CHAPTER 3

INTERRELATIONSHIP AMONG LIFETIME COW FERTILITY, COW SIZE, PRE-WEANING AND POST-WEANING CALF GROWTH IN SANTA GERTRUDIS CATTLE

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3.1 ABSTRACT

The study was conducted to determine the associations between lifetime cow fertility and cow frame size, also between lifetime cow fertility and pre-weaning as well as post-weaning calf growth in tropically adapted Santa Gertrudis cattle. A total of 2 506 Santa Gertrudis cows were divided according to their average lifetime calving interval (CI) into short calving interval (SCI, < 400 days, n = 914 cows) and long calving interval (LCI, > 400 days, n = 1 592 cows) groups. Calves were weighed at weaning at approximately 7 months of age. Hip height of cows and pre-weaning gain of calves of the SCI cows (135 cm and 1.01 kg/day) were significantly ($p < 0.05$) lower than those of the LCI cows (141 cm and 1.25 kg/day). Calves from SCI cows were born significantly earlier in the calving season than calves from LCI cows as measured by age at weaning (221 vs 189 days). As a result of compensatory growth there was no significant difference for yearling weight between progeny of SCI and LCI cows (348 vs 349 kg). It is concluded that SCI cows are smaller in size, with significantly lighter calves at weaning. A negative correlation exists between fertility and pre-weaning calf growth. Post-weaning calf growth is compatible with high cow fertility.

Keywords**:** cow frame size, calving interval, pre-weaning growth, post-weaning growth, Santa Gertrudis.

3.2 INTRODUCTION

Improvement of fertility and growth through selection in beef cattle are becoming increasingly important, as beef production is determined by the reproductive rate, growth rate of calves and weight of culled cows. It is generally accepted that smaller cows are more fertile under extensive grazing conditions because small body size is an adaptive attribute, but that larger cows produce more milk and, therefore wean heavier calves (Olson, 1994 Mercadante *et al.,* 2000, Minick *et al.,* 2001). However, success of the real practice in different breeds and under different production systems needs to be demonstrated and the effect of lifetime cow fertility on traits such as mature size, weaning weight and post-weaning growth rate need to be evaluated. Calving interval (CI) was used as a measure of reproductive efficiency in this study. The objective of this paper was to study the associations between lifetime cow fertility and cow frame size, and between lifetime cow fertility and pre-weaning as well as post-weaning calf growth in tropically adapted Santa Gertrudis cattle.

3.3 MATERIAL AND METHODS

Data was obtained from the Santa Gertrudis Cattle Breeders Society of South Africa. Calving and growth records were analysed from three production systems in the southern African Region over a 12-year period. These production systems were managed extensively and the animals had to survive on natural pastures with a summer and winter lick. The breeding seasons were limited to 90 days for heifers and 60 days for the cows. The calves were weaned between 7 and 8 months of age. The bulls were all fertility tested before the breeding season commenced and they were put in with the cows at a 4% ratio. Only cows, which had calved twice, or more were used in this study. Cows were divided into 2 groups according to their average lifetime CI: Those with a CI < 400 days (SCI); and, those cows with a CI > 400 days (LCI). Calving date, weaning weight, 12 month and 18-month weights were recorded. Hip height was also recorded as a measure of cow frame size. Data were analysed using the General Linear Models procedure of Statistical Analysis Systems (SAS 1995). Traits were analysed by the least squares means of variance and the model of analysis included affect due to CI (SCI and LCI), age of dam, previous lactation status, sex of calf, weaning weight, 12 month weight, 18 month weight, hip height of the cows and a regression effect of day of birth.

3.4 RESULTS

The least squares mean for weaning-, 12 month- and 18 month weight of calves, as well as hip height of the cows, for the SCI and LCI groups are presented in Table 2.1.

Cows with higher lifetime fertility (SCI) were significantly smaller and also weaned significantly lighter calves. These cows dropped 78% of their calves during the first half of the calving season, while only 52% of the LCI cows dropped their calves during the same period, resulting in calves of the SCI group being significantly older (221 days compared to 189 days) at weaning.

