ESTIMATION OF GENETIC AND NON-GENETIC PARAMETERS FOR GROWTH TRAITS IN TWO BEEF CATTLE BREEDS IN BOTSWANA

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Declaration

I hereby declare that this submission is my own work and that it has not, as a whole or partially, been submitted to any other university for the purpose of acquiring a degree.

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Summary

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Research conducted on beef cattle in Botswana investigated both growth and reproduction. These studies however, did not specifically determine the influence of the different environmental factors on growth in the Tswana and Composite beef cattle breeds. The establishment of a national beef herd recording and performance testing scheme requires knowledge on the appropriate adjustment methods of field data for the fixed effects such as sex of calf and age of dam. A fair comparison of birth and weaning weights between male and female calves, and calves born from young, mature and old dams will be derived from these adjustment factors. There is no information on adjustment factors for the Tswana and Composite cattle breeds in the country. Genetic parameters for growth traits in these breeds are not known and are needed for the implementation of the performance scheme in Botswana.

The Composite breed resulted from a controlled crossbreeding programme using the Simmental, Brahman, Tswana, Tuli and the Bonsmara breeds. The Tswana animals are indigenous to the country and were sourced locally at the beginning of the growth evaluation trial in the two breeds.

The objectives of the study were to use data collected from Tswana and Composite cattle breeds to estimate the influence of non-genetic factors on growth traits in the two breeds; to develop adjustment factors for the effects of sex of calf and age of dam; and to estimate genetic parameters (heritabilities and genetic correlations) for future genetic evaluations in both breeds. Data were collected over the period 1988 to 2006. A total of 2 257 records for the Composite breed and 5 923 records for the Tswana breed were available for analyses. Growth characteristics of interest in this study were birth weight (BW), weaning weight (WW), pre-weaning average daily gain (ADG1), 18 months weight (18MW) and post-weaning average daily gain (ADG2).

Study 1 indicated that non-genetic effects of breed of calf, sex of calf, month and year of birth, previous parous state, weight of cow at parturition, age of dam, and age of calf at weaning significantly affected BW, WW, 18MW, ADG1 and ADG2 in both breeds. The Composite breed had higher BW, ADG1 and WW whereas the Tswana had higher ADG2 and 18MW. Pre-weaning growth rate increased with an increase in the age of the dam, reaching a peak in mature (5-12 years) cows and declined in cows 13 years and older. Conversely, post-weaning growth rates declined as age of dam advanced but increased in old (13 years and older) dams. Male calves were heavier than female calves for all the growth traits. Birth weight increased as calving season progressed whilst a decrease in WW was observed over the same period. Heifers gave birth to lighter calves when compared to mature multiparous dams. The Composite breed can therefore be considered for weaner production under ranch conditions while the Tswana can be reared under extensive systems due to its adaptability to the environment.

Additive correction factors for effects of sex of calf and age of dam on BW and WW were studied separately for the Tswana and Composite in study 2. The least squares means procedure was used to derive age groups and the adjustment factors. The three age groups were young (4 years and below) dams, mature (5-12 years) dams and older (13 years and above) dams. Male calves were heavier than their female counterparts. The sex of calf adjustments for BW and WW were 2.75 and 8.21 kg in the Tswana, and corresponding values for the Composite 2.84 and 10.11 kg, respectively. Birth weight and WW increased as age of dam increased, reached maximum in mature dams and declined in older dams. Age of dam adjustment factors for BW in the 3, 4 and 13+ years age groups for the Tswana were 1.74, 0.96 and 1.87 kg, respectively. The corresponding values for the Composite were 2.28, 0.94 and 2.06 kg, respectively. Age of dam adjustment factors for weaning weight in the Tswana were 10.36 and 5.46 kg for age groups 3-4 and 13+ years, respectively. Adjustment factors for WW in the Composite were 13.84, 3.20 and 9.58 kg for age groups 3, 4 and 13+ years. The differences in adjustment factors obtained between the two breeds emphasize the need to compute and apply these factors within breed.

Study 3 involved the estimation of genetic parameters for BW, WW, ADG1, 18MW and ADG2. Single-trait and multi-trait analyses were used in the estimation of (co)variance components by fitting an individual animal model (AM) and the animal maternal model (AMM) for the two breeds. Direct heritabilities for BW, WW, ADG1, 18MW and ADG2 in the Tswana were 0.45, 0.32, 0.37, 0.31 and 0.31, respectively from a single-trait AM analysis. Fitting the AMM resulted in direct heritabilities of 0.31, 0.20 and 0.16 for BW, WW and ADG1, respectively, while the maternal heritabilities were 0.11, 0.15 and 0.21, respectively. For the Composite the direct heritabilities for BW, WW and ADG1 were 0.58, 0.32 and 0.30, respectively with single-trait AM. Partitioning using the AMM resulted in the direct heritabilities for BW, WW and ADG1 of 0.55, 0.17 and 0.14, respectively, while corresponding maternal effects were 0.09, 0.15 and 0.15, respectively. The genetic correlations between direct and maternal effects were positive and ranged from 0.20 to 0.89. When using the multi-trait analysis and fitting the AM, the direct heritabilities for the Tswana were 0.45, 0.37, 0.34, 0.39 and 0.31 for BW, WW, ADG1, 18MW and ADG2, respectively. Genetic correlations between the growth traits ranged from 0.16 to 0.97. Direct (and maternal) heritabilities for BW, WW and ADG1 were 0.31(0.11), 0.19(0.15) and 0.14(0.17), respectively, in the Tswana. Correlations between direct heritabilities for BW, WW and ADG1 ranged from 0.45 to 0.95, while maternal effects ranged from 0.12 to 0.99. The magnitude of the heritabilities indicates an existence of the opportunity to make genetic progress through selection in both breeds. Selection based on WW seems to be the ideal procedure to bring genetic improvement in the Tswana without detrimental long term effects.

Opsomming

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Navorsing wat op die vleisbeesrasse in Botswana gedoen is, het hoofsaaklik op beide groei en reproduksie gehandel. Hierdie studies het egter nie spesifieke gefokus op die bepaling van die invloed wat verskillende omgewingsfaktore op die groei van saamgestelde (d.i. *Composite*) en die Tswana vleisbeesrasse het nie. Die bepaling van ŉ nasionale vleisbees rekordhouding- en prestasietoetsskema verg kennis van die mees gepaste metode om velddata vir vaste effekte soos geslag van die kalf en ouderdom van die moeder aan te pas. Hierdie aanpassingsmetodes sal lei tot die regverdige vergelyking van geboorte- en speengewigte tussen manlike en vroulike diere, sowel as van kalwers gebore van jong, volwasse of ou moeders. Tans is daar geen inligting oor aanpassingfaktore vir die Tswana en saamgestelde vleisbeesrasse in Botswana bekend nie. Geen genetiese parameters vir groei-eienskappe vir geeneen van die rasse is beskikbaar nie en word benodig vir die implementering van die prestasie skema in Botswana.

Die saamgestelde ras is die produk van ŉ beheerde kruisteeltprogram, wat onderskeidelik die Simmental, Brahman, Tswana, Tuli en die Bonsmara beesrasse ingesluit het. Die Tswana ras is inheems aan Botswana en vanaf plaaslike bronne vir die groei evaluasie studie bekom.

Die doelwitte van die studie was eerstens die analisering van data wat van beide die Tswana en saamgestelde rasse ingesamel is, om die invloed van nie-genetiese faktore op die groei eienskappe te bepaal om ten einde aanpassingsfaktore vir die effek van geslag van die kalf en ouderdom van die moederdier te ontwikkel. ŉ Tweede doelwit was die bepaling van genetiese parameters (oorerflikhede en genetiese korrelasies) vir die gebruik in toekomstige genetiese evaluering van beide rasse. Data is vanaf 1988 tot 2006 ingesamel. ŉ Totaal van 2 257 waarnemings vir die saamgestelde ras en 5 923 waarnemings vir die Tswana ras is ontleed. Groei eienskappe wat in die studie ondersoek is, het geboortegewig (BW),

speengewig (WW), voorspeen gemiddelde daaglikse toename (ADG1), 18-maand gewig (18MW) en naspeense gemiddelde daaglikse toename (ADG2) ingesluit.

Studie een het aangedui dat nie-genetiese effekte van die ras van die kalf, die geslag van die kalf, maand en jaar van geboorte, vorige dragtigheidsstatus, koei se gewig met geboorte van kalf, ouderdom van die moederdier en die speenouderdom van die kalf het ŉ betekenisvolle invloed op BW, WW, 18MW, ADG1 en ADG2 van beide rasse gehad. Die saamgestelde ras het hoër waardes vir BW, ADG1 en WW gehad, terwyl die Tswana ras hoër waardes vir ADG2 en 18MW geopenbaar het. Voorspeense groeitempo het toegeneem met ŉ toename in die ouderdom van die moederdier, met ŉ piek in volwasse (d.i. 5-12 jaar ouderdom) moeders en ŉ afname in koeie 13 jaar en ouer. Omgekeerd het naspeen groeitempo afgeneem met ŉ toename in die ouderdom van die moederdier en weer begin toeneem vir ou (d.i. 13 jaar en ouer) koeie. Geboortegewig het toegeneem met die verloop van die kalfseisoen, terwyl ŉ afname in WW vir dieselfde periode aangeteken is. Verse het, wanneer hulle met volwasse koeie vergelyk is, het geboorte aan ligter kalwers gegee. Die saamgestelde ras kan dus oorweeg word vir die produksie van speenkalwers onder kommersiële intensiewe toestande, terwyl die Tswana ras, op grond van sy beter aanpassing by ekstensiewe omstandighede waar die moederlike invloed nie voorkom nie, vir produksie onder ekstensiewe omstandighede gebruik kan word.

In studie 2 is die additiewe korreksie faktore vir die invloed van geslag van die kalf en moederouderdom op BW en WW apart vir die twee rasse bestudeer. Die geslag van die kalf x ouderdom van die moederdier interaksie was nie betekenisvol vir enige van die rasse nie. Dus kan geen aanpassing vir die ouderdom van die moeder binne geslagte vir enige van die twee rasse gemaak word nie. Die kleinste kwadraat gemiddeldes metode is gebruik om die ouderdomsgroepe en aanpassingsfaktore te bepaal. Die drie ouderdomsgroepe was jong (d.i. 4 jaar en jonger) koeie, volwasse (d.i. 5-12 jaar ouderdom) en ouer (d.i. 13 jaar en ouer) koeie. Daar is gevind dat manlike kalwers swaarders as hulle vroulike eweknieë is. Die aanpassingswaarde vir die geslag van die kalf vir BW en WW was 2.75 kg en 8.21 kg in die Tswana en 2.84 kg en 10.11kg vir die saamgestelde ras. Geboortegewig en WW het toegeneem met ŉ toename in die ouderdom van die moeder. Dit het ŉ maksimum bereik in volwasse koeie en afgeneem vir koeie ouer as 13 jaar. Die aanpassingsfaktore vir die ouderdom van die moederdier vir BW in die 3, 4 and 13+ jarige ouderdomsgroepe vir die Tswana ras was onderskeidelik 1.74 kg, 0.96 kg en 1.87 kg. Die ooreenstemmende waardes vir die saamgestelde ras was onderskeidelik 2.28 kg, 0.94 kg en 2.06 kg. Aanpassingsfaktore vir WW vir die Tswana ras was 10.36 kg en 5.46 kg vir onderskeidelik die 3-4 jaar en 13+ jaar en ouer ouderdomsgroepe. Aanpassingsfaktore vir WW in die *Composite* ras was 13.84 kg, 3.20 kg en 9.58 kg vir onderskeidelik die 3 jaar, 4 jaar en 13 jaar en ouer ouderdomsgroepe. Verskille in die onderskeie parameters vir die twee rasse beklemtoon die noodsaaklikheid vir die berekening en toepassing van die onderskeie aanpassingfaktore vir en binne elke ras.

Studie 3 het die bepaling van die genetiese parameters vir BW, WW, ADG1, 18MW en ADG2 behels. Enkel- en multivariaat analises is gebruik vir die skatting van die (ko)variansie komponente deur ŉ direkte diermodel (AM) en ŉ dier-maternale model (AMM) vir die twee rasse te pas. Direkte oorerflikhede vir BW, WW, ADG1,

18MW en ADG2 vir die Tswana ras was onderskeidelik 0.45, 0.32, 0.37, 0.31 en 0.31, vir ŉ enkelvariaat AM analise. Die pas van ŉ AMM het direkte oorerflikhede van 0.31, 0.20 en 0.16 vir onderskeidelik BW, WW and ADG1 gegee, terwyl die maternale oorerflikhede onderskeidelik 0.11, 0.15 en 0.21 was. Vir die saamgestelde ras was die direkte oorerflikhede vir BW, WW en ADG1 onderskeidelik 0.58, 0.32 en 0.30 vir die enkelvariaat AM analise. Verdeling (partisie) van die AMM het direkte oorerflikhede vir BW, WW en ADG1 van onderskeidelik 0.55, 0.17 en 0.14 gegee, terwyl die ooreenstemmende maternale effekte onderskeidelik 0.09, 0.15 en 0.15 was. Die genetiese korrelasies tussen die drekte en maternale effekte was positief en tussen 0.20 en 0.89. Met die multivariaat analise en die pas van die AM, is direkte oorerflikhede van 0.45, 0.37, 0.34, 0.39 en 0.31 vir onderskeidelik BW, WW, ADG1, 18MW en ADG2, vir die Tswana ras bereken. Genetiese korrelasies tussen die groei eienskappe het gewissel tussen 0.16 tot 0.97. Direkte (en maternale) oorerflikhede vir BW, WW en ADG1 was onderskeidelik 0.31(0.11), 0.19(0.15) en 0.14(0.17), vir die Tswana ras. Korrelasies tussen die direkte oorerflikhede vir BW, WW en ADG1 het gewissel tussen 0.45 en 0.95, terwyl die maternale effekte tussen 0.12 en 0.99 gewissel het. Die grootte van die oorerflikhede dui op die moontlikheid van genetiese vordering wat deur seleksie in beide rasse gemaak kan word. Seleksie op grond van WW blyk die mees gepaste wyse te wees waarmee genetiese vordering binne die Tswana ras gemaak kan word, sonder enige langtermyn nadelige effekte.

Dedication

To my father Gabakgonwe Raphaka and my mother Ditsothe Raphaka who wholeheartedly contributed to my education.

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CHAPTER 1

GENERAL INTRODUCTION

The livestock industry in Botswana is dominated by beef production. The beef sector plays an important socio-economic role in the lives of the people, especially in rural communities. The sector also contributes to the country's gross domestic product (GDP) as 80% of the beef output is exported to the European Union (Machacha, 2003). Beef production is however, highly dependent on the communally raised cattle which comprise 96% of the national beef cattle population. The remaining 4% is raised commercially on ranches (Central Statistics Office, 2004). The indigenous cattle breeds that are found in the communal sector include the Tswana, Tuli and Afrikaner (Buck & Light, 1982). One of the disadvantages of the communal land-tenure system is uncontrolled breeding which compromises production and thus impacts negatively on the economic viability of cattle rearing.

The Tswana is the major indigenous cattle breed in Botswana and has traditionally contributed significantly to the beef industry. Trail *et al*. (1977) and Swanepoel & Setshwaelo (1995) observed that indigenous breeds in tropical regions were adapted to the tropical conditions and have demonstrated superior fertility when compared to the mostly exotic *Bos taurus* breeds (Moyo, 1995; Moyo *et al*., 1996, Mhlanga *et al*., 1999). Studies conducted in Botswana however, indicated that local breeds in traditional farming systems displayed poor growth abilities (Lethola & Trail, 1981). Tawonezvi *et al.* (1988), Moyo *et al.* (1996) and Mhlanga *et al*. (1999) found that calves from indigenous breeds were lighter when compared to calves from exotic breeds and their crosses.

In an effort to increase growth performance and reduce haphazard crossbreeding that existed in communal areas, the Department of Agricultural Research (DAR) in Botswana embarked on the process of creating a composite breed. The Composite breed comprises of the Simmental (26.3%), Brahman (22.6%), Tswana (28.4%), Tuli (4.4%) and Bonsmara (18.3%) (Mpofu *et al*., 1996). Schoeman *et al*. (2000) indicated that the advantage of a synthetic breed lies in combining the desirable and complimentary characteristics of all breeds into one breed. Since its inception, the Composite breed has not been extensively evaluated for environmental and genetic factors that influence its growth.

Performance evaluation of the Tswana breed by the DAR started in the late seventies. Selection in the Tswana herds was primarily based on phenotype. Bulls from this selection system have been widely used by farmers for breeding purposes. There are no genetic parameter estimates for beef cattle breeds in Botswana including the Tswana. Availing this information will help in designing proper selection programs to improve growth traits among breeds. It is important to incorporate improved methods of genetic evaluation, especially through the estimation of genetic parameters such as heritability estimates and correlations among traits, so that an understanding of the dynamics of gene transmission between generations of a breed is gained.

No work has been done to estimate the genetic parameters for growth traits in the Composite breed. As a potential alternative breed in the country's beef sector, it is imperative that an effective genetic improvement program for it be established. The availability of this information will help farmers who are interested in keeping the breed to objectively identify superior animals and use them as parents of the next generation.

In beef cattle production, growth characteristics of the animals are important in determining the system's sustainability and profitability. There are no studies that have been conducted to evaluate the influence of environmental factors on the growth performance of the Tswana and Composite breeds of cattle in Botswana. Information on how the different non-genetic effects affect growth traits in the Tswana and Composite breeds will facilitate not only the evaluation of the breeds for growth potential but also to help in other aspects of management and husbandry of animals. Moreover, to improve accuracy of evaluating cattle for growth traits such as birth weight, weaning weight and 18 months weight, adjustment factors for some environmental effects such as sex of calf, age of the dam and age of the calf are required (Rossi *et al*., 1992). Currently, there are no published adjustment factors for beef cattle breeds in Botswana.

The implementation of the national beef herd recording and performance-testing scheme called Beef Improvement Botswana (BIB) by the DAR (Jeyaruban & Raphaka, 2006) will derive long-term benefits from knowledge generated from this study.

The objective of this study, therefore, was to use recorded performance data of the Tswana and Composite breeds in Botswana to:

1) estimate the effects of environmental factors on birth weight, weaning weight, 18-months weight, pre-weaning and post-weaning average daily gain of the Tswana and Composite cattle breeds;
2) develop adjustment factors for birth weight and weaning weight of the Tswana and Composite cattle breeds and;
3) estimate genetic parameters for birth weight, weaning weight, 18-months weight, pre-weaning and post-weaning average daily gain of the Tswana and Composite cattle breeds.

