Effects of non-genetic factors on beef production in a communal system in Botswana

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ABSTRACT
Effects of non-genetic factors on beef production in a communal system in Botswana

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For years indigenous cattle breeds in communal areas have been and still are managed in adverse production environments. As a result, their growth and reproduction efficiency have been affected. Poor management, high temperatures and low rainfall generally contribute to low productivity more so in areas where cattle only feed off the veld. Improved management can however boost growth, conception and fertility levels of these animals. The study focused on the effects of breed type, sex, cow age, cow size, previous parous state, month and year of calving on reproduction and general growth traits of extensively managed Tswana and Composite beef cattle in a communal production system. A total of 6725 BWT, 5779 WWT, 5258 18MWT, 6753 CPWT, 5747 CWWT and 5313 ICP records were included in the analyses. Complete growth and reproduction records collected by the Department of Agricultural Research (DAR) of Botswana from 1993 - 2014 were analysed by means of the General Linear Model (GLM) procedure in SAS, and differences between means were tested at $P < 0.05$. Results revealed that Composite calves grew faster and were more responsive to harsh environmental conditions. The Tswana calves showed little weight changes during years when rainfall was above and below average. Bull calves were heavier than heifers at all stages of growth. The study also found significant cow size and age effects on weight traits in both breeds. Calves born early in the season were lighter at birth but heavier at weaning and 18 months in both breeds. The effect of month of calving on cow weights showed that late calving Composite cows lost more weight from parturition to weaning than early calvers. Intercalving period varied between 361.1 - 692.5 days for Composite cows, while for Tswana cows the variation ranged from 395.5 - 705.4 days. Most cows had delayed conception for 6 - 7 months after their last calving.

DECLARATION

I, Anna Nelago Shaanika declare that this thesis which I hereby submit for the degree MSc Agric Animal Science at the University of Pretoria is my own work and has not previously been submitted by me for a degree at this or any other institution.

Signature…………………………

Date………………………………

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LIST OF ABBREVIATIONS

18 MWT	18 months weight
AFC	Age at first calving
ARC	Agricultural Research Council
BCS	Body condition score
BWT	Birth weight
CE	Cow efficiency
CPWT	Cow parturition weight
CWWT	Cow weight at calf weaning
DTC	Days to conception
DAR	Department of Agricultural Research
GHG	Greenhouse gases
GLM	General linear model
HE	Herd efficiency
ICP	Intercalving period
MAX	Maximum
MCF	Mastercard foundation
MIN	Minimum
N	Number of observations
PPS	Previous parous state
SAS	Statistical analysis systems
SC	Scrotal circumference
SD	Standard deviation
SE	Standard error
VS	Versus
WWT	Calf weaning weight

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CHAPTER 1:
INTRODUCTION

1.1 Project title

Effects of non-genetic factors on beef production in a communal system in Botswana

1.2 Project theme

Livestock production and ecology with a focus on animal - environment interaction between two breeds (Tswana and Composite) in a communal area where cattle are fully dependent on the natural veld.

1.3 Aim

To quantify the effects of non-genetic factors on beef production (reproduction and calf growth) in a communal system in Botswana.

Specific objectives were:

i. To quantify the effects of breed type (Tswana vs. Composite) on beef production (reproduction and calf growth) in a communal system in Botswana.
ii. To quantify the effects of cow size on beef production (reproduction and calf growth) in a communal system in Botswana.
iii. To quantify the effects of age on beef production (reproduction and calf growth) in a communal system in Botswana.

1.4 Motivation

Beef production is an important part of the agricultural sector of some countries in southern Africa e.g. Botswana, as it contributes greatly to the economy. For example, in Botswana 96% of the beef population comes from the communal areas (Raphaka, 2008). It is thus of vital importance to consider growth and reproduction parameters to boost production levels. In Africa, communal production systems are characterized by low levels of production and management inputs (Mpofu, 2002a), hence the most adapted cattle tend to be of smaller frame size. Therefore, in a communal production system where feed is restricted, and cattle rarely receive any form of supplementation, cow size and breed type may influence reproduction in terms of reconception and intercalving period (ICP). It is important to retain productive animals in a herd and ICP is one of the factors that determines the reproductive performance of cows. Cows with the shortest calving intervals are often considered most fertile and are reproductively the most efficient, thus preferred over cows with longer calving intervals (MacGregor & Casey, 1999). It therefore follows that a cow should be able to rear a strong calf and reconceive within 3 months after calving (Gusha *et al.*, 2013). However, in semi-arid regions, poor nutrition and heat stress have been identified as major causes of long calving intervals (Ball & Peters, 2004).

Growth performance of indigenous breeds is relatively slower compared to exotic breeds. In extensive beef production, cow size and growth rate should be considered in relation to feed availability. Although it is evident from several studies that dam age influences weight traits of calves of different breeds (MacGregor & Casey, 2000; Renquist *et al*., 2006; Mangwiro *et al*, 2013; Scholtz *et al*., 2017), there is paucity of information under natural conditions in communal production systems. Furthermore, calf growth and cow reproduction may be influenced by other non-genetic factors e.g. season or month of calving, year of birth and previous parous state. Sex of calf may genetically influence calf growth as well. Therefore, it would be unwise to ignore these factors in cattle production.

Breed types generally kept in communal systems tend to be mostly indigenous cattle. Farmers recently started employing exotic breeds in crossbreeding programs to improve cattle production. Botswana keeps the indigenous Tswana cattle and these animals are increasingly crossed with Composite cattle breeds. Indigenous breeds have shown production differences, especially in arid regions (Moyo *et al.*, 1996; Strydom, 2008). Their performance is often considered lower over exotic breeds, but under right management their production levels can be satisfactory (Schoeman, 1989). Reproductive performance and survival in exotic breeds may differ from that of indigenous breeds due to lack of adaptation (Mpofu, 2002a). However, the perception is that they perform relatively well with regards to progeny growth and respond well to feeding in intensive production systems e.g. feedlots. There is some speculation that the adaptability and performance of Botswana Composite cattle may be the same as that of the Tswana breed since the Botswana Composite breed was developed back in the 1970s.

Knowledge on the performance of indigenous breeds, in particular the Tswana breed, is relevant in comparing the effectiveness of native breeds to exotic breeds. Furthermore, there is insufficient information on the production efficiency of indigenous cattle in natural conditions (Du Plessis *et al.*, 2006). The increasing pressure on sustainable cattle production systems with minimal environmental impact has raised concerns about the use of Composites as opposed to indigenous cattle breeds. There is an associated increase in cow size and production characteristics but the long-term effects on beef production and reproduction efficiency in communal systems in Serowe, Botswana are uncertain.

The purpose of the current study was to investigate the effects of breed type, cow size and age and on reproduction traits (in this study quantified in terms of intercalving period and days to conception) in addition to the general growth factors. The study was not on ranching systems, but rather in communal cattle production systems where comprehensive and accurate data is very limited. Furthermore, there is minimal production and management inputs in communal systems e.g. additional feed or lick supplement, so the study will give a true indication of the maximum interaction between the animals and the environment.

1.5 Hypotheses

The study hypothesized that:

H_0: Non-genetic factors do not influence beef production in a communal system in Botswana.

H_A: Non-genetic factors influence beef production in a communal system in Botswana.

CHAPTER 2:
LITERATURE REVIEW

This chapter highlights beef production in southern Africa, cattle breeds commonly found in southern Africa and performance difference between indigenous and exotic breeds. Southern Africa is indigenous to breeds such as Nguni, Tuli, Tswana, Mashona, Afrikaner, Nkone, Brahman and Bonsmara. The exotic breeds include Hereford, Simmental, Santa Gertrudis and Charolais etc. The chapter further discusses the difference between communal and commercial production system. It reviews cattle production systems with emphasis on the communal production system in Botswana and how cattle perform under natural veld conditions in terms of production and reproduction. Factors affecting cow reproduction as well as growth performance of calves.

2.1 Beef production

Beef cattle in southern Africa are mostly reared on natural pasture in extensive production system (Webb & Erasmus, 2013), either on communal or commercial land. The term cattle include domesticated cattle of European origin (*Bos Taurus* known as exotic or taurine cattle), Indian and African origin (*Bos indicus* known as Zebu cattle) (Hafez, 1968). *Bos indicus* cattle have a hump on their shoulders, whereas the *Bos taurus* are hump less. The *Bos indicus* breeds have the ability to tolerate the hot environmental conditions of southern Africa compared to taurine breeds, which are exotic (Schoeman, 1989). Breed is a population of animals that share a common ancestry, possess certain common physical characteristics (i.e. colour, horn shape and size, presence and location of hump) (Herring, 2014). They share similar production characteristics related to body composition, size and growth potential. Environmental conditions in which livestock is produced greatly varies (Hafez, 1968). It is these environmental conditions that influence the productivity and performance of animals. Southern African environments are characterized by high temperatures with erratic summer rainfall and varying biomes e.g. savanna, Nama Karoo, Deserts, succulent Karoo and grasslands (Rutherford *et al*., 2006). The quality of natural veld or pasture tend to vary depending on rainfall and geology of the region. The goal of commercial beef production is to have cows that calve annually to maintain an acceptable reproduction rate and hence production efficiency.

"Adaptation" is the capacity and process of adjustment of the animal to itself, to other living material and to its external physical environment (Hafez, 1968). Prayaga & Henshall

(2005), defined adaptation in the context of survivability and ability of an animal to reproduce within its defined environment. Adaptation determines livestock production efficiency, such that there must be favourable interaction between the total environment and total genetic make-up of the animal (Bonsma, 1980; Meaker, 1984). Cattle which fail to adapt to heat often lack appetite which may result in stunted growth and lower fertility (De Lange, 2000).

Bos indicus breeds are known for late puberty than European breeds and therefore heifers are mated as late as 3 or 4 years (Maule, 1973; Mukasa-Mugerwa, 1989; Bishop & Pfeiffer, 2008). Ideally heifers should be mated at about 18-24 months, because this is the time when they are expected to have reached puberty (Taylor *et al*., 2008). This means that heifers and cows should be mated when they have attained the right body weight for maximum conception. The right breeding weight is determined when the heifer reaches 60-65% of its expected mature weight (Bergh, 2004). Different breeds of cattle are found in southern Africa depending on the environment and production purpose. For example, the Afrikaner breed which was developed from the Brahman breed was one of the earliest breeds introduced in Africa more specifically in south Africa, Zambia, Zimbabwe and eastern Africa (Hafez, 1968). Commonly found cattle breeds in Namibia are Afrikaner, Bonsmara, Hereford, Santa Gertrudis, Simmental, Brahman and Nguni (Schoeman, 1989). The indigenous cattle breeds found in Botswana are mostly Tuli and Tswana while exotic breeds are Brahman, Simmental, Hereford, south Devon, Santa Gertrudis, Holstein Friesian, Charolais, Sussex and Jersey (Nsoso & Morake, 1999). Mashona, Tuli and Nkone breeds are native to Zimbabwe (Mpofu, 1996). Mozambique is known for Landim, Angone and Bovino de Tete cattle breeds (Bessa *et al*., 2009)

2.2 Performance of indigenous and exotic breeds

The production and reproduction potential of cattle differs based on genetics and environmental factors. A study by Du Plessis *et al*. (2006) found that Nguni was the most effective breed in terms of reproduction traits. This was in comparison to the Afrikaner, Bonsmara and Simmental breeds. Furthermore, large framed breeds e.g. Simmental were observed to give birth to fast growing calves that were heavier at weaning and therefore ideal for feedlot systems. Maule (1973) concurred with the latter and stated that European breeds are heavier at weaning in comparison to indigenous breeds. The author ruled out some factors that influence weaning weight such as season of calving, breed, age of cow, milk production and climate. Small framed, indigenous breeds e.g. Nguni perform well under extensive grazing system and may be better suited to extensive finishing systems (Du Plessis *et al*., 2006). Maule

(1973) observed that the Afrikaner breed performed poor in terms of calving rate as compared to other indigenous breeds. Also, the latter breed's performance is affected by location, such that Afrikaner cattle from Omatjene research station may perform differently from the one in Mara research station. Based on Omatjene research station reports from 1977- 1986, Nguni breed was reported to have shown outstanding performance in terms of calving percentage of 89.9% (Maule, 1973). On the other hand, exotic breeds were reported to have a sound calving rate as well: Santa Gertrudis (79.6%), Hereford (77.9%), Simmental (77.6%) and Afrikaner (74.6%). In another investigation, the Afrikaner cattle breed was regarded as the least efficient breed (Schoeman, 1989). The experiment showed that Sanga and Santa Gertrudis breeds did not experience any dystocia and had relatively low birth to weaning mortalities (3.61 % and 4.52%). The author concluded that low mortality is a good indication of reproductive efficiency of indigenous breeds under extensive production systems. Most exotic breeds are expected to have higher birth weights than indigenous breeds. This was confirmed by Schoeman (1996) when Shorthorn, Angus, Charolais, Santa Gertrudis and Simmental calves had relatively higher birth weights than Nguni, Afrikaner, Brahman, Bonsmara, Hereford and Limousin calves. Furthermore, shorthorn, Santa Gertrudis and Simmental showed the highest preweaning efficiency while the Afrikaner, Nguni, Hereford and Sussex were the least efficient.

2.3 Beef production systems

Beef production systems deal with how animals are managed or reared to get outputs e.g. meat, wool or milk from them. Production systems in developing countries focus on increasing livestock numbers rather than productivity (Webb & Erasmus, 2013). The authors further noted that due to an increase in livestock numbers rather than productivity, developed countries continue to supply the demand of food in developing countries. Different production systems exist based on the purpose of production, input and management level. Two common systems exist namely communal or commercial.

2.3.1 Communal beef production system

Communal beef production system is often called "subsistence". This type of production system is highly characterized by low levels of production and management inputs (Mpofu, 2002a). Indigenous cattle breeds make up a larger portion of the communal sector (Strydom, 2008). In a communal set up, cattle rely entirely on the natural pasture and do not receive any form of supplementation (Tavirimirwa *et al*., 2013). In Zimbabwe, cattle are mostly herded as they graze during the day and at night kept in kraals (Tavirimirwa *et al*., 2013). Since animals are reared on the veld and the pasture relies mainly on rainfall (Du Plessis, 2005), drought is quite common in these areas. Unlike in the commercial areas where farmers can afford feedstuffs for livestock, in communal areas such is uncommon. Webb & Erasmus (2013) stated that grass feeding results in slower growth rates due to absence of hormonal growth implants and concentrate feeds. Young animals on natural pasture need supplementation during the year, more especially when the grass matures because plant structures toughen as they mature. Consequently, this slows down the rate of digestion for the ruminants such that the animal's energy for growth and maintenance is not met fast enough (Fuquay & Bearden, 1991). This explains why some of these cattle grow slower.

2.3.1.1 Communal beef production system in Botswana

According to Nsoso & Morake (1999), communal areas in Botswana practice predominantly traditional farming. This type of traditional farming is called "cattle post" system (Perkins, 1995). Cattle post system involves letting out the animal to graze in the morning and return later for night kraaling. Kraaling is an effective way of protecting the animals from predators (Perkins, 1995). The latter author stated that water is pumped from boreholes into a water trough with routine drinking in the late afternoons. Cattle in communal areas in Botswana are kept for subsistence purposes such as milk and meat production, provision of draught power, manure for the crops, cross and pure breeding (Mpofu, 1996). Conroy (2005) indicated that livestock in Botswana is also kept as a liquid asset and for cultural festivals. However, these farmers are faced by several challenges as well. There is minimal controlled breeding in these areas and as a result, it was estimated that pure Tswana cattle only makes up 50% of the cattle population and the remaining 50% is crossbreds (Senyatso & Masilo, 1996). As in other parts of southern Africa where rainfall in unreliable, drought is a common phenomenon during years when rainfall below average.

