cows that were culled at a young age did not produce enough calves to recover development costs. Due to age, approximately 29 cows were culled, which is indicative of the herd's average longevity and the opportunity to recover development costs.

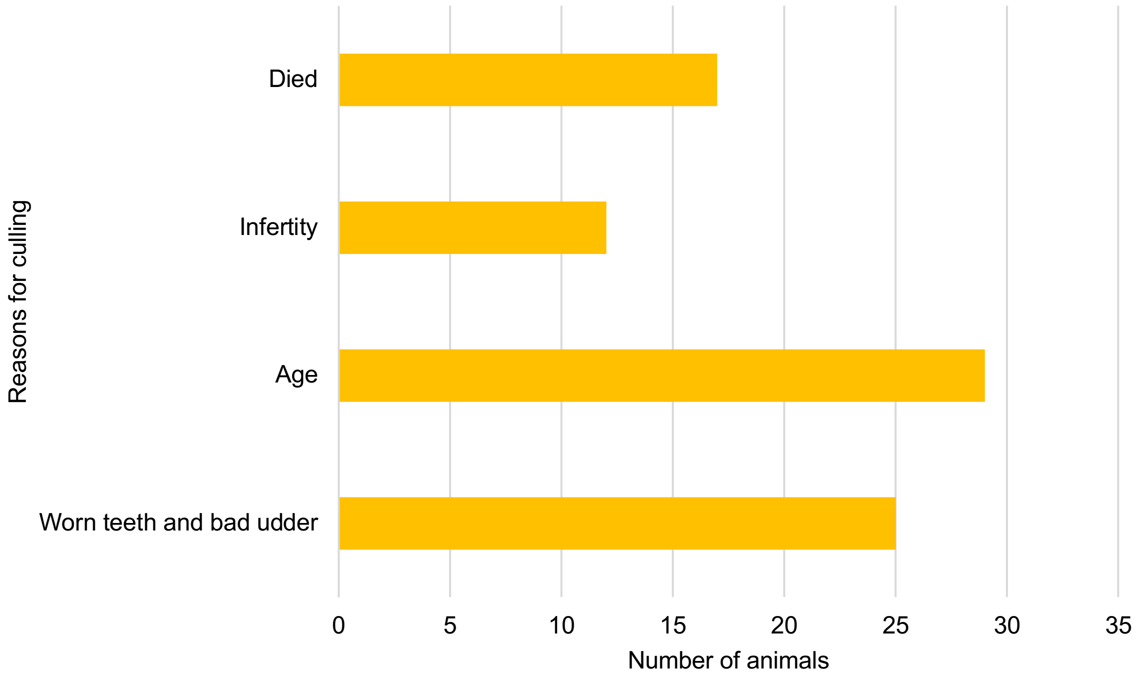

Figure 5.2 Reasons for culling in the Koopmansfontein Bonsmara herd (2014–2021)

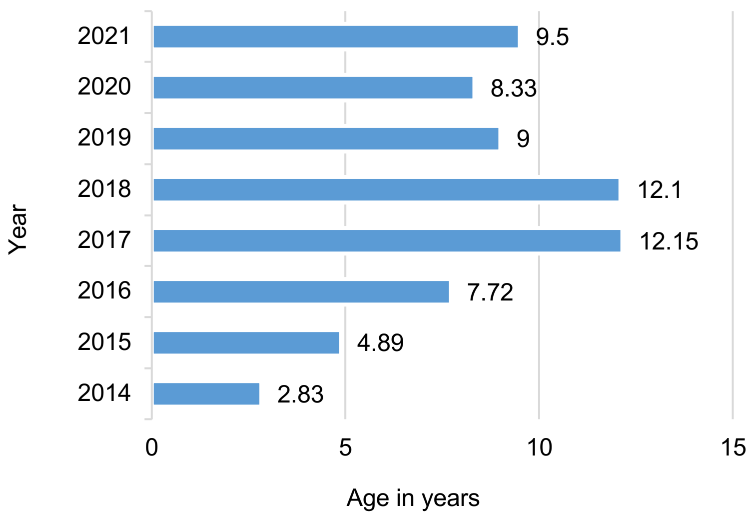

Figure 5.3 Average age of Bonsmara cows that were culled in the Koopmansfontein herd (2014–2021)

Figure 5.3 shows the average age of the animals that were culled during each year from 2014 to 2021. The number of animals culled per year were as follows: 6 in 2014, 9 in 2015, 23 in 2016, 13 in 2017, 20 in 2018, 4 in 2019, 6 in 2020, and 2 in 2021. When supplementation feeding began in 2019, the culling rate was lower than in 2018. The reasons for the difference in culling rate over different years was not clear indication that supplementation had an effect on the culling rate of the animals.