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CHAPTER 2

LITERATURE REVIEW

The cattle genetic resources in Botswana include the *Bos taurus* breeds e.g. the Charolais, Simmental, and South Devon; the Sanga type breeds e.g. the Tswana, Tuli, and Afrikaner; the *Bos indicus* mainly the Brahman; and Composite breeds such as the Bonsmara, Santa Gertrudis, Beefmaster and Botswana Composite. Most of these breeds are reared under the communal grazing set-up in Botswana. Various factors determine the profitability of beef production among which vigorous growth of animals from birth is an important component. This literature review examines the subject of growth and how it is influenced by environmental and genetic factors.

2.1 Growth in Sanga and Composite breeds

Growth in livestock is defined as an increase in tissue mass (Owens *et al*., 1993), comprising of muscle, fat and bone. Growth has a crucial effect in the value and profitability of beef cattle and is usually measured at different stages of an animal's growth.

2.1.1 Sanga cattle breeds

Several studies involving the growth performance of indigenous breeds have been carried out in different parts of Southern Africa. Trail *et al.* (1977) compared the growth performance of the Tswana, Tuli and Afrikaner at different stages of growth in Botswana (Table 2.1). Growth performance was compared for birth weight (BW), weaning weight (WW) and 18-months weight (18MW).

Table 2.1 Least squares means (kg) of BW, WW and 18MW of the Tuli, Tswana and Afrikaner breeds in Botswana.

Breed	BW	WW	18MW
Tuli	28.8	169.6	283.6
Tswana	30.7	174.6	278.5
Afrikaner	29.9	166.1	269.7

The Tswana and Afrikaner were heavier than the Tuli at birth. Tswana calves were the heaviest at weaning and the Tuli and Tswana were heavier than the Afrikaner at 18 months of age. The results reported above for the Tswana, for birth and weaning weight averages are comparable to those reported by Mpofu (1996) on unselected Tswana line 1 (earmarked for selection on weaning weight) kept from 1988 to 1993. However, the Line 1 Tswana were lighter at 18 months (269 kg) compared to 278.5 kg reported earlier by Trail *et al*. (1977). Results for birth weight of Tswana line 2 (for future selection on 18-months weight), kept over the same period (Mpofu, 1996) were comparable to those of Tswana line 1 and Tswana cattle from the study by Trail *et al*. (1977). The means for weaning weight and 18-months weight were lower for Tswana line 1 compared to those of the other mentioned Tswana populations.

Schoeman (1989) reported birth weight, weaning weight and 18-months weight of respectively 33.5 kg, 197 kg, and 319 kg for the Afrikaner. These weights were higher than those reported by Trail *et al*. (1977) on the same breed. Kgati *et al*. (1999) acknowledge this by explaining that the same breed reared under different environments can differ in terms of performance. Corresponding means for the Sanga population from the study of Schoeman (1989) were respectively 29.1, 180 and 297 kg for the three traits. Pre-weaning average daily gain (ADG) for the Afrikaner and Sanga type breeds were 0.80 and 0.73 kg, respectively.

Results from studies on the Mashona, Tuli and Nkone cattle breeds of Zimbabwe (Mhlanga *et al*., 1999) are in Table 2.2. Moyo (1995) also reported weaning weight and 18-months weight for the same breeds (results in parenthesis).

Table 2.2 Comparative performance of beef breeds evaluated in Zimbabwe.

Breed	**BW**	**WW**	**18MW**
Tuli	32.1	180.0 (187)	294.0 (275)
Mashona	24.3	156.2 (176)	267.2 (261)
Nkone	31.4	187.5 (188)	278.8 (279)

The results indicated that at birth and later stages of growth the Tuli and the Nkone were heavier than the Mashona. These breeds are believed to share a common ancestral background with the Tswana.

Mhlanga *et al*. (1999) also reported average daily gains for the above breeds. Pre-weaning average daily gain for the Mashona, Tuli and Nkone breeds were 0.48, 0.62 and 0.63 kg, respectively. Post-weaning daily gains were 0.33 and 0.47 kg for the Mashona and Tuli, respectively.

Another study done by Tawonezvi *et al*. (1988) compared calves from purebred cows of both indigenous and exotic types for weaner production. Weaning weights (at 240 days) were 184, 172, 187, and 184 kg for the Afrikaner, Mashona, Nkone, and Tuli, respectively. Beffa (1995) reported average birth weight, weaning weight and 18-months weight of 31, 153 and 267 kg respectively for the Afrikaner.

Carvalheira *et al*. (1995) studied a comparison of the Landim, a beef breed from Mozambique, and the Afrikaner. The results showed that Afrikaner calves were on average 16, 9, and 7% heavier than the Landim calves at birth, weaning, and 18 months. The lighter weights of the Landim calves were attributed to the breed's adaptational ability to subsist on unimproved pastures by maintaining a small body size.

Lusweti (2000) conducted a study to compare the performance of the Nguni, Afrikaner and Bonsmara under drought conditions in the Limpopo Province in South Africa. The birth weights for the respective breeds were 30.3, 30.2, and 31.1kg, while the 200 day weights were 135.6, 173.6, and 150.6 kg, respectively. The Afrikaner performed better than the other breeds at weaning, even though they had an almost similar average birth weight.

2.1.2 Composite cattle breeds

Crossbreeding trials carried out in Botswana during the seventies yielded results that would eventually lead to the idea of producing the country's first composite breed. The comparisons done by Trail *et al*. (1977) between different crossbred types created from crossbreeding Simmental, Brahman, Bonsmara and Tuli sires to Tswana dams displayed growth advantage through heterosis. Calves produced from Simmental and Brahman sires were heavier than purebred Tswana calves at all stages of growth. The Bonsmara sired calves were heavier than their Tswana contemporaries at birth and 18 months, while the Tuli was only heavier than the Tswana at 18 months. At 18 months the Simmental and Brahman crosses weighed 324 and 304 kg respectively, compared to 279 kg for pure Tswana. Bonsmara and Tuli crosses also proved to be superior to the Tswana by respectively weighing 294 and 290 kg (Trail *et al*., 1977).

Light *et al*. (1982) conducted an analysis on the productivity of calves produced from Simmental, Bonsmara, Brahman and Tuli crossbred cows. The progeny from Simmental and Bonsmara crossbred cows were still heavier than for the other crosses. Calves from Simmental cross cows weighed 214 kg at weaning while the Bonsmara and Brahman cross cows weighed 203 and 198kg, respectively. These weights were significantly higher compared to calves from Tuli and Tswana cross dams, which weighed 187 and 184 kg, respectively. Tawonezwi *et al*. (1988) showed that *Bos-taurus* x *Bos-indicus* cross cows were superior pertaining to reproduction when compared to Sanga x Sanga, Sanga x Zebu, *Bos-taurus* x Sanga, and *Bos-taurus* x *Bos-taurus* cows. Even though heterosis was positive for all the traits (averaging 15%) it was three times higher in the *Bos-taurus* x *Bos-indicus* crosses. The breeds involved in the study were the Brahman, Mashona, Nkone, Afrikaner, Charolais and Sussex.

During the on-station evaluation of the Composite breed in Botswana, its growth performance was compared to that of the Tswana, Tuli and Bonsmara. The Bonsmara is a composite breed developed in South Africa by combining the Afrikaner, Hereford and Shorthorn (Mpofu *et al*., 1996). Table 2.3 shows results from the comparison.

Table 2.3 Least squares means for growth traits for the Composite breed as compared to those for the Tswana, Tuli and Bonsmara breeds.

Breed	BW	WW	18MW
Composite	34.59	190.45	286.29
Tuli	29.09	173.12	247.45
Tswana	33.91	179.27	265.76
Bonsmara	34.13	190.22	273.83

The Composite breed outperformed both the Tswana and Tuli at all stages of growth. Despite its better performance compared to the indigenous breeds, it was found that there were no significant differences between birth and weaning weights of the Composite and the Bonsmara breeds. However, the Composite breed was heavier than the Bonsmara at 18 months of age. Maiwashe *et al*. (2002) reported averages for birth weight and weaning weight of respectively 37.0 and 228.9 kg for Bonsmara bull calves. These were higher than the averages reported by Mpofu *et al*. (1996) for a study conducted in Botswana.

In Australia, Burrow (2001) studied two types of composite breeds which are genetically related to the Bonsmara breed of South Africa. The average birth, weaning and 18 months weights were 34.9, 182, and 313 kg, respectively. The results for birth weight were similar to those reported for the Composite breed in Botswana (Mpofu *et al*., 1996). The latter was however, heavier at weaning but lighter at 18 months when compared to the Australian composites. The average daily gains reported by Burrow (2001) were 0.77 kg pre-weaning and 0.44 kg post-weaning.

Another composite breed, the Santa Gertrudis, which is also used in South Africa, was studied by Schoeman (1989). The BW, WW (205-day weight), and 18MW for the breed were respectively 34.3, 234 and 345 kg. These means were higher than means reported for the Composite breed by Mpofu *et al*. (1996) in Botswana. The Santa Gertrudis had a pre-weaning ADG of 0.98.

2.2 Non-genetic effects on growth of beef cattle

Growth in beef cattle is a result of both genetic and environmental effects. Breeding values are obtained by correcting the animal's phenotype for known environmental effects and therefore are predicted using mixed models which contain both genetic and non-genetic (or fixed) effects. Fixed effects commonly include sex of calf, calf breed type, month and year of birth, age of dam, previous parous state and weight of cow at parturition.

2.2.1 Sex of calf

Most studies have identified sex of calf as having a significant influence on growth in beef cattle (Burfening *et al*., 1978; Gregory *et al*., 1978; Lawlor *et al*., 1984; McElhenny *et al*., 1986; Newman *et al*., 1993; Carvalheira *et al*., 1995; Plasse *et al*., 1995; Dzama *et al*., 1997; Melka, 2001). Differences in growth between male and female calves are partly due to testosterone, a hormone present in high amounts in males. Testosterone is known to enhance muscular development and growth in general. For example, Dillard *et al*. (1980) indicated that male calves were 2.2 kg heavier at birth and 10 kg heavier at weaning than female calves. Dillard *et al*. (1980) indicated that male calves grew 0.04 kg /day faster than females, while Burfening *et al*. (1978) recorded a 0.08 kg/day difference between the two gender classes. Other studies showed a similar trend (Gotti *et al*., 1988; Newman *et al*., 1993). Conclusive sex differences, where bull calves exhibited considerably higher post-weaning average daily gain and 18-months weight than females are reflected in previous research (Tawonezwi, 1989; Kars *et al*., 1994; Carvalheira *et al*., 1995; Dzama *et al*., 1997).

2.2.2 Breed of calf

Discrepancies in growth between breeds results from different inherent growth abilities and potential. Previous research has found breed of calf to be a significant source of variation for birth weight, weaning weight and pre-weaning average daily gain in beef cattle (Reynolds *et al*., 1980; Lawlor *et al*., 1984; Sacco *et al*., 1991; Carvalheira *et al*., 1995; Plasse *et al*., 1995). Accordingly, Kars *et al*. (1994), Carvalheira *et al*. (1995), Plasse *et al*. (1995) and Dzama *et al*. (1997) reported breed of calf to have a significant influence on post-weaning average daily gain and weight at 18 months.

2.2.3 Month of birth

Plasse *et al*. (1995) found month of birth to have a significant influence on birth weight. Carvalheira *et al*. (1995) indicated that calves born in the early rainy season were lighter than those born later in the same season. Differences in birth weight could also be attributed to the condition of dams during the calving month (Plasse *et al*., 1995). Differences in the availability of forage resources which affect the milk production of the dam and the nutrition of the calf also affected daily gain from birth to weaning and weaning weight (Carvalheira *et al*. 1995). The effect of month of birth was found to be significant up to 18-months weight (Plasse *et al*., 1995).

2.2.4 Year of birth

Similarly year of birth significantly affected birth weight (Gray *et al*., 1978; Sacco *et al*., 1991; van Zyl *et al*., 1992; Kars *et al*., 1994; Plasse *et al*., 1995); weaning weight (Gray *et al*., 1978; Sacco *et al*., 1991; van Zyl *et al*., 1992; Kars *et al*., 1994; Carvalheira *et al*., 1995; Plasse *et al*., 1995); pre-weaning average daily gain (Sharma *et al*., 1982; McElhenny *et al*., 1986); and post-weaning growth traits (Sharma *et al*., 1982; Kars *et al*., 1994, Plasse *et al*., 1995) in different beef cattle breeds. In most studies the influence was due to the variation in environmental conditions from year to year.

2.2.5 Age of dam

The significance of age of dam on growth traits has been well documented (Anderson & Wilham, 1978; Gray *et al*., 1978; Dillard *et al*., 1980; Sharma *et al*., 1982; Lawlor *et al*., 1984; Gregory *et al*., 1985; Elzo *et al*., 1987; Sacco *et al*., 1991; van Zyl *et al*., 1992; Schoeman *et al*., 1993; Plasse *et al*., 1995; Dzama *et al*., 1997). Sacco *et al*. (1991) and Newman *et al*. (1993) indicated that birth weight increased with an increase in the age of the dam. The same general trend was realized for weaning weight (Lawlor *et al*., 1984; Newman *et al*., 1993). Studies showed that as the age of the dam increased from 2-4 years, weaning weight increased by 19 kg (Dillard *et al*., 1980). Anderson and Willham (1978) found that weaning weight increased as the age of the dam increased to maturity (5-6 years), plateaued for mature cows, and declined as the age of the dam went beyond 10 years. This trend may be related to a study conducted by Robison *et al*. (1978), which showed that milk yield estimates increased markedly from 2-5 years of age, remained fairly level through 8 years of age and then decreased for older cows. Burfening *et al*. (1978) indicated that pre-weaning average daily gain increased with an increase in the age of the dam. Calves from 5-year-old dams expressed greater post weaning average daily gains than calves from 2 year old dams (Newman *et al*., 1993). Daily gains increased by 0.08 kg when age of dam increased from 2-4 years (Dillard *et al*., 1980). Gray *et al*. (1978) indicated that age of the dam significantly affected weaning weight. The effect of age of dam was found to be non-significant for weight at 18 months of age (Plasse *et al*., 1995).

2.2.6 Weight of cow at parturition

The influence of cow parturition weight has mainly been studied as pertaining to reproduction than for growth traits in beef cattle. A study on the influence of cow parturition weight on reproduction has also been conducted in Botswana (Light *et al*., 1982). The study entailed observed weight loss in the Simmental, Brahman, Bonsmara, Tswana and Tuli crossbred cows from parturition to weaning. Cows which reared a calf lost a significant amount of weight in that period. This could depict the advantage that large dams have, due to increased reserves that could be converted to milk produced for the calf. Roberson *et al*. (1986) found that large dams usually produce large calves, and attributed this to the direct and maternal genetic influence. Koch & Clark (1955) suggested that changes in size, weight and physiological function which accompany aging might be expected to influence maternal environment and have a direct effect on birth and weaning weights.

2.2.7 Previous parous state

Little information exists on the effect of previous parous state on growth in beef cattle. It was however, found that calves reared by dams parous the previous year were generally lighter at weaning than calves from dams which were non-parous and therefore rested the previous year (Buvanendran & Mason, 1982). From the study it was suggested that classes into which animals should be grouped are parous, parous but not having raised a calf and non-parous. Carvalheira *et al*. (1995) indicated that first-calvers gave birth to lighter calves than cows which are mature and usually multiparous. From the same study parity was found to be a less important source of variation for 18-months weight than for earlier weights.

2.2.7 Age of calf at weaning

Age at weaning is an important measurement which is usually used in conjunction with weaning weight. McElhenny *et al*. (1986) and Gray *et al*. (1978) reported that age at weaning was significant for weaning weight. Newman *et al*. (1993) concluded that older animals tended to be heavier at weaning, and expressed heavier final weights due to the linearity of the regression coefficients of the two traits. The effect of the age of the calf at weaning was also significant for average daily gain (Dillard *et al*., 1980). The significance of age of calf at weaning as a covariate of weaning weight was also reported by Melka (2001).

Leighton *et al*. (1982) carried out a study on Hereford cattle and found that only sex of calf and age of dam explained a biologically significant portion of the variation in weaning weight. Consequently he developed adjustment factors for these effects only.

2.3 Adjustment factors

Adjustment factors are important in beef cattle genetic evaluations because they allow for a fair comparison of animals during performance evaluations. For beef cattle, birth weight and weaning weight records are usually adjusted for sex of calf, age of dam and the age of calf at weaning when weaning weight is considered (Dzama *et al*., 1997).

Published reports show that average weights of male and female calves differ at all ages even when raised under similar environmental conditions (Koch *et al*., 1959), males being heavier than females. Average weaning weights were found to be higher for bull calves than for heifer contemporaries (Nelsen & Kress, 1981). Adjustment of weights for these differences is therefore desired for fair comparison between bull and heifer calves. Correction factors for sex in weights can either be additive or multiplicative. Literature shows that differences between sexes for birth weight range between 1.8 to 2.7 kg (Burris & Cecil, 1952; Botkin & Whatley, 1953; Koch & Clark, 1955). Brinks *et al*. (1961) recorded significant sex differences in birth weight of 2.34 kg.

Another adjustment that is done in beef cattle is correction for age of the dam. The general consensus from an extensive review of age-of-dam adjustment factors by Rumph & Van Vleck (2004) is that both birth and weaning weight are affected by age of dam. Therefore adjustment factors are necessary for accurate national genetic evaluations. Elzo *et al*. (1987) hypothesized that mature (5 to 8 years old) dams had a greater ability to provide adequate nutrients and the optimal uterine environment for the fetus compared to younger dams which are still developing themselves, while older dams may show diminishing uterine environmental effects. There is also a possibility of older dams sustaining sub-clinical damage to the udder tissue hence milk production being impaired.

Sex of calf x age of dam interactions were previously considered to establish if age of dam adjustment factors could be done within sexes or not. Cunningham & Henderson (1965), Minyard & Dinkel (1965), and Cardellino & Frahm (1971) found this interaction to be non-significant, indicating that there was no need to calculate sex-specific age of dam adjustment factors. Contrary results were however, reported in other studies (Barlow *et al*., 1974; Schaeffer & Wilton, 1974a; Anderson & Wilham, 1978 and Sharma *et al*., 1982).

For the most part some countries have been using age-of-dam adjustment factors developed by the United States Beef Improvement Federation (BIF). However, the general applicability of these adjustments to the tropical countries of Southern Africa can be debated. A country like Botswana has completely different conditions when compared to those prevailing in the United States. Moreover, the adjustment factors generated by the BIF are mostly for those breeds that are rendered exotic to Botswana. Breeds which are indigenous to this country (such as the Tswana) are not included.