Post-weaning growth rate for the progeny from the SCI group of cows was significantly ($p < 0.05$) greater than those progeny from the LCI group, resulting in the actual weight for the two groups not differing significantly ($p < 0.05$) at 12 months of age. Additional compensating growth was evident in the progeny of the SCI cows resulting in significantly ($p < 0.05$) higher 18 month weights in favour of the SCI group.

Table 3.1 : Least squares means and standard errors (±SEM) for weights at weaning, 12 month and 18 month of calves, pre-weaning, weaning – 12 months gain and 12 months – 18 months gain, as well as hip height of the cows, for short (SCI) and long (LCI) calving interval

Trait	SCI		LCI		Test of Significance
	Mean	±SEM	Mean	±SEM	
Number of cows (n)	914		1592		
Hip height (cm)	135	2.01	141	2.0	*
Weaning weight of calves (kg)	222	39.8	239	44.38	*
Pre-weaning gain (kg/day)	1.01	0.14	1.25	0.16	*
Age at weaning (days)	221	3.1	189	4.0	*
Yearling weight of calves (kg)	348	72.38	349	77.48	n/s
Weaning – 12 months gain (kg/day)	1.15	0.12	0.92	0.14	*
18 month weight of calves (kg)	385	44.33	354	46.84	*
12-18 months gain (kg/day)	0.21	0.01	0.03	0.01	*
* $p < 0.05$					

3.5 DISCUSSION

Since the SCI cows were significantly smaller in size than the LCI group, it is likely that early and regular reproduction restrict mature size. Under extensive conditions, small size is a desirable adaptive attribute, generally associated with early and regular reproduction. This may be ascribed to high inherent fertility of the tropically adapted, synthetic Santa Gertrudis breed, which offers more flexibility under stressful conditions to increase productivity, without sacrificing expressed fertility (Swanepoel and Lubout 1992, Taylor and Swanepoel, 1999).

Seifert and Rudder (1975), Lalman *et al.* (2000) and MacNeil (2005), stated that cows with less than average live weight, tended to have lighter progeny at weaning due to reduced milk production. Reduced lactational performance may be partly responsible for the higher fertility of the smaller cows. The present study suggests that there may be a close relationship between cow fertility and progeny growth from birth to weaning age. LCI cows produced calves with the highest pre-weaning growth and the heaviest weaning weight. The least fertile cows were generally the heaviest (McMorris and Wilton 1986, Nesamvuni, 1995, Heuer *et al.,* 1999) and larger (Olson, 1994, Haile-Mariam *et al.,* 2004, Chase *et al.,* 2005), with better udders (Taylor, 1995), with which they produced more milk (Van Raden *et al.,* 2004, Windig *et al.,* 2006). They were mostly those that missed at least one calving season. Perhaps they were able to recover more rapidly from the stress of reproduction and nursing a calf and build up better body reserves for a subsequent calving.

Reduced lactational performance as such has been suggested as a contributing factor to the improved fertility in cattle (Hetzel *et al.,* 1989, Davis *et al.,* 1992, Borman *et al.,* 2004). If this is the case, it can be explained by the physiological interaction between lactation and depression of ovarian function that is related to pituitary dysfunction, which is associated with lactation (Short *et al.,* 1994, Opsomer *et al.,* 2000, Hooijer *et al.,* 2001). During intense lactation, prolactin function is maximal, limiting the secretion of FSH and LH releasing factor. The duration of anoestrus is closely related to length and intensity of lactation (Hafez, 1980, Lopez-Gatius et al., 2001). Bulls were usually put with the cows two months after calving and milk production usually peaked at this stage. An attempt could be made to substantiate this by the fact that larger cows usually produce more milk (Seifert and Rudder, 1975, Bourdon and Brinks, 1983, Doren *et al.,* 1986), therefore they calved later in the season. These results do suggest a negative endo-environmental interaction between fertility and pre-weaning growth. Other authors (McMorris and Wilton, 1986, Swanepoel *et al*., 1992, Savagea *et al.,* 2004) agree that positive correlations between cow weight and either milk production or calf weaning weight exist. Bourdon and Brinks (1983) and Doren *et al.* (1986) reported a positive influence of weaning weight on cow fertility. Small cow frame size, reduced milk production and correspondingly lighter weaning weights are actually adaptive characteristics found in tropically adapted beef cattle (Rege, 1993, Tomo *et al.,* 2000).