5.3 ANIMAL PRODUCTION RESULTS OF THE KOOPMANSFONTEIN BONSMARA HERD (2015-2023)

5.3.1 Calf Birth Weights

Cattle breeding relies heavily on calf birth weight as it can impact the herd's overall productivity and profitability. Birth weight is defined as the calf's live weight measured three days after birth (Vermaak, 2006). Due to its correlation with early survival and difficult calving, this trait is highly significant. Calves that are born with very low birth weights are more susceptible to environmental stresses, including cold and diseases, and require intense animal husbandry. On the other hand, extremely high birth weights result in mortality of calves and cows due to dystocia (Holland & Odde, 1992; Dzama *et al*., 2001). Birth weight of calves is related to the frame size of the breed. For different beef breeds, the reported average birth weight ranges from 15 to 51 kg (Collins-Lusweti, 2000; Maiwashe *et al*., 2002; Raphaka, 2008; Neser *et al*., 2012; Bignardi *et al*., 2014).

Table 5.1 shows that there was no significant difference in calf birth weight between 2015 and 2016. However, in 2017 and 2018, there was a significant difference. The calves had a higher mean weight in 2017 (37.3 kg) than in 2018 (34.1 kg). The fact that Koopmansfontein is a very dry area may have contributed to the low number of calves born in 2016 and 2018, yet more calves were born in the other years. Since supplemental feeding began in 2018, more calves with greater birth weights were produced by cows from 2019 to 2022. There was no significant difference in calf birth weight between 2019 and 2022, with approximately the same mean weight in those years.

Table 5.1 Corrected birth weights (kg) ± standard deviation of Bonsmara calves at Koopmansfontein Research Station (2015–2022)

Year	N	Mean	± SD
2015	40	35.5	± 3.2^{a,b}
2016	14	35.2	± 4.4^{a,b}
2017	40	37.3	± 4.1^{a}
2018	15	34.1	± 6.9^{b}
2019	30	36.6	± 5.6^{a}
2020	46	35.7	± 4.8^{a,b}
2021	49	36.7	± 5.2^{a}
2022	38	36.4	± 3.9^{a,b}

^{a,b} Means with different superscripts differ significantly at $P \leq 0.05$

5.3.2 Calf Weaning Weights

The weights of the calves at weaning in 2015 and 2016 differed significantly. Although the calves weaned in 2015 weighed less (119.9 kg) on average than the calves weaned in 2016 (133.5 kg), it should be noted that there were more calves weaned in 2015 than in 2016. At weaning, there was no discernible difference between the mean weight of the 2017 (145.8 kg) and 2018 (148.4 kg) calves. Although more calves were weaned in 2017 than in 2018, the calf weights were similar. From 2019 to 2022, the weaning weights of the calves were approximately the same. The years 2015 to 2018 saw the lowest calf weaning weights, which ranged from 119.9 kg to 148.4 kg, and the years 2019 to 2022 had substantially higher calf weaning weights, which ranged from 168.9 kg to 183.5 kg.

The first four years of weaning and the latter four years show a significant difference. Supplementary feeding had a positive effect on the body condition of lactating cows, leading to increase milk production. Higher milk yield positively influenced the calf growth rate, resulting in higher weaning weights. These finding could, in part, be explained by weather conditions. In 2015, the Northern Cape experienced an extremely dry and warm year, which had a significant impact on livestock in the region. The combination of low rainfall and high temperatures resulted in limited available grazing pastures. The scarcity of rainfall during that year stunted the growth and regeneration of the vegetation and grasslands in the Northern Cape. This resulted in lack of nutritious pastures for the livestock to graze on, leading to weight loss. However, supplementary feeding began in 2018 at Koopmansfontein, which had a significant impact on calf growth rate and weaning weights, causing them to be higher in the last four years of weaning than in the first four years. The weight of calves during weaning can be positively influenced by proper feeding. These results are in agreement with those of Chang *et al*. (2021), who state that calves that are heavier at birth are more likely to have higher weaning weights, which could improve the reproductive performance of the dam.