Age-of-dam adjustment factors were derived by Dzama *et al*. (1997) for Zimbabwean beef cattle, including the indigenous Mashona breed. The results were compared to those of the BIF at dam ages of 2, 3, 4, mature (5-12 years for Hereford and Sussex, and 5-13 years for Mashona), and old (13 years and older) cows. The results indicated that the adjustment factors for the Mashona breed differed significantly from those recommended by BIF at 3 years, 4 years and at old age (13 years and older).

Adjustment factors vary greatly across breeds (Rumph & Van Vleck, 2004) and therefore should be analyzed and implemented on a within herd basis (Cardellino & Frahm, 1971). Age-of-dam effects can be affected by herd or management effects (Nunn *et al*., 1978; Buchanan & Nielsen, 1979).

2.4 Genetic parameter estimates

The phenotype of an animal is not only due to its genetic makeup but also subject to environmental factors. The genetic potential of an animal is measured by estimating the transferable (additive) genetic merit for a specific trait to the progeny of a specific animal. This is known as the estimated breeding value (EBV) of that particular animal for the specific trait. Important genetic parameters are heritabilities (h^2) and correlations (r_{xy}). By definition, heritability is the proportion of the phenotypic variation which is due to additive genetic effects; while correlations are measures of relationships among traits (Sivarajasingam *et al*., 1998). Heritability estimates are usually calculated for direct and maternal effects for live weights at birth and weaning. For both traits, the direct effect is related to the contribution of the calf's own genes to its capacity to grow. On the other hand, the maternal genetic effect on a calf's birth weight is assumed to be related to the dam's provision of the uterine environment for growth, while at weaning it is associated with the ability for the dam to provide a good physical environment, mainly through mothering ability (milk production and calf protection). Post-weaning, the calf fends for itself and heritability is calculated directly from its inherent genetic growth capacity. Genetic correlations are a measure of the association among traits, and can be highly antagonistic (-1), unrelated (0), or highly related (1) for a specific combination of traits. According to Koots *et al*. (1994b), estimates of genetic correlations are necessary inputs in designing breeding programmes and for other genetic evaluation methods.

Genetic parameter estimates for birth and growth traits are calculated as functions of the (co)variance components. The variance components are useful for depicting the genetic variability existent in populations.

Genetic parameters are important because they estimate gene transmission from one generation of a population to the next. They are also important for selection of superior individuals. Selected genetic parameter estimates for different breeds from literature are given in Tables 2.4 and 2.5.

Table 2.4 Literature estimates for genetic parameters on birth weight

Breed	**Country**	h^2_a	h^2_m	r_{am}	**Reference**
			Birth weight		
Nelore	Brazil	0.22	0.12	-0.72	Eler *et al*. (1995)
Nguni	South Africa	0.36	0.13	-0.43	Norris *et al*. (2004)
Synthetic breeds	South Africa	0.66	0.22	-0.32	Schoeman *et al*. (2000)
Angus	Australia	0.34	0.10	0.27	Meyer (1994)
Boran	Ethiopia	0.24	0.08	-0.55	H-Mariam & K-Messa (1995)
Bonsmara	South Africa	0.32	0.13	-	Maiwashe *et al*. (2002)
Hereford	Australia	0.38	0.14	0.05	Meyer (1992a)
De los Valles	Australia	0.32	0.13	-	Gutierrez *et al*.(1997)
Ndama and West African Shorthorn	Ghana	0.45	0.00	-	Ahunu *et al*.(1997)
Multibreed pop.	Canada	0.51	0.09	0.17	Tosh *et al*. (1999)
Hereford	New Zealand	0.23	0.14	0.30	Waldron *et al*. (1993)
Angus	New Zealand	0.31	0.09	0.26	Waldron *et al*. (1993)
Belmont red	Australia	0.57	0.18	-0.25	Burrow (2001)
Bonsmara and Belmont red	Australia	0.23	0.10	-0.09	Corbet *et al*. (2006b)
Brahman	Venezuela	0.31	0.09	0.16	Martinez & Galindez (2006)
Multi-crossbreds	Australia	0.38	0.08	-	Hetzel *et al*. (1990)

h^2_a, heritability of direct additive effects; h^2_m, heritability of maternal effects; r_{am}, genetic covariance between direct and maternal genetic effects.

Table 2.5 Literature estimates for genetic parameters on weaning weight and pre-weaning ADG

Breed	**Country**	**h^2_a**	**h^2_m**	**r_{am}**	**Reference**
			Weaning weight		
Nelore	Brazil	0.13	0.13	-0.32	Eler *et al*. (1995)
Nguni	South Africa	0.29	0.16	-0.52	Norris *et al*. (2004)
Synthetic breeds	South Africa	0.53	0.36	-0.53	Schoeman *et al*. (2000)
Zebu Crosses	Australia	0.59	0.49	-0.74	Meyer (1994)
Angus	Australia	0.19	0.18	0.20	Meyer (1994)
Bonsmara	South Africa	0.25	0.18	-	Maiwashe *et al*. (2002)
De los Valles	Australia	0.60	0.30	-0.73	Gutierrez *et al*.(1997)
Ndama and West African Shorthorn	Ghana	0.38	0.32	-0.29	Ahunu *et al*.(1997)
Multibreed pop.	Canada	0.33	0.13	-0.11	Tosh *et al*. (1999)
Hereford	New Zealand	0.14	0.41	-0.40	Waldron *et al*. (1993)
Angus	New Zealand	0.12	0.28	0.04	Waldron *et al*. (1993)
Belmont red	Australia	0.17	0.34	-0.19	Burrow (2001)
Bonsmara	Australia	0.11	0.17	-0.38	Corbet *et al*. (2006b)
Belmont red	Australia	0.14	0.23	0.21	Corbet *et al*. (2006b)
Brahman	Venezuela	0.17	0.11	0.12	Martinez & Galindez (2006)
Multi-crossbreds	Australia	0.16	0.16	-	Hetzel *et al*. (1990)
			Pre-weaning ADG		
Belmont	Australia	0.14	0.30	-0.17	Burrow (2001)
Bonsmara and Belmont red	Australia	0.13	0.18	-0.12	Corbet *et al*. (2006b)
Zebu crosses	Australia	0.16	0.31	0.00	Mackinnon *et al*. (1991)
Multi-crossbreds	Australia	0.14	0.18	-	Hetzel *et al*. (1990)

h^2_a, heritability of direct additive effects; h^2_m, heritability of maternal effects; r_{am}, genetic covariance between direct and maternal genetic effects.

2.4.1 Sanga cattle breeds

Information on genetic parameters for growth performance in Tswana cattle is lacking. There are however, genetic parameters which have been estimated for other indigenous breeds in Southern Africa. These Sanga-type breeds are believed to be related to the Tswana. Mhlanga *et al*. (1999) reported genetic parameter estimates from a review of previous studies on two breeds indigenous to Zimbabwe, the Mashona and Nkone. The heritability for the birth weight of Mashona cattle was estimated to be 0.30, while the direct and maternal heritabilities for weaning weight were 0.24 and 0.39, respectively. The correlation between direct and maternal genetic effects was -0.28 hence showing some antagonism in the two effects. The heritability for 18 months weight was 0.39. The heritability for the Nkone breed for birth weight was 0.32. Heritability estimates for weaning weight and 18 months weight were respectively 0.30 and 0.38 for the Nkone. These results indicate that growth from birth to 18 months of age in these breeds is moderately heritable. This is in agreement with a study carried out by Wasike *et al*. (2006) on the Boran cattle breed in Kenya. The heritability estimates for birth, weaning and 18-months weights were respectively 0.36, 0.40 and 0.21. Genetic correlations among the growth traits were positive and varied from 0.36 to 0.94. This means that selection at any stage will have an indirect but favourable effect on other growth traits. The heritability estimate for birth weight from a study carried out by Abdullah *et al*. (2006) on the tropical N'dama breed was 0.27.

Genetic parameters for another breed indigenous to Botswana, the Tuli, were estimated by Norris *et al*. (2004). Heritability estimates for direct effects (maternal effects in parenthesis) for birth weight and weaning weight were reported as respectively 0.36 (0.13) and 0.29 (0.16). The direct-maternal correlations were negative for all the growth traits. Genetic parameter estimates for the Afrikaner, another local breed were reported by Beffa (2005). Direct and maternal (in parenthesis) heritability estimates for birth, weaning and 18-months weights were respectively 0.39 (0.14); 0.19 (0.21), and 0.36 (0.15). Direct maternal genetic correlations for the growth traits ranged from -0.35 to -0.57, and were all moderately negative except for birth weight where it was non-significant.

Kars et al. (1994) reported heritability estimates for Nguni cattle in South Africa for birth, weaning and 18-months weights. The direct heritability estimates were 0.41, 0.29 and 0.19; maternal heritability estimates were 0.16, 0.20 and 0.003, and total heritability estimates were 0.44, 0.40 and 0.21, respectively. The correlations between the direct and maternal components were -0.49, -0.39 and -0.97. These results indicated that it was necessary to include both direct and maternal breeding values in a selection programme based on birth weight and weaning weight. Results for 18-months weight indicated that the maternal component was less important at that stage of growth.

2.4.2 Composite cattle breeds

There are currently no genetic parameter estimates for the composite breed developed in Botswana. It is therefore necessary to generate those, so that these parameters can be compared with that of other breeds. There have been studies conducted on a South African synthetic breed, the Bonsmara, which was the only synthetic breed that was compared to the Composite breed in Botswana through phenotypic data. Maiwashe *et al*. (2002) reported direct (maternal in parenthesis) heritabilities for birth weight as 0.32 (0.25) for Bonsmara bull calves. Corresponding results for the weaning weight were 0.13 (0.18). The heritability of ADG was 0.17 while the genetic correlation between direct and maternal additive effects was estimated to be -0.54. Another study on a synthetic Wakwa beef cattle breed in the tropical environment of Cameroon by Tawah *et al*. (1993) estimated heritabilities for direct effects of birth weight and weaning weights as 0.65 and 0.29, respectively. The corresponding heritabilities for maternal effects were 0.22 and 0.27. Estimates of genetic correlations between direct and maternal effects were negative for birth weight (-0.93) and weaning weight (-0.39). Heritability estimates for the direct effect for birth weight was higher than that reported by Mohiuddin (1993) in his review of genetic parameters published for beef cattle from different countries of the world.

The Belmont Red is a tropically adapted synthetic breed that was developed from ½ Afrikaner + ¼ Hereford + ¼ Shorthorn in Australia (Corbet *et al*., 2006a). Genetic parameter estimates for growth of the Bonsmara and the Belmont Red in South Africa were reported by Corbet *et al*. (2006b). Direct heritability estimates for growth traits from this study ranged from 0.11 to 0.42 (low to moderate) while the genetic correlations among growth traits ranged from 0.27 to 0.95 (moderate to high). The correlations between growth traits imply that selection for increased weight at any stage of growth will indirectly increase weight at all other growth stages. The heritabilities for direct additive effects for birth weight, weaning weight and 18-months weight were 0.23, 0.14, and 0.42 respectively, for the two breeds. Direct heritability estimates for pre-weaning gain and post-weaning gain were respectively 0.13 and 0.19. These estimates were in agreement with those obtained from Belmont Red herds in Australia and other Bonsmara herds in South Africa (Corbet *et al*., 2006b). In general the estimated direct heritabilities were comparable to those reported by Koots *et al*. (1994a) and Mohiuddin (1993).

Bennet *et al*. (1996) compared genetic (co)variances in composite populations (MARC 1 comprising of 5 parental breeds, as well as MARC 2 and MARC 3 comprising of 4 parental breeds) and their parental populations in the USA. Results from this study showed that the heritability estimates for the composite populations were higher than those reported for the parental breeds. The direct heritabilities for MARC 1, MARC 2, and MARC 3 for birth weight were respectively 0.56, 0.54 and 0.54. The corresponding heritabilities for 200-day weight were respectively 0.40, 0.36 and 0.34. These estimates were higher than the estimates given by Koots *et al*. (1994a).

Burrow (2001) reported direct and maternal heritabilities for two composite breeds with genetic lineage to the South African Bonsmara breed. The variance ratio for the direct additive genetic effect was high (0.57) for birth weight. However, the maternal additive genetic effect at birth was only 0.18. The direct, additive heritability (maternal heritability in parenthesis) at weaning and at 18 months were 0.17 (0.34) and 0.34 (0.06). Matching heritabilities for pre- and post-weaning average daily gains were 0.14 (0.30) and 0.21, respectively. Genetic correlations between the direct and maternal additive genetic effects were lowly to moderately negative for birth weight, weaning weight and pre weaning average daily gain (-0.17 to -0.25), but moderately positive for 18 months weight. Results from the study also showed high positive genetic correlations between weaning weight and 18-months weight. This indicates that genetic gains in growth rate to 18 months can be achieved by selection for weight at weaning. However, the relationships between weights at birth and those recorded at maturity were low.

The current study will focus on the influence of both environmental and genetic factors on growth in Tswana and Composite beef cattle breeds.

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CHAPTER 3

NON-GENETIC FACTORS INFLUENCING GROWTH TRAITS IN TSWANA AND COMPOSITE BEEF CATTLE BREEDS IN BOTSWANA

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3.1 Abstract

Data from 8,180 Composite and Tswana calves were analyzed to determine the influence of non-genetic (fixed) factors on birth weight (BW), weaning weight (WW), pre-weaning average daily gain (ADG1), 18 months weight (18MW) and post-weaning average daily gain (ADG2). All non-genetic factors included in the analysis were significant sources of variation for the growth traits. Sex of calf influenced growth more than the other effects. The Composite genotype gained weight faster than the Tswana from birth to weaning but the reverse was true post-weaning. Male calves grew faster than female calves at all stages of growth. The calves' pre-weaning growth increased with age of dam and declined when cows advanced towards old age (above 8 years) while post-weaning growth decreased as age of dam advanced and increased in old dams. BW increased as calving season advanced whereas WW decreased over the same period. Heavier cows seemed to give birth to heavier calves while calves from heifers were lighter than those from mature multiparous dams. The results show the importance of considering the influence of non-genetic factors for accurate genetic evaluations for growth in Tswana and Composite breeds.

Keywords: Birth weight, weaning weight, 18-months weight, sex of calf, age of dam.

3.2 Introduction

An animal's phenotype stems from two components; the genetic and the environmental effects. In generating breeding values, the goal is to correct for the known environmental effects and retain the genetic part of the phenotype. According to Eltawil *et al*. (1970) and Van Wyk *et al*. (1993), genetic improvement through selection of superior individuals to be parents of the next generation is hampered by environmental factors that tend to mask the actual breeding values of the individuals being selected. The variation due to these environmental effects should therefore be minimized before genetic parameters are estimated. Non-genetic factors influencing the accuracy of predicted breeding values can either be controlled experimentally or eliminated statistically (Van Wyk *et al*., 1993). Breeding values are predicted using mixed models which contain both genetic and non-genetic effects.

Environmental factors commonly known to determine growth characteristics in beef cattle are sex of the calf, calf genotype, age of calf at weaning, age of dam and month and year of birth. The contribution of these effects to overall phenotypic variation in growth traits in beef cattle have been widely studied (Holland *et al*., 1977; Dillard *et al*., 1980; Leighton *et al*., 1982; Van Zyl *et al*., 1992; Newman *et al*., 1993; Schoeman *et al*., 1993; Kars *et al*., 1994; Nephawe, 1998; Melka, 2001). In these studies, a range of non-genetic effects were commonly found to be significant sources of variation for growth characteristics in beef cattle breeds.

It is imperative that the proportion which the fixed effects contribute to growth traits in the Tswana and Composite cattle be quantified. This will provide a basis for including these factors in models that describe the biological processes affecting the specified trait. Quantifying contribution of traits also highlights the important factors which management should focus on to improve the traits. Therefore, the objective of this study was to estimate the effects of environmental factors on birth weight (BW), weaning weight (WW), 18 months weight (18MW), and pre- and post-weaning average daily gain (ADG1 and ADG2) in the Tswana and Composite beef cattle breeds in Botswana.

3.3 Materials and Methods

3.3.1 Study site

The data used in the study was collected at Musi ranch in Botswana located at latitude 25°35'S and longitude 25°13'E. The ranch is managed by the Animal Production and Range Research Division of the Department of Agricultural Research. Musi is at an elevation of approximately 1200m above sea level, with soils of the Kalahari unit of fine sand. The vegetation of the sand veld region consists of an open shrub savanna and is dominated by *Eragrostis lehmanniana*, *Stipagrostis uniplumis* and *Anthephora pubescens* as the major perennial grass species. The area receives summer rainfall averaging 550mm, between the months of October and March. Temperatures in the summer season may reach as high as 40°C while the winter season can have temperatures below 0°C between the months of June and July (Light *et al*., 1982).

3.3.2 Breeds

The breeds from which data was collected were the Composite and the Tswana breeds. The Composite breed was created from a controlled breeding system using the Simmental, Brahman, Tswana, Tuli and the Bonsmara breeds. These breeds were mated to form three groups of crosses. The crosses were then mated to produce the first generation of the Composite breed. Further inter-se mating was practiced for four generations with the resultant genetic makeup of the breed being Tswana (28.4%), Tuli (4.4 %), Brahman (22.6%), Simmental (26.3%) and Bonsmara (18.3%) (Mpofu *et al*., 1996). The proposed development of the Composite cattle breed is described in detail by Lethola (1981). The Tswana animals used in the comparison were already locally available when the on-station evaluation of the Composite breed commenced.

3.3.3 Management

Both the Composite and Tswana cattle were grazed on a rangeland at a stocking rate of 10 livestock units (LSU) per hectare. A phosphate lick of dicalcium phosphate was availed to the animals as the only supplementation and water was provided ad-libitum. The animals were provided with routine veterinary care such as dipping and vaccination for anthrax, black quarter, contagious abortion, lumpy skin disease and botulism. Natural service with corresponding sire breeds was used as the mating method in a three-months breeding season that took place from the beginning of January to the end of March every year. Pregnancy diagnosis was carried out in July annually and calving occurred during the rainy season, i.e. in October, November, December and early January. Calf birth weights and cow parturition weights were recorded within 24 hours of birth. The calf's birth date, dam identity and sire identity were recorded, and the calf was ear-tagged for easy identification. Any treatment given to the calf during its growth was recorded. The calves were allowed to run with their dams until they were weaned. All the animals were weighed monthly. The calves were weaned at seven months of age and at that stage, they were dehorned, permanently branded and separated into different paddocks according to sex. Replacement heifers were bred at 18 months and were allowed to join the breeding stock.