Davis *et al.* (1992) found compensatory growth in both the wet and dry seasons for a SCI and LCI group, with the largest proportionate difference between the two fertility groups being in the dry season. This suggests that there may have been a correlated improvement in efficiency when feed was limited. This possibility is supported by this study, as the main compensatory growth occurred between weaning and 12 months of age, corresponding with the dry (winter) season. Compensatory growth still continued to take place in the wet season (12 - 18 months), but the difference between the growth-rate of the progeny from the two CI groups in the wet period was not as big as between the weaning and 12 month period.

Calves from the SCI group may have been better adapted to grazing at weaning due to the likely lower milk production of the cows as indicated by the lower weaning weight of the progeny. These calves were therefore better adapted to the available grazing and could express the compensatory growth after weaning. The calves from more fertile groups may have had better developed rumens, as they were older and may have had to survive on less milk and more of the natural grazing than the progeny from the less fertile group. However, no work has been done to substantiate this and it should be investigated further.

Tomo *et al.* (1999) and Corbet *et al.* (2006) have maintained that there is no genetic antagonism between high cow fertility and post-weaning growth of their progeny, provided that strict selection is practiced for both traits. Selecting for growth rate alone may lead to reduced fertility (Olson, 1994, Archer *et al.,* 1998). Meyer *et al.* (1991) reported a favourable genetic correlation between reproduction and growth traits in cattle, and Wolfe *et al.*

(1990) also concluded that selection for weaning weight, final weight and muscling score had no detrimental effects on age at puberty in heifers. MacNeil (1988) also reported that male progeny with a relatively high growth rate were produced by cows which tended to be more fertile. This was also supported by Moyo *et al.* (1996).

Hetzel and Mackinnon (1989) concluded that high lifetime cow fertility measured in terms of the estimated breeding value for pregnancy rate, was not incompatible with the post-weaning growth rates of their progeny. Compensatory growth took place in the progeny of the high fertility group to such an extent that at 12 months of age there was no significant difference in the weights of the progeny between the high and low line fertility groups.

3.6 CONCLUSIONS

Cows of higher lifetime fertility (SCI) are smaller in size, have significantly lighter calves at weaning. Early and regular reproduction may restrict mature size. A negative endo-environmental correlation exists between fertility and pre-weaning calf growth.

Compensatory growth occurs after weaning especially in progeny from more fertile cows. The high post-weaning growth rates of the progeny of higher fertile cows therefore minimise the weight advantage of the calves from the less fertile cows even though the latter weaned calves with higher weights. The result is that at 12 months of age there is no significant difference in weight between the two groups. Post-weaning growth rate is therefore compatible with high cow fertility.

3.7 REFERENCES.

ARCHER, J. A., ARTHUR, P. F., PARNELL, P. F., AND VAN DE VEN, R. J. (1998). Effect of divergent selection for yearling growth rate on female reproductive performance in Angus cattle. *J. Anim. Sci*. 57, pp 33 - 40**.**

BORMAN, J. M., MACMILLAN, K. L., AND FAHEY, J. (2004). The potential for extended lactations in Victorian dairying: a review. *Aust. J. of Exper. Agric.* 44, pp. 507 – 519.

BOURDON, R.M. AND BRINKS, J.S. (1983). Calving date versus calving interval as a reproductive measure in Beef cattle. *J. Anim. Sci*. 57, pp. 1412 - 1417.