Two breeds of cattle are commonly found in Botswana namely Tswana and Composite. Tswana belongs to the Sanga type of cattle found in southern Africa (Mangwiro *et al*., 2013). It is native to Botswana but also found in Northern Cape, South Africa (Figure 2.3.1.1). The breed is characterized by different colour patterns of black, brown, grey and white (Mpofu, 1996). It is more adaptable to Botswana's harsh environmental conditions thus thrives better on poor quality and quantity nutritional stress. Therefore, it is more suited for Botswana's communal production than crossbreeds (Nsoso & Morake, 1999). Tswana is a multipurpose breed (Senyatso & Masilo, 1996), that is fertile, and the females are known for calving ease. On average, age at first calving is between 36 - 48 months (http://agtr.ilri.cgiar.org/). On the other hand, Composite cattle breed was successfully developed in Botswana under a controlled crossbreeding program. Composite breed was developed by mating different breeds in the following proportions: Tswana (28.2%), Brahman (22.6%), Simmental (26.3%), Tuli (4.4%) and Bonsmara (18.3%) (Raphaka, 2008). The Composite breed was observed to perform relatively well in terms of birth and weaning weight when compared to the Tswana breed (Raphaka & Dzama, 2009).

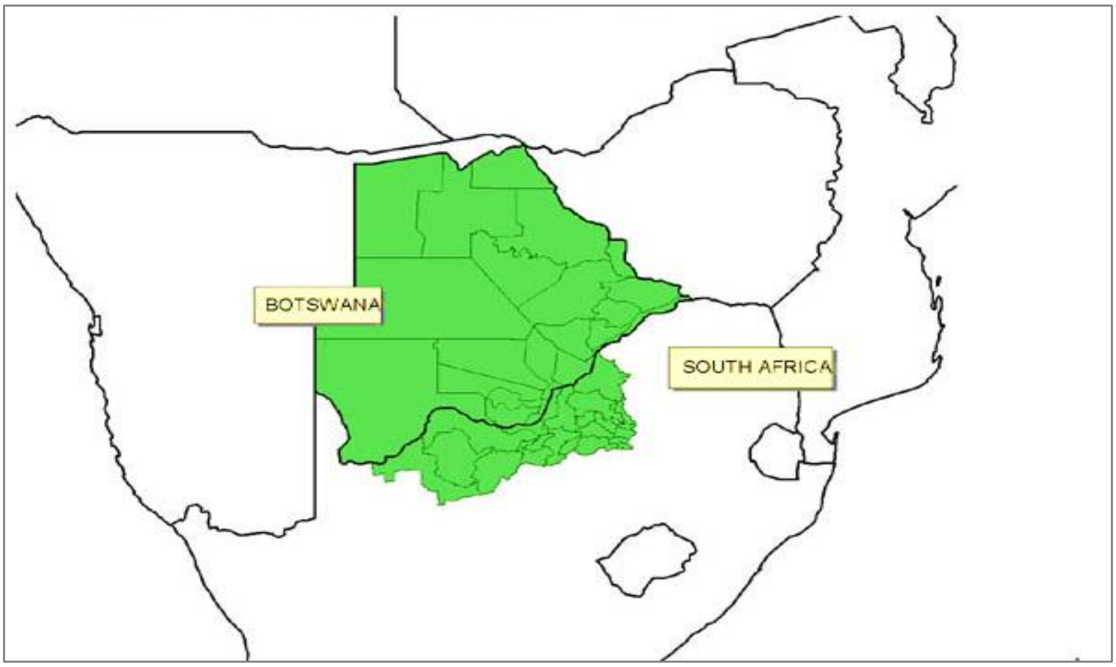

Figure 2.3.1.1 Distribution of Tswana cattle breed in Botswana and South Africa
Source : (http://agtr.ilri.cgiar.org/)

2.3.2 Commercial beef production system

Commercial beef production systems can be further subdivided into extensive and intensive beef production. According to Strydom (2008), the commercial set up comprises mostly of European and British breeds also known as "exotics". Cattle in a commercial set up are highly managed in terms of health care such as dipping and vaccination (Nowers *et al*., 2013) and controlled breeding is a common practice. Since the commercial sector is driven by profit maximization, they easily have access to formal markets (Chingala *et al*., 2017). They are therefore into weaner production (7 months), self-produced steers (27 months) and bought-in steers (bought in at 7 months and sold at 27 months) (Du Plessis, 2005). According to Du Plessis (2005) such production systems allow the producer to maintain the stocking rate and focus on the breeding cows.

2.3.2.1 Extensive and Intensive beef production

In extensive production system, animals graze on the veld freely, selecting what they prefer to feed on and often supplemented with summer or winter licks. Extensive production system is characterized by rotational grazing, where grazing is controlled by means of camps or paddocks. With rotational grazing, 50 % of the land is utilized while the remaining is being rested (Herring, 2014). In this production system, stocking density and carrying capacity assists in assessing and monitoring the available grazing to the number of animals kept on the land. Intensive production is where animals are kept in enclosed areas and do not have access to the veld but instead fed concentrates for a reason e.g. dairy and poultry production. Intensive production system is costly in terms of feeds, labour and veterinary treatments (Mpofu, 2002a).

2.4 Production efficiency

Production efficiency means the capacity to convert physical inputs (feed) into marketable product (beef) under prevailing production conditions (Notter, 2002). Scholtz *et al*. (2016) noted that an efficient cow may remain so in one environment but may not perform the same in another environment. It is, therefore, important to understand that when environmental conditions are not favourable, cattle performance declines. Production efficiency is influenced by the different environments the cattle is subjected to, hence there is no single best breed for all environments (Schoeman, 1996). Improved cattle productivity is very crucial for sustainable production without causing detrimental irreversible effects on the environment. There are ways to improve production efficiency such as through crossbreeding, breed choice and selection within breeds.

Recent studies found that livestock contributes about 5-10% towards greenhouse gas (GHG) emissions (Meissner *et al*., 2012). Due to these emissions, there is a need to make livestock production more efficient and reduce the carbon footprint of livestock in agriculture. One of the most plausible approaches to reduce the carbon footprint of livestock is by increasing production per animal. Improvement of productivity will result in reduced livestock numbers (Scholtz *et al*., 2013; 2016). There are some parameters that can be used to assess production efficiency. Based on Whittemore (1993), growth rate is one of them. It is a good indicator of efficiency because a higher growth rate is associated with a lower maintenance requirement and therefore saving on feed costs. Growth rate includes birth, pre-weaning, weaning, yearling, mature body and slaughter weight.

2.4.1 Growth as a measure of production efficiency

Growth is the change in body size as an animal matures (Herring, 2014). Animal growth exhibit what is called sigmoid or S-shaped curve (Arango & Van Vleck, 2002; Figure 2.5.1). The curve represents growth patterns of an animal as it passes through the different stages of growth namely: conception, birth, weaning and until maturity stage (Herring, 2014). The shape or steepness of the curve can vary depending on whether nutrients are in excess or deficient (Herring, 2014). From conception and throughout gestation there is little weight gain. After birth, weight begins to increase at an increasing rate. Thereafter, moving on to the exponential phase, where the animal experiences rapid growth (Hossner, 2005). The exponential phase is followed by slow growth until the animal reaches maturity which is called growth plateau and the animal stops growing (Hossner, 2005). Physiological maturity types of cattle are generally associated with the size and adaptability of cattle, e.g. earlier maturity types are fouvoured in arid and semi-arid environments since the limited natural resources are more likely to sustain smaller framed cattle as opposed to large framed cattle. Adaptation is a priority for cattle in resource constrained environments, before efficient reproduction and survival can occur. Growth efficiency is important because of the low rate at which cattle reproduce followed by the high maternal maintenance (Arango & Van Vleck, 2002).

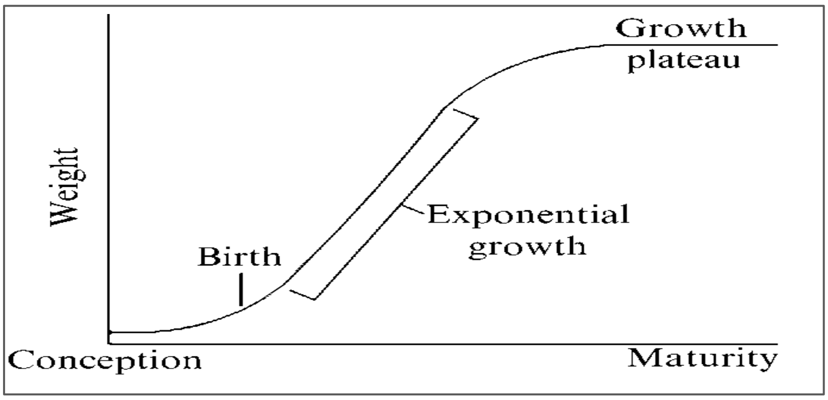

Figure 2.4.1 Growth curve
Source: Hossner (2005)

2.4.2 Factors affecting calf growth

There are several factors that affect the growth performance of calves in livestock production. These factors may be genetic or non - genetic. Calf sex and breed of sire and dam genetically influence the growth performance of calves. The non-genetic factors that can affect weight gain of beef calves may be health status of the calf, cow weight during gestation and parturition, season of calving, cow age and other environmental factors such as rainfall and temperature.

2.4.2.1 Cow breed and age

A study was done to investigate the effect of dam age and sex of calf on weaning weight of Tswana and Composite calves. The results showed that birth and weaning weight both increased with an increase in dam age and reached its peak when the animal matured (Raphaka & Dzama, 2009). Similarly, in Mashona cows the birth and weaning weight increased as well with an increase in age and showed a declining trend from 10 years (Mangwiro *et al*., 2013). MacGregor & Casey (2000) reported that beef calves from 7 year - old cows were heavier at birth than those from 3-year- old cows. Van Zyl *et al*. (1992a) also agreed that birth and weaning weight increases until 8-10 years and gradually starts to decrease. Based on results from Nguni and Nguni x Angus calves, weaning weight increased with an increase in cow age until 5 years and thereafter started declining. Crossbred calves were reported to have heavier weaning weights than pure bred calves (Scholtz *et al*., 2017). In Simmental breed, cow age showed similar results, where the birth weight was highest in calves from mature cows (Elzo *et al*., 1987). Older cows (8+ years) have a diminishing ability in provision of nutrients to the growing fetus in the uterine environment, hence the difference in weight between mature and older cows (Elzo *et al*., 1987). However, the weaning weight of Simmental calves was heavier than that of Hereford and Angus (Elzo *et al*., 1987). The differences were possibly caused by differences in milk production between the three breeds. Mature cows may have well developed mammary tissues hence they tend to wean heavier calves (Abera *et al*., 2013).

2.4.2.2 Calf sex

Many studies found that there is a difference in weight traits between the sexes, where male calves are heavier than female calves at birth and weaning (Taylor *et al*., 2008; Raphaka & Dzama, 2009; Mangwiro *et al*., 2013; Abera *et al*., 2013; Herring, 2014; Scholtz *et al*., 2017). Mangwiro *et al.* (2013) studied the effect of sex of calf on growth at weaning, yearling and 18 months. The results between male and female calves were as follows (178.1 vs 157.8 kg), (195.3 vs 177 kg) and (290.8 vs 263.2 kg) respectively. The differences in how male and female calves gain weight has a lot to do with hormonal effects (Sushma *et al*., 2006). Testosterone hormone is responsible for such changes due to its presence in higher amounts in males than females (Raphaka, 2008).

2.4.2.3 Season and year of birth

Drought is an ongoing phenomenon in Africa and southern Africa is not an exception. Livestock production is therefore directly affected by drought. Mangwiro *et al.* (2013) observed year of birth as a factor that affects the growth performance of beef calves. The study pointed out that production variations from one year to another might be attributed to the quality and availability of forage. For example, Scholtz *et al.* (2017) indicated a difference of 18.4 % in weaning weight of calves born in 2011 (180 kg) and those born in 2012 (152 kg) and concluded that this may be more pronounced in arid environments where rainfall varies. Calves should be born during the rainy season when there is ample grazing, this calls for mating cows early when it's breeding season. Calves born in December respond more favourably in terms of weight gain than calves born in September (Scholtz *et al*., 2017).

2.4.2.4 Sire breed

There is a positive correlation between sire effect on birth and weaning weight of calves (Clark *et al*., 2004). Van Zyl *et al*. (1992a) observed the growth traits of calves sired by Afrikaner, Hereford, Bonsmara and Simmental bulls. The author indicated that Simmental sired calves were heaviest at birth (39.81 kg) and weaning (232.57 kg). Bonsmara calves followed with a birth weight of 38.56 kg and weaning weight of 226.53 kg. The birth and weaning weight of Hereford calves was 37.24 kg and 230.59 kg. Afrikaner calves displayed the least birth and weaning mass 35.03 and 211.36 kg. Breed of sire should be carefully selected because it can cause calving difficulty. Rakwadi *et al*. (2016) studied growth traits in Bonsmara, Brahman and Tuli breeds under ranch conditions. Bonsmara and Brahman breeds had higher weights than Tuli breed for birth, weaning and 18-month weight. In another investigation, Charolais sired calves were reported heavier than Hereford calves at birth and weaning (Dadi *et al*., 2002). Weaning weight is an indicator of 18 months weight (Rakwadi *et al*., 2016), which implies that the higher the weaning weight the higher the 18 months weight.

2.4.3 Reproduction as a measure of production efficiency

Another parameter of production efficiency is reproduction. Reproduction efficiency is a function of the animals age in days at calving and the number of calves produced (Taylor *et al*., 2008). Reproduction efficiency reflects calves weaned per cow exposed (Notter, 2002). Cow reproductive efficiency can be improved by maintaining a short interval between parturition and subsequent conception (Messine *et al*., 2007). In beef production, the targeted reproductive efficiency is a 12-months calving interval with a gestation period of 9.5 months

(McGowan *et al*., 2014). Such reproductive efficiency is achievable if cows conceive within 2.5 months after calving. Reproduction is not entirely dependent on the cow, fertility of the bull plays a role in terms of libido and mating ability as well (Herring, 2014; Webb *et al*., 2017).

2.4.3.1 Factors affecting reproductive performance of cows

Some common parameters that affect or are used to measure reproductive efficiency are: age at first calving (AFC), intercalving period (ICP), nutrition (fertility) and breeding soundness evaluation (bull). In addition to the latter, there are several other factors that help improve a cow's reproductive performance. These factors include body condition score (BCS), cow mass, calf survival, production system as well as calf suckling.

2.4.3.1.1 Age at first calving (AFC)

Age at first calving marks the beginning of the cow's reproductive life (Dayyani *et al*., 2013). Heifers that reach maturity early will have more calves over their reproductive life than those than calve late for the first time. Some studies found that heifers mated early (13 - 15 months) before they have attained the correct weight results in poor reproductive performance (Schoeman, 1989; Scholtz *et al*., 1991). Simmental heifers mated at 14 and 26 months were reported to have achieved a calving rate of (60.8 vs 79.5 %) (van der Merwe & Schoeman, 1995). Even though 14 months old heifers had more calves over their productive life, calf mortalities were high among this age group (16.1 vs 3. 3 %). Another investigation was conducted on the influence of age at first calving in Nguni heifers (Lepen *et al*., 1993). These heifers were however reared differently and mated for the first time at 13 and 15 months. Thirteen months heifers were stall fed while 15month calves were reared off the veld. The authors found that the veld reared Nguni heifers had a slightly higher calving rate (75.9%) than the stall fed (73.3%) which calved first. A 66 % calving rate was achieved by heifers that calved at 2 years, which was lower than the 93.7% achieved by 3-year-old heifers (Meaker *et al*., 1980). The authors noted that calving rate increased with subsequent calvings in both age categories. According to Meaker *et al*. (1980) and Wiltbank (1970), high calving rates is possible among 2-year-old heifers calving for the first time, but they must reach puberty before or at least at breeding.

2.4.3.1.2 Intercalving period (ICP)

Intercalving period (ICP) is the period between two successive calvings (Rust & Groeneveld, 2001; Webb *et al*., 2017). It is divided into 2 components: calving to conception interval and gestation period (Ball & Peters, 2004). The ideal calving interval should be between 360 days and 420 days. This allows the cow to conceive early in the breeding season, calve early in the calving season without problems as well as breed back on time (Herring, 2014). Recent investigations revealed that the ICP for some breeds in southern Africa lies between 398 - 477days. This was observed in Hereford, Shorthorn, Huguenot and Bonsmara cows (Webb *et al*., 2017). They further suggested that 80 - 90 days is enough time for a cow to reconceive after calving but it differs from breed to breed. Mukasa - Mugerwa (1989) indicated that first - calving zebu heifers and older cows had the longest calving interval whereas mature cows (6 to 9 years) had the shortest. ICP contributes greatly to cow efficiency (Scholtz *et al*., 2016). ICP was observed in small, medium and large framed exotic cows. The results indicated that it contributed 41 - 51% when compared to weaning weight that contributed (32-33%). Barnard & Venter (1983) found that Sanga cattle from Omatjene research station had a relatively low intercalving period of 372 days, which might justify the high calving rates. Additionally, Medina *et al*. (2009) also reported different calving intervals among different breeds (Table 2.4.3.1.2).