3.3.4 Records

The Animal Production and Range Research Division (Department of Agricultural Research) availed a total of 2,257 performance records for the Composite breed and 5,923 for the Tswana breed. The available records ran from the year 1988 to 2006. The information contained in the data set included birth dates, birth weights, sex, breed type, previous parous state (PPS), cow parturition weight (CPW), weaning weights, date of weaning, 18MW and the interval in days from weaning to 18 months.

Editing of the data was achieved by running a preliminary analysis using the PROC MEANS and UNIVARIATE procedures in the Statistical Analysis System (SAS, 2004). Dam ages between 2 and 3 years, and between 12 and 15 years were each pooled to form classes of 3 years and under, and 12 years and above, respectively, to balance the number of observations per age group. For months of birth, December and January born calves were pooled together since the latter month had fewer animals.

Pre-weaning average daily gain (ADG1) and post-weaning average daily gain (ADG2) were calculated using the following formulae:

$$\text{ADG1} = \frac{\text{(Weaning weight – Birth weight)}}{\text{Age at weaning (AWN) in days}}$$

$$\text{ADG2} = \frac{\text{(18 months weight – Weaning weight)}}{\text{(Age at 18 months) – (Age at weaning)}}$$

The total number of records and means for all the traits available for analysis after editing are presented in Table 3.1

Table 3.1 Properties of the data set for the calves' BW, WW, 18MW, ADG1 and ADG2

Trait	Number of records	Minimum	Maximum	Mean	Standard deviation
Birth weight (kg)	7979	15.00	51.00	32.8	5.26
Weaning weight (kg)	7452	70.00	298.00	180.0	29.52
18 months weight (kg)	5696	117.00	650.00	263.5	65.79
Pre-weaning ADG (kg/day)	6965	0.19	1.24	0.7	0.14
Post-weaning ADG (kg/day)	5239	0.01	1.26	0.3	0.17

3.3.5 Statistical Analysis

Linear models were fitted to estimate the impact of different non-genetic effects on BW, WW, 18MW, ADG1 and ADG2. The fixed effects included the sex of the calf, month of birth, year of birth, age of calf at weaning, age of dam and calf breed type. Age of calf at weaning was fitted as a linear covariate. The General Linear Models (GLM) procedure in the Statistical Analysis Systems (SAS, 2004) was used to analyze the data.

The following models were fitted:

Birth weight

$$\mathbf{Y_{ijklmn} = \mu + S_i + G_j + M_k + Y_l + A_m + P_n + b_0\,(CPW)_{ijklmn} + e_{ijklmn}}$$

Where: Y_{ijklmn} = birth weight (kg)

μ = population mean

S_i = fixed effect of the i^{th} sex (i= 1, 2) male / female

G_j = fixed effect of the j^{th} genotype (j= 1, 2) Tswana / Composite

M_k = fixed effect of the k^{th} month of birth (k= 3) October, November, December

Y_l = fixed effect of the l^{th} year of birth (l = 88, 89….06)

A_m = fixed effect of the m^{th} age of dam (m = 3…12)

P_n = fixed effect of the previous parous state (n=1…3)1- previously heifers, 2- did not calve or raise a calf the previous year, 3- calved the previous year

CPW_{ijklmn} = cow parturition weight fitted as a linear covariate

b_0 = linear regression coefficients of $Y_{ijklmno}$ on cow parturition weight (CPW)

e_{ijklmn} = random error

Weaning weight

$$\mathbf{Y_{ijklmn} = \mu + S_i + G_j + M_k + Y_l + A_m + P_n + b_0 (CPW)_{ijklmn} + b_1 (BW)_{ijklm} + b_2 (AW)_{ijklmn} + e_{ijklmn}}$$

Where: Y_{ijklmn} = weaning weight

μ = population mean

S_i = fixed effect of the i^{th} sex of calf (i= 1, 2) male / female

G_j = fixed effect of the j^{th} genotype of calf (j= 1, 2) Tswana / Composite

M_k = fixed effect of the k^{th} month of birth (k= 3)

Y_l = fixed effect of the l^{th} year of birth (l= 18) years 1988-2006

A_m = fixed effect of the m^{th} age of dam (m = 3…12)

P_n = fixed effect of the previous parous state (n= 1…3) 1- previously heifers, 2- did not calve or raise a calf the previous year, 3- calved the previous year

CPW_{ijklmn} = cow parturition weight fitted as a linear covariate

$b_{0,}$ $b_{1,}$ b_2 = linear regression coefficients of Y_{ijklm} on cow parturition weight (CPW), birth weight (BW) and age at weaning (AW)

e_{ijklmn} = random error

Pre-weaning ADG (ADG1)

The same model was applied for this trait as for WW but with the exclusion of birth weight (BW) and age at weaning (AW).

18 months weight

$$\mathbf{Y_{ijklmn} = \mu + S_i + G_j + M_k + Y_l + A_m + P_n + b_0 (CPW)_{ijklmn} + b_1 (BW)_{ijklmn} + b_2 (WW)_{ijklmn} + b_3 (ADG1)_{ijklmn} + e_{ijklmn}}$$

Where: Y_{ijklmn} = 18 months weight

μ = population mean

S_i = fixed effect of the i^{th} sex of calf (i= 1, 2) male / female

G_j = fixed effect of the j^{th} genotype of calf (j= 1, 2) Tswana / Composite

M_k = fixed effect of the k^{th} month of birth (k= 3)

Y_l = fixed effect of the l^{th} year of birth (l= 18) years 1988-2006

A_m = fixed effect of the m^{th} age of dam (m = 3…12)

P_n = fixed effect of the previous parous state (n= 1…3) 1- previously heifers, 2- did not calve or raise a calf the previous year, 3- calved the previous year

CPW_{ijklmn} = cow parturition weight fitted as a linear covariate

b_0, b_1, b_2, b_3 = linear regression coefficients of Y_{ijklm} on birth weight (BW), weaning weight (WW) and pre-weaning average daily gain (ADG)

e_{ijklmn} = random error

Post-weaning ADG (ADG2)

The same model as for the 18-months weight was fitted for this trait except that weaning weight as a covariate was excluded.

3.4 Results and Discussion

The biological importance of each fixed effect to the overall variation in a particular growth trait was depicted by expressing the sum of squares for such an effect as a percentage of the total corrected sum of squares (TCSS) (Leighton *et al*., 1982).

The analysis of variance for birth weight (BW), weaning weight (WW), 18-months weight (18MW), pre-weaning average daily gain (ADG1) and post-weaning average daily gain (ADG2) is given in Table 3.2. In addition, least squares means for these growth traits are presented in Table 3.3. All the fixed effects were a significant source of variation for the growth traits except BW when fitted as a covariate for 18MW and ADG2. In contrast, Dzama *et al*. (1997) found BW to affect 18-months weight and pre- and post-weaning growth rate of some indigenous and exotic breeds in Zimbabwe. However, in the current study BW and age at weaning were both related ($P< 0.001$) to weaning weight.

The amount of variation on BW, WW, 18MW, ADG1 and ADG2 attributable to the fixed effects, denoted by the R-square value was 22, 47, 53, 41 and 30 %, respectively, as shown in Table 3.2. Nephawe (1998) and Melka (2001) reported R-square values of respectively 27 and 44% for the variation in BW that could be explained by the fixed effects included in their analyses. In general, the influence of environmental factors of calf breed, sex of calf, age of dam, month and year of birth in beef cattle growth traits have been widely studied. However, reports on the effects due to previous parous state and cow parturition weight on beef cattle growth traits are scarce.

Breed of calf influenced ($P < 0.001$) BW, WW, 18MW, ADG1 and ADG2. The corresponding percentage contributions of these effects on the traits were respectively 0.6, 1.2, 0.2, 1.2 and 0.9 % (Table 3.2). Previous research has also found breed of calf to be a significant source of variation for BW, WW and ADG1 (Reynolds *et al*., 1980; Lawlor *et al*., 1984; Sacco *et al*., 1991; Carvalheira *et al*., 1995; Plasse *et al*., 1995) whereas Carvalheira *et al*. (1995), Plasse *et al*. (1995) and Dzama *et al*. (1997) reported breed of calf as a significant source of variation for ADG2 and 18MW. Differences in growth performance between breeds can in part be attributed to both direct and maternal influences (Schoeman *et al*., 1993), hence the differences in performance of the Tswana and Composite breeds in the current study (Table 3.3).

Growth performance of the Tswana and Composite breeds differed ($P < 0.05$) throughout the growth stages. From birth to weaning, the Composite breed was heavier than the Tswana. The BW, WW and ADG1 for the Composite were 33.3, 182.7 and 0.71 kg, respectively, while the corresponding figures for the Tswana were 32.8, 177.6 and 0.69 kg, respectively. However, post weaning, the Tswana gained an average of 0.02 kg daily more than the Composite to reach an average 18MW of 264.1 kg while the latter weighed 260.5 kg at the same age. A possible explanation to the observed pattern is that during the pre-weaning growth phase the Composite dams presented a favourable maternal influence to its calves mainly due to milk production and mothering ability which were not available after weaning (Bourdon, 2000). According to Carvalheira *et al*. (1995), the maternal influence diminishes after weaning, whereafter growth depends on the interactions between the animal's genotype with the surrounding environment, especially nutrition and health. Furthermore, the Simmental breed forms a considerable proportion, 26.3%, of the Composite breed genetics, and the Simmental x Tswana were reported to produce on average 0.8 kg of milk more than purebred Tswana (Mpofu, 1996). The use of Simmental sires in crossbreeding trials in Botswana improved milk production in the resultant dam crosses (Light *et al*., 1982) hence they weaned heavier calves. The differences in the growth pattern between the breeds post-weaning could show the adaptability of the Tswana to the predominantly tropical environment in Botswana.

The least squares means for BW, WW and 18MW in the Tswana and Composite from the current study are generally lower than those reported for the same breeds in previous studies (Table 3.4). For instance, the Composite breed calves from the current study were 1.3, 7.8 and 26.6 kg lighter at birth, weaning and 18 months than those reported by Mpofu *et al*. (1996). Results from the previous study were generated using part of the data used in the current study and this might have caused the discrepancy. The weaning weight for the Tswana were comparable to those reported in earlier studies (Table 3.4) while the 18MW was only in agreement with results reported by Mpofu *et al*. (1996) and lower than in other earlier studies (APRU, 1976; Trail *et al*., 1977; Lethola *et al*., 1984). During the evaluation of the Composite breed for growth performance in Botswana, it was mostly compared to the Bonsmara breed from South Africa. Mpofu *et al*. (1996) reported averages of 34.1, 190.2 and 273.8 kg for BW, WW and 18MW, respectively, for the Bonsmara breed in Botswana. Compared to the weights of the Composite breed in the current study, the results for the Bonsmara were generally higher.

Table 3.2 Mean squares, significance level and proportional contribution of fixed effects (FE %) to the overall variance for BW, WW, 18MW, ADG1 and ADG2

		BW		WW		18MW		ADG1		ADG2	
Source of variation	**DF**	**MS**	**FE (%)**	**MS**	**FE (%)**	**MS**	**FE (%)**	**MS**	**FE (%)**	**MS**	**FE (%)**
Breed of calf	1	294.18^{**}	0.6	35106.86^{***}	1.2	21236.59^{**}	0.2	0.61^{***}	1.2	0.37^{***}	0.9
Age of dam	9	131.77^{***}	0.3	5327.57^{***}	0.2	9574.76^{**}	0.1	0.06^{***}	0.1	0.09^{***}	0.2
Month of birth	2	2342.14^{***}	4.7	175181.79^{***}	6.0	6299.76^{*}	0.05	4.27^{***}	8.1	0.12^{**}	0.3
Year of birth	18	536.69^{***}	1.1	54870.99^{***}	1.9	168172.12^{***}	1.3	1.42^{***}	2.7	1.61^{***}	3.9
Previous parous state	2	520.42^{***}	1.1	9819.04^{***}	0.3	10127.08^{***}	0.1	0.22^{***}	0.4	0.11^{**}	0.3
Sex of calf	1	14706.27^{***}	29.7	122316.23^{***}	4.2	909083.52^{***}	7.1	4.47^{***}	8.5	10.7^{***}	25.8
Cow parturition weight	1	9575.80^{***}	19.4	291004.72^{***}	10.0	44699.12^{***}	0.3	7.99^{***}	15.2	0.73^{***}	1.7
Birth weight	1			386939.46^{***}	13.3						
Age at weaning	1			143355.15^{***}	4.9						
Weaning weight	1					3061723.51^{***}	23.8				
R-square value		0.22		0.47		0.53		0.41		0.30	
Error mean square		21.56		475.66		2068.52		0.011		0.020	
Coefficient of variation		14.16		12.11		17.25		15.04		55.8	

***P< 0.001

**P< 0.01

*P< 0.05

The pre-weaning average daily gain of 0.69 kg reported for the Tswana is comparable to that of the Tuli (0.62 kg) and Nkone (0.63 kg) but higher than that of the Mashona (0.48 kg). The post-weaning ADG for the Mashona and Tuli were 0.33 and 0.45 kg, respectively, and both were higher than the 0.25 kg reported for the Tswana. Schoeman (1989) reported pre-weaning ADG of respectively 0.8 and 0.73 for the Afrikaner and a group of Sanga type breeds. In Australia, Burrow (2001) studied two types of composite breeds which are genetically related to the Bonsmara, and found average daily gains of 0.77 kg pre-weaning and 0.44 kg post-weaning. The Australian Composite breeds gained more than the Composite in the current study both pre- and post-weaning.

Sex of calf accounted for respectively 29.7, 4.2, 7.1, 8.5 and 25.8 % of the variation in BW, WW, 18MW; ADG1 and ADG2, making it the overall most important environmental factor affecting growth (Table 3.2). Differences between sexes were existent ($P< 0.001$) for all traits in this study. The differences in BW, WW, 18MW, ADG1 and ADG2 between male and female calves were 2.7, 7.8, 26.6, 0.05 and 0.09 kg, respectively. Other studies have shown a similar trend. For example, a study undertaken on beef cattle crossbreds by Dillard *et al*. (1980) showed that male calves were 2.2 kg heavier at birth and 10 kg heavier at weaning than female calves.

Table 3.3 Least squares means (kg ± S.E.) for BW, WW, 18MW, ADG1 and ADG2 for Tswana and Composite beef breeds of cattle in Botswana

	Trait									
Fixed effect	BW		WW		18MW		ADG1		ADG2	
	N	kg ± S.E.	N	kg ± S.E.	N	kg ± S.E.	N	kg ± S.E.	N	kg ± S.E.
Breed										
Tswana	5715	32.8 ± 0.09 ^{a}	4707	177.6 ± 0.45 ^{a}	3655	262.2 ± 1.01 ^{a}	4707	0.69 ± 0.002 ^{a}	3221	0.25 ± 0.003 ^{a}
Composite	2239	33.3 ± 0.12 ^{b}	2238	182.7 ± 0.59 ^{b}	2003	257.8 ± 1.35 ^{b}	2238	0.71 ± 0.002 ^{b}	2003	0.24 ± 0.004 ^{b}
Month										
Oct	1861	31.9 ± 0.12 ^{a}	1690	189.9 ± 0.64 ^{a}	1396	258.2 ± 1.40 ^{a}	1690	0.75 ± 0.003 ^{a}	1321	0.24 ± 0.005 ^{a}
Nov	3843	33.1 ± 0.10 ^{b}	3426	181.8 ± 0.53 ^{b}	2771	261.9 ± 1.18 ^{b}	3426	0.70 ± 0.002 ^{b}	2569	0.25 ± 0.004 ^{b}
Dec	2250	34.2 ± 0.13 ^{c}	1829	168.8 ± 0.67 ^{c}	1491	259.9 ± 1.51 ^{ab}	1829	0.65 ± 0.003 ^{c}	1334	0.24 ± 0.007 ^{ab}
PPS										
1	1866	33.2 ± 0.20 ^{a}	1673	175.5 ± 0.97 ^{a}	1400	257.0 ± 2.22 ^{a}	1673	0.68 ± 0.005 ^{a}	1339	0.23 ± 0.007 ^{a}
2	1466	33.1 ± 0.10 ^{b}	1347	183.2 ± 0.71 ^{b}	980	259.5 ± 1.70 ^{ab}	1347	0.72 ± 0.003 ^{b}	952	0.24 ± 0.006 ^{ab}
3	4622	34.2 ± 0.09 ^{c}	3925	181.8 ± 0.46 ^{b}	3278	263.5 ± 0.98 ^{b}	3925	0.71 ± 0.002 ^{b}	2933	0.26 ± 0.003 ^{b}
Sex										
Female	3729	31.7 ± 0.10 ^{a}	3277	175.8 ± 0.52 ^{a}	2861	246.7 ± 1.16 ^{a}	3277	0.68 ± 0.002 ^{a}	2649	0.20 ± 0.004 ^{a}
Male	4225	34.4 ± 0.10 ^{b}	3668	184.6 ± 0.50 ^{b}	2797	273.3 ± 1.17 ^{b}	3668	0.73 ± 0.002 ^{b}	2575	0.29 ± 0.004 ^{b}

Least squares means with different superscripts differ significantly ($P < 0.05$)

PPS 1- previously heifers

PPS 2- did not calve or raise a calf the previous year

PPS 3- calved the previous year

Table 3.4 Least squares means for BW, WW, and 18MW reported for the Tswana and Composite breeds in previous studies

Breed	BW	WW	18MW	Reference
Tswana	-	177.2	284.4	APRU (1976)
Tswana	30.7	174.6	278.5	Trail *et al*. (1977)
Tswana	-	179.1	293.5	Lethola *et al*. (1984)
Tswana	33.9	179.3	265.8	Mpofu *et al*. (1996)
Composite	34.6	190.5	286.3	Mpofu *et al*. (1996)

As shown in Table 3.2, month of birth had an effect ($P< 0.001$ or $P< 0.05$) on BW, WW, 18MW, ADG1 and ADG2. Calves' BW increased through the calving months with averages of respectively 31.9, 33.1 and 34.2 kg for October, November and December (see Table 3.3), indicating that calves born early in the rainy season were lighter than those born late in the season. This is likely caused by cows calving early in the season when they are in a relatively poor condition, with low tissue reserves, following a nutritionally stressful season. Therefore lighter calves are being born from these cows (Carvalheira *et al*., 1995). Carvalheira *et al*. (1995) also acknowledged that the improvement in body condition of cows calving late in the rainy season was reflected in the greater weights of their calves at birth. Conversely, WW decreased as the calving season advanced. Calves born in October, November and December averaged 189.9, 181.8 and 168.8 kg (Table 3.3) at weaning. These results are consistent with findings from a study on the Mozambican Landim and Afrikaner cattle (Carvalheira *et al*., 1995). Lighter calves, born early in the rainy season, benefit from a nutritional environment provided by dams that are producing milk from a better forage resource. Cows calving late in the rainy season are exposed for a longer period to limited, mature and less digestible pastures than dams of calves born earlier, resulting in a reduced milk yield (Carvalheira *et al*., 1995). Daily gain from birth to weaning followed a similar trend. At 18 months of age, there were no differences ($P> 0.05$) between calves born in October or November and those born in December even though different weights were recorded for the first two months. The same was true for ADG2. This inconsistency may reflect the independence of calves in growth abilities after weaning (Elzo *et al*., 1987).