CORBET, N.J., SHEPHERD, R.K., BURROW, H.M., PRAYAGA, K.C., VAN DER WESTHUIZEN, J., AND BOSMAN, D. J. (2006). Evaluation of Bonsmara and Belmont Red cattle breeds in South Africa. 2. Genetic parameters for growth and fertility. *Aust. J. of Exper. Agric*. 46, pp. 213 - 223.

CHASE, C.C., RILEY, D.G., OLSON, T.A., COLEMAN, S.W. (2005). Evaluation of Brahman and tropically adapted *Bos taurus* breeds in the humid subtropics. American Society of Animal Science Southern Section Meeting, February 4-8, Little Rock, Arkansas.

DAVIS, G.P., GORBET, N.J., MACKINNON, M.J., HETZEL, D.J.S., ENTWISTLE, K.W. AND DIXON, R. (1992). Correlated responses to selection for female fertility in a tropical beef cattle herd. *(Unpublished).*

DOREN, P.E., LONG, C.R., AND CARTWRIGHT, T.C. (1986). Factors affecting the relationship between calving interval of cows and weaning weights of calves. *J. Anim. Sci*. 62, pp. 1194 - 1202.

HAFEZ, C.S.E. (1980). Reproduction in farm animals 4th ed. Lear and Febiger, Philadelphia.

HAILE-MARIAM, M., BOWMAN, P.J., AND GODDARD, M.E. (2004). Genetic parameters of fertility traits and their correlation with production, type, workability, live weight, survival index, and cell count. *Austr. J. of Agri Res.* 55, pp. 77-87.

HETZEL, D.J.S., MACKINNON, M.J., DIXON, R., AND ENTWISTLE, K.W. (1989). Fertility in a tropical beef herd divergently selected for pregnancy rate. *Anim. Prod.* 49, pp. 73 - 81.

HETZEL, D.J.S., AND MACKINNON, M.J. (1989). Selection for high fertility in the tropics. *1st National conference of the Beef Improvement Association. Armidale, NSW.*

HEUER, C., SCHUKKEN, Y.H., AND DOBBELAAR, P. (1999). Postpartum body condition score and results from the first test day milk as predictors of disease, fertility, yield and culling in commercial dairy herds. *J. Dairy Sci.* 82, pp 295 – 311.

HOOIJER, G.A., LUBBERS, R.B.F., DUCRO, B.J., VAN ARENDONK, J.A.M., KAAL-LANSBERGEN, L.M.T.E., AND VAN DER LENDE, T. (2001). Genetic parameters for cystic ovarian disease in Dutch black and white dairy cattle. *J. Dairy Sci.* 84, pp 286 - 291

LALMAN, D.L., WILLIAMS, J.E., HESS, B.W., THOMAS, M.G., AND KEISLER, D.H. (2000). Effect of dietary energy on milk production and metabolic hormones in thin, premiparous beef heifers. *J. Anim. Sci.* 78(3), pp. 530 - 541.

LOPEZ-GATIUS, F., SANTOLARIA, P., YANIZ, J., RUTLLANT, J., AND LOPEZ-BEJAR, M. (2001). Persistent ovarian follicles in dairy cows: A therapeutic approach. *Theriogenology*. 56(4), pp. 649 - 659.

MACNEIL, M.D. (2005). Genetic evaluation of the ratio of calf weaning weight to cow weight. *J. Anim. Sci.* 83, pp. 794 - 802.

MACNEIL, M.D. (1988). Consequences of selection for growth and tissue development on material qualities. *Proc 3rd World Congress Sheep Beef Cattle Breed*. 1, pp. 415 - 427.

MCMORRIS, M.D., AND WILTON, J.W. (1986). Breeding system, cow weight and milk yield effects on various biological variables in beef production. *J. Anim. Sci.* 63, pp. 1361 - 1372.

MERCADANTE, M.E.Z., LÔBO, R.B., AND OLIVEIRA, H.N. (2000). Estimativas de (co)variâncias entre características de reprodução e de crescimento em fêmeas de um rebanho Nelore. *Revista da Sociedade Brasileira de Zootecnia,* 29 (4), pp. 997 - 1004.