Table 2.4.3.1.2 Least square means of calving interval (days) of different breeds

Breed of dam	N	Calving Interval (S.E)
Angus	261	489.0^{a} (16.5)
Brahman	773	426.6^{b} (13.8)
Brangus	88	438.0^{b} (17.9)
Brown Swiss	219	486.8^{a} (15.5)

Means with different letters are statistically different ($P < 0.05$)
Source: modified from Medina *et al*. (2009)

2.4.3.1.3 Nutrition

Extensive production systems often have limited resources from the natural pasture limiting cattle performance (Taylor *et al*., 2008). This in return aggravates the animal's fertility because the animal will be undernourished and in poor body condition. Fertility in cows is expressed as a percentage of cows mated that finally conceive or calve (Mukasa-Mugerwa, 1989). Under traditional management, fertility rates are generally low and can be boosted through improved management e.g. nutrition. In a situation where an animal is undernourished, it will use most of its energy for maintenance instead of reproduction and therefore does not come on heat. Supplementing cows with protein feeds has demonstrated high calving rates (Martin, 2007). On the contrary, cows fed energy supplements were reported to perform better than those fed protein supplements (Marston *et al*., 1995). It was reported that cows on energy supplement attained a higher pregnancy rate than protein fed cows (90 vs 79.7 %). However, calf birth weight between the two feeding regimes only differed by 1 kg (37 vs 38). Another study by Stalker *et al*. (2007) found no difference in pregnancy rates between protein supplemented and non-supplemented cows. The protein effect was however observed in calf growth before and after weaning, as the calves from protein supplemented cows attained heavier weight. Reduced dietary intake lowers fertility, Rhodes *et al*. (1996) reported ovulation failure in heifers. The authors indicated that it may be caused by low levels of luteinizing hormone released in the body, making it impossible to stimulate the maturation of the dominant follicle. Older cows tend to have reduced fertility than younger cows. Low fertility rates in older cows might be a result of the aging process as their teeth get worn out. Therefore, the cows experience a loss in body condition because of the inability to graze properly. Research has confirmed that pregnancy rate is highest (89 - 90%) in cows from 4 to 7-year-old (Osoro and Wright, 1992). Cows that are 7+ years tend to show a declining trend in pregnancy rates (Osoro & Wright, 1992). (Mukasa-Mugerwa, 1989) found that 6 to 7-year-old cows were more fertile (82%) than 2.5 years-old and older cows which had a fertility rate of <70%.

2.4.3.1.4 Breeding soundness evaluation

There is a need for breeding soundness evaluation because any defects or abnormalities with the bull may affect the reproduction potential of cows. A bull's fertility can be assessed through scrotal circumference (SC). Scrotal circumference is a measure of the testicular size, which indicates the bull's semen production (Rusk *et al*., 2002). It has been reported that scrotal circumference influences reproductive maturity and AFC of their female offspring (Grossi *et al*., 2009). The latter authors indicated that bulls with a greater SC are more likely to sire daughters that reach early reproductive maturity and AFC. A sound breeding bull should be structurally fit with masculinity. For example, it should have well-built legs, that are not bowed or knocked. A bull's hind quarter is expected to be physically smaller than the front quarter and should be wider. This aids in mounting ease and enables the cow to withstand mounting pressure. Similarly, the internal reproductive organs should be free of any defects as well. A study by Swanepoel *et al*. (2008) found that semen quality can be greatly affected in overfed bulls than in undernourished bulls. This is explained by the fact that fat accumulates in the scrotum taking up most of the space that was meant for semen (Swanepoel *et al*., 2008). Bulls that produce sperm cells that are not viable causes fertilization failure (Burns *et al*., 2010). This is because the sperm cell's ability to reach the ova is compromised. It is therefore important to adequately monitor the bull's nutrition level.

2.4.3.1.5 Calf suckling

How early or late a cow conceives may be influenced by calf suckling. Investigations by Escrivão *et al*. (2012) indicated a 21% difference in conception rates between cows that had their calves removed and those that remained with their calves until weaning. Cows that are suckled *ad libitum* do not only have low conception rates, but also have longer intervals than those with suckling restriction. Evidence proves that calf separation from the cow allows recommencement of estrous cycle (Sanz *et al*., 2003; Diskin & Kenny, 2016). Messine *et al*. (2007) correspondingly showed that restricted suckling in Gudali cows resulted in resumption of ovarian activity earlier and shorter interval from calving to conception. Herring (2014) stated that early weaning is an advantage as it allows cows to breed back on time. However, in extensive production systems, cows stop nursing as they approach the next parturition stage. Meaker (1984) also agreed that early calving cows wean early and get enough rest because the interval between calving and breeding will be shorter. So, for this reason reconception rates will increase. The opposite is expected for cows that calve late, because they do not get adequate rest after parturition. This implies that they do not return to estrus early when it's breeding season. These experiments therefore concluded that the less time calves suckle from the dam, the less time a cow takes to conceive and the higher the conception rates and vice versa.

2.4.3.1.6 Cow mass

Cows have a specific target body mass at which conception is highest. Meaker (1984) stated that above that weight there will be no further increase in conception rates. The author argued that cow mass as a measure of reconception is limited by the fact that it does not account for cow size. Van der Merwe & Schoeman (1995) suggested that Simmental heifers should reach 60 % of the mature cow weight or at least 238 kg to achieve a 70 % calving rate. Similarly, Scholtz *et al*. (1991) indicated that Nguni heifers should reach 215 kg for conception to occur. Cow hip size was also reported to have an influence on calving rate. Taylor *et al*.

(2008) observed this in Santa Gertrudis cattle under extensive production system. The results indicated that small, medium and large framed cows showed different calving rates from 1st - 3rd parity. Small and medium cows had higher calving rate (90-84%) but large framed cows had slightly lower calving rate, more especially in second parity (45.4 %). Another study by Buttram & Willham (1989), proved that small framed cows tend to be more efficient than large framed cows. This was determined after small framed cows showed a higher calving rate than large cows.

2.4.3.1.7 Body condition score (BCS)

Body condition score is a visual tool used in the assessment of fat cover on an animal's body (Roche *et al*., 2009; Petrovska & Jonkus, 2014; Akbar *et al*., 2015). It reflects the animal's health and nutritional status (Gillund e*t al*., 2001; Roche *et al*., 2009). Body condition affects reproductive performance of cows such that it can influence estrus and reconception. Cows need to be in good body condition prior to breeding and calving because this will determine the duration of anestrus (Diskin & Kenny, 2014). Nicholson & Butterworth (1986) reported that the interval between breeding and parturition tended to decrease with improved body condition of the cow. Body condition was observed to have a more significant effect on reproductive performance of cows at the beginning of the mating period than at the end (Osoro & Wright, 1992). Cows that gain weight before rebreeding have an advantage over those that lose weight (Herring, 2014). In Brahman cattle, heifers and cows with a favorable body score had a higher calving rate as well as calved earlier (Vargas *et al*., 1999). Using the American BCS scale (1-9), cows with a score of 5 or greater postpartum are in a better reproduction position because they will have adequate reserves (Mackey *et al*., 2000).

2.4.3.1.8 Calf survival

Calf survival is a component of the dam's mothering ability, which is the ability to nurture and wean a healthy vigorous calf. This inherent characteristic may be absent in exotic breeds because of the production purpose breeds are used for, a good example is the Holstein dairy breeds. However, most indigenous breeds manifest this ability due to the harsh environmental conditions they have been exposed to. In another study, survival of calves from birth to weaning was highest in indigenous breeds and was least in Charolais and Brahman calves (Mpofu, 2002b).

2.4.3.1.9 Production system

It is known that production and reproduction performance of cattle differs from one production system to another as well as management. Nowers *et al*. (2013) studied the production and reproduction performance of cattle reared under communal management and their response to commercial management. Average calving and reconception rates for communal management was relatively lower (35.7 and 25.2 %) than for those under commercial management (82.6 and 83.9%). In another experiment, Afrikaner and Simmental cows performed rather different when they were observed under sourveld and thornveld management (van Niekerk, 1986). The Simmental breed showed better calving and weaning rates than Afrikaner breed in both management systems. Although the low performance of the Afrikaner breed was not surprising due to similar results in other studies (Maule, 1973; Schoeman, 1996; Moyo *et al*., 1996), it is important to note that reproductive response of cows is greatly affected by the environment they are managed in.

CHAPTER 3:
MATERIALS AND METHODS

3.1 Study area

This study was approved by the Natural and Agricultural Sciences ethics committee of the University of Pretoria (ref no. EC171009-154). The study was based on an external data set collected by the Department of Agricultural Research (DAR) of Botswana from 1993 to 2014 in Serowe, Botswana. Botswana is a semi - arid to arid country in southern Africa that lies between latitudes 18 and 27° S and longitudes 20 and 29° E and covers an area of 58200 km^2 (Batisani & Yarnal, 2010). Serowe is a communal farming area in the eastern part of Botswana. Rainfall is highly erratic with annual figures that vary from 650 mm to <250 mm. Daily maximum temperature from July to January varies between 22 and 33 °C while minimum daily figures varies from 5 to 20 °C in July to January (Moreki & Tsopito, 2013). Seventy five percent of the country is made up un-arable land due to the Kalahari Desert (Perkins, 1996).Vegetation in the country is dominated by grass plains with clusters of trees in the eastern part and tall shrubs in central parts (www.knowbotswana.com). Botswana has a cattle population of *ca*. 2.5 million (Moreki & Tsopito, 2013).

3.2 Data collection

Data originated from extensively managed beef cattle that were in separate herds but similar conditions. These cattle were raised in large communal areas in a "Low input system" with no summer or winter supplements. Animals received veterinary care e.g. dipping (dip tank) which was provided as a government service. Breeding was by natural mating and started from January to March. Calving season was from October to January. The cows were bred with bulls of the same breed type. Pregnancy diagnosis was done 3 months after the cows were introduced to the bulls. It was performed by rectal palpation, udder observation and actual calving date. Cow age was confirmed based on the number of permanent teeth. All weight measurements were determined by means of an electronic weight scale. The information collected included birth weight (BWT), weaning weight (WWT), 18-month weight (18 MWT), date of calf birth, sire breed, dam breed and age, calf sex and identity, cow weight at parturition and calf weaning. From the reproduction aspect the information collected included previous parous state (PPS) namely: (calved: cows that gave birth for that year, skipped: cows that skipped a year without conceiving, aborted: cows that conceived but did not calve because of abortion and lastly heifers: cows that were heifers the previous breeding season). The calves remained with their dams until weaning at 7 months.

3.3 Breeds and breeding procedure

The study investigated two cattle breeds namely: Tswana and Composite. Tswana is a small framed indigenous breed in Botswana, commonly recognized by its many colour patterns. Botswana Composite on the other hand, is a crossbreed that was successfully developed by mating 5 different breeds (Tswana, Brahman, Simmental, Tuli and Bonsmara) (Raphaka, 2008). The two breeds were of interest because they make up a larger percentage of cattle in Botswana's communal systems within this region. Furthermore, recent data was availed which allows an investigation into the similarities and production potential between the two breeds. Breeding was by natural mating and started from January to March. Calving season was from October to January. Composite and Tswana cows were bred with bulls of the same breed type. A total of 160 bulls were used over the 21-years that the data was collected. Pregnancy diagnosis was done 3 months after the cows were introduced to the bulls. It was performed by rectal palpation, udder observation and actual calving date.

3.4 Statistical analyses

The data was captured in Excel spread sheet, checked for accuracy, duplicates and corrected for outliers before analyses. Outliers were removed based on values deviating more than 2 standard deviation units from biological norms. Only complete data for all reproduction and growth aspects under review were used in this study. Spread sheets were imported into SAS (2018) for statistical analyses by means of the General Linear Model (GLM) procedure. Differences between means were tested at (P <0.05) level of significance. Bonferroni's multiple range test (Samuels, 1989) was employed to determine differences between least square means and to correct for differences in the number of observations between treatment groups. Most calves were born from October to January, therefore months of calving were partitioned into two categories: (Early = October and November, Late = December and January), to distinguish between cows that calved early and late in the calving season. Cow size was divided into 3 categories based on frequency and statistical distribution of parturition weight: (Small = 425 kg, medium = 425 kg < medium < 475 kg, big = 475 kg). Previous parous state was divided into parous (1 = heifer, 2 = calved) and non - parous (3 = skipped, 4 = aborted). Year of birth was partitioned into 5 categories based on a 3-year interval, except for year 5 which had a 5-year interval. Years: 1 = 1993-1996, 2 = 1997-2000, 3 = 2001-2004, 4 =

2005-2008, 5 = 2009-2014. Cow age was done as described by Raphaka & Dzama (2009). Three and 4-year-old cows were considered young; 5-12 years as mature and older cows were ≥13 years. ICP was calculated as the difference between two successive years. Only ICP between 300 and 800 days were considered in the analyses. Days to conception was calculated using the formula:

Equation 1: ICP - 282.5 days

= reconception days

Conversion of reconception days to months:

Equation 2: $\frac{\text{reconception days}}{30.5 \text{ days}}$

= reconception in months

Note: 282.5 is the gestation period which was calculated as: (280+285/2)

(Typically, the gestation period lies between 280 and 285 days (Ball & Peters, 2004))

: 30+31=30.5 days

The linear model used is described by the following equation:

$$Y_{ijklmno} = \mu + B_i + M_j + S_k + R_l + D_m + C_n + P_o + \text{significant interactions} + eijklmno$$

Where $Y_{ijklmno}$ = variable studied during the period
μ = overall mean of the population
B_i = effect of the i^{th} dam breed
M_j = effect of the j^{th} month of calving
S_k = effect of the k^{th} sex of calf
R_l = effect of the l^{th} year category
D_m = effect of the m^{th} cow age category
C_n = effect of the n^{th} cow parturition weight
P_o = effect of the o^{th} previous parous state
$e_{ijklmno}$ = error associated with each Y

Table 3.4 Data summary of selected production and reproduction traits of Composite and Tswana cattle from 1993 to 2014 in Serowe, Botswana

Variable (trait)	Breed	Number of records	Total number of records
Birth weight	Composite	2226	6725
	Tswana	4499	
Cow parturition weight	Composite	2230	6753
	Tswana	4523	
Calf weaning weight	Composite	1873	5779
	Tswana	3906	
Cow weights at calf weaning	Composite	1864	5747
	Tswana	3883	
18 months weights	Composite	1741	5258
	Tswana	3517	
Intercalving period	Composite	1757	5313
	Tswana	3556	

CHAPTER 4:
RESULTS AND DISCUSSION

Summary statistics of variables that were recorded in this study are presented in Table 4.1. The results of the contribution of the fixed variables in the General Linear Model for calf growth traits, cow weights and intercalving period are presented in Table 4.2 and 4.3.