Similarly, year of birth affected ($P< 0.001$) all the traits studied. It contributed 1.1, 1.9, 1.3, 2.7 and 3.9 % (Table 3.2) to the variation in respectively BW, WW, 18MW, ADG1 and ADG2. Similar results pertaining to the effects of year of birth were reported for BW (Gray *et al*., 1978; Sacco *et al*., 1991; van Zyl *et al*., 1992; Kars *et al*., 1994; Plasse *et al*., 1995), WW (Gray *et al*., 1978; Sacco *et al*., 1991; van Zyl *et al*., 1992; Kars *et al*., 1994; Carvalheira *et al*., 1995; Plasse *et al*., 1995), ADG1 (Sharma *et al*., 1982; McElhenny *et al*., 1986), and post weaning growth traits (Sharma *et al*., 1982; Kars *et al*., 1994; Plasse *et al*., 1995). These reports indicated that variation in environmental conditions from year to year influence growth traits in beef cattle. According to Carles & Riley (1984), Carvalheira *et al*. (1995) and Plasse *et al*. (1995), the erratic year differences are expected in tropical extensive grazing conditions where the levels of nutrition depend on climate and its influence on pasture availability and quality.

Information on the effect of previous parous state (PPS) of dams on growth of beef cattle calves is limited. In the current study, PPS of dams influenced ($P< 0.001$) all the traits studied, and it accounted for 1.1, 0.3, 0.1, 0.4 and 0.3 % of the variation in respectively BW, WW, 18MW, ADG1 and ADG2 (Table 3.2). The birth weight means shown in Table 3.3 indicate that calves from cows that were previously heifers and those that did not calve previously were both lighter than those born by cows that were parous the previous year. This is a result of first calvers giving birth to lighter calves than cows which are mature and usually multiparous (Carvalheira *et al*., 1995). Perceivably, this is because heifers are still growing. The maternal effects of previously non-parous dams might have diminished during the rested period when compared to the dams previously in calf hence the smaller calf birth weight. Similarly, at weaning calves from heifers were 6.3 kg lighter than those from cows which had previously calved. However, calves raised by dams parous the previous year were lighter at weaning than those calves from dams which were non-parous or did not raise a calf (hence rested) the previous year (Buvanendran & Mason, 1982). There were no differences ($P> 0.05$) observed in ADG1 between calves from previously parous and non-parous dams. Nonetheless, calves from the two groups gained faster than calves from first calvers ($P< 0.05$). Post-weaning, calves from previously parous cows gained more than first calvers ($P< 0.05$). The two groups were, however, similar ($P> 0.05$), from calves from previously non-parous dams. The results corroborate the conclusion by Carvalheira *et al*. (1995) that PPS is a less important source of variation for 18MW than for earlier growth traits.

Age of dam was also found to be a source ($P< 0.001$) of variation for all the growth traits studied. The effects of dam age on growth traits have been broadly studied and results from these studies (Anderson & Wilham, 1978; Gray *et al*., 1978; Dillard *et al*.,1980; Sharma *et al*., 1982; Lawlor *et al*.,1984; Gregory *et al*., 1985; Elzo *et al*.,1987; Sacco *et al*., 1991; van Zyl *et al*., 1992; Schoeman *et al*.,1993; Plasse *et al*., 1995; Dzama *et al*., 1997) established that age of dam significantly affected growth characteristics in beef cattle. Regressions of age of dam on BW, WW, 18MW, ADG1 and ADG2 are shown in Figures 3.1, 3.2, 3.3, 3.4 and 3.5, respectively. A curvilinear relationship existed between age of dam and the weights of her calves. The BW generally increased with increasing dam age and reached a maximum between 6 and 8 years, where-after it continuously dropped with advancing age of dam. These results are in agreement with findings of Swiger (1961). Elzo *et al*. (1987) also suggest that this trend reflects a greater ability by mature cows to provide the foetus with the necessary nutrients and environmental conditions for its development. This ability seems to be compromised in cows older than 8 years.

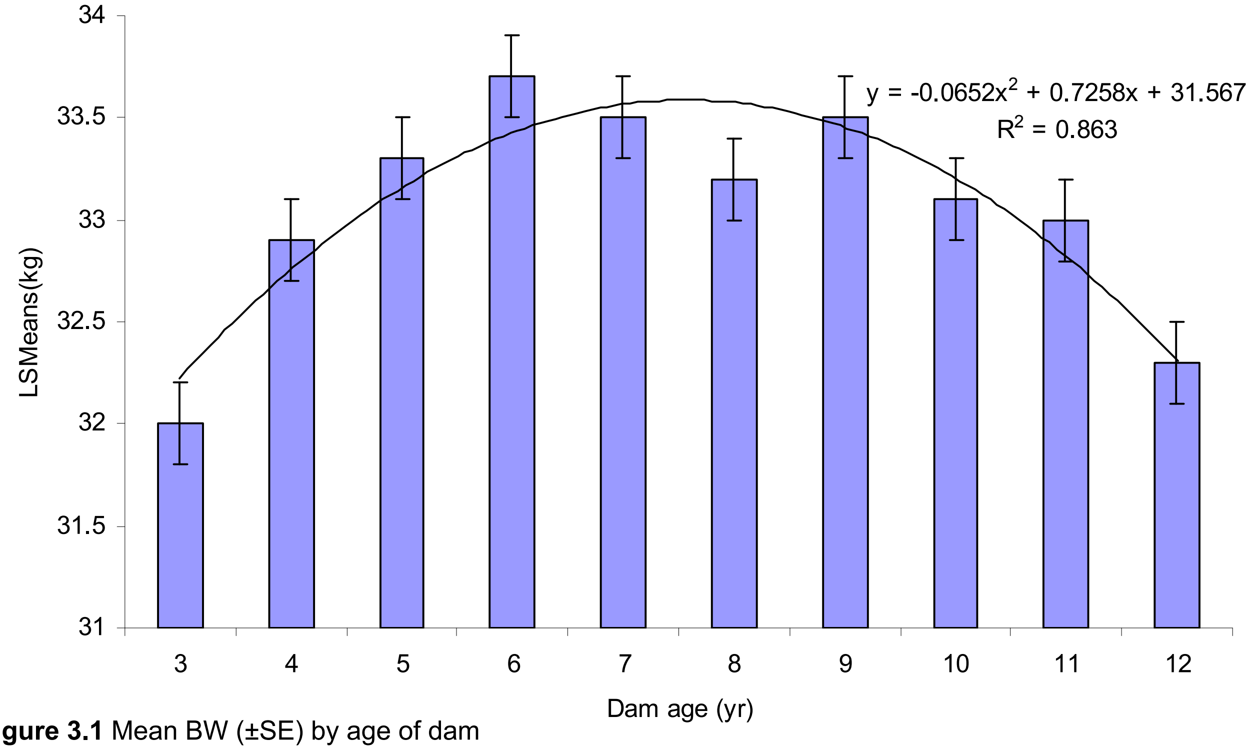

Figure 3.1 Mean BW (±SE) by age of dam

Weaning weight generally increase with increasing dam age and decrease after about 8 years (Figure 3.2). Milk production of the dam has been found to be one of the major factors affecting weaning weight of the calf (Notter *et al*., 1978; Robison *et al*., 1978). It is therefore reasonable to suggest that the milking ability of cows accounted for the observed trend, with mature cows producing the most milk while younger and older cows producing less. The regression of WW on dam age did not fit the quadratic model as well as that of BW. These inconsistencies might arise as a consequence of the Tswana and Composite calves being affected differently by age of dam. Dzama *et al*. (1997) found that different breeds had different year ranges under which mature cows could be assigned. Pre-weaning average daily gain (ADG1) was also higher for calves from mature cows than calves from younger and older cows (Figure 3.3), still owing to the maternal influence. The regression trend for ADG1 was similar to that of BW.

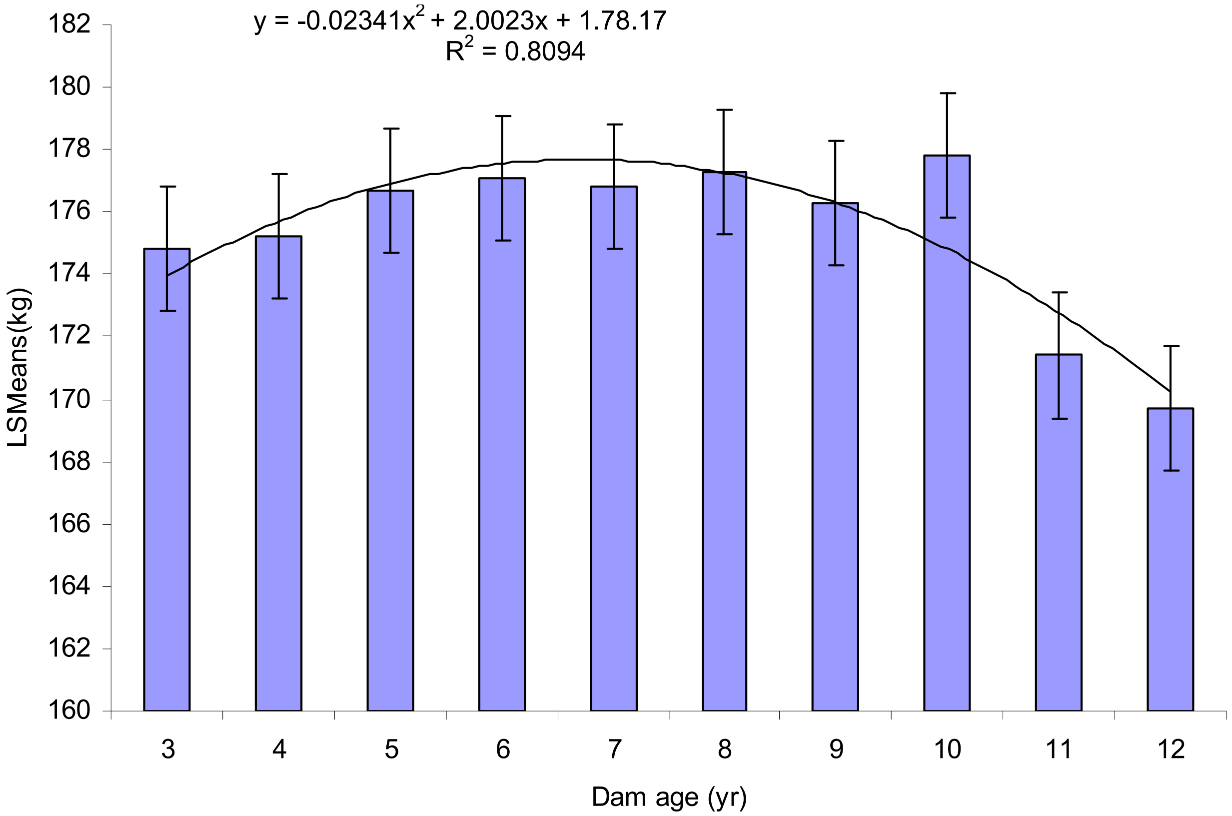

Figure 3.2 Mean WW (±SE) by age of dam

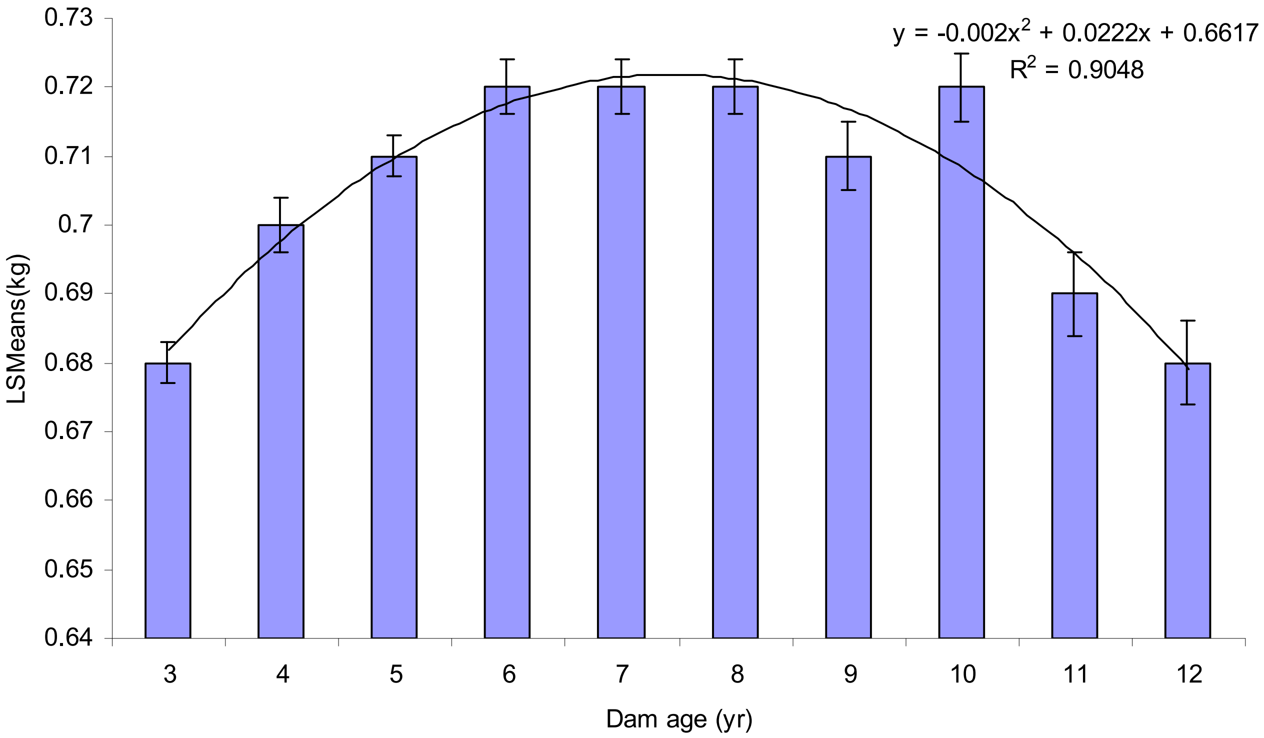

Figure 3.3 Mean ADG1 (±SE) by age of dam

A different scenario occurs post-weaning. In general, a reduction in ADG2 and 18MW was observed with an increased age of dam (Figures 3.4 and 3.5) until at 10 years, after which averages for growth picked up.

Elzo *et al*. (1987) pointed out that age of dam effects for post-weaning weights were indirect environmental effects, and therefore after weaning the calf's post weaning growth depends exclusively on its ability to grow, independent of the age of its dam. Furthermore, even if the pre-weaning environment provided by the dam was insufficient, a calf may experience post-weaning compensatory growth (Tawonezvi, 1989). Conversely, if the maternal environment was too abundant these calves may gain less weight during post-weaning period (Young *et al*., 1978).

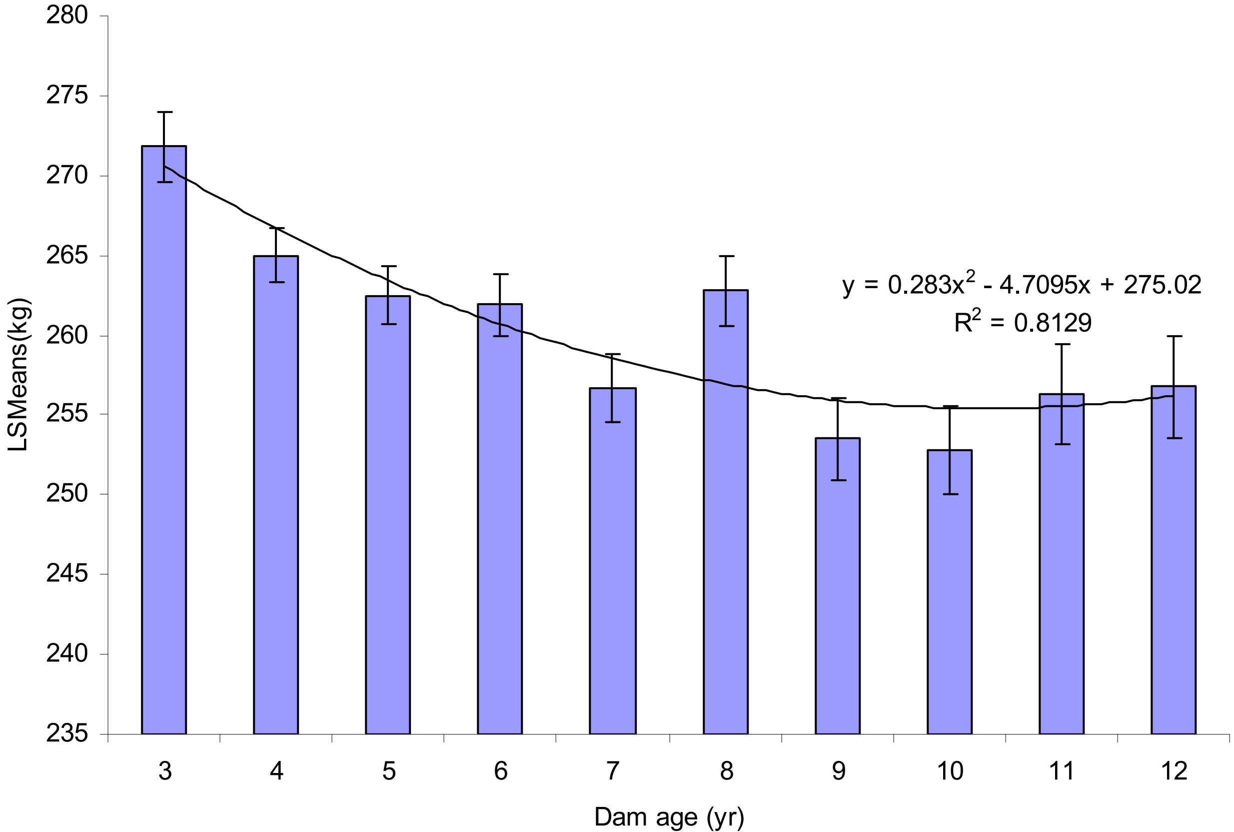

Figure 3.4 Mean 18MW (±SE) by age of dam

Cow parturition weight (CPW) affected (P< 0.001) all the growth traits when fitted as a covariate. Even though the effects of CPW have been studied mostly for fertility traits in previous studies, Light *et al*. (1982), results from the current study indicated that CPW has an important effect on the pre-weaning growth of calves. This is because it accounted for 19.4, 10 and 15.2 % of the variation in respectively BW, WW and ADG1, while it was responsible for only 0.3 and 1.7 % (Table 3.2) of variation in respectively 18MW and ADG2. Roberson *et al*. (1986) indicated that large cows usually produce large calves, attributable to genetic maternal effect as well as genetically transmitted effect. Koch & Clark (1955) hypothesized that changes in size, weight and physiological function which accompany aging might be expected to influence the maternal environment and have a direct effect on BW and WW.