MEYER, K., HAMMOND, K., MACKINNON, M.J., AND PARNELL, P.E. (1991). Estimates of covariance's between reproduction and growth in Australian beef cattle. *J. Anim. Sci.* 69, pp. 3533 - 3544.

MINICK, J.A., BUCHANAN, D.S., AND RUPERT, S.D. (2001). Milk production of crossbred daughters of high- and low-milk EPD Angus and Hereford bulls. *J. Anim. Sci.* 79 (6), pp.1386 - 1393.

MOYO, S., SWANEPOEL, F.J.C., AND REGE, J.E.O. (1996). Evaluation of indigenous, exotic and crossbred cattle for beef production in a semi-arid environment: Reproductive performance and cow productivity. *Proc. Aust. Soc. Anim. Prod.* 21, pp. 352 - 363.

NESAMVUNI, A.E. (1995). Genetic and Phenotypic trends for growth and overall efficiency in Bonsmara beef cattle. Ph.D Thesis. Oklahoma State University. USA.

OLSON, T.A. (1994). The effect of cow size on reproduction. Factors affecting calf crop. Butterworth's. ISBN 0-8493-8754-X, pp 243 - 249.

OPSOMER, G., GRÖHN, Y.T., HERTL, J., CORYN, M., DELUYKER, H., AND DE KRUIF, A. (2000). Risk factors for post partum ovarian dysfunction in high producing dairy cows in Belgium: a field study. *Theriogenology* 53, pp. 841 - 857.

REGE, J.E.O. (1993). Proceedings of the Developing Areas Branch Symposium of the *SA Society of Animal Science, Eiland, South Africa*, pp. 1 - 15.

SEIFERT, G.W., AND RUDDER, T.H. (1975). Principles of Cattle Production. *Proceedings of the Easter School in Agricultural Science, (Ed: W.H. Broster and H. Swan*), Butterworths: London, pp. 373 - 385.

SAS. (1995). SAS/STAT* User's Guide (Release 6.03). SAS Inst., Inc., Cary, NC.

SAVAGEA, D.B., GAUGHANB, J.B., MURRAYB, P.J., LISLEC, A.T., AND PEATLING, S.R. (2004). Effect of breeder body condition and weight on pregnancy and calf growth in three age groups of composite-bred beef cattle. Proceedings of the 25th Biennial Conference of the Australian Society of Animal Production. University of Melbourne, Victoria. http://www.publish.csiro.au/nid/197/paper/SA0401040.htm

SHORT, R.E., STAIGMILLER, R.B., BELLOWS, R.A., ADAMS, D.C. AND BERADINELLI, J.C. (1994). Effect of suckling on postpartum reproduction. Factors affecting calf crop. Butterworth's. ISBN 0-8493-8754-X. pp. 179 – 187.

SWANEPOEL, F.J.C., SEIFERT, G.W., AND LUBOUT, P.C. (1992). The relationship of lifetime fertility of Bonsmara cows with growth and scrotal circumference of their claves. *Proc. Aust. Assoc. Anim. Breed. Genet.* 10, pp. 362 - 536.

SWANEPOEL, F.J.C., AND LUBOUT, P.C. (1992). Selecting for fertility in cattle in tropical and sub-tropical environments. *Proceedings, First All Africa Conference in Anim. Agric.* Nairobi, Kenya.

TAYLOR, W.T. (1995). Relationship of lifetime fertility of Bonsmara cows with the growth and scrotal circumference of their calves. M.Sc Thesis, University of Pretoria, RSA.

TAYLOR, G.J., AND SWANEPOEL, F.J.C. (1999). Selecting for fertility in tropical and sub-tropical environments. Beef cattle production information workshop. Hooglandpers, Bethlehem, RSA. ISBN 0-86886-547-8. UOVS

TOMO, P.S.M., TAWAH, C.L., SWANEPOEL, F.J.C., AND HOOGENBOEZEM, J.M. (1999). Production characteristics of Angoni cattle in Mozambique: 1. Non-genetic influences on pre- and post-weaning growth. *Trop. Sci.* 39, pp. 187 - 193.