Table 4.1 Descriptive statistics of selected production and reproduction traits of Composite and Tswana cattle from 1993 to 2014 in Serowe, Botswana

Variable	Breed	Mean	SD	Min	Max
Birth weight	Composite	32.5	5.37	15.00	50.00
	Tswana	32.4	5.19	15.00	50.00
Cow parturition weight	Composite	444.1	70.35	232.00	632.00
	Tswana	419.5	74.46	222.00	640.00
Calf weaning weight	Composite	183.1	30.18	100.43	260.00
	Tswana	168.8	28.49	100.00	259.06
Cow weights at calf weaning	Composite	429.0	61.15	231.86	612.33
	Tswana	420.0	65.65	230.11	617.86
18 months weights	Composite	248.4	45.12	130.64	397.50
	Tswana	236.4	44.94	130.24	398.07
Intercalving period	Composite	457.1	149.42	308.00	796.00
	Tswana	447.8	145.06	301.00	800.00

Table 4.2 Least square means and significance of fixed effects for birth, weaning and 18 months weights of Composite and Tswana cattle breeds in Botswana during the period under investigation

		BWT				WWT				18 MWT			
Source of variation	DF	Type III SS	Mean Squares	F Value	Pr > F	Type III SS	Mean Squares	F Value	Pr > F	Type III SS	Mean Squares	F Value	Pr > F
Overall mean			32.43				173.45				240.36		
Breed type	1	130.26	130.26	5.68	0.0172	18933.11	18933.11	36.08	<0.0001	5290.79	5290.79	4.68	0.0305
Sex	1	2061.69	2061.69	89.84	<0.0001	33560.57	33560.57	63.95	<0.0001	123690.15	123690.15	109.45	<0.0001
Month of calving	1	850.76	850.76	37.07	<0.0001	43229.09	43229.09	82.38	<0.0001	25281.62	25281.62	22.37	<0.0001
Year of calving	4	553.48	138.37	6.03	<0.0001	40816.71	10204.18	19.44	<0.0001	167880.35	41970.09	37.14	<0.0001
Cow age	3	756.73	252.24	10.99	<0.0001	18954.18	6318.06	12.04	<0.0001	10680.16	3560.05	3.15	0.0239
Cow size	2	1037.33	518.67	22.60	<0.0001	1829.57	914.79	1.74	0.1751	14718.95	7359.48	6.51	0.0015
Previous parous state	3	473.66	157.89	6.88	0.0001	25339.60	8446.53	16.1	<0.0001	8844.11	2948.04	2.61	0.499
R-square			0.18				0.42				0.46		
Mean square error			4.79				22.91				33.62		
Coefficient of variation			14.77				13.21				13.99		

Table 4.3 Least square means and significance of fixed effects for cow weights at parturition, calf weaning and intercalving period of Composite and Tswana cattle breeds in Botswana during the period under investigation

		CPWT				CWWT				ICP			
Source of variation	DF	Type III SS	Mean Squares	F Value	Pr > F	Type III SS	Mean Squares	F Value	Pr > F	Type III SS	Mean Squares	F Value	Pr > F
Overall mean			427.61				422.91				450.86		
Breed type	1	137358.70	137358.70	35.56	<0.0001	317.80	317.80	0.15	0.6943	7140.97	7140.97	1.46	0.2269
Sex	1	-	-	-	-	2495.23	2495.23	0.21	0.2707	-	-	-	-
Month of calving	1	1704.03	1704.03	0.44	0.5066	50060.25	50060.25	24.34	<0.0001	696194.83	696194.83	22.37	<0.0001
Year of calving	4	332574.98	83143.74	21.52	<0.0001	118895.30	29723.82	14.45	<0.0001	534879.00	133719.75	37.14	<0.0001
Cow age	3	1569025.91	523008.64	135.38	<0.0001	448087.52	149362.51	72.63	<0.0001	48287.34	16095.78	3.15	0.0197
Cow size	2	-	-	-	-	10590.26	5295.13	2.57	0.0763	7618.65	3809.33	0.78	0.4588
Previous parous state	3	645171.90	215057.30	55.67	0.0001	-	-	-	-	81447797	27149265	5553	<0.0001
R-square			0.30				0.51				0.77		
Mean square Error			62.16				45.35				69.92		
Coefficient of variation			14.54				10.72				15.51		

4.1 The effects of non-genetic factors on calf growth of Composite and Tswana cattle breeds in Botswana

4.1.1 The effects of breed type on Composite and Tswana calf growth

Table 4.1.1 Effects of breed type on birth, weaning and 18 months weights (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

	Growth traits (kg)					
Breed	N	BWT	N	WWT	N	18 MWT
Composite	2226	32.1(0.26)^{A}	1873	174.2(1.47)^{A}	1741	238.3(2.20)^{A}
Tswana	4449	32.8(0.21)^{B}	3906	164.0(1.10)^{B}	3517	232.4(1.79)^{B}
Total observations	6725		5779		5258	

$^{A, B}$ Means in the same column with different superscript letters differ (*P* <0.05)
BWT~ birth weight, WWT~ calf weaning weight, 18 MWT~18 months weight

The effect of breed type was highly significant for all growth traits between the two cattle breeds (Table 4.1.1). Birth weight of Tswana calves was higher than Composite calves (*P* <0.05), but the numeric difference was small (700g), although the larger breed was expected to have higher birth weights. Nonetheless, Composite calves were 10.2 kg heavier than Tswana calves at weaning, and they also outweighed Tswana calves at 18 months, probably due to the hybrid vigour and complementarity of the Composite breed.

Although the results agree with those reported by Raphaka (2008), there were small differences in his findings, e.g. the author observed that Composite calves were only heavier (*P* <0.05) than the Tswana calves at birth and weaning. Based on the results by Rakwadi *et al*. (2016), a study conducted on Bonsmara, Brahman and Tuli calves, the birth weight (BWT) of the Bonsmara calves (32.1 kg) was comparable to that of Composite calves (32.1 kg). Boonprong *et al*. (2008) reported similar BWT (32.16 kg) in Kabinburi calves. In the same study, Thai Brahman calves weighed 28.51 kg at birth which is 3.59 and 4.29 kg less than the BWT of Composite and Tswana calves. Bonsmara and Belmont red calves were reported to have a BWT of 37.3 and 35.9 kg (Corbet *et al*., 2006). In another investigation, Dadi *et al*.

(2002) also reported that the BWT of Bonsmara calves was 35.0 kg. The weight of the latter calves was 2.9 kg heavier than that observed in the Composite calves. These values were higher than that observed in the present study.

Weaning weights (WWT) of Composite and Tswana calves in this study were higher than that reported in Thai Brahman (142.82 kg) but lower than that of Kabinburi (188.24 kg) calves (Boonprong *et al*., 2008). In another study, Brahman calves had a WWT comparable to that of Composite calves (174.2 vs 175.0 kg) (Rakwadi *et al*., 2016). Corbet *et al*. (2006) reported WWT in Bonsmara and Belmont red calves as 199 and 198 kg. The weights of the latter breed types were relatively heavier than that of the Composite and Tswana calves.

According to Rakwadi *et al*. (2016) there is a linear relationship between WWT and 18 MWT, implying that the higher the WWT the higher the 18MWT. Literature has proven that Composite or exotic breeds usually outweigh the natives e.g. Tswana and Tuli (Schoeman, 1989; Moyo *et al*., 1996; Schoeman, 1996). In General, that may not necessarily make them superior, but rather a genetic effect and size differences (Schoeman, 1996).

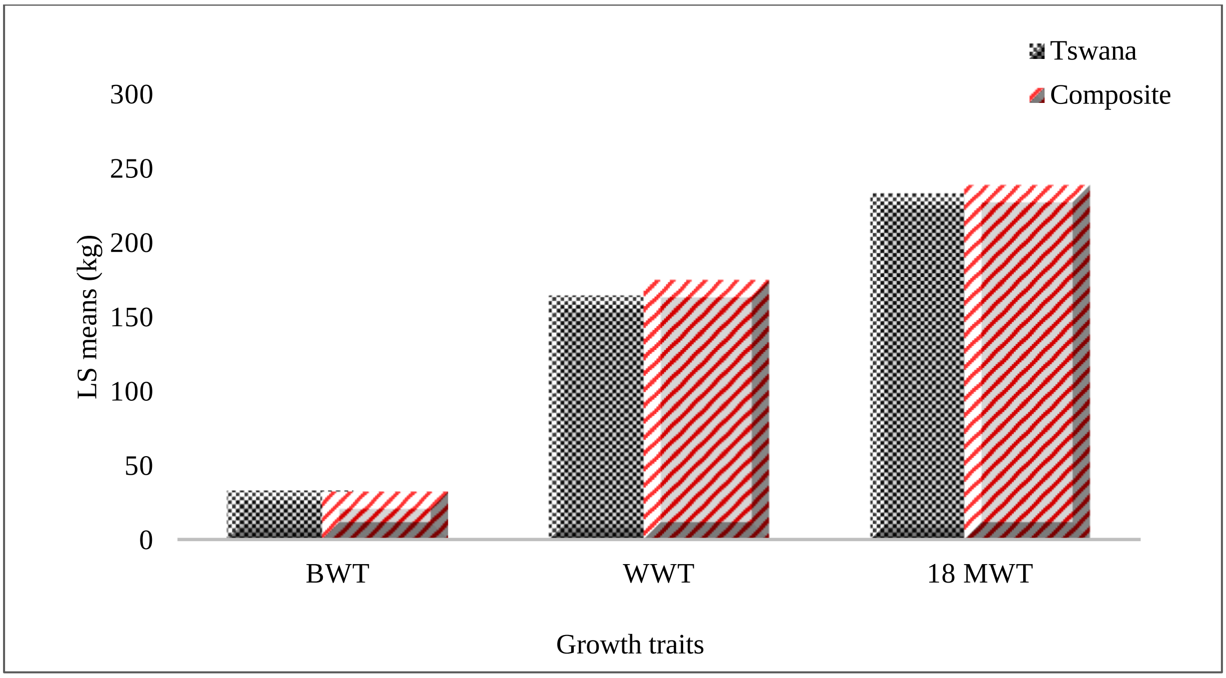

Figure 4.1.1 Effects of breed type on birth, weaning and 18 months weights of Tswana and Composite calves

4.1.2 The effects of sex on Composite and Tswana calf growth

Sex of calf was a source of variation for all growth traits in this study (Table 4.1.2). Male calves were heavier (P <0.05) than female calves by a difference of 2.2 kg at birth in both breeds. These results correspond with those of several authors (Vargas *et al*., 1999; Taylor *et al*., 2008; Chase *et al*., 2004; Corbet *et al*., 2006; Raphaka & Dzama, 2009; Haile *et al*., 2011; Nweze *et al*., 2012; Mangwiro *et al*., 2013; Bayou *et al*., 2015; Mezgebe *et al*., 2018). These studies have indicated hormones as the major cause of weight differences between male and female calves.

According to Raphaka (2008), male weight is influenced by the testosterone hormone which is absent in females. Testosterone exerts a direct anabolic effect on protein synthesis in many non-reproductive organs and tissues of the body (Smith, 2010). As a result, males grow faster and reach maturity with a greater weight than females that reach maturity much slower with a lesser weight (Bayou *et al*., 2015). Masculinity and large framed size of male animals is also explained by the testosterone hormone. Furthermore, male calves tend to have longer gestation periods than their female counterparts, so this may be another possible cause of heavier weights during birth (Messine *et al*., 2007; Smith, 2010; Apori & Hagan, 2014).

On the contrary, Rahman *et al*. (2015) found no differences (P >0.05) at birth between male and female calves (29.89 vs 28.56 kg). Gunawan & Jakaria (2011) also reported no significant influence on birth weight of Bali calves, but rather only on yearling weights. Female calves crossbred from Brahman cows and Angus bulls had a heavier BWT than males (31.6 vs 30.8 kg) (Riley *et al*., 2007). Putra *et al*. (2018) found that Sumba Ongole male calves were heavier than female calves, but the values between the two sexes did not differ significantly.

In both breeds the least square means for WWT was significantly different (P <0.05). Composite male calves had a higher weaning weight as compared to the female calves (179.5 vs 168.8 kg) and the same was observed in Tswana calves (168.6 vs 159.3 kg) respectively. These differences in WWT between the sexes agrees with those reported by Raphaka (2008); Riley *et al*. (2007); Taylor *et al*. (2008) and Mangwiro *et al*. (2013). Mangwiro *et al*. (2013) observed that Mashona male calves weighed 178.1 kg at weaning as compared to 157.8 kg in female calves. The authors weight findings for male calves were comparable to that of Composite male calves while the female weight was closer to that of the Tswana female calves. Abera *et al*. (2013), found opposing results in which the females were heavier than the males both at weaning and post weaning. Female calves were reported to be heavier due to special management that was provided to them as a means of improving their growth rate to reach puberty earlier. At 18 months, bull calves still weighed more than heifers in both breeds (Table

4.1.2). The results presented a difference (*P* <0.05) between the Composite and Tswana heifers, but the weight of bull calves between the two breeds did not differ (*P* >0.05).

Table 4.1.2 Effects of breed type and calf sex on birth, weaning and 18 months weights (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

	Growth traits (kg)											
	BWT				WWT				18 MWT			
Calf sex	N	Composite	N	Tswana	N	Composite	N	Tswana	N	Composite	N	Tswana
Female	1042	31.0 (0.30)^{Aa}	2190	31.7 (0.24)^{Ab}	883	168.8 (1.68)^{Aa}	1916	159.3 (1.25)^{Ab}	888	231.1 (2.44)^{Aa}	1916	219.6 (2.04)^{Ab}
Male	1184	33.2 (0.29)^{Ba}	2309	33.9 (0.24)^{Bb}	990	179.5 (1.63)^{Ba}	1990	168.6 (1.31)^{Bb}	853	245.6 (2.51)^{B}	1990	245.0 (2.08)^{B}
Total observations	2226		4499		1873		3906		1741		3517	

$^{a, b}$ Means of each variable in the same row with different superscript letters differ (P <0.05)

$^{A, B}$ Means in the same column with different superscript letters differ (P <0.05)

BWT~ birth weight, WWT~ calf weaning weight, 18 MWT~18 months weight

4.1.3 The effects of month of calving on Composite and Tswana calf growth

Month of calving (e.g. early or late in the calving season) had an influence (P <0.05) on birth, weaning and 18 months weights. Calves born late in the calving season were heavier at birth in both breeds than those born early in the season (Table 4.1.3). These results agree with the findings of Morris & Cullen (1988), who reported 31.1 kg for calves born early and 33.2 kg for late calves. Scholtz *et al*. (2017) indicated that December born calves respond more favorably in terms of weight gain than calves born in September. Cows that start calving later in the summer season have a higher nutritional level, and this often manifest in the high birth weights of their calves (Bergh, 2004).

Late season calves are born by cows that are well nourished because there is ample grazing after the good rains. Such calves will certainly be raised by cows producing enough milk. Heavier BWTs can however not be discussed without mentioning dystocia incidences that might be associated with it. A study on the effects of breeding season length and calving season on range beef cow productivity reported similar findings (Deutscher *et al*., 1991). According to the researchers, March (early season) calving cows that were bred 30 days into the season gave birth to calves with less weights than those bred 45 and 70 days later in the early group (38.5 < 39.6 < 40.3 kg).

Results of the present study agree with those reported by Raphaka (2008), in terms of the marked effects of month of calving consistently on BWT of Composite and Tswana calves. The lower BWT of early born calves may be explained by the fact that during the months of October when these calves were born, the veld had little grazing to offer the animals. These cows therefore do not get enough forage from the veld to produce enough milk for the new-born calves. Furthermore, when it’s dry, cows may be in poor body condition and do not have enough reserves to maintain themselves and the growing foetus (Raphaka, 2008; Smith, 2010). These cows will need more time to restore the reserves needed to nurse their calves (Messine *et al*., 2007). In contrast to Bayou *et al*. (2015), calves born in the dry season attained higher birth weight than those born during the main and short rainy season. The latter concurs with findings by Putra *et al*. (2018), who found that the BWT of Sumba Ongole calves born during the dry season was numerically higher than those born in the rainy season.