Light *et al*. (1982) studied CPW and body weight loss in the Simmental, Brahman, Bonsmara, Tswana and Tuli crossbred cows in Botswana. They found that cows which reared a calf lost a significant amount of weight in the period between birth and weaning. This could depict the advantage that large dams may have due to increased reserves that could be converted to milk production. Therefore CPW might be a very important trait in studying pre-weaning growth traits.

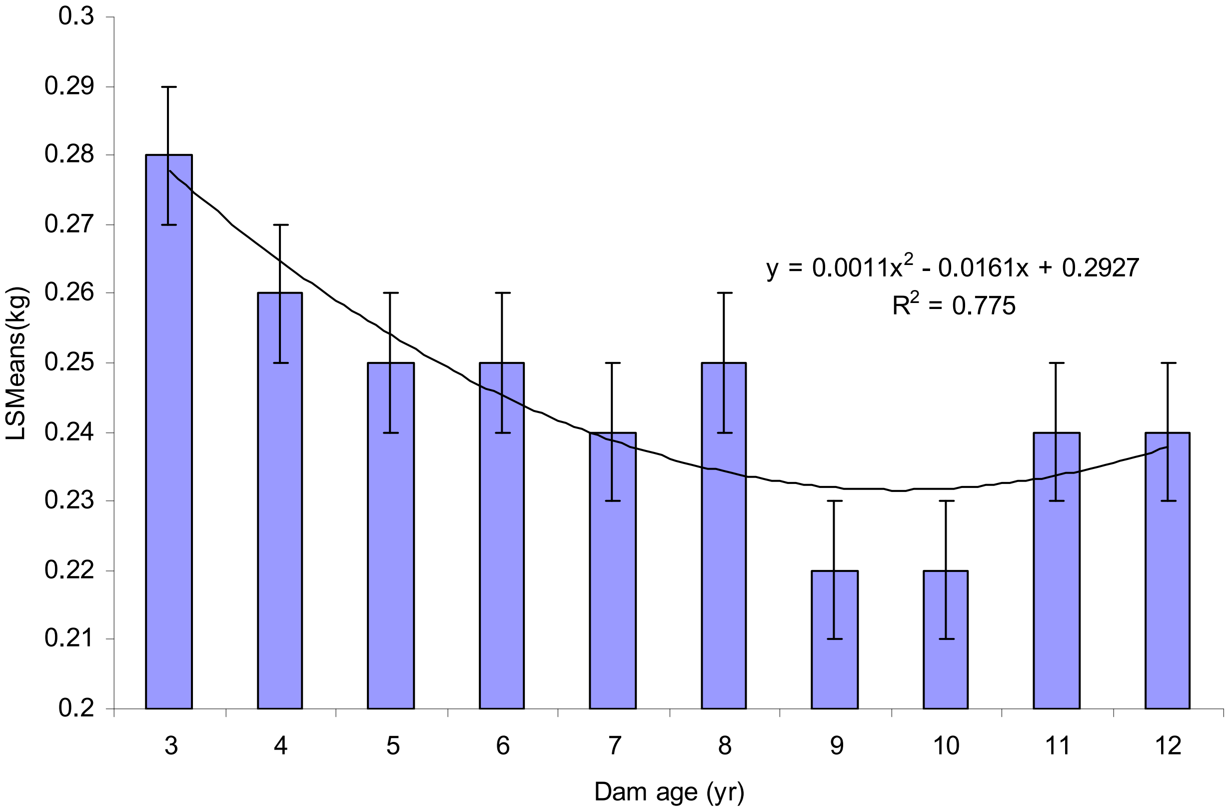

Figure 3.5 Mean ADG2 (±SE) by age of dam

When fitted as linear covariates, age at weaning and BW influenced ($P< 0.001$) WW, accounting for 4.9 and 13.3 % of the variation observed in this trait. This is in agreement with findings of Gray *et al.* (1978), McElhenny *et al*. (1986), Newman *et al*. (1993), Plasse *et al*. (1995) and Melka (2001). Age at weaning and BW both gave linear regression coefficients. Newman *et al*. (1993) reported linear regression coefficient for age at weaning when fitted as a covariate for weaning weight and indicated that older animals were heavier at weaning. Age of calf may become an important production trait influencing the weight and value of calf produced particularly where mating occurs in a restricted season and calves are weaned all the time (Koger *et al*., 1975). Weaning weight affected ($P< 0.001$) 18MW and accounted for 23.8 % of the variation on the trait.

3.5 Conclusion

The non-genetic factors of breed of calf, sex of calf, month and year of birth, previous parous state, cow parturition weight, age of dam and age of calf at weaning were significant sources of variation for BW, WW, 18MW, ADG1 and ADG2 in Tswana and Composite breeds in Botswana. These factors should be considered when selection procedures for these breeds are developed. The Composite breed was heavier than the Tswana from birth to weaning. However, it was overtaken by the Tswana breed in post-weaning gain and 18-months weight. The Composite breed could therefore be considered for weaner production especially when reared under ranch conditions while the Tswana could do well even under extensive farming conditions due to its ability to grow faster post weaning.

Considering the influence of non-genetic factors in growth of the Tswana and Composite breeds, it is important to adjust data for some of these factors for accurate performance evaluations in these breeds.

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CHAPTER 4

SEX OF CALF AND AGE OF DAM ADJUSTMENT FACTORS FOR BIRTH AND WEANING WEIGHT IN TSWANA AND COMPOSITE BEEF CATTLE BREEDS IN BOTSWANA

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4.1 Abstract

Records on 2,257 Composite and 5,923 Tswana calves born between the period of 1988 and 2006 in Botswana were used to calculate additive correction factors for the effects of sex of calf and age of dam on birth weight (BW) and weaning weight (WW). The sex of calf x age of dam interactions were not significant in both breeds. Adjustment factors and mature age groups were derived through the use of the least squares means procedure. The mature age group in both breeds for the two growth characteristics was 5-12 years old dams. Male calves were heavier than their female contemporaries throughout the pre-weaning growth period. The sex of calf adjustments for BW and WW were 2.75 and 8.21 kg in the Tswana while the corresponding values for the Composite were 2.84 and 10.11 kg. BW and WW increased with advancing age of dam, reached peak in mature dams and declined when dams achieved an old age. Age of dam adjustment factors for BW in 3, 4 and 13+ years age groups were respectively 1.74, 0.96 and 1.87 kg in the Tswana. Corresponding values for the Composite were respectively 2.28, 0.94 and 2.06 kg. Age of dam adjustment factors for weaning weight were respectively 10.36 and 5.46 kg for age groups 3-4 and 13+ years in the Tswana. Adjustment factors for WW in the Composite breed were respectively 13.84, 3.20 and 9.58 kg for age groups 3, 4 and 13+ years. These results indicate that adjustment factors for BW and WW should be considered separately for sex of calf and dam age in these breeds, and also that these adjustments need to be applied within the breeds from which they were derived.

Keywords: mature age, old age, male calves, female calves.

4.2 Introduction

Adjustment factors are important in beef cattle genetic evaluations because they allow for a fair comparison of animals during performance evaluations. For beef cattle, birth weight and weaning weight records are usually adjusted for sex of calf, age of dam and the age of calf at weaning for weaning weight (Dzama *et al*., 1997).

Average weights of bull calves and heifer calves differ at all ages regardless of them having been raised under similar environmental conditions (Koch *et al*., 1959) with males being heavier than females. According to Rumph & Van Vleck (2004), the need for adjustment factors for sex and contemporary group effects is obvious because bull calves generally grow faster than heifer calves and therefore it is not fair to compare heifers to their male counterparts without adjustments. At weaning, Nelsen & Kress (1981) found the average weaning weights for bull calves to be higher than those of their heifer contemporaries. Correction factors for sex in weights can either be additive or multiplicative.

The correction of birth weight and weaning weight records for age of dam is equally important. The general result from a wide review of age-of-dam adjustment factors by Rumph & Van Vleck (2004) is that both birth and weaning weight are affected by the age of the dam. Since first-calf heifers are not mature both physically and biologically, the nutrients they consume are not only partitioned into lactation, maintenance and gestation, but also channeled towards growth. First calvers therefore generally give birth to and wean smaller calves, which have a disadvantage if they are to be compared to their contemporaries bred from older dams. Likewise, cows will reach peak production at their mature age and will decline in efficiency when they reach old age. As a result they will have smaller calves than those calves they had earlier in their life (Rumph & van Vleck, 2004). Elzo *et al*. (1987) hypothesized that mature dams aged 5 to 8 years had a greater ability to provide the nutrients and the optimum uterine environment for the foetus compared to younger dams which are also still developing themselves, while older ones may also show diminishing uterine environmental effects.

Even though a great deal of research has been done to estimate appropriate age of dam adjustment factors for birth weight and weaning weight of beef cattle, most of the research was conducted in temperate environments and for exotic beef breeds (Rumph & Van Vleck 2004). The paucity of information on adjustment factors is especially pronounced for tropical cattle, therefore calling for development of such for the beef breeds such as the Tswana and the Composite. The purpose of the present study was therefore to develop adjustment factors for birth weights and weaning weights for the Tswana and Composite cattle breeds of Botswana.

4.3 Materials and Methods

Performance data were obtained from Tswana and Composite calves kept at Musi ranch for the period of 1988 to 2006. The ranch is under the management of the Animal Production and Range Research Division, a division under the Department of Agricultural Research in Botswana. The animals were reared on natural pastures. Breeding systems, management and recording procedures for the two cattle breeds were described in detail in Chapter 3.

4.3.1 Statistical Analysis

Linear models were fitted to estimate the impact of different fixed effects acting on a given observation and these included fixed effects of sex of calf, month of birth, year of birth, age of calf at weaning, age of dam, calf breed type, cow parturition weight and previous parous state. The models fitted were as described in Chapter 3. Where necessary dam ages were pooled together since some age of dam groups were represented by few animals. For example, dam ages 2 and 3 years, and from 13 to 15 years were pooled together.

The General Linear Models (GLM) procedure in the Statistical Analysis Systems (SAS, 2004) was used to generate least squares means for the respective environmental effects. After running an analysis of variance, pair-wise comparisons were made using Tukey's test. This facilitated the development of different age of dam groups by pooling together age of dams which did not differ significantly. Age of dam adjustment factors for birth weight and weaning weight to a mature basis were derived from least squares constants. Adjustment factors were computed as differences of the other age of dam groups from mature age group (base). Sex of calf adjustments were computed by taking the least squares means differences between male and female calves.

4.4 Results and Discussion

The sex of calf, breed of calf, age of dam, month and year of birth, previous parous state, cow parturition weight affected ($P< 0.01$ or $p< 0.05$) birth weight and weaning weight in both the Tswana and Composite breeds. However, previous parous state did not affect ($P> 0.05$) either birth weight or weaning weight in the Composite breed. Birth weight and age of calf at weaning were significant in both breeds when fitted as covariates for weaning weight.

Sex of calf x age of dam interactions did not affect ($P> 0.05$) weaning weight in both breeds. These results were in agreement with findings of Cunningham & Henderson (1965), Minyard & Dinkel (1965) and Cardellino & Frahm (1971), who also found the interaction between sex of calf and dam age to be non-significant. This is however, contrary to other studies which found these interactions to be significant (Barlow *et al*., 1974; Schaeffer & Wilton, 1974a; Anderson & Wilham, 1978; Sharma *et al*., 1982). A significant sex of calf by age of dam interaction effect would indicate a need for separate additive age of dam correction factors within each sex (Nelsen & Kress, 1981). In contrast, the results from the current study and in some literature cited would suggest that age of dam correction factors need not be separated by sex in the population of Tswana and Composite breeds that were studied.

Figures 4.1 and 4.2 show the plot of Tswana birth weight and weaning weight against age of dam, respectively, while Figures 4.3 and 4.4 show corresponding plots for the Composite breed. The effects of age of dam for birth weight and weaning weight were curvilinear and concurred with findings of Swiger (1961). There was an increase in birth weight from 3 year old dams to 6 year olds in the Tswana. A peak was reached between the dam ages 6 and 9 years, where-after it tended to decrease with an advancing age. Swiger *et al.* (1962) estimated that calves produced by 8 to 9 year old dams had the heaviest birth weights. Similarly, in the Composite breed birth weight increased as age of dam increases but unlike in the Tswana, the highest birth weights were obtained at ages of 11 and 12 years old.

Younger dams and older dams gave birth to lighter calves when compared to mature dams. According to Elzo *et al*. (1987), this trend is probably a reflection of a greater ability by mature cows to provide the fetus with the necessary nutrients and environmental conditions for its development. It also suggests a reduction of this ability in both younger and older cows. Since first-calf heifers are not physically or biologically mature and still developing themselves, the nutrients they consume are partitioned not only into lactation, maintenance and gestation, but also towards their own growth (Rumph & Van Vleck, 2004). Likewise, as cows become older, their ability to provide an adequate environment may diminish.

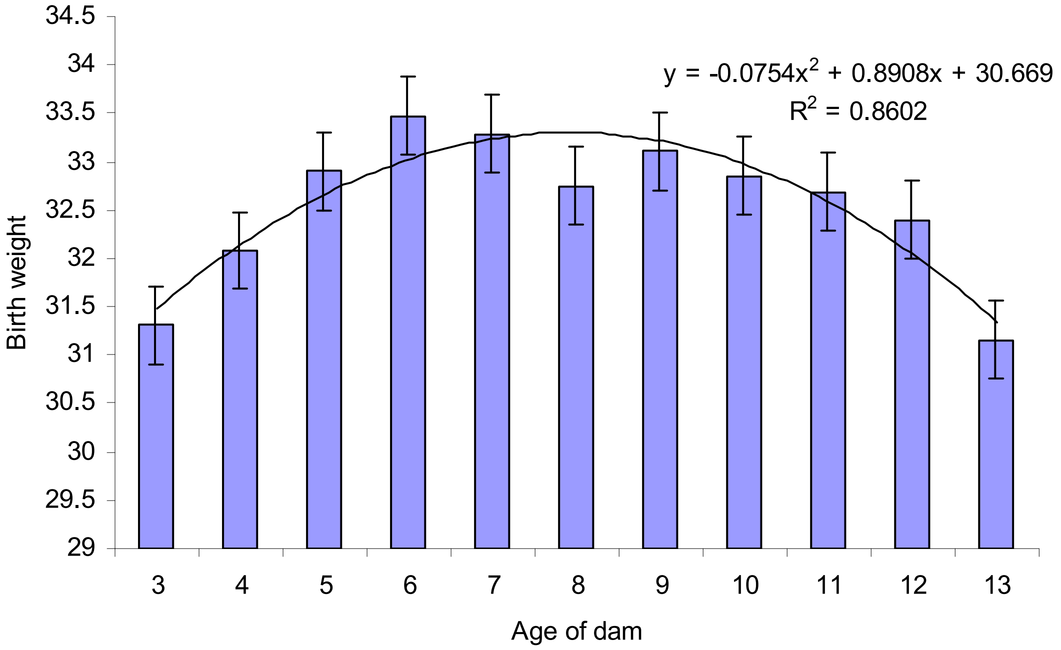

Figure 4.1 Plot of BW vs age of dam in Tswana cattle

Age of dam adjustment factors for birth weight to a mature basis derived from least squares means for the Tswana and Composite breeds are presented in Table 4.1. For both breeds, the age of dam groups were similar, i.e. 3, 4, 5-12, and 13 years and older. The mature cows were considered to be 5-12 years old in the Tswana and Composite and the results are similar to those found by Dzama *et al*. (1997) for the Hereford and Sussex breeds in Zimbabwe. In the same study it was also found that mature cows were 5-13 years for the Mashona, a breed with common ancestral origin with the Tswana. The Beef Improvement Federation (BIF) denotes mature cows to be between ages 5 and 10 years for birth weight in the United States (BIF, 2002). Adjustment factors for the Composite were larger than those for the Tswana for ages 3 and 13+ years but were lower for dams belonging to the 4-year-old group.

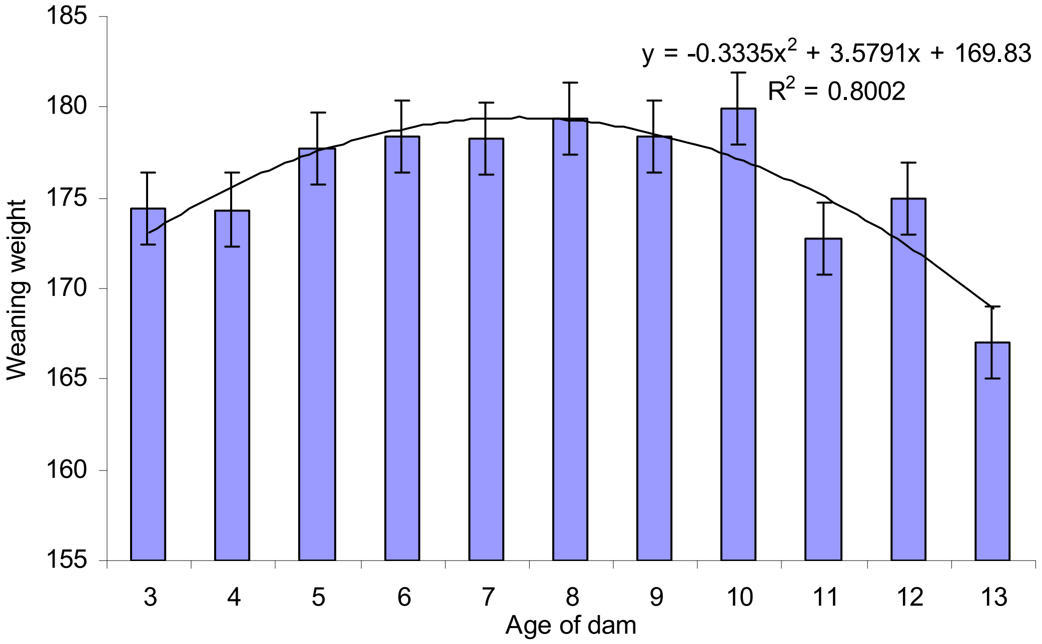

Figure 4.2 Plot of WW vs age of dam in Tswana cattle

Age of dam adjustment factors for age groups 3, 4 and 13+ years for the birth weight of the Composite breed were respectively 2.3, 0.9 and 2.1. Unlike in the Tswana, these results show that younger dams (3 and 4 years of age) gave birth to lighter calves when compared to older dams (13+ years). The age of dam adjustment factors for age group of 3 and 4 years were similar to those in the U.S.A. (BIF, 2002).