TOMO, P.S.M., TAWAH, C.L., SWANEPOEL, F.J.C., AND HOOGENBOEZEM, J.M. (2000). Production characteristics of Angoni cattle in Mozambique: 2. Non-genetic influences on survival, fertility and productivity. *Trop. Sci.* 40, pp. 53 – 64.

VAN RADEN, P.M., SANDERS, A.H., TOOKER, M.E., MILLER, R.H., NORMAN, H.D., KUHN, M.T., AND WIGGANS, G.R. (2004). Development of a national genetic evaluation for cow fertility. *J. Dairy Sci*. 87, pp. 2285 – 2292.

WINDIG, J. J., CALUS, M.P.L., BEERDA, B., AND VEERKAMP, R. F. (2006). Genetic Correlations between Milk Production and Health and Fertility Depending on Herd Environment. *J. Dairy Sci.* 89 (5), pp. 1765 - 1775.

WOLFE, M.W., STUMPF, T.T., WOLFE, P.L., DAY, M.L., KOCH, R.M., AND KINDER, J.E. (1990). Effect of selection for growth traits on age and weight at puberty in bovine females. *J. Anim. Sci*. 61, pp. 1595 - 1608.

CHAPTER 4

EFFECT OF HEIFER FRAME SIZE ON THEIR SUBSEQUENT REPRODUCTIVE PERFORMANCE AND ON THE PRE-WEANING PERFORMANCE OF THEIR CALVES

4.1 ABSTRACT

The effects of heifer frame size (FS) on their subsequent performance and the pre-weaning growth of their calves were evaluated using records collected from 1989 to 1998 from the Waterburg Estates at Otjiwarongo, Namibia. Based on hip height at 18 months of age, heifers were assigned to three different frame size (FS) groups: small (< 124 cm), medium (125 to 135 cm), or large (>136 cm). Calving rate (CR), calving date (CD), calf survival rate (CSR), reproductive efficiency (SANDEX), weaning rate (WR), birth weight (BW), weaning weight (WWT), pre-weaning ADG (P-ADG), and kilograms of calf produced per cow bred (KCB) were collected from first (n = 830), second (n = 623) and third and greater-parity (n = 571) cows. Frame size of heifers significantly influenced ($p < 0.001$) their calving rate as second-parity cows. In spite of heavy culling of cows that had large FS as heifers, calving rates of second parity cows in this category were 41% less than that of second parity cows that had small and medium FS as heifers. In third or greater-parity cows, CR was greater ($p < 0.05$) for small FS than for medium and large FS. CSR was similar for heifers with a small, medium and large FS for the first, second and third and greater parity groups. Weaning rates of large FS (34.2 ± 11.27), second-parity cows were less ($p < 0.001$) than those of small (82.9 ± 5.58)

and medium (79.0 ± 4.67) FS animals. Among all parity groups, BW of calves born to large FS were significantly higher ($p < 0.05$) than those of small and medium FS cows. Calves weaned by small FS animals as first parity cows, had lower ($p < 0.05$) WWT than those weaned by medium and larger FS, but large FS females weaned heavier calves ($p < 0.05$) than small and medium FS females in the third and greater-parity group. In first parity cows, calves of large FS had greater P-ADG ($p < 0.05$) than those from small FS, but in second parity cows the calves from medium FS ($p < 0.05$) out performed those of small and large FS, while calves from third and greater parity cows of medium and larger FS had greater ($p < 0.05$) P-ADG than cows with a small FS. Male calves were heavier ($p < 0.05$) at birth, at weaning and grew faster (P-ADG) than their female counterparts. KCB was similar among small and medium FS cows, but both tended to be greater ($p < 0.05$) than KCB of large FS cows and as second parity cows the small and medium FS cows had an even greater ($p < 0.001$) advantage over the large FS animals. Small and medium FS females calved earlier, and had greater calving rates and weaning rates, as well as greater kilogram of calf produced per cow exposed than the large FS females. The performance (fertility and the growth performance of their calves to weaning) traits of the large FS were generally similar to those of smaller cows in the third and greater parity. Due to the later calving dates the reproductive efficiency (SANDEX) of large FS at first, second, third and greater parity were lower ($p < 0.001$) compared to the small and medium FS. Therefore, selecting cattle for the hot and dry climatic regions of Southern Africa, under extensive management conditions and with limited supplementary feeding, the recommended cow frame size should be a medium frame. These animals have similar levels of fertility compared to small framed cows, but with similar or even better growth performances than large framed cows.