Calves born early attained more weight at weaning than those calves born late. Tswana calves born early were 11.9 kg heavier than their late counterparts, while early Composite calves were 13 kg heavier. Similarly, early born calves were reported to be 15 kg heavier at weaning than the late born calves (Morris & Cullen, 1988). Raphaka (2008) observed that at weaning, Composite and Tswana calves that were born early in the season outperformed the calves born late. The present study agrees with the results of Gunawan & Jakaria (2011), who stated that calves born during the dry season perform better than those born late. Sheko calves in Ethiopia that were born during the dry season were also reported to be heavier at weaning than those born during the rainy season (Bayou *et al*., 2015). They noted that it might be caused by late dry season cows getting exposed to the pasture from the first or early rains just before the main rain season begins. MacGregor & Casey (2000) found that early born calves tend to have a higher (P <0.01) average daily gain before weaning than calves born late and hence the higher WWTs. The authors indicated that at weaning early born calves are older than the calves born late. Similarly, Putra et al. (2018) observed a similar trend where calves born during the dry season were heavier at weaning than those born during the rainy season. On the contrary, the results of the present study do not agree with the findings of Deutscher et al. (1991) on weaning weight. The latter authors found no differences (P >0.01) in weaning weight between calves born early and late in the season, but these calves were in a more temperate environment

Post weaning growth (18 months) between the two breeds was significantly different (P <0.05). Composite calves indicated a 10.4 kg between the early and late born calves, while Tswana calves had a difference of 8.4 kg. Raphaka (2008) and Gunawan & Jakaria (2011) reported a similar weight trend on the effect of calving month and post weaning growth. It is therefore important to consider early calving because these cows utilize the veld when the nutritive value of the veld is at its peak after calving. For that reason, cows produce more milk and hence better calf weaning and yearling weight.

Table 4.1.3 Effects of breed type and month of calving on birth, weaning and 18 months weights (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

Month of calving	BWT				WWT				18 MWT			
	N	Composite	N	Tswana	N	Composite	N	Tswana	N	Composite	N	Tswana
Early	1728	31.4 (0.26)^{Aa}	3116	32.1 (0.22)^{Ab}	1451	180.7 (1.40)^{Aa}	2736	169.9 (1.13)^{Ab}	1327	243.5 (2.11)^{Aa}	2358	236.1 (1.97)^{Ab}
Late	498	32.8 (0.34)^{Ba}	1383	33.6 (0.27)^{Bb}	422	167.7 (1.95)^{Ba}	1170	158.0 (1.47)^{Bb}	414	233.1 (2.91)^{B}	1159	227.7 (2.23)^{B}
Total observations	2226		4499		1873		3906		1741		3517	

Growth traits (kg)

$^{a,\, b}$ Means of each variable in the same row with different superscript letters differ (*P* <0.05)

$^{A,\, B}$ Means in the same column with different superscript letters differ (*P* <0.05)

Early~ October and November, Late~ December and January

BWT~ birth weight, WWT~ calf weaning weight, 18 MWT~18 months weight

4.1.4 The effects of cow size on Composite and Tswana calf growth

Cow size was partitioned into small (425 kg), medium (425 < medium < 475kg) and big (475 kg) based on parturition weight. Birth and weaning weights were significantly affected by cow size in the Tswana breed. Within the Composite breed, weaning (Figure 4.1.2) and 18 MWT (Figure 4.1.3) were not influenced (P >0.05) by cow size. Calf weight at birth varied depending on cow size. Heavier cows tended to give birth to heavier calves while small cows produced lighter calves (Table 4.1.4). Tswana calves from big and medium cows showed no difference (P >0.05) in birth weight, but there was a difference (P <0.05) in calves from (big vs small) as well as (medium vs small cows). Influence of cow size on birth weight in the current study agrees with the results found by (Vargas *et al*., 1999, Taylor *et al*., 2008).

The results further indicate that there was a difference (P <0.05) in weaning weights of calves from large and small Tswana cows as well as between medium and small cows. Cow size did not affect (P >0.05) weaning weight of Composite calves (Table 4.1.4). Similar results were also reported by Vargas *et al*. (1999) who found no significant differences among weaning weights of calves from second parity cows. Scasta *et al.* (2015) found that WWT of calves increased with cow size regardless of the rainfall fluctuations over the years. The authors therefore reported that the WWT of calves from small, medium and large cows during the driest and wettest years was (192 vs 276, 219 vs 257, 229 vs 240 kg).

Cow size has an overriding influence on weaning weight such that larger cows generally wean calves with heavier weight (Steenkamp *et al*., 1974). Results obtained by Taylor *et al*. (2008) from small, medium and large framed Santa Gertrudis cows indicated that there is a correlation between cow size and weaning weight. The least square means for Composite calves at 18 MWT proves that cow size did not have an influence on weight after weaning. In 2010, Raphaka & Dzama found no maternal effect on 18 - months weights in Composite and Tswana breeds. According to Klosterman *et al*. (1976), large animals or breeds tend to produce calves which are larger and gain more rapidly at a given age than smaller ones.

Table 4.1.4 Effects of breed type and cow size on birth, weaning and 18 months weights (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

	Growth traits (kg)											
	BWT				WWT				18 MWT			
Cow size (kg)	N	Composite	N	Tswana	N	Composite	N	Tswana	N	Composite	N	Tswana
Big	741	33.4 (0.39)^{A}	1031	33.7 (0.35)^{A}	637	175.0 (2.09)^{a}	917	167.2 (1.72)^{Ab}	611	238.4 (2.87)	892	235.6 (2.47)^{A}
Medium	589	32.0 (0.35)^{Ba}	1061	33.1 (0.29)^{Ab}	511	174.8 (1.86)^{a}	940	166.3 (1.57)^{Ab}	460	238.6 (2.90)	804	234.8 (2.59)^{A}
Small	896	30.9 (0.30)^{Ca}	2407	31.7 (0.22)^{Bb}	725	172.8 (1.74)^{a}	2049	158.4 (1.23)^{Bb}	670	238.0 (2.67)^{a}	1821	226.7 (2.06)^{Bb}
Total observations	2226		4449		1873		3906		1741		3517	

$^{a, b}$ Means of each variable in the same row with different superscript letters differ (*P* <0.05)
$^{A, B}$ Means in the same column with different superscript letters differ (*P* <0.05)
BWT~ birth weight, WWT~ calf weaning weight, 18 MWT~18 months weight

4.1.5 The effects of cow age on Composite and Tswana calf growth

Growth traits under study were observed to increase with cow age until mature age (5-12 years) and started to decrease in older cows (≥13 years). There was a significant difference (P <0.05) between BWTs of Composite calves from young and older cows (29.9 vs 32.6 kg). The influence of cow age was not significant (P >0.05) within Tswana calves from cows that belonged to these age groups (3 vs ≥13, 4 vs ≥13 and 5-12 vs ≥13-year old). Both breeds indicated that from a numerical point, mature cows gave birth to the heaviest calves. Young and older dams have been reported to give birth to calves with the lowest weight (Renquist *et al*., 2006; Riley *et al*., 2007; Smith, 2010; Mangwiro *et al*., 2013). Gaertner *et al*. (1992) discussed a similar trend in crossbred calves (Simmental-sires × Brahman-Hereford dams) born in different seasons from <3.5, 3.5 to 12 and 12 to 17-year-old cows. They reported heavier BWTs for spring born calves (37.55 vs 36.70 vs 34.36 kg) than in the present study. Riley *et al*. (2007) observed the heaviest BWT in calves from mid age cows (5-10 years) while the lowest weight was in ≥ 4 and ≥11-year-old cows.

Table 4.1.5 illustrates the BWT among the different cow age groups as observed from the Tswana and Composite breeds. Apori & Hagan (2014) indicated that heifers produce lighter calves because they are still growing, however, as they grow older so does the womb size. This means that the womb's ability to accommodate bigger fetuses increases as well. A cow's ability to provide nutrients to the growing fetus in the uterine environment lessens with age hence the difference in weight between mature and older cows (Elzo *et al*., 1987).

At weaning, mature cows in both breeds weaned calves that were significantly heavier (P <0.05) than those from the other age groups. Wasike (2006) indicated that mature cows may have well developed mammary tissues. This means that these cows can provide enough milk for the calf, which explains the heavier weight of their calves at weaning. Three-year-old Composite cows weaned calves that weighed 12.3 kg more than the Tswana calves. Calves from ≥13-year-old cows were not different (P >0.05) from those of 3 and 4-year-old cows in both breeds in terms of weight. There is similar evidence to support the findings of the present study (Raphaka, 2008; Mangwiro *et al*., 2013; Smith, 2010). Gaertner *et al*. (1992) observed that calves from 12 to 17-year-old cows were numerically heavier at weaning than those from 3.5-year-old cows.

Cow age had no influence (P >0.05) on 18 MWT within the Tswana breed (Table 4.1.5). This may lead to the assumption that cow age has minimal contribution to post weaning weight. Composite calves from 4-year-old and mature cows were different (P <0.05) in weight by 8 kg. The breed further showed a variation (P <0.05) between mature and older cows by 14.1 kg.

Both breeds indicated a difference (*P* <0.05) in 18 MWT between calves from 3 and 5-12-year-old cows. The effects of cow age on Composite and Twana calves from birth to post weaning has been illustrated in Figure 4.1.5, 4.1.6 and 4.1.7.

Post weaning weight reflects the calf's own growth potential and adaptation ability (Elzo *et al*., 1987). The researchers stated that when calves are provided with an adequate environment during pregnancy and pre-weaning improves their growth potential after weaning. On the other hand, if the environment is not adequate, calves go through what is called compensatory growth (Elzo *et al*., 1987).

Table 4.1.5 Effects of breed type and cow age on birth, weaning and 18 months weights (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

	Growth traits (kg)											
	BWT				WWT				18 MWT			
Cow age (years)	N	Composite	N	Tswana	N	Composite	N	Tswana	N	Composite	N	Tswana
3	332	29.9 (0.66)^{Aa}	558	31.9 (0.50)^{Ab}	260	170.8 (3.48)^{Aa}	474	158.5 (2.53)^{Ab}	265	239.2 (4.99)^{a}	425	228.3 (3.82)^{b}
4	259	32.3 (0.37)^{B}	478	32.9 (0.32)^{B}	212	172.5 (2.02)^{Aa}	404	164.3 (1.68)^{Bb}	210	237.4 (2.97)^{A}	365	235.6 (2.55)
5-12	1554	33.7 (0.25)^{C}	3331	33.7 (0.17)^{C}	1345	180.3 (1.34)^{Ba}	2925	171.5 (0.93)^{Cb}	1209	245.4 (2.11)^{Ba}	2644	235.2 (1.53)^{b}
≥13	81	32.6 (0.76)^{BC}	132	32.9 (0.55)^{ABC}	56	173.1 (4.37)	103	161.5 (3.02)^{AB}	57	231.3 (6.81)^{A}	83	230.3 (5.07)
Total observations	2226		4499		1873		3906		1741		3517	

$^{a, b}$ Means of each variable in the same row with different superscript letters differ (*P* <0.05)
$^{A, B}$ Means in the same column with different superscript letters differ (*P* <0.05)
BWT~ birth weight, WWT~ calf weaning weight, 18 MWT~18 months weight

The weight of Tswana calves after weaning was not affected much by cow age. As discussed earlier that calf weight increases with cow age, Figure 4.1.7 shows that after Tswana cows reach maturity, the weight of their calves starts to decline at a slower rate. While in Composite calves, the change in weight after the cow matures decreases faster than that of the Tswana calves. It appears that once Composite cows reach mature age, their productivity level becomes insignificant. In such a case, culling would be most appropriate. However, Tswana cows can still be kept in the herd for few more years before culling them, because although their performance is declining, it happens at a slower rate. This suggests that crossbreds in comparison to indigenous breeds have a shorter longevity. Similar results were reported by Arango & Van Vleck (2002), who concluded that *Bos indicus* cattle may have superior longevity for maternal performance.

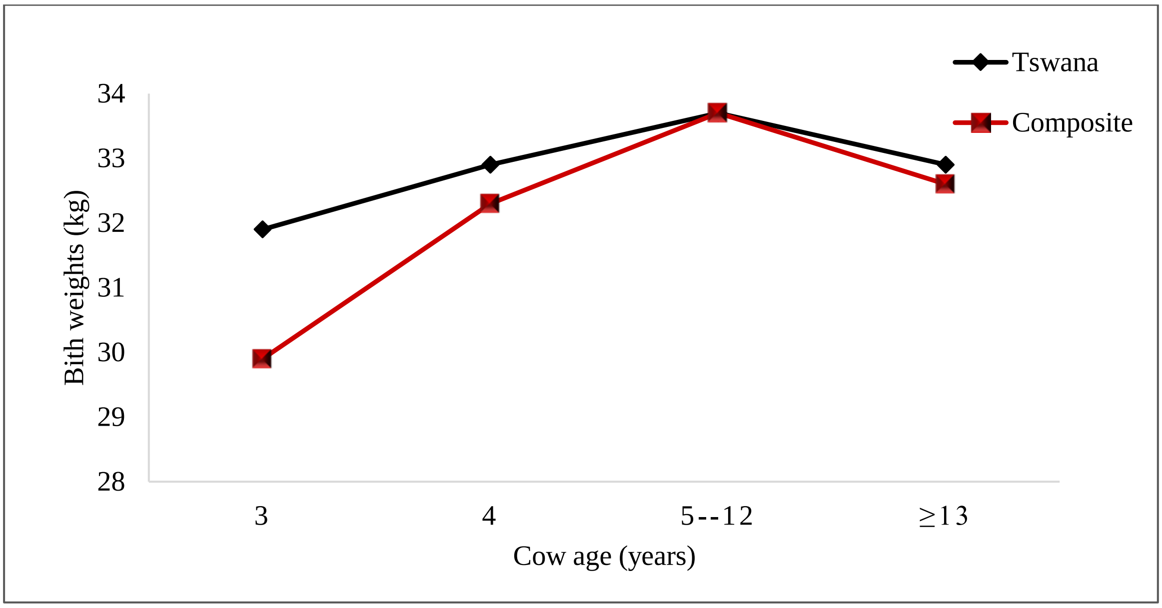

Figure 4.1.5 Effects of breed type and cow age on birth weights of Tswana and Composite calves

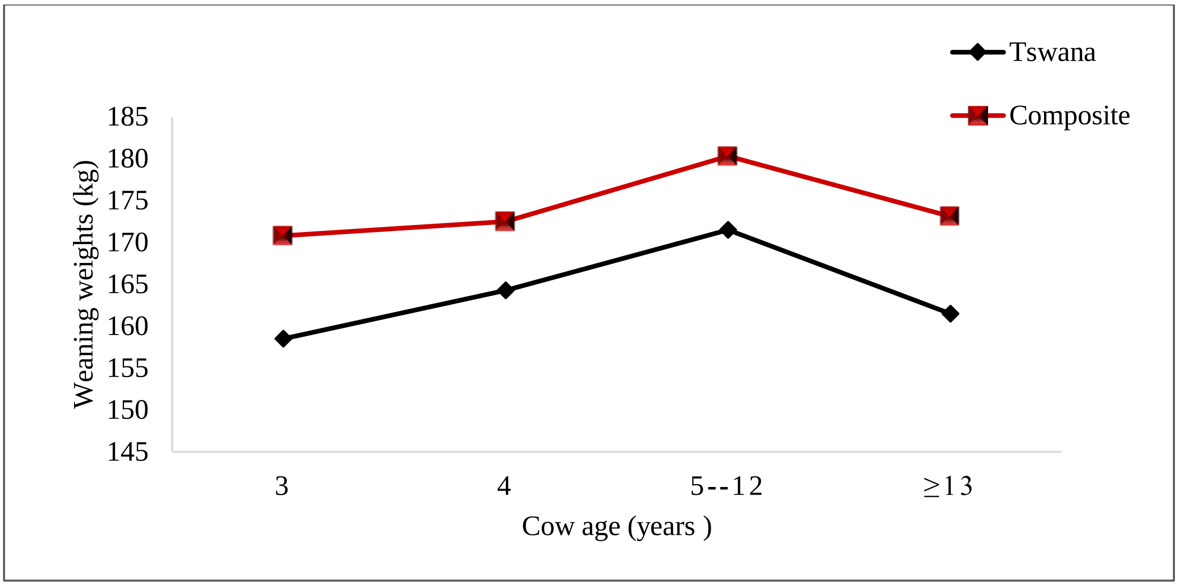

Figure 4.1.6 Effects of breed type and cow age on weaning weights of Tswana and Composite calves