Table 4.1 also shows the age of dam adjustment factors for weaning weight to a mature basis for the two breeds. In both breeds the mature cows were found to be represented between ages of 5-12 years. The mature cow basis for weaning weight (5-12 years) was similar to that for birth weight. In the Tswana, the category for younger cows were however, represented by 3- and 4-year-old dams pooled together and therefore the categories for adjustment factors based on age of dam were 3-4, 5-12 and 13+ years for the breed. Age of dam adjustment factor categories in the Composite were 3, 4, 5-12 and 13+ years for weaning weight, age groups similar to those obtained for birth weight.

In general, the adjustment factors were on average lower than those obtained in other studies (Cardellino & Frahm, 1971; Nelsen & Kress, 1981; Sharma *et al.*, 1982; Dzama *et al.*, 1997). On the other hand, the adjustment factor for dams of 13 years and older was comparable to that obtained by Dzama *et al*. (1997) for the Sussex (5.4 kg) and by Cundiff *et al*. (1966a) for the Angus (5.6 kg). These results also indicate that for weaning weight, calves from younger dams were lighter than those from older dams, thus resulting in larger adjustment factors. This is opposite to the trend observed for birth weight. This outcome may be explained by other factors apart from the calf's own ability to grow. During the pre-weaning growth period (birth to weaning) the maternal influence provided by the dam is no longer the uterine environment but it is essentially mothering ability, which is mainly based on milk production by the dam (Robison *et al.*, 1978).

Table 4.1 Additive adjustments factors for the age of dam (± SE) for birth weight and weaning weight in the Tswana and Composite breeds

Age of dam	Birth weight	±SE	Age of dam	Weaning weight	±SE
Tswana					
3	1.74	± 0.31	**3 – 4**	10.36	± 1.32
4	0.96	± 0.22	**5 – 12**	0.00	± 0.00
5 – 12	0.00	± 0.00	**≥13**	5.46	± 1.58
≥13	1.87	± 0.46			
Composite					
3	2.28	± 0.62	**3**	13.84	± 2.93
4	0.94	± 0.33	**4**	3.20	± 1.77
5 – 12	0.00	± 0.00	**5 – 12**	0.00	± 0.00
≥13	2.06	± 1.09	**≥13**	9.58	± 5.66

In the Composite breed, age of dam adjustment factors for age groups 3, 4 and 13+ years were respectively 13.8, 3.2 and 9.6 kg. Considering the average differences between male and female calves, the BIF (1996) results for 3 year old dams in the Angus and Charolais were comparable to those of the current study. The adjustment factors for 4 year old dams were generally lower compared to those reported by Rumph & Van Vleck (2004). For cows of 13 years and above, Dzama *et al*. (1997) found an adjustment factor of 10.6 kg for the Hereford in Zimbabwe.

The differences in weight between sexes are presented in Table 4.2. These differences between male and female calves for weights of beef cattle are well documented (Burfening *et al*., 1978; Gregory *et al*., 1978; Lawlor *et al*., 1984; McElhenny *et al*., 1986; Newman *et al*., 1993; Carvalheira *et al*., 1995; Plasse *et al*., 1995; Dzama *et al*., 1997; Melka 2001). These researches indicate that male calves were heavier than female calves throughout their growth period. The adjustment factors for sex of calf were higher for the Composite than those for the Tswana. The adjustment factors for birth weight and weaning weight in the Composite were 2.84 and 10.11 kg, respectively. Corresponding adjustment factors for the Tswana were 2.75 and 8.21 kg, respectively.

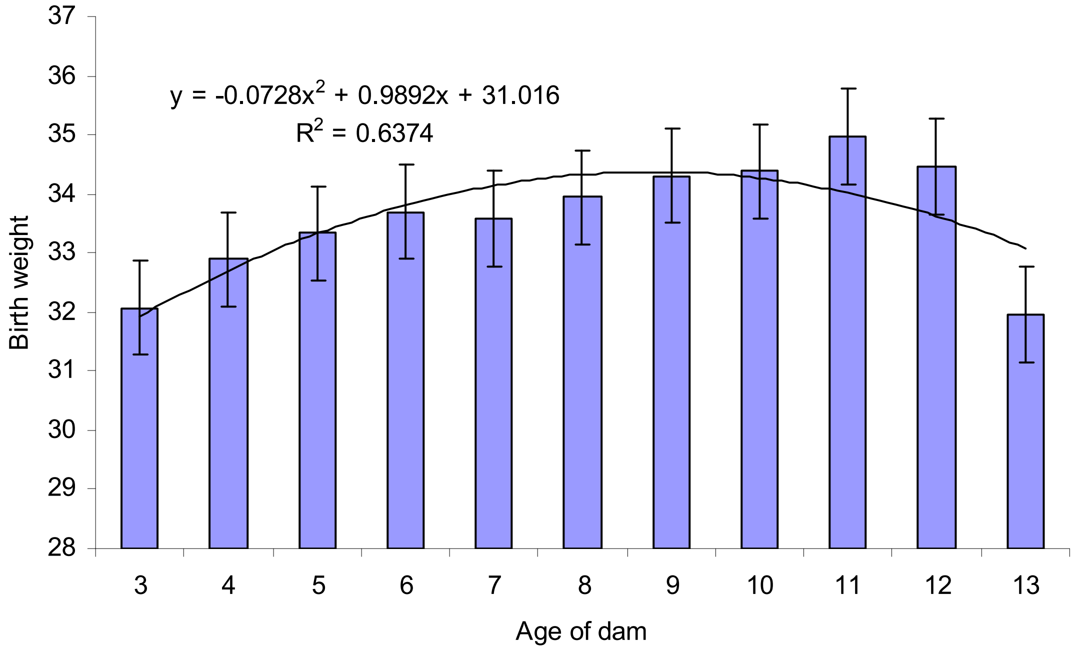

Figure 4.3 Plot of BW vs age of dam in Composite cattle

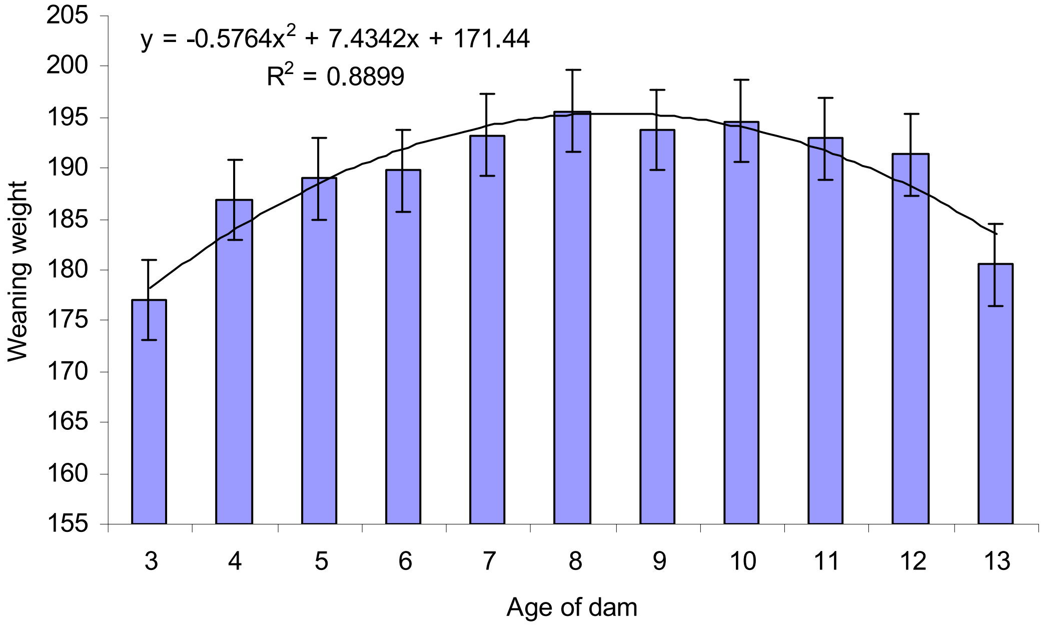

Figure 4.4 Plot of WW vs age of dam in Composite cattle

Table 4.2 Least squares means (kg ±SE) indicating sex of calf differences in birth weight and weaning weight of the Tswana and Composite cattle breeds of Botswana

Breed		Male	SE	Female	SE	Contrast
Tswana	BW	33.92	± 0.11	31.17	± 0.12	2.75
	WW	180.07	± 0.60	171.86	± 0.62	8.21
Composite	BW	35.02	± 0.20	32.18	± 0.20	2.84
	WW	194.58	± 0.88	184.47	± 0.90	10.11

The sex of calf adjustment for birth weight in the Tswana was higher than the adjustment factors reported by Kars *et al.* (1994) for the Nguni (1.86 kg) and Tawonezvi (1989) for the Mashona (1.0 kg). For weight at weaning, the 8.21 kg obtained for the Tswana was closer to the correction factor of 8.0 kg derived for the Mashona (Tawonezvi, 1989). The sex of calf adjustment factors for the Composite was also higher than those found by Burris & Cecil (1952) for Angus, Hereford and Shorthorn, and by Koch & Clark (1955) for Hereford cattle. However, it was lower than the adjustment factor of 16.5 kg derived by Newman *et al*. (1993) for a composite line of beef cattle. The differences in adjustment factors reported in several studies are probably due to the differences in climates between regions, management and other environmental effects.

4.5 Conclusion

In both the Tswana and Composite breeds, birth weight and weaning weight of calves increased with age of dam until the dams reached their mature age, after which the calves' weights decreased. The age of dam by sex interaction was non-significant and therefore age of dam adjustment factors need not be considered within sexes for these breeds. In general, adjustment factors for the Tswana were lower than for the Composite. In both breeds the birth weight and the weaning weight of male calves were higher than those of their female counterpart. Due to the differences in adjustment factors obtained between the two breeds there is a need to compute these factors within breeds and also apply them in the breeds that the factors were derived from.

Like other non-genetic factors, age of dam and sex of calf are necessary for accurate estimation of genetic parameters for growth in the Tswana and Composite breeds.

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CHAPTER 5

ESTIMATION OF GENETIC PARAMETERS FOR GROWTH TRAITS OF TSWANA AND COMPOSITE BEEF CATTLE BREEDS IN BOTSWANA

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5.1 Abstract

Genetic parameters for birth weight (BW), weaning weight (WW), pre-weaning average daily gain (ADG1), 18-months weight (18MW) and post-weaning average daily gain (ADG2) were estimated using single-trait and multi-trait analyses. Data consisted of 2,257 records for the Composite and 5,923 records for the Tswana collected between the period of 1988 and 2006 in Botswana. The individual animal model (AM) and animal maternal model (AMM) were fitted in both analyses. Direct heritabilities for BW, WW, ADG1, 18MW and ADG2 in the Tswana were respectively 0.45, 0.32, 0.37, 0.31 and 0.31, when the AM was fitted in single-trait analyses. Fitting the AMM gave direct and (maternal) heritabilities of respectively 0.31(0.11), 0.20(0.15) and 0.16(0.21) for BW, WW and ADG1 in the Tswana breed. Direct heritabilities for BW, WW and ADG1 in the Composite when the AM was fitted in single-trait analyses were respectively 0.58, 0.32 and 0.30. Direct and (maternal) heritabilities when the AMM was fitted for single-trait analyses in the Composite were 0.55(0.09), 0.17(0.15) and 0.14(0.15), respectively. When using multi-trait analyses and fitting the AM, the direct heritabilities for the Tswana were respectively 0.45, 0.37, 0.34, 0.39 and 0.31 for BW, WW, ADG1, 18MW and ADG2. Genetic correlations among the live weight and growth traits ranged from 0.16 to 0.97. Direct and (maternal) heritabilities for BW, WW and ADG1 were respectively 0.31(0.11), 0.19(0.15) and 0.14(0.17) in the Tswana using the multi-trait analysis. Correlations between direct heritabilities for BW, WW and ADG1 ranged from 0.45 to 0.95 while maternal correlations ranged from 0.12 to 0.99. The magnitude of the heritabilities indicates an opportunity to make genetic progress through selection in both breeds.

Keywords: heritabilities, correlations, single-trait, multi-trait, growth

5.2 Introduction

The genetic potential of an animal is measured by estimating the transferable (additive) genetic merit of the animal for a specific trait to its progeny. According to Mohiuddin (1993), the potential for genetic change in economically important traits in beef cattle depends mostly on the magnitude of the genetic variances and heritabilities of the characters considered during selection. Knowledge of these parameters is therefore important when designing effective breeding programs (Burrow, 2001).

Genetic parameters, such as heritability estimates and genetic correlations are computed as functions of variance and covariance components. Growth traits are influenced not only by their genetic makeup (direct effects) but also by the prenatal and postnatal environments (maternal effects) of the animal (Nelsen *et al*., 1984). Before weaning, maternal effects are mainly represented by the dam's milk production and mothering ability (Meyer, 1992a). It is equally important to consider the relationships that exist between direct and maternal effects, and genetic relationships among the traits as selection for one trait may have a future implication on the other especially when antagonistic correlations exist (Swalve, 1993).

The animal maternal model (AMM) and individual animal model (AM) are some of the models which are used to predict variance components as described by several authors (Mackinnon *et al*., 1991; Meyer, 1992a; Schoeman & Jordan, 1999; Burrow, 2001; Melka, 2001; Maiwashe *et al*., 2002). Other models include the sire and maternal-grandsire (MGS) models (Quaas *et al*., 1985; Bertrand & Benyshek, 1987; Trus & Wilton, 1988; Wright *et al*, 1991).

The unavailability of published results on the genetic parameters for the Tswana (Mpofu, 1996) and the Composite breeds in Botswana is a limitation, since these estimates are needed for prediction of breeding values and the formulation of breeding plans (Kars *et al*., 1994). The maternal ability of the Tswana is of interest especially since the breed is widely used as a dam line in crossbreeding with other breeds. On the other hand, the need for genetic parameters for the Composite breed, as a relatively new breed in the beef industry in Botswana, cannot be overemphasized. The objective of this study was therefore to estimate genetic parameters in these two cattle breeds for subsequent use in genetic evaluations and breeding programs.

5.3 Materials and Methods

Performance data were obtained from Tswana and Composite calves kept at Musi ranch and recorded for the period of 1988 to 2006. The ranch is run by the Animal Production and Range Research Division of the Department of Agricultural Research. The animals were reared on natural pastures. Breeding systems, management and recording procedures for the two cattle breeds are described in detail in Chapter 3.

Preliminary analyses used the Statistical Analysis System (SAS, 2004) for editing purposes. Where necessary, dam ages were pooled since some age of dam groups had few animals. For example dam ages 2 and 3 years, and 11 to 15 years were represented by few animals, and were pooled. The total numbers of records, as well as the number of sires and dams in the data for estimation of genetic parameters for each breed are shown in Table 5.1.

Table 5.1 Characteristics of the data set for growth traits in each breed

Breed	Trait	Number of records used	Number of sires	Number of dams
Tswana				
	Birth weight	5923	127	1520
	Weaning weight	5923	125	1457
	Pre-weaning ADG	5362	125	1457
	18-months weight	3838	117	1262
	Post-weaning ADG	3838	117	1254
Composite				
	Birth weight	2257	46	732
	Weaning weight	2257	46	731
	Pre-weaning ADG	2249	46	731

5.3.1 Statistical Analysis

Variance and covariance components were estimated using ASREML2 (Gilmour *et al*., 2002). An individual animal model (AM) and an animal maternal model (AMM) were both used in single- and multi-trait analysis of birth weight (BW), weaning weight (WW), pre-weaning ADG (ADG1), 18-months weight (18MW) and post-weaning ADG (ADG2). Genetic parameters for ADG2 and 18MW were however, not calculated for the Composite breed mainly because there were few animals to support computation of reasonable genetic parameters for the two traits. The AM model only considered the direct additive genetic effect while the AMM partitioned the genetic additive effects into direct and maternal genetic components. Both the AM and the AMM models involved the same fixed effects. Genetic parameters, such as direct heritabilities, maternal heritabilities and the correlations between direct and maternal genetic effects were subsequently obtained from the (co)variance estimates.

The fitted models were:

Model 1: $Y = X\mathbf{b} + Z_1\mathbf{a} + \mathbf{e}$ (AM)

Model 2: $Y = X\mathbf{b} + Z_1\mathbf{a} + Z_2\mathbf{m} + \mathbf{e}$ (AMM)

where:

Y = the vector of records

$\mathbf{b}$ = the vector of fixed effects

X = the matrix that relates $\mathbf{b}$ with Y

$\mathbf{a}$ = the random vector for direct additive genetic effects

$\mathbf{m}$ = the random vector for maternal genetic effects

Z_1, Z_2 = matrices relating Y to the random effects of $\mathbf{a}$ and $\mathbf{m}$

$\mathbf{e}$ = the vector of residual effects

Additionally, it is assumed that:

$\mathrm{Var}(a) = \mathbf{A}\,\sigma^2_a$

$\mathrm{Var}(m) = \mathbf{A}\,\sigma^2_m$

$\mathrm{Var}(e) = \mathbf{I}\,\sigma^2_e$

$\mathrm{Cov}(a,m) = \mathbf{A}\,\sigma_{am}$

$\mathrm{Var}(y) = \sigma^2_a + \sigma^2_m + \sigma_{am} + \sigma^2_e$

where:

$\mathbf{A}$ = the numerator relationship matrix
$\mathbf{I}$ = an identity matrix
σ^2_a = additive genetic variance
σ^2_m = maternal genetic variance
σ^2_{am} = genetic covariance between direct and maternal effects
σ^2_a = the residual variance

Heritabilities were estimated as follows:

1. Direct additive genetic effects

$h^2_a = \sigma^2_a / \sigma^2_p$ where σ^2_p is the phenotypic variance

2. Maternal genetic effects

$h^2_m = \sigma^2_m / \sigma^2_p$

3. Genetic correlation between direct and maternal effects

$r_{am} = \sigma_{am} / (\sigma^2_a\,\sigma^2_m)^{0.5}$

5.4 Results and Discussion

5.4.1 Single-trait Analysis

Variance and covariance components, together with genetic parameters for birth weight (BW), weaning weight (WW), pre-weaning average daily gain (ADG1), 18-months weight (18MW) and post-weaning average daily gain (ADG2) for the Tswana and Composite breeds are presented in Table 5.2.