4.2 INTRODUCTION

In the late seventies and early eighties, there was a general trend in cattle farming to select large framed animals. The preference for increased frame size in cattle may have been justified, due to the favourable correlation that exists between frame size and growth rate in beef cattle (Olson 1994, Du Plessis *et al.,* 2005). Large frame sizes favour high input systems of beef cattle production. However, beef cattle production in Southern Africa is predominately practised extensively in areas with limited cropping potential. Environmental factors such as low and unpredictable rainfall, low soil fertility and high ambient temperatures not only limit crop production but also place limits on pasture production. Reduced levels of nutrient production from the natural pastures regularly limit cattle performance under extensive conditions. Furthermore, Long *et al.* (1975), Jenkins and Ferrell (2003), Llewellyn (2003) and Du Plessis *et al.,* (2005) reported that genetic differences among herds and cattle breeds for mature size affect efficiency of cattle, due to differences in nutrient requirements for growth and maintenance of heifers and of cows. The requirements for lactation and the finishing of calves also follow this principle. Although the general shape of the growth curve is not different, regardless of frame size, cattle of similar age or weight will not be at similar points on the growth curve, if they differ in frame size. Anderson (1990), stated that independent of breed effects, increased frame size results in increased rate of growth, increased time required to reach a specific carcase grade, decreased fat thickness and marbling at equal weight, and increased weight at equal fat thickness. Since large framed cattle are actually less mature than small framed cattle at equal weight or age, their gains during the growth period are more efficient. This is because at that age the large framed cattle are gaining more muscle, which contains more water, and less fat. The latter obviously contains a great deal of energy. However, when fed to equal carcass composition, large and small framed cattle are usually similar in efficiency. The effect of cow frame size on various measures of efficiency have been experimentally evaluated by Carpenter *et al.* (1972a,b) Klosterman *et al.* (1968b), Kress *et al.* (1969), Brown *et al.* (1972a,b), Long *et al.* (1975), Morris and Wilton (1976), Morris and Wilton (1977), and Buttram and Williams (1989). These authors studied the effect of frame size in crossbred populations, which makes it difficult to determine whether the differences in performance of the cattle were attributable to differences in frame size or breed composition (Olson, 1993). Furthermore, the results presented to date are mostly generated under intensive feedlot conditions. Therefore, under extensive management conditions with limited inputs, the effect of frame size on female fertility traits and breeding efficiency may be negative. Vargus *et al.* (1999) attempted to explain the influence of frame size on production traits in Brahman cattle in the hot and humid conditions of Florida, while Du Plessis *et al.* (2005) aimed at quantifying herd efficiency between breeds based on the average mature weight of the different breeds. It was assumed that variation within breeds evaluated would be similar and were not taken into account fully. Information on herd efficiency within a breed, differing in frame size is limited under extensive management conditions. The aim of this research was to study the effect of frame size on the reproductive and pre-weaning growth performance of pure bred Santa Gertrudis cattle under the arid sub-tropical (hot and dry) conditions of Southern Africa.