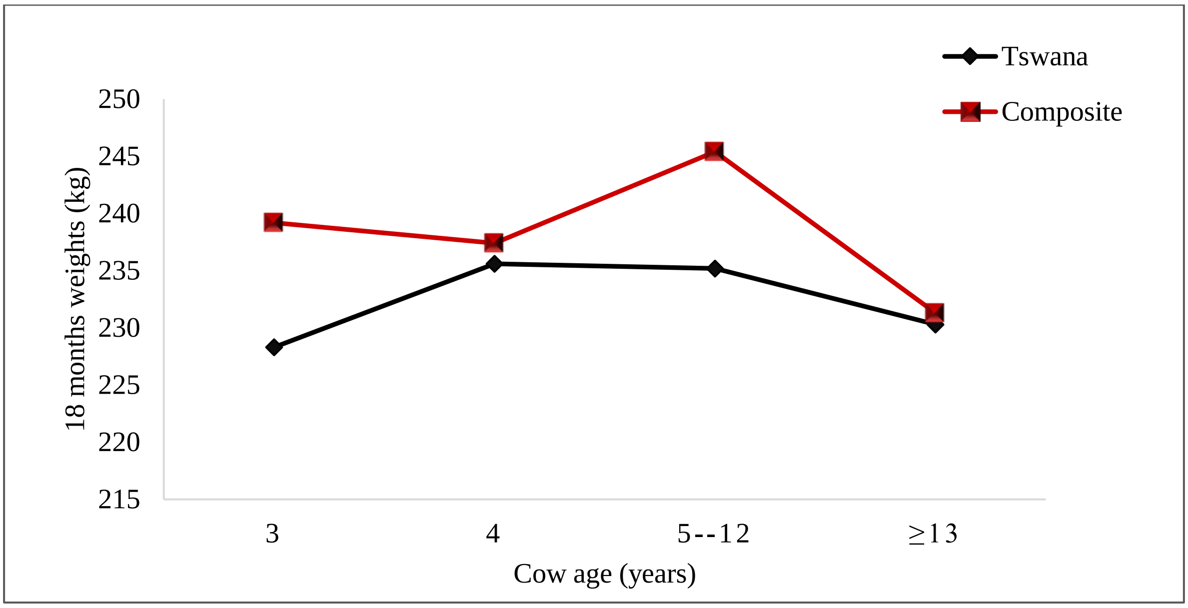

Figure 4.1.7 Effects of breed type and cow age on 18 months weights of Tswana and Composite calves

4.1.6 The effects of year of calving on Composite and Tswana calf growth

Year affected (*P* <0.05) birth, weaning and 18 months weight of Composite and Tswana calves in the present study. Composite calves were heaviest at birth from 1993-1996 and the weight started decreasing as the years progressed. Tswana calves recorded the heaviest BWT from 1993-1996 (33.8 kg) but this value was not significantly different from that recorded in 1997-2000 and 2001-2004 (33.0 vs 33.1 kg). Table 4.1.6 shows BWT change over the years between the two breeds. It appears that the Tswana breed may be better adapted to the harsh environmental conditions of Botswana, due to less fluctuations in production performance over the years of this study compared the Composite cattle. Rainfall patterns over the 21 years as illustrated in Figure 4.1.8 show that the BWT of Composite calves coincided with the good rains received from 1993-1996. By contrast, calves from the Tswana breed had more consistent birth weights even during years of low rainfall as opposed to Composite calves. Rainfall fluctuation has been reported to adversely influence growth traits in Bonsmara calves (Webb *et al*., 2017), which is representative of some of the most successful composite breeds in South Africa. Smith (2010) also reported variations in growth traits in Simbra calves and concluded that the variability may be a result of environmental and management factors.

Composite cows weaned the lightest (*P* <0.05) calves in year 3 (2001-2004) while the Tswana calves were lightest in year 5 (2009-2014). Composite cows weaned the heaviest (*P* < 0.05) calves during the first two years, although there was a decrease in WWT from year 1 to 2. Tswana cows weaned the heaviest calves in year 2 followed by year 1 and then 3. Despite the differences in WWT from year 1 to 5, overall results indicate that the heaviest calves were weaned from 1993-2000 in both breeds. These observations coincided with the years when Serowe recorded the highest rainfall (Figure 4.1.8). The WWT in the present study is lower than that reported by Scasta *et al*. (2015) in 2012, 2013 and 2014 (216, 250 and 256 kg).

With reference to the work of Raphaka (2008), Gunawan & Jakaria (2011), Mangwiro *et al*. (2013), Scasta *et al*. (2015), Scholtz *et al*. (2017) and Putra *et al*. (2018), year of birth has been a significant factor contributing to variation in WWT. The differences in WWT from year to year may be a result of quality and quantity of the available forage (Mangwiro *et al*., 2013; Putra *et al*., 2018). Another possible explanation for the differences may be management between the years (Gunawan & Jakaria 2011; Putra *et al*., 2018). Scasta *et al*. (2015) noted that high WWT was observed in years with above-average precipitation and the lowest WWT when drought was severe.

Post weaning (18 months) weight was heaviest (*P* <0.05) in year 1 (1993-1996) and has since then been declining until year 5 (Table 4.1.6). The lowest WWT was observed in year 3 and there was no difference (*P* >0.05) in weight between year 3 and 5; year 4 and 5. Similarly, Tswana calves had the heaviest 18 MWT in year 1, while the lowest weight was in year 5. The significance of year influence on post weaning weight in the present study agrees with yearly fluctuations observed in growth traits of Mashona calves (Mangwiro *et al*., 2013). The variations in post weaning weight from year to year may be attributed to the rainfall fluctuations (Figure 4.1.8).

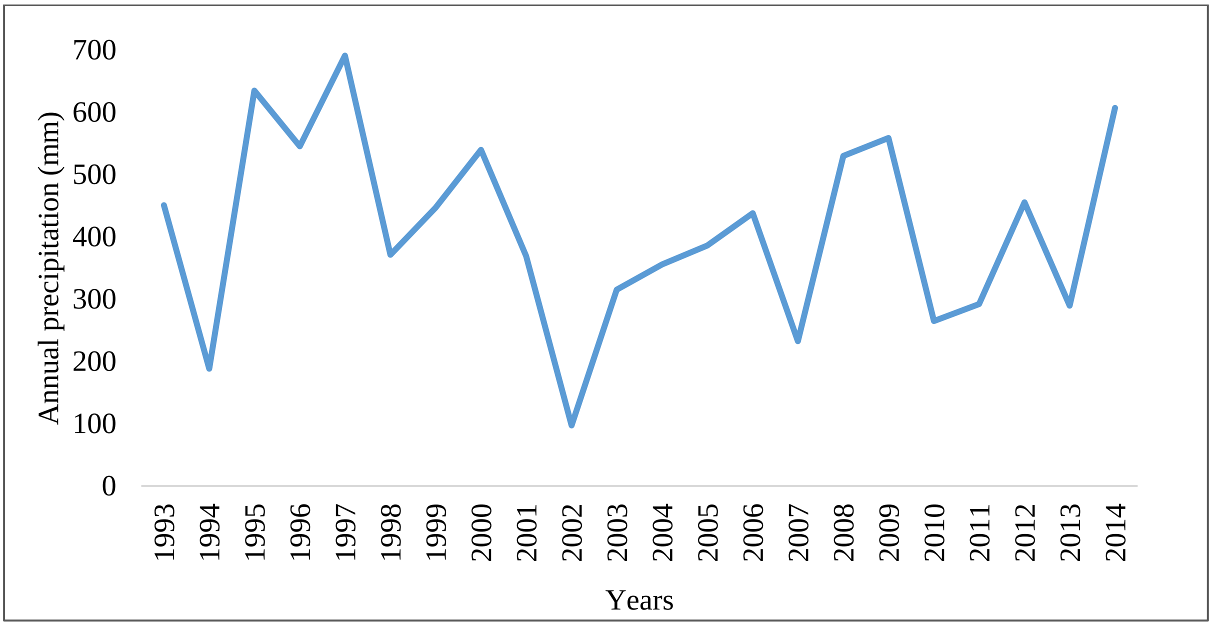

Figure 4.1.8 Annual precipitation for Serowe, Botswana (1993-2014)

Annual rainfall in Serowe has shown a fluctuating trend over the years. The wettest years were recorded from 1995 to 1997. The year 2002 was the driest on record with *ca.* 100 mm received in the area. Precipitation gradually increased from 2003 until 2007 where it decreased again. Thereafter it increased again in 2008 and 2009 and remained low until 2014 where *ca.* 600 mm was recorded.

Table 4.1.6 Effects of breed type and year of calving on birth, weaning and 18 months weights (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

	Growth traits (kg)											
	BWT				WWT				18 MWT			
Year of calving	N	Composite	N	Tswana	N	Composite	N	Tswana	N	Composite	N	Tswana
1993-1996	377	33.7 (0.49)^{A}	818	33.8 (0.40)^{A}	346	191.9 (3.11)^{Aa}	763	167.5 (2.65)^{Ab}	370	287.1 (4.83)^{Aa}	759	271.5 (4.06)^{Ab}
1997-2000	724	32.1 (0.45)^{Ba}	1008	33.0 (0.34)^{Ab}	632	185.6 (2.45)^{B}	912	181.9 (1.82)^{B}	550	248.3 (3.98)^{Ba}	745	254.8 (2.97)^{Bb}
2001-2004	531	31.5 (0.38)^{Ba}	1052	33.1 (0.42)^{Ab}	461	157.4 (2.00)^{Ca}	917	164.0 (2.27)^{Ab}	433	209.4 (3.05)^{Ca}	912	225.2 (3.37)^{Cb}
2005-2008	341	31.2 (0.39)^{BCa}	961	32.0 (0.28)^{Bb}	276	169.2 (2.50)^{Da}	810	157.4 (1.10)^{Cb}	247	227.6 (3.95)^{Da}	778	207.0 (3.22)^{Db}
2009-2014	253	32.0 (0.40)^{B}	660	32.2 (0.37)^{AB}	158	166.9 (3.28)^{Da}	498	148.9 (2.98)^{Db}	141	219.1 (5.01)^{CDa}	323	203.2 (5.13)^{Db}
Total observations	2226		4499		1873		3900		1741		3517	

$^{a, b}$ Means of each variable in the same row with different superscript letters differ (*P* <0.05)

$^{A, B}$ Means in the same column with different superscript letters differ (*P* <0.05)

BWT~ birth weight, WWT~ calf weaning weight, 18 MWT~18 months weight

4.1.7 The effects of previous parous state on Composite and Tswana calf growth

Composite heifers gave birth to calves that were heavier (*P* <0.05) than those from cows that calved the previous year, skipped a year without calving as well as aborted (Table 4.1.7). The BWT of calves from cows that previously calved, skipped and aborted was not significantly different (*P* >0.05). Although numerically, calves from cows that aborted were lighter (31. 5 kg). On the contrary, within the Tswana breed, BWT was heaviest (*P* <0.05) in calves from non-parous cows (skipped and aborted), but their weight was not significantly different (*P* >0.05) from that of calves born by heifers. Previous parous state did not affect (*P* >0.05) 18 MWT of Composite calves. The Tswana calves, however exhibited a difference (*P* <0.05) in post-weaning weights of calves from cows that calved and skipped a year without calving. There are few studies that were conducted on the effect of previous parous state on calf growth. Raphaka (2008) found results that were higher than those from the present study.

Cows that skip a year without calving may be in a better state to conceive the following year. These cows are likely to be in good body condition during the mating season. For example, van der Merwe & Schoeman (1995) reported a 75.9 % calving rate in heifers that did not conceive the previous season. They also indicated that only 51 % from the heifers that calved the previous season managed to reconceive. Cows that just calved may take longer to recover from postpartum stress. They may not pick up weight or put on the right body condition for mating and parturition. This in return affects calf growth and worsens the cow's reproduction life. Raphaka (2008) stated that non-parous cows tend to rest for longer periods and this may negatively affect the cow's maternal ability hence the lighter birth weights.

Table 4.1.7 Effects of breed type and previous parous state on birth weight, weaning weight and 18 months weights (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

	Growth traits (kg)											
Previous parous state	BWT				WWT				18 MWT			
	N	Composite	N	Tswana	N	Composite	N	Tswana	N	Composite	N	Tswana
Heifer	416	33.5 (0.48)^{A}	745	32.8 (0.34)	323	169.6 (2.63)^{Aa}	630	162.8 (1.78)^{b}	320	231.0 (4.05)	560	230.0 (2.87)
Calved	1225	31.7 (0.33)^{B}	2696	32.2 (0.24)^{A}	1058	173.4 (1.78)^{Aa}	2353	160.9 (1.28)^{Ab}	965	240.7 (2.66)^{a}	2153	231.4 (2.03)^{Ab}
Skipped	477	31.8 (0.39)^{Ba}	873	33.3 (0.29)^{Bb}	404	179.8 (2.08)^{Ba}	766	166.5 (1.53)^{Bb}	372	241.7 (3.18)	668	236.0 (2.43)^{B}
Aborted	108	31.5 (0.54)^{Ba}	185	33.0 (0.41)^{Bb}	88	173.9 (2.92)^{Aa}	157	165.6 (2.14)^{Bb}	84	239.9 (4.37)	136	232.1 (3.40)
Total observations	2226		4499		1873		3906		1741		3517	

$^{a, b}$ Means of each variable in the same row with different superscript letters differ (P <0.05)

$^{A, B}$ Means in the same column with different superscript letters differ (P <0.05)

BWT~ birth weight, WWT~ calf weaning weight, 18 MWT~18 months weight

4.2 The effects of non-genetic factors on cow weights at parturition and calf weaning of Composite and Tswana cattle breeds in Botswana

4.2.1 The effects of breed type on Composite and Tswana cow weights at parturition and calf weaning

Table 4.2.1 Effects of breed type on cow weights at parturition and calf weaning (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

	Growth traits (kg)			
Breed	N	CPWT	N	CWWT
Composite	2230	430.4(3.17)^{A}	1864	414.08(0.82)
Tswana	4523	407.2(2.35)^{B}	3883	412.80(1.98)
Total observations	6753		5747	

$^{A, B}$ Means in the same column with different superscript letters differ (P <0.05)
CPWT~ cow parturition weight, CWWT~ cow weight at calf weaning

Composite and Tswana cows displayed a significant difference (P <0.05) in weights recorded from parturition to weaning. Composite cows showed 16.3 kg weight decrease while the Tswana cows had a 5.6 kg weight gain (Figure 4.2.1). On the other hand, cow weights at calf weaning (CWWT) between the Composite and Tswana cows did not differ (P >0.05). CWWT in the present study (Table 4.2.1) did not differ much from the values reported by Moyo *et al*. (1996). The CWWT reported for Nkone (402 kg) and Mashona cows (368 kg) were lower than that observed in the Composite and Tswana cows. However, the weight of Tuli (423 kg), Afrikaner (420 kg), Brahman (444 kg) cows were heavier than that of the Tswana and Composite cows.

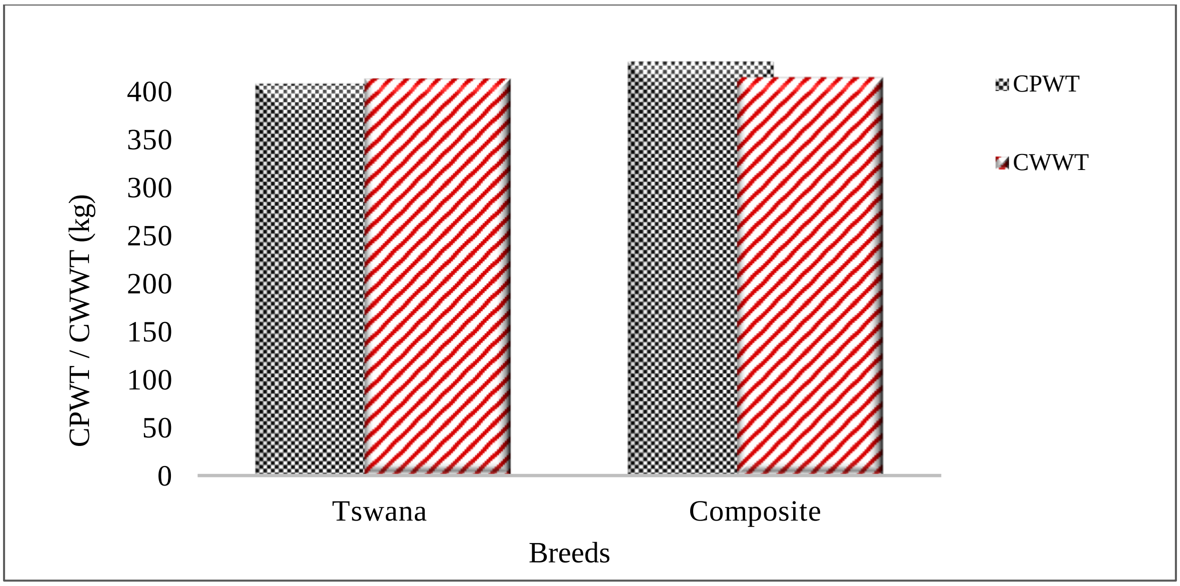

Figure 4.2.1 Effects of breed type on cow weights at parturition and calf weaning of Tswana and Composite cattle breeds in Botswana

Figure 4.2.1 illustrates that at parturition the Composite cows were heavier than Tswana cows. However, the study observed that Composites had lost weight between calving and weaning. These two breeds therefore had weight differences of 1.28 kg at calf weaning. According to Webb (2016) adapted animals are less affected by environmental limitations. Therefore, the weight change experienced by Composite cattle may be related to poor adaptability, whereas the Tswana breed may have a superior ability.