Table 5.2 205-day corrected weaning weights (kg) mean ± standard deviation of calves weaned (2015–2022)

Year	N	Mean ± SD
2015	30	119.9 ± 30.2c
2016	14	133.5 ± 26.6b,c
2017	39	145.8 ± 25.2b
2018	15	148.4 ± 30.4b
2019	27	183.5 ± 21.9a
2020	44	168.9 ± 26.8a
2021	48	173.7 ± 42.6a
2022	38	169.0 ± 34.5a

^{a,b,c} Means with different superscripts differ significantly at $P \leq 0.05$

5.3.3 Average Daily Gain of Weaner Calves

The amount of weight that an animal gains each day is referred to as ADG (USDA, 2011). The ADG of weaner calves in South African cattle varies depending on factors such as agro-ecological zone, season of birth, and management practices (Mpofu *et al*., 2017). In this study, the ADG was calculated by subtracting birth weight from weaning weight (at 205 days) and then dividing it by 205 to determine the daily gain.

Table 5.3 shows an overview of the ADG mean ± standard deviation at Sterkfontein for each year from 2015 to 2022. It can be seen that weaner calves did not gain a significant amount of weight every day for all the years analysed. From 2015 to 2018, the weaner calves had the lowest ADG values. The ADG of calves was the highest and their growth rate was faster between 2019 and 2022. These findings demonstrate that supplementation has a favourable influence on cow efficiency, which shows that more calves with greater birth weights were born from 2019 to 2022 after supplementary feeding began in 2018. Rainfall in 2020–2022 also had a positive impact on livestock ADG since there was enough nutritious pasture for all the cows to graze and maintain good body condition. Good grazing is also beneficial for farmers, as they can spend less on supplemental feed, which in turn reduces the overall cost of raising heifers. According to a previous study (De Vries *et al*., 2005), feeding cattle more regularly increases feed intake and possibly decreases the prevalence of acidosis. Gibson (1981) observed that enhanced ADG is correlated with a higher intake of dry matter.

Table 5.3 Average daily gain (kg) of weaner calves mean ± standard deviation

Year	Mean ± SD
2015	0.41 ± 0.14c
2016	0.47 ± 0.13b,c
2017	0.53 ± 0.11b
2018	0.55 ± 0.13b
2019	0.71 ± 0.10a
2020	0.64 ± 0.12a
2021	0.66 ± 0.20a
2022	0.64 ± 0.16a

5.3.4 Cow Weight Before Mating and Body Condition Score

It has been found that a cow's weight prior to mating significantly influences her ability to reproduce and her long-term productivity. Numerous research studies have looked at the relationship between different reproductive and production traits and cow weight prior to mating.

In this study, body weight was recorded electronically and BCS was recorded by a single operator on a scale of 1 to 5. The weight data were subjected to a factorial analysis of variance (ANOVA) to test for significant main effects and interactions using SAS version 9.4 statistical software (SAS Institute, 2016). The residuals were examined for deviations from normality, and outliers causing skewness were removed. Fisher's protected t-LSD (Least Significant Difference) was calculated to compare treatment means of significant effects (Ott, 1998).

From Table 5.4, it can be seen that cow weight before mating in 2015/2016 varied greatly. The mean weight of the calving cows was higher ($P < 0.05$, 356.45 kg) than that of the non-calving cows (299.73 kg). In the subsequent year, 2016/2017, there was no discernible variation in the animals' weight before mating; those that did not calve had a mean weight of 386.86 kg, while those that calved had a mean weight of 396.00 kg. In 2017/2018, there was a significant difference in the weight of the cows that did not calve (365.86 kg) compared to those that calved (404.35 kg), indicating that the cows that calved were in a much better body condition. There was an observable difference in weight before mating between the years 2018 and 2023. Animals that calved had a significantly higher mean weight than those that did not calve. The animals that successfully calved had a substantially higher weight overall, indicating that they were able to fall pregnant and calve.

Table 5.4 Mean ± standard deviation of cow weight for those that did not calve vs those that calved

	Did not calve		Calved	
Year	**N**	**Mean ± SD**	**N**	**Mean ± SD**
2015/2016	56	299.73 ± 57.8^{i}	40	$356.45 \pm 43.8^{g,h}$
2016/2017	37	$386.86 \pm 43.5^{c,d,e,f}$	35	$396.00 \pm 29.5^{c,d,e}$
2017/2018	28	$365.86 \pm 23.0^{f,g,h}$	40	$404.35 \pm 40.5^{c,d}$
2018/2019	37	$379.43 \pm 48.2^{d,e,f,g}$	15	407.87 ± 41.9^{c}
2019/2020	29	344.62 ± 50.9^{h}	30	$414.67 \pm 57.3^{a,b,c}$
2020/2021	34	346.12 ± 52.3^{h}	45	$375.60 \pm 81.1^{e,f,g}$
2021/2022	26	$355.00 \pm 39.0^{g,h}$	50	$434.40 \pm 57.8^{a,b}$
2022/2023	39	$366.67 \pm 43.7^{f,g,h}$	38	438.45 ± 47.9^{a}