The heritabilities of direct additive genetic effects obtained using the AM were higher than values resulting when the AMM was used. Unlike the AMM the AM ignores the maternal component. Waldron *et al*. (1993) found that animal models which ignore maternal effects tended to overestimate direct heritabilities. Maternal heritabilities were lower than direct heritabilities for all traits except for ADG1 in both breeds. Similar trends where maternal heritabilities were lower than direct heritabilities were observed in previous studies by Bertrand & Benyshek (1987), Kars *et al*. (1994), Maiwashe *et al*. (2002) and Norris *et al*. (2004) for BW and WW; by Brown *et al*. (1990) for ADG1; by Garrick *et al*. (1989) for ADG2; and by Mackinnon *et al*. (1991) for 18-months weight. There are however, a few reports where higher maternal heritabilities than direct heritabilities were obtained for growth traits (Nelsen *et al*., 1984; Cantet *et al*., 1988; Mackinnon *et al*., 1991; Meyer, 1992a).

The direct heritability (h^2_a) for BW in the Tswana breed using the AM was 0.45 and the result was comparable to that obtained by Meyer (1994) in Australian Angus cattle and Ahunu *et al*. (1997) in

Ndama and West African Shorthorn cattle. Estimates of h^2_a and the maternal heritability (h^2_m), obtained under the AMM, were respectively 0.32 and 0.11. This is in agreement with findings of Mohiuddin (1993) who reported estimates averaging 0.30 for h^2_a and 0.10 h^2_m for BW. Gutierrez *et al.* (1997) also reported similar results for the De los Valles cattle breed in Australia.

Table 5.2 Variances, covariances and genetic parameters estimated from single-trait analyses of BW, WW, ADG1, 18MW and ADG2 for Tswana and Composite beef breeds of Botswana

	(Co)variance components and genetic parameters						
Model	σ^2_a	σ^2_m	σ^2_e	σ^2_p	h^2_a	h^2_m	r_{am}
Tswana							
Birth weight							
AM	9.66		11.82	21.47	0.45		
AMM	6.54	2.23	12.26	21.03	0.31	0.11	0.33
Weaning weight							
AM	132.95		277.16	410.10	0.32		
AMM	93.01	66.71	296.48	456.20	0.20	0.15	0.69
Pre-weaning ADG							
AM	0.0036		0.0060	0.0095	0.37		
AMM	0.0015	0.0019	0.0059	0.0094	0.16	0.21	0.64
18 months weight							
AM	728.00		1618.19	2346.00	0.31		
Post-weaning ADG							
AM	0.0064		0.015	0.021	0.31		
Composite							
Birth weight							
AM	13.18		9.49	22.67	0.58		
AMM	12.51	1.93	8.38	22.82	0.55	0.09	0.20
Weaning weight							
AM	145.35		310.41	455.80	0.32		
AMM	72.36	62.20	291.53	426.10	0.17	0.15	0.88
Pre-weaning ADG							
AM	0.0029		0.0069	0.0098	0.30		
AMM	0.0014	0.0014	0.0068	0.0096	0.14	0.15	0.89

σ^2_a, direct additive genetic variance; σ^2_m, maternal additive genetic variance; σ^2_e, error variance; σ^2_p, phenotypic variance; h^2_a, heritability of direct additive effects; h^2_m, heritability of maternal effects; r_{am}, genetic covariance between direct and maternal genetic effects.

The direct heritabilities of 0.58 and 0.55 for the Composite breed under both models were high compared to most results from literature (Meyer, 1992a; Mohiuddin, 1993; Koots *et al.*, 1994a). Nevertheless, similarly high direct heritabilities were also reported in other studies (Meyer, 1994; Gutierrez *et al.*, 1997; Tosh *et al.*, 1999; Burrow, 2001). Schoeman *et al.* (2000) reported a h^2_a of 0.66 for BW in a multi-breed synthetic beef cattle population. Despite the h^2_m of 0.09 for the Composite breed being low, it concurred with findings of Haile-Mariam & Kassa-Messa (1995) and Bertrand & Benyshek (1987). The higher h^2_a estimates than h^2_m estimates suggest that the direct heritability is an important genetic parameter for BW in the two breeds studied. Ahunu *et al*. (1997) found h^2_m to be unimportant for BW in purebred and crossbred Ndama and West African Shorthorn cattle.

The direct-maternal correlations (r_{am}) were 0.33 and 0.20 for BW in the Tswana and Composite, respectively. Mohiuddin (1993) found that r_{am} varied widely in the literature from -1.05 to 0.55. These results were in agreement with those of Meyer, (1992a), Waldron *et al*. (1993), Tosh *et al*. (1999) and Melka, (2001) where r_{am} were positive for BW. In general the magnitude of the genetic parameter estimates obtained for BW especially in the literature, in the Tswana and Composite presents a considerable opportunity for genetic improvement of the trait through selection.

In this study, heritability estimates for weaning weight ranged from 0.15 to 0.32 for both breeds and these results were within the confines of the average estimates of 0.07 to 0.66 reported by Mohiuddin (1993). Estimates of h^2_a of 0.32 were obtained for weaning weight in both breed when the AM was fitted. Mrode & Thompson (1990) also found a h^2_a of 0.32 using the AM for Simmental cattle. When the heritability was partitioned into direct and maternal effects the h^2_a for the Tswana was 0.20 while that of the Composite was 0.17. The results for the Tswana agreed with those of Hetzel *et al*. (1990) and Mackinnon *et al*. (1991). Burrow (2001) found a h^2_a similar to that of the Composite. Estimates for h^2_m of 0.15 reported for both the Tswana and Composite were in agreement with findings of Bertrand & Bennyshek (1987). The derived estimates of r_{am} of 0.69 for the Tswana and 0.88 for the Composite were in contrast with several reported estimates (Meyer 1992a, Kars *et al*., 1994). Selection based on either the direct or the maternal effect will result in improvement of the other effect, which simplifies the selection process. The results for h^2_m however, suggest the maternal influence to be more pronounced for WW than BW in both breeds. This means that consideration of h^2_a in the genetic improvement of BW through selection will yield timely response while improvement of WW should entail selection based on either direct and/or maternal effects in these breeds.

Direct heritability estimates derived from the AM for pre-weaning average daily gain in the Tswana and Composite were respectively 0.37 and 0.30. Moderate h^2_a estimates for pre-weaning ADG from the AM were also reported by Gutierrez *et al*. (1997). Further partitioning of the heritabilities through the AMM resulted in estimates of 0.16 for h^2_a and 0.21 h^2_m for the Tswana breed. Corresponding estimates of respectively 0.14 and 0.15 were derived for the Composite breed. Estimates of h^2_a in both breeds were comparable to results from other studies (Mackinnon *et al*. 1991; Burrow, 2001) while h^2_m estimates were consistent with findings of Corbet *et al*. (2006b). It is worth noting that for pre-weaning ADG, h^2_m were higher than h^2_a for both breeds. This is in contrast to what the results for WW would indicate. This shows the importance of the maternal genetic influence over a period of time (from birth to weaning) compared to when it is observed at a particular time as for WW, thereby making breeding values derived from h^2_m possible aids to selection when an increased average gain is desired. Direct-maternal correlations for pre-weaning ADG were similar to those obtained for WW. The r_{am} for the Tswana breed was 0.64 while that for the Composite breed was 0.89. Equally for this trait, selection based on direct and maternal breeding values will result in a positive correlated response in both effects, unlike when the two were unfavourably related.

The h^2_a for 18-months weight and post-weaning ADG in the Tswana were moderate (0.31) for both traits when the AM was fitted. The results for 18-months weight were comparable to h^2_a estimates derived by Waldron *et al*. (1993) and Burrow (2001), which were respectively 0.37 and 0.34. However, h^2_a for post-weaning ADG was higher compared to those reported by several studies (Mackinnon *et al*., 1991; Meyer, 1993; Burrow, 2001; Corbet *et al*., 2006b). However, it was comparable to the h^2_a of 0.37 reported for Hereford cattle by Meyer (1992). Preliminarily an AMM was fitted to ascertain whether maternal effects extended beyond weaning in the Tswana breed. There were however, no significant maternal effects for post-weaning growth. Even though maternal effects have been reported for 18-months weight in some previous studies (Mackinnon *et al*., 1991; Meyer, 1993; Waldron *et al*., 1993) and for post-weaning gain (Mackinnon *et al*., 1991) the h^2_m estimates were usually very low and even negligible in some cases. The heritability estimates obtained for post-weaning growth depict that moderate genetic progress can result from selection of the Tswana basing on live weight at 18 months and for post-weaning ADG. However, according to Khombe *et al*. (1995), selecting animals at ages when maternal effects were not important may be undesirable since large numbers of animals have to be kept for prolonged periods before selection decisions are made. Such practices may lengthen the generation interval, thereby reducing the rate of response.

5.4.2 Multi-trait analysis

Heritability estimates from a multi-trait analysis were available for the Tswana breed only. The heritability estimates and genetic correlations between BW, WW, ADG1, 18MW and ADG2 derived from the AM are provided in Table 5.3. In general, the multi-trait analysis results were similar to those obtained from the single-trait analyses when the AM was fitted. All the traits were moderately heritable in both instances. However, h^2_a values of WW and 18MW showed an increase. A slight reduction was observed for h^2_a of pre-weaning ADG, when comparing results from the multi-trait analysis to those of the single-trait analyses. Haile-Mariam & Kassa-Messa (1995) suggested that an increase in the h^2_a of post-weaning weight may be related to removal of bias which was introduced due to selection based on WW.

The estimates of h^2_a for BW, WW, ADG1, 18MW and ADG2 were respectively 0.45, 0.37, 0.34, 0.39 and 0.31. Tawonezvi (1989) reported genetic parameter estimates for the Mashona cattle breed, a Sanga breed of cattle found in Southern Africa. The multi-trait analysis results obtained for BW, WW, ADG1, 18MW and ADG2 in the Mashona study were in close agreement with the present findings. Further afield, Meyer (1994) reported a similar h^2_a for BW (0.43) in Australian beef cattle, while Mackinnon *et al*. (1991) derived a h^2_a estimate of 0.42 for 18MW in tropical beef cattle.

Table 5.3 Heritabilities and genetic correlations between BW, WW, ADG1, 18MW and ADG2 estimated from a multi-trait animal model for Tswana cattle

	Heritabilities and genetic correlations				
Trait	BW	WW	ADG1	18MW	ADG2
BW	**0.45**	0.44	0.29	0.30	0.16
WW		**0.37**	0.97	0.60	0.28
ADG1			**0.34**	0.61	0.27
18MW				**0.39**	0.93
ADG2					**0.31**

Heritabilities on diagonal and genetic correlations above diagonal

Genetic correlations among live weight and growth traits ranged from 0.16 to 0.97. These correlations were low to moderate for BW with WW, ADG1, ADG2 and 18MW. These results accorded with the findings of Tawonezvi (1989) and were in general agreement with results of Mackinnon *et al*. (1991). In the current study, low correlations were also found between WW and ADG2 and between ADG1 and ADG2. Tawonezvi (1989) accordingly found low but negative correlations between these traits. The results were however, similar to those obtained by Burrow (2001). High genetic correlations were observed for WW with ADG1 and 18MW; for ADG1 with 18MW; and for 18MW with ADG2. Similar results were obtained by Tawonezvi (1989). Low genetic correlations of pre-weaning traits with post-weaning gain were attributed to compensatory growth effects. The positive correlations between the traits suggest that selection for one trait will result in a correlated response in the other trait. High positive genetic correlations between weight at weaning and at 18 months indicate that increases on weight at 18 months can readily be achieved by selection at weaning (Burrow, 2001). In contrast to results obtained for the Tswana and Mashona, Corbet *et al*. (2006b) derived high genetic correlations among all growth traits from birth to 18 months, suggesting that selection for increased weight at later stages will indirectly increase weights measured earlier in life. Increased BW is often undesirable because it is associated with an increased incidence of dystocia. It would seem therefore that selection based on WW is the positive and balanced way forward for the Tswana breed.

The heritability estimates and genetic correlations derived from the AMM for maternally influenced traits (BW, WW and ADG1) are presented in Table 5.4. Direct and maternal heritabilities obtained from the multi-trait analysis using the AMM were similar to those obtained from the single-trait analyses except for slight reductions in both h^2_a and h^2_m estimates for ADG1. The decrease in h^2_a of ADG1 was also observed when the AM was fitted in the multi-trait analysis. The h^2_a obtained from multi-trait analysis using the AMM was lower than those derived from the multi-trait analysis results using the AM. This indicates the effectiveness of partitioning heritabilities into direct and maternal components (Waldron *et al*., 1993; Melka, 2001).

Table 5.4 Estimates of direct and maternal heritabilities and genetic correlations among BW, WW, ADG1, 18MW and ADG2 using multi-trait analysis

	Direct heritabilities and correlations			**Maternal heritabilities and correlations**		
Trait	BW	WW	ADG1	BW	WW	ADG1
BW	**0.31**	0.57	0.45	**0.11**	0.25	0.12
WW		**0.19**	0.95		**0.15**	0.99
ADG1			**0.14**			**0.17**

Heritabilities on diagonal and genetic correlations above diagonal

The direct genetic correlations (r_g) among BW, WW and ADG1 varied from 0.45 and 0.95, indicating medium to high genetic association observed between the traits. The r_g between WW and ADG1 was higher than between BW and WW, and between BW and ADG1. The r_g's between BW and WW and between BW and ADG1 were higher than the average positive genetic correlations reported from the review of literature by Koots *et al*. (1994b) of respectively 0.50 and 0.26 as well as those estimates of respectively 0.45 and 0.28 reported by Maiwashe *et al*. (2002) for the Bonsmara breed. The results from the current study together with literature results suggest that selection for a higher WW or ADG1 would increase BW. The association of BW with calving difficulty might reduce productivity. Schoeman & Jordaan (1999) suggested an index of cow efficiency as the appropriate selection criteria when the objective is to improve WW without a concurrent increase in BW. The high r_g between WW and ADG1 was expected since WW is a component of ADG1.

Maternal genetic correlations (r_m) were positive and ranged from low (0.12) between maternal components of BW and ADG1 to high (0.99) between WW and ADG1. Even though the r_m between BW and WW was similar to the values found by Rust *et al*. (1998) and Quaas *et al*. (1985) it was lower than those reported by Haile-Mariam & Kassa-Messa (1995), Koots *et al*. (1994b) and Maiwashe *et al*. (2002). Conversely, the r_m between WW and ADG1 in the current study was very high when compared to the estimate of 0.03 reported by Maiwashe *et al*. (2002), while it was similar to the 0.99 reported by Melka (2001). Estimates or r_m indicate the existence of positive maternal genetic relationships between the traits, thus posing an opportunity for selection mainly based on WW for improved maternal capabilities in future generations.

5.4 Conclusion

Heritability estimates of growth traits (from birth to 18 months) from both AM and AMM models ranged from low to high. Birth weight had relatively high h^2_a compared to the other growth traits, most of which were moderately heritable. It however, had low h^2_m than all other maternally influenced traits. Considering the magnitudes of the heritability estimates in general, it is possible that genetic improvement could be realized for both breeds through planned selection. This conclusion is also supported by the positive correlations that exist between direct and maternal effects. The genetic correlations among traits were positive and varied from low to high. Selection based on the BLUP of breeding values for weaning weight seems to be ideal for the genetic improvement of the Tswana breed, as long as birth weight can be kept under control. This calls for the development of a selection index to alleviate any adverse effects in future due to selection.

5.5 References

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CHAPTER 6

GENERAL CONCLUSIONS

Important non-genetic factors have been demonstrated to influence growth traits in the Tswana and Composite breeds. Therefore, these fixed effects which include breed of calf, sex of calf, month and year of birth, previous parous state, cow parturition weight and age of dam should be considered during genetic evaluation. When fitted as a covariate, age of calf at weaning significantly affected weaning weight. The composite was heavier than the Tswana from birth to weaning after which the Tswana overtook the Composite for post-weaning gain and 18 months weight. Therefore, the Composite seems to be better for consideration in weaner production under ranch conditions while the Tswana could be also reared under extensive communal farming systems which prevail in Botswana due to its adaptational qualities. There were significant influences of BW on WW and in turn of WW on 18MW, suggesting a need to investigate underlying relationships between these traits further.

Sex of calf and age of dam were used to obtain correction factors for BW and WW. These adjustment factors could be used for fair comparison of calves within these breeds in future evaluations. Adjustment factors for the Composite were generally larger in magnitude than those obtained for the Tswana. In both breeds, birth and weaning weights of male calves were higher than those of females. Calves' birth weight and weaning weight increase with an increase in age of dam, reaching a peak for mature dams, and decreases thereafter as dams grow older. Due to the different growth patterns, these adjustment factors should be calculated within breeds and also applied in those breeds that they are derived from.

Heritabilities and correlations as measures of inheritance and the relationships between BW, WW, ADG1, 18MW and ADG2 were obtained from the study. Heritability estimates of growth traits derived from both the individual animal model (AM) and the animal maternal model (AMM) varied from low to high. The magnitude of the heritability estimates support a theory that genetic improvement in the two breeds through selection should be feasible. This is supported by the positive genetic correlations among the traits. The correlations ranged from low to high. Selection based on weaning weight would result in positive genetic response in other important growth traits for the Tswana.

Future studies should focus on identifying the breeding goals for the Tswana and the Composite breeds so that their intended use can be identified for the beef sector. There is a need to record the growth traits under field conditions and compare the genetic relationships with data from on-station trials. Studies on optimum selection programmes for both breeds and of the economic value derived for crossbreeding systems would be beneficial for beef producers in Botswana. It is also important to investigate calving and carcass traits both of which are economically valuable in beef enterprises. Ideally, an economic merit index incorporating all these traits should substantially improve the beef cattle industry in Botswana.