4.2.2 The effects of month of calving on Composite and Tswana cow weights at parturition and calf weaning

Table 4.2.2 Effects of breed type and month of calving on cow weights at parturition and calf weaning (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

Growth traits (kg)								
Month of Calving	CPWT				CWWT			
	N	Composite	N	Tswana	N	Composite	N	Tswana
Early	1732	430.3 (3.10)[a]	3134	409.3 (2.51)[b]	1444	420.9 (2.52)[A]	2726	419.4 (2.08)[A]
Late	498	430.5 (4.28)[a]	1389	405.1 (3.15)[b]	420	407.3 (3.64)[B]	1157	406.3 (2.75)[B]
Total observations	2230		4523		1864		3883	

[a, b] Means of each variable in the same row with different superscript letters differ (*P* <0.05)
[A, B] Means in the same column with different superscript letters differ (*P* <0.05)
Early~ October and November, Late~ December and January
CPWT~ cow parturition weight, CWWT~ cow weight at calf weaning

Month of calving had an influence (*P* <0.05) on cow parturition weight between but not within breeds (Table 4.2.2). Breed effect was significantly (*P* <0.05) observed as Composite cows were heavier than the Tswana cows in both calving months. Cows that calved early (October and November) were heavier (*P* <0.05) at weaning than cows that calved late (December and January). Early calving cows may be advantaged because the grazing might have been most palatable between calving and weaning. Cows that calved late in the season had lower weights. It is possible that the veld has started to lose its nutritive value by the time these cows were approaching weaning.

Composite cows that calved early and late in the season both lost weight between parturition and weaning. The loss was more distinct in cows that calved late. This notable change in weight by Composite cows may demonstrate how sensitive the breed is. It may also mean that the breed may require more time to gain appropriate weight pre-breeding. On the contrary, early and late calving Tswana cows both showed improvement (10.1 vs 1.2 kg) in weight from calving to weaning. Bellindo *et al*. (1981) reported a similar trend as that observed in Tswana cows. They indicated that cows that were bred early gained more weight than those bred late.

4.2.3 The effects of year of calving on Composite and Tswana cow weights at parturition and calf weaning

Table 4.2.3 Effects of breed type and year of calving on cow weights at parturition and calf weaning (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

Growth traits (kg)								
Year of Calving	CPWT				CWWT			
	N	Composite	N	Tswana	N	Composite	N	Tswana
1	379	453.2 (6.28)^{Ba}	822	387.6 (4.57)^{Ab}	345	449.3 (6.03)^{Aa}	762	427.5 (5.15)^{Ab}
2	724	448.8 (5.72)^{A}	1020	442.3 (4.24)^{B}	628	431.5 (4.70)^{Ba}	904	441.0 (3.50)^{Bb}
3	533	424.0 (4.69)^{B}	1057	415.4 (5.25)^{C}	461	407.6 (3.79)^{Ca}	911	424.2 (4.40)^{Ab}
4	341	413.8 (4.75)^{B}	962	410.2 (3.24)^{C}	274	398.3 (4.81)^{C}	811	393.4 (3.83)^{C}
5	253	412.1 (4.73)^{BCa}	662	380.4 (4.09)^{Ab}	156	383.6 (6.37)^{C}	495	278.3 (5.81)^{Da}
Total observations	2230		4523		1864		3883	

$^{a, b}$ Means of each variable in the same row with different superscript letters differ (P <0.05)
$^{A, B}$ Means in the same column with different superscript letters differ (P <0.05)
1~1993-1996, 2~1997-2000, 3~2001-2004, 4~2005-2008, 5~2009-2014
CPWT~ cow parturition weight, CWWT~ cow weight at calf weaning

Cow weights at parturition and calf weaning showed a declining trend over the years in both breeds with some significant differences as illustrated in Table 4.2.3. The difference between the Composite and Tswana cows was only significant (P <0.05) in year 1 and 5. Composite cows were heaviest at parturition in year 1, while the lowest weight was observed in year 5. Tswana cows had a lower (P >0.05) parturition weight in year 1 and 5. The variation in parturition weight within the breeds may be explained by environmental factors e.g. temperature and rainfall (Figure 4.1.8) which are the two most important factors that play a role in determining the quality of the grazing. Composite cows displayed a heavier (P <0.05) weight at weaning during the first 3 years, while year 4 and 5 were characterised by lower cow weights at calf weaning (P >0.05). Tswana cow weights at calf weaning did not differ (P >0.05) between year 1 and 3. Furthermore, cow weights at calf weaning were different (P <0.05) between the breeds in year 1, 2 and 3. Composite cows weighed 21.8 kg more than Tswana cows at weaning in year 1, but in year 2 and 3, the Tswana cows weighed more than the Composite cows by 9.5 and 16.6 kg.

When comparing the CWWT of Composites with the annual rainfall for year 1 (Figure 4.1.8), it can be observed that the breed outperformed Tswanas during good rains. However, as the years progressed, and rainfall decreased below that of the previous year e.g. year 3, Tswana cows outweighed or maintained their weights better compared to the Composite cows. This can be analysed from an adaptation point of view between the two breeds. Irrespective of the ever-changing climatic conditions of Botswana, the Tswana breed was able to thrive despite more unfavourable environmental conditions. The present data suggest that the Composite breed was more sensitive to environmental conditions and found it more difficult to adapt, with subsequent adverse effects on their overall production and reproduction performance.

4.2.4 The effects of cow age on Composite and Tswana cow weights at parturition and calf weaning

Table 4.2.4 Effects of breed type and cow age on cow weights at parturition and calf weaning (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

	Growth traits (kg)							
	CPWT				CWWT			
Cow age (years)	N	Composite	N	Tswana	N	Composite	N	Tswana
3	33	352.6 (7.29)^{A}	566	347.4 (5.07)^{A}	57	381.5 (4.65)^{A}	473	383.1 (3.74)^{A}
4	259	416.0 (4.43)^{Ba}	482	386.8 (3.36)^{Bb}	212	407.5 (3.84)^{B}	402	408.3 (3.20)^{B}
5-12	1557	473.5 (3.16)^{Ca}	3343	436.7 (2.18)^{Cb}	1339	430.3 (1.7)^{C}	2906	433.8 (1.12)^{C}
≥13	81	479.4 (9.80)^{C}	132	457.8 (7.09)^{D}	56	437.0 (8.32)^{C}	102	426.4 (5.81)^{C}
Total observations	2230		4523		1864		3883	

$^{a, b}$ Means of each variable in the same row with different superscript letters differ (*P* <0.05)
$^{A, B}$ Means in the same column with different superscript letters differ (*P* <0.05)
CPWT~ cow parturition weight, CWWT~ cow weight at calf weaning

Age × breed interaction on CPWT between the Composite and Tswana cows was significant (*P* <0.05) in both young and older cows (Table 4.2.4). Cow weights at parturition increased with increasing cow age. Three-year-old cows had the lowest weight at calving in both breeds. Mature and older Composite cows showed no difference (*P* >0.05) in parturition weight, while Tswana dams displayed the opposite. Renquist *et al*. (2006) reported the lowest cow parturition weight in 3-year-old cows. The authors indicated that cow weight at parturition was highest in 8-year-old cows and thereafter started declining.

4.2.5 The effects of previous parous state on Composite and Tswana cow weights at parturition

Table 4.2.5 Effects of breed type and previous parous state on cow weights at parturition (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

		Growth traits (kg)		
		CPWT		
Previous parous state	N	Composite	N	Tswana
Heifer	417	$439.9 (6.16)^{Aa}$	756	$414.5 (4.19)^{Ab}$
Calved	1226	$404.9 (3.99)^{Ba}$	2704	$393.3 (2.83)^{Bb}$
Skipped	497	$436.0 (4.80)^{Ca}$	876	$409.7 (3.52)^{Ab}$
Aborted	108	$440.8 (6.89)^{Ca}$	187	$411.2 (5.13)^{Ab}$
Total observations	2230		4523	

$^{a, b}$ means in the same row with different superscript letters differ (P <0.05)
$^{A, B}$ means in the same column with different superscript letters differ (P <0.05)
CPWT~ cow parturition weight

Parturition weights of Tswana heifers were heavier (*P* <0.05) than cows that calved the previous year. The variation between the Tswana heifers and the non-parous cows was not significant (*P* >0.05). However, within the Composite cows the difference between the parous and non- parous cows was significant (*P* <0.05; Table 4.2.5). Composite heifers were heavier (P <0.05) than cows that skipped a year without calving and cows that aborted. A study by Fitzhugh *et al*. (1967) reported that non-porous cows were heavier (*P* <0.05) than the other cows. Numerically, in the present study that is true for cows that aborted in both breeds. Composite cows that aborted weighed 4.8 kg more than the cows that skipped a year without calving, but in the Tswana breed the weight difference between the cows that skipped or aborted was only 1.5 kg. According to Fitzhugh *et al*. (1967) non-parous cows tend to be heavier because flesh accumulates during the non-lactating period.

4.2.6 The effects of size on Composite and Tswana cow weights at parturition

Table 4.2.6 Effects of breed type and size on cow weights at calf weaning (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

Growth traits (kg)				
CWWT				
Cow size (kg)	N	Composite	N	Tswana
Big	636	445.1 (4.10)^{A}	908	448.8 (3.30)^{A}
Medium	508	414.8 (3.48)^{B}	935	418.4 (2.10)^{B}
Small	720	382.3 (3.18)^{Ca}	2040	371.4(2.23)^{Cb}
Total observations	1864		3883	

$^{a, b}$ Means in the same row with different superscript letters differ (*P* <0.05)
$^{A, B}$ Means in the same column with different superscript letters differ (*P* <0.05)
CPWT~ cow parturition weight

From Table 4.2.6, cow weight at calf weaning varied significantly (*P* <0.05) between all sizes within each breed. It was observed that the larger the cow, the heavier the weight at calf weaning. The results found that there was a difference (*P* <0.05) of 10.9 kg between small Composite and Tswana cows. The big and medium Tswana cows were numerically heavier than the Composite cows by 3.7 and 3.6 kg respectively

4.3 The effects of non-genetic factors on intercalving periods and days to conception of Composite and Tswana cows in Botswana

The GLM analyses indicate that the calving intervals of Composite and Tswana cows were not affected (*P* >0.05) by breed type, sex of calf, month and year of calving. The study however found significant interaction effects *(P* <0.05) between breed type with previous parous state, cow age and size.

4.3.1 Effects of cow age on intercalving period of Composite and Tswana cows

In both breed types, there were only few cows that were a representative of heifers or 3-year-old cows (Table 4.3.1). These were most probably the heifers that were born late in the calving season and therefore conceived and calved later in the season. The rest of the young cows that were born early were therefore included in the 4-year-old category. Three-year-old cows that were born early in the season grew faster, attained breeding weight early, conceived and calved down earlier than the rest of the heifers.

Table 4.3.1 Effects of breed type and cow age on intercalving period (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

			ICP (days)			
Cow age (years)	N	Composite	N	Tswana	Total observations	Average
3	4	416.0 (35.47)^{Aa}	6	535.7 (28.9)^{b}	10	475.8 (22.86)
4	158	507.4 (8.13)^{B}	295	488.9 (5.83)^{A}	453	498.2 (5.01)^{A}
5-12	1514	511.2 (6.64)^{B}	3124	501.6 (4.77)^{B}	4638	506.4 (4.12)^{B}
≥13	81	516.1 (10.09)^{Ba}	131	487.5 (7.67)^{b}	212	501.8 (6.37)
Total observations	1757		3556		5313	

$^{a, b}$ Means in the same row with different superscript letters differ (*P* <0.05)
$^{A, B}$ Means in the same column with different superscript letters differ (*P* <0.05)

Three-year-old Composite cows had the shortest (*P* <0.05) intercalving period (ICP) compared to the other 3 age groups. There were no significant differences between 4, 5-12 and ≥13-year-old Composite cows. By contrast, the influence of cow age on ICP was only different (*P* <0.05) between 4 and 5-12-year-old Tswana cows. Tswana cows of 5-12-years calved 12.7 days later than 4-year-old cows. Variation in ICP between these two age groups differed by less days in comparison to Composite cows. From a numerical point, 3-year-old Tswana cows had the longest ICP while ≥13-year-olds exhibited the shortest ICP interval. Older Tswana cows had a shorter (*P* <0.05) ICP than Composite cows. Composite cows exhibited a larger variation (*P* <0.05) in ICP between 3-year-old cows and the rest of the age groups. The variation in days was: ≥13 vs 3-year-old = 100.1 days, 5-12 vs 3-year-old = 95.2 days and 4 vs 3-year-old = 91.4 days. Furthermore, young cows are still growing, so after calving, most nutrients are partitioned in order of priority (Short *et al*., 1990; Zindove & Chimonyo, 2015). Thus, heifers first partition energy for self-maintenance and lastly reproduction. This may explain the longer ICP of 3-year-old Tswana cows in the present study.

In Mexico, cow age was reported to have a significant effect on ICP, with 2 and 3-year-old cows having the longest interval (433 vs 420 days) (Hinojosa *et al*., 1980). MacGregor & Casey (1999) also reported longer ICP in 3-year-old beef cows (377.13 days). Numerically, both studies had ICP intervals shorter than that of the present study. The calving interval observed in 4-year-old Tswana cows (488.9 days) did not differ much from the calving interval (484.8 days) of cows with two calvings (Medina *et al*., 2009). Cows with four or more calvings were reported to have an interval of 441.6 days (Medina *et al*., 2009). This value is 74.5 days longer when compared to older Composite cows and 46.2 days longer in Tswana cows.

The ICP (416 days) of 3-year-old Composite cows in the present study was longer than that observed by Bolacali & Öztürk (2017) in Simmental cows (376.92 days) of corresponding age. According to Vergara *et al*. (2009) low aged cows tended to have shorter intervals for the first time. They further discussed that these heifers return to estrus quickly when they get enough time to replenish their energy reserves. However, Mukasa - Mugerwa (1989) is not in agreement with the latter and stated that such cows take longer to return to estrus post-partum than pluri-parous cows. MacGregor & Casey (1999), reported the shortest interval in 6-year-old cows, opposing that observed in 3-year-old Composite cows. Results by Titterington *et al*. (2017) agrees with those observed in Composite cows. The authors found the shortest ICP in cows that were <48 months and longest in cows that were >144 months. Bolacali & Öztürk (2017) also reported the shortest interval (374.22 days) in 2-year-old Simmental heifers whilst the longest interval (404.23 days) was observed in 9-year-old cows. Cows that have the shortest intervals are often those that calve late for the first time (Bellido *et al*., 1981; Bourdon & Brinks, 1983; Werth *et al*., 1996; Webb *et al*., 2017). Bourdon & Brinks (1983), further noted that selecting for such cows, or their offspring means indirectly selecting for later age at puberty.