^{a,b,c,d,e,f,g} Means with different superscripts differ significantly at $P \leq 0.05$

Table 5.5 Means ± standard deviation of cow body condition score before mating

	Did not calve		Calved	
Year	**N**	**Mean ± SD**	**N**	**Mean ± SD**
2015/2016	56	2.69 ± 0.60^{f}	40	$3.30 \pm 0.50^{b,c,d}$
2016/2017	37	$3.54 \pm 0.47^{a,b}$	35	3.66 ± 0.28^{a}
2017/2018	28	$3.25 \pm 0.28^{c,d}$	40	3.68 ± 0.35^{a}
2018/2019	37	$3.37 \pm 0.44^{b,c}$	15	3.70 ± 0.36^{a}
2019/2020	29	3.10 ± 0.52^{d}	30	3.76 ± 0.43^{a}
2020/2021	34	$3.07 \pm 0.50^{d,e}$	45	$3.52 \pm 0.58^{a,b,c}$
2021/2022	26	$2.82 \pm 0.46^{e,f}$	50	3.68 ± 0.64^{a}
2022/2023	39	$3.03 \pm 0.40^{d,e}$	38	3.73 ± 0.50^{a}

^{a,b,c,d,e,f} Means with different superscripts in the table differ significantly at $P \leq 0.05$

Table 5.5 shows that there was a significant difference in the BCS of the cows prior to mating in 2015/2016; the animals that did not calve had a lower BCS than the ones that calved. Additionally, of the 96 animals that were mated in that year, only 40 calved. The animals in the 2016/2017 breeding season had the same BCS score before mating, therefore there was no discernible variation. However, the 35 cows that calved had a BCS of 3.66. Between 2017 and 2022, there was a notable variation in BCS throughout the years. Compared to animals that did not calve, those that calved had a significantly greater BCS. Supplementary feeding began in 2018 and can thus be seen to have had a significant impact on the animals' ability to reproduce. Tables 5.4 and 5.5 show that supplementary feeding helped the animals achieve the optimal weight and BCS before mating. According to Nazhat (2021), low BCS causes a longer ICP, lower fertility, and delay the start of oestrus. This study thus confirms that there is a correlation between fertility and management of nutrition.

According to Scholtz *et al*. (2016), beef calf weaning weight is a significant factor in cow efficiency, and it contributes to the overall productivity of beef production. Breed, age of dam, year of birth, and sex of the calf are some of the factors that influence the weaning weight of the calf (Szabo & Dakay, 2009; Scholtz *et al*., 2016).

Furthermore, John *et al*. (2022) state that cow LSU is a measure of feed requirements and linked to daily feed intake. Additionally, it makes a smaller contribution to cow efficiency compared to weaning weight and ICP.

5.3.5 Effect on cow productivity

The study evaluated the weights of the beef calves for 205-day weaning weights of the cow LSU and kg calf weaned/LSU. As mentioned in Chapter Three, the medium-frame LSU equation was used calculate to the LSU (Mokolobate *et al*., 2015):

$$\mathrm{Y} = 0.220714286 + 0.0030978571{*}\mathrm{X} - 0.0000010714{*}\mathrm{X}^2$$

The carrying capacity of Koopmansfontein Research Station is 18 LSU/ha. The kg calf weaned/LSU was divided by 18 LSU/ha to get the kg calf weaned/ha.

Some of the calves died before they could be weaned, hence fewer calves were weaned than were born.

Table 5.6 The kg calf weaned/LSU, total kg calf weaned/year, and kg calf weaned/ha at Koopmansfontein (2016–2023)

Year	N (cow-calf unit)	LSU	kg calf weaned/LSU	Total kg calf weaned/year	kg calf weaned/ha
2016	35	1.25 ± 0.13^{a}	99.9 ± 21.8^{e}	3496.5	5.56
2017	12	$1.20 \pm 0.06^{a,b,c}$	$112.2 \pm 22.5^{e,d}$	1346.4	6.23
2018	39	$1.21 \pm 0.16^{a,b}$	$123.6 \pm 31.5^{c,d}$	4820.4	6.86
2019	14	1.13 ± 0.15^{d}	$135.5 \pm 35.8^{c,b}$	1897.0	7.53
2020	27	1.14 ± 0.16^{d}	163.6 ± 27.0^{a}	4417.2	9.08
2021	44	1.15 ± 0.12^{d}	146.9 ± 21.5^{b}	6463.6	8.16
2022	48	$1.20 \pm 0.10^{a,b,c}$	144.2 ± 31.6^{b}	6921.6	8.01
2023	38	$1.17 \pm 0.12^{b,c,d}$	145.2 ± 27.9^{b}	5517.6	8.06