Comparatively, the average ICP of 3 (475.8 days), 4 (498.2 days) and 5-12-year-old (506.4 days) Composite and Tswana cows in the present study was longer than the intervals (370.2 vs 366.5 vs 367.3 days) reported by Bourdon & Brinks (1983) in cows of corresponding age. MacGregor & Casey (1999) found that ICP of 4, 5 and 10+ year old beef cows was 372.34, 372.04 and 374.34 days, these ICP values were still lower than that observed in Tswana and Composite cows. Larson & Berglund (2000) stated that longer intervals are beneficial in terms of fertility, as cows get enough postpartum recovery to restart their normal ovarian cyclicity.

4.3.2 Effects of cow size on intercalving period of Composite and Tswana cows

Table 4.3.2 Effects of breed type and cow size on intercalving period (Least square means and standard errors (S.E)) of Composite and Tswana cattle breeds in Botswana during the period under investigation

			ICP (days)			
Cow size (kg)	N	Composite	N	Tswana	Total observations	Average
Big	682	495.2 (9.97)^{A}	943	501.5 (8.91)	1625	498. 3 (6.69)^{A}
Medium	500	486.7 (10.2)^{B}	906	503.7 (8.83)	1406	495. 2 (6.69)
Small	575	481.1 (9.83)^{B}	1706	505.1 (8.72)	2282	493.1 (6.58)^{B}
Total observation	1757		3555		5313	

$^{a, b}$ Means in the same row with different superscript letters differ (*P* <0.05)
$^{A, B}$ Means in the same column with different superscript letters differ (*P* <0.05)
ICP~ intercalving period

Within the Composite breed, big cows had the longest (*P* <0.05) ICP. The ICP interval between medium and small Composite cows was not different (*P* >0.05). In the present study, cow size × ICP interaction in Tswana cows was the same (*P* >0.05), meaning that cow size had little influence on calving intervals of Tswana cows. The results did not display any significance between the two breeds but in numerical terms, Tswana cows had longer ICP than Composite cows.

In India, the shortest calving interval reported for crossbred (Holstein Friesian × Deoni) cows was 400.76 days while the longest was 440.67 days (Zewdu *et al*., 2015). These intervals remain shorter than that of Tswana and Composite cows reported in this study, but nutritional environments also differ between India and Botswana. Amin *et al*. (2013) reported an average of 454.9 days in red Chittagong cattle, which is still less days than the intervals observed in Composite and Tswana cows of different sizes. Calving interval of suckled N'Dama cattle of Gambia was 544 days (Sanyang *et al*., 1995). The latter value is comparable to that of Tswana cows but was 42.5, 40.3 and 38.9 days longer than that observed in big, medium and small cows. Non-suckled cows of the same breed were reported to have an interval of 406 days which is shorter than the ICP observed in Composite cows of all sizes (Sanyang *et al*., 1995). Similarly, Maciel *et al.* (2013) reported Nguni and Landim cows had ICP's of 422 and 466 days. Corbet *et al*. (2006) also found an ICP interval of 455 and 440 days in Bonsmara and Belmont red cows. van Zyl *et al*. (1992b) reported the longest intervals in Simmental (409.22 days) and Afrikaner (401.30 days) cows. However, Hereford and Bonsmara cows from the same study exhibited shorter intervals (389.56 and 374.78 days). Most ICP values reported in the literature are shorter than that recorded for both breeds in the present study, but the latter were arguably in a much harsher environment.

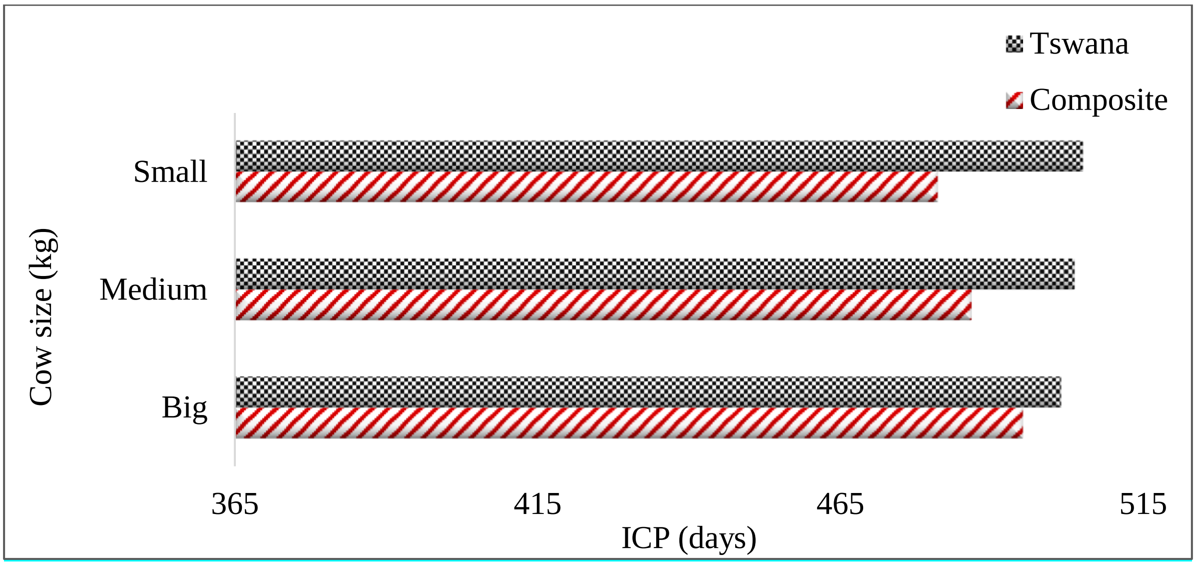

Figure 4.3.2 Effects of cow size on intercalving period of Tswana and Composite cattle breeds in Botswana

Figure 4.3.2 shows that calving intervals between Tswana cows of different sizes varied between 2 - 4 days. Composite cows had slightly more days between the different sizes and the variation was between 5 days to 2 weeks. Several investigations (Buttram & Willham, 1989; Vargas *et al*., 1999; Taylor *et al*., 2008; Webb *et al*., 2018) reported on the effect of cow size on reproduction and have concluded that small to medium framed cows were more efficient.

4.3.3 Effects of previous parous state on intercalving period of Composite and Tswana cows

Table 4.3.3 Effects of breed type and previous parous state on intercalving period (Least square means and standard errors (S.E)) of Composite and Tswana cows in Botswana during the period under investigation

			ICP (days)			
Previous parous state	N	Composite	N	Tswana	Total observations	Average
Heifer	9	532.3 (23.37)^{A}	16	520.0 (18.97)$_{A}$	25	526.1 (15.5)^{A}
Calved	1219	361.1 (9.69)^{Ba}	2646	395.5 (7.41)^{Bb}	3865	378.3 (6.10)^{B}
Skipped	421	692.5 (10.21)^{C}	705	705.4 (7.91)^{C}	1126	698.9 (6.47)^{C}
Aborted	108	364.8 (11.58)^{Ba}	189	392.7 (8.92)^{Bb}	297	378.7 (7.33)^{A}
Total observations	1757		3556		5313	

$^{a, b}$ Means in the same row with different superscript letters differ (*P* <0.05)
$^{A, B}$ Means in the same column with different superscript letters differ (*P* <0.05)
ICP~ intercalving period

As shown in Table 4.3.3, cows that calved or aborted the previous season had the shortest ICP in both breeds. Although the shortest intervals were observed in cows that calved and aborted, a comparison between the two breeds showed that Tswana cows had a longer (*P* <0.05) ICP than Composite cows. Tswana cows that calved the previous year had an ICP of 395.5 days while Composite cows of the corresponding category had 361.1 days. Tswana cows therefore had an interval of 34.4 days more than Composite cows. Tswana cows may have calved earlier than the Composite cows. Results of Tswana cows that calved corresponds with those reported by Titterington *et al*. (2017). The study reported an interval of 395 days for Limousin, Simmental and Blonde d'Aquitaine cows. Hereford, Charolais and Belgian blue on the other hand had an interval slightly longer by few days (396, 399 and 400 days). Aberdeen

Angus cows showed the shortest interval (392 days) which is comparable to Tswana cows that aborted.

MacGregor & Casey (1999) observed that cows that calved latest the previous year had shorter intervals the subsequent year than those that calved earliest. Within the aborted cows, the difference between Composites and Tswanas was 27.9 days. Mukasa-Mugerwa (1989) reported that calving intervals of cows whose calves died tend to be shorter by months, while for aborted cows it is reduced by several days. In another study, cows that lost their calves shortly after calving were observed to return to estrus earlier (58. 5 days) (Dawuda *et al*., 1988), this means that they are likely to have shorter ICP than other cows.

There was no significant difference (P >0.05) in ICP between heifers of both breeds but numerically, Composite cows had longer intervals than Tswana cows by 12.3 days (532.3 vs 520.0 days). Similarly, for cows that skipped a year without conceiving, the same variation was observed (P >0.05) except that from a numerical point, Tswana cows bypassed the Composite cows with 12.9 days. Results indicate that Composite and Tswana cows that skipped a calving season had the longest ICP (692.5 and 705.4 days). These cows failed to conceive for *ca.* 22 months after their last calving. There may be a possibility that these cows were under severe nutritional stress. This means that they needed sufficient time to fully recover because of the resource limited environment they are reared in. Additionally, from a production point, such intervals are not economical and hence calls for culling.

The ICP values of the present study in relation to abortion are lower than those reported by Bronner *et al*. (2015). The authors reported calving interval within the range of 691-726 days, which is closely like the ICP of cows that skipped years without conceiving. Abortions in cows may be a result of diseases e.g. Brucellosis, Vibriosis, Q fever and Trichomoniasis (Robert & BonDurant, 2005; Bronner *et al*., 2015; Bishi *et al*., 2018). According to Zewdu *et al*. (2015), cows with longer intervals tend to have fewer calves than cows of the same herd life that exhibited shorter intervals. Calving intervals can be shortened through improved herd management, focusing more specifically on the period between calving and first estrus (Zewdu *et al*., 2015).

4.3.4 Days to conception of Composite and Tswana cows

Table 4.3.4.1 Effects of cow size on days to conception of Composite and Tswana cows in Botswana during the period under investigation

	DTC			
	Composite		Tswana	
Cow size (kg)	Days	Months	Days	Months
Big	212.7	6.97	219	7.18
Medium	204.2	6.70	221.2	7.25
small	198.6	6.51	222.6	7.30

Table 4.3.4.2 Effects of cow age on days to conception of Composite and Tswana cows in Botswana during the period under investigation

	DTC			
	Composite		Tswana	
Cow age (years)	Days	Months	Days	Months
3	133.5	4.38	253.2	8.30
4	224.9	7.37	206.4	6.77
5-12	228.7	7.50	219.1	7.18
≥13	233.6	7.66	205	6.72

Table 4.3.4.3 Effects of previous parous state on days to conception of Composite and Tswana cows in Botswana during the period under investigation

	DTC			
	Composite		Tswana	
Previous parous state	Days	Months	Days	Months
Heifer	249.8	8.19	237.5	7.79
Calved	78.6	2.58	113	3.70
Skipped	410	13.44	422.9	13.87
Aborted	82.3	2.70	110.2	3.61

Days to conception (DTC) of Composite and Tswana cows in this study exceeded the standard 80 - 90 days recommended in some studies (Peters, 1984; Werth *et al.*, 1996, Ball & Peters, 2004; Crowe, 2008; Webb *et al.*, 2017). On average, both Composite and Tswana cows took *ca*. 6 - 7 months to conceive again after calving. Some cows went beyond the 6 - 7 months, such as 3-year-old Tswana heifers (Table 4.3.4.2), Composite cows that were heifers the previous year as well as those that skipped a calving season (Table 4.3.4.3). From Table 4.3.4.1, it follows that Tswana cows delayed conception by more days as compared to Composite cows. Composite and Tswana cows weaned their calves at 7 months. Interestingly this is close to the time when they resumed their ovarian cyclicity. This relates well to previous findings that reported a longer intercalving period caused by the effects of calf sucking (Meaker, 1984; Sanz *et al*., 2003; Messine *et al*., 2005; Brar & Nanda, 2008; Escrivão *et al*., 2009; Escrivão *et al*., 2012; Diskin & Kenny, 2016).

The 133.5 days intercalving period recorded for young Composite cows does not differ much from the 131.5 days reported by Dawuda *et al*. (1988). Zewdu *et al*. (2015) reported an overall period of 149.15 days, which was slightly higher than that of young Composite cows. However, Dawuda *et al*. (1988) reported 119 days for cows with more than two calvings which is comparable to the 113 and 110.2 days of the Tswana cows that calved and aborted respectively. Amin *et al*. (2013) reported intercalving periods of 178.6 days from red Chittagong cows which is shorter than the values from this study except for calved, aborted cows and young Composite cows. Another study reported only 97 days to conception in Angus × Friesian crosses and 90 days for both Angus × Kiwi and Angus × Jersey crosses (Hickson *et al*., 2012). However, pure bred Angus and Friesian heifers from the same study required 101 days for conception. Overall the values reported in previous studies do not differ much from that of Composite and Tswana cows that calved or aborted in the present study.

CHAPTER 5:
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the study it can be deduced that the effects of breed type, sex of calf, year of birth, month of calving, previous parous state, cow size and age significantly (P <0.05) influenced the growth and reproduction of Composite and Tswana cattle. Composite calves were generally heavier than the Tswana calves, but results indicate that BWT of Tswana calves was heavier compared to Composite calves. Composite calves outweighed the Tswana calves at both weaning and 18 MWT. From these observations, it follows that the Composites grow faster than the indigenous Tswana cattle. Furthermore, bull calves had heavier weight than the heifers in both breeds pre- and post-weaning.

Calf weight at birth increased with cow age until the cows reached maturity (5- 12 years), thereafter the weight started to decline as the animal got older (≥13 years). Although older cows gave birth and weaned heavier calves in both breeds, the study found that cow age did not influence 18 MWT of Tswana heifers. Calf weight was also found to reflect the cow's size as larger cows had calves with heavier BWTs and vice versa for small framed cows.

Composite and Tswana calves born early in the calving season tended to have lighter birth weights than calves born later in the season. However, the same calves that were born early were heavier at weaning, possibly because they were older than the calves born later in season. Late born calves were heavier at birth only and it was perhaps due to the availability of pasture during December and January months. The weight traits of the calves varied from year to year, but the results indicate that the weight of Composite calves was high when there was good rainfall. Tswana calves on the other hand maintained a better weight even when rainfall was low. The influence of previous porous state on BWT between the two breeds differed (P <0.05), with non-parous Composite cows producing calves that weighed less while the opposite was true for parous Tswana cows.

Results proved that Composite cows lost more weight from parturition to weaning while Tswana cows gained. This was a good indicator of adaptability between the two breeds. Composite cows showed an increase in ICP as the cows got older, meaning that younger cows had a shorter ICP than the matured and older cows. Within the Tswana breed, 3-year-old cows portrayed the longest interval but was not different (P >0.05) from the rest of the age groups. However, there was a significant difference (P <0.05) between 4 and 5-12-year-old cows. The study observed that for Tswana cows, ICP decreased with an increase in cow age.

There was no effect *(P* >0.05) of cow size on ICP of Tswana cows. Numerically, small Tswana cows had the longest interval (505.1 days) followed by the medium (503.7 days) and the big cows (501.5 days). In the Composite breed, ICP increased with cow size but the interval between medium and small cows was quite insignificant (*P* >0.05). As expected, cows that skipped a year without calving had the longest ICP followed by heifers. Tswana cows also took longer to conceive than the Composite cows. Lastly, both breeds showed extended intervals of more than 365 days, except calved and aborted Composite cows.

5.2 Recommendations

Early calving and weaning are highly recommended in extensive beef production systems, because calves born early in the season had higher weaning weights. Furthermore, due to longer intercalving periods for both Tswana and Composite cows, it is advisable to introduce calf suckling restriction to improve early reconception rates and production. Factors such as management and production environment may be the causes of the variation in reproduction rates observed in this study, therefore, management in communal areas should be improved to shorten the lengthy calving intervals. Improvements may be achieved by means of several strategies such as early breeding and calving, 48-hour calf removal and supplementation, better management of body condition scores, bull fertility management and strategic lick supplementation. The effects of cow size seem negligible in Tswana cows, but it is recommended that medium or small frame Composite cows are selected for breeding since large sized Composite cows had longer ICP's with lower longevity.

CHAPTER 6:
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