^{a,b,c} Means with different superscripts in the table differ significantly at $P \leq 0.05$

In 2016 and 2017, kg calf weaned/LSU (99.9 kg and 112.2 kg, respectively) did not differ ($P > 0.05$). Although there were 35 calves weaned in 2016 compared to 12 in 2017, their kg calf-weaned/LSU were almost the same. In 2018, the kg calf weaned/LSU (123.6 kg) was much higher than in 2016 and 2017, and more calves (39) were weaned as well. The 2018 kg calf weaned/LSU (123.6 kg) did not differ significantly from the 2019 kg calf weaned/LSU (135.5 kg); however, there were fewer (14) calves weaned in 2019 than in 2018 (39 calves); hence, the 2019 kg calf weaned/LSU was 135.5 kg. With 27 calves weaned in 2020, this year had the highest kg calf weaned/LSU (163.6 kg) compared to other years. In 2021–2023, there was little change in the kg calf weaned/LSU, and their mean weights were almost the same.

There was a significant difference in the total kg calf-weaned/LSU/year among all years. The kg calf weaned/year in 2016 (3496.5 kg) was substantially higher than in 2017 (1346.4 kg). The total kg calf weaned/year amount was lower in 2017 and 2019, but higher in the other years, indicating an increase in productivity over time.

The kg calf weaned/ha showed an increase over the years, with the highest kg in 2020 (9.08 kg/ha) and the lowest in 2016 (5.56 kg/ha).

These results show that there is significant difference in productivity of the LSU in terms of kg calf weaned/year across the different years.

Table 5.7 Calving percentage of the animals mated (2016–2023)

Years	N (cows that did not calve)	N (cows that calved)	Calving %
2016	56	40	41.67
2017	38	14	26.92
2018	28	40	58.82
2019	37	15	28.85
2020	29	30	50.85
2021	34	46	57.50
2022	26	50	65.79
2023	39	38	49.35

Table 5.7 shows that, with some variation in between, the number of cows that failed to calve decreased from 56 in 2016 to 26 in 2022. It is possible that, after arriving at the Koopmansfontein Research Station in 2015 from Wesselsvlei Farm in the Northern Cape province, the animals were still adapting to their new surroundings. However, the number of cows that calved varied from year to year, with the highest number recorded in 2022 (50) and the lowest in 2017 (14).

Experimental data involving frequencies may be subjected to analysis by the contingency table method – that is, the Chi-square test for an R x C contingency table. In this study, the Chi-square test was applied on the proportion of calves born in the different years.

Between 2017 and 2022, calving percentage varied from 26.92 to 65.79%. This indicates that there was a difference in the percentage of cows that successfully calved over the years. The cows began to receive production lick in 2018, and the calving percentage started to improve accordingly from 2020 to 2023.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

The weight of cows before mating plays a crucial role in their ability to conceive and successfully produce calves. Cows with higher weights are more likely to become pregnant and have healthier calves. This study confirms a correlation between fertility and nutrition management, suggesting that maintaining appropriate nutrition levels through measures like supplementary feeding can improve reproductive outcomes in cows. It is important for cows' reproductive success to manage and optimise their nutrition, with higher BCS being associated with increased chances of successful calving and improved fertility rates. Proper supplementation can positively influence calf weights during weaning, aligning with previous research that suggests heavier calves at birth have higher weaning weights and improved reproductive performance. Furthermore, higher rainfall and subsequent improved grazing conditions can increase the carrying capacity of the land. This means that more livestock can be sustained on the available pastures, allowing farmers to expand their herd. This, in turn, can have a positive economic implication for livestock farmers, as it potentially increases their production and profitability.

The study demonstrates significant differences in kg calf weaned per year and per LSU between the years analysed. There was an improvement in productivity over time, with higher values observed in later years. Additionally, there was a consistent increase in kg calf weaned per ha over the years.

The culling of cows at Koopmansfontein Research Station was mainly due to worn teeth, age, poor cow teats, and infertility, which has a significant impact on cow efficiency. Cows culled at a young age did not produce enough calves to recover development costs, and the average age of culled animals varied each year.

From this study, it is clear that supplementing growing heifers with production lick during the winter months in the Kalahari bushveld has a positive effect on growth and calving percentage. This study also recommends that faster growth rates may result in higher cow weight at calving. Providing good nutrition and supplementation to heifers before their first breeding season and afterwards can significantly improve calving percentage and calf weaning weight up to the third calving season, as supported by previous studies. This highlights the importance of proper feeding and supplementation to enhance heifer reproductive performance and overall efficiency.

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