4.3 MATERIAL AND METHODS

The data were collected from first parity (n = 830), second parity (n = 623) and third or greater parity (n = 571) Santa Gertrudis females born between 1988 and 1998 on the Waterburg Estates at Otjiwarongo, Namibia and collated with registration records maintained by the Santa Gertrudis Cattle Breeders Society in Bloemfontein, South Africa. The geographical coordinates of the Waterburg Estates are 17° east, 20.5° south and 1 500 m above sea level. The ranch comprises an area of 55 000 ha in size, of which 42 000 ha was used for commercial cattle ranching. The herd was kept on extensive natural pasture from which the heifers and calves had to acquire their nutritional needs supplemented only by a salt-phosphate lick. The natural pasture can be classified as "thorn bush savannah". The vegetation in the area includes woody species such as *Acacia tortilis, Commiphora pyracanthoides, Boscia albitrunca* and grass species, *Eragrostis rigidior, Panicum maximum* and *Digitaria eriantha*. A short duration grazing (less than 3 weeks) and long rest (5 – 8 month) rotational grazing system was practiced.

Average annual rainfall for the specific area since 1872 - 1979 was 485 mm, but from 1979 - 1998 the average was only 403 mm (drought). The frequency of rainfall is denoted by approximately 45 days of rain per annum mostly falling in summer, with a 35% average deviation from the annual rainfall average. Rainfall has a seasonal distribution with 80 - 90% of the rainfall occurring between October to March and with evaporation potential in the region of 2600 to 2800 mm per year.

Average year-round temperature is approximately 20°C, with average maximum temperatures of 32°C for the hottest months and average minimum temperatures of 3°C for the coldest months. The area experiences approximately 30% wind-free days, while the average wind speed varies between 3 to 6 meters per second. The soils are predominantly sand and loam, with scattered areas comprising acid granite.

In order to determine the effect of frame size on the reproductive and pre-weaning performance of the cattle in this herd, the heifers were assigned to small (< 124.0 cm), medium (125.0 to 135.0 cm), and large (> 136 cm) FS groups based on their 18-month hip height measurements. The mean hip height for the group of heifers selected for this trial was 128.3 cm. Similar guidelines used in studies conducted by Buttram and Willham (1989) and Vargas *et al.* (1999) were applied to allocate heifers to the various groups. According to the results presented by, Buttram and Willham (1989), Olson (1994) and Vargas *et al.* (1999) hip height of heifers taken at approximately two years of age is significantly correlated with mature size. Therefore, once allocated to a frame size group at 18 months of age (based on hip height measurements) they were not re-allocated another frame size group for later parities. Females with physical defects (e.g. Skew mouth, over or under shot jaw, devils grip, udder, feet, and leg problems) or reproductive disorders (e.g. not pregnant) were eliminated from the study.

All sires used were purebreds obtained from other purebred herds or bred from own herds. However, own-bred bulls comprised the majority of the bulls used in the breeding program. Bulls were not selected on size or specifically allocated to a cow frame size group based on the size of a sire, but rather applied to various cow groups according to a fixed breeding strategy of the herd and to avoid inbreeding. The sires used for breeding purposes were tested for fertility and sheath washed for vibriosis *(Compylobacter foetus)* and trichomoniases *(Trichomonas foetus)* before the onset of the breeding season. Three weeks before the breeding season commenced semen were collected by means of electro-ejaculation and the breeding soundness examination endorsed by the society of animal Theriogenology (Ball *et al.,* 1983) served as the guidelines for the evaluation of spermatozoa.

A 90-day breeding season for the heifers and a 60-day breeding season for the cows were used in the study. Heifers were first bred at approximately 18 to 24 months of age. Calves were born from October to early December. Calves remained with their dams on natural pastures for the small, medium and large FS groups until weaning early in June. All calves were weaned on the same day and grouped according to sex.

Pregnancy diagnosis of the cows was done when the calves were weaned. Calving status was determined from calving records and coded as a categorical trait (1 = calved, 0 = did not calve).

Reproductive traits recorded for the dams included calving rate (CR), calving date (CD), calf survival rate (CSR), weaning rate (WR) and cow reproductive efficiency (SANDEX). The production traits measured on their calves were birth weight (BW), weaning weight (WWT), pre-weaning average daily gain (P-ADG) and production efficiency per cow (KCB). Calving rate (CR) was calculated as the number of cows that calved subsequent to the breeding season as a percentage of exposed during the breeding season. Calf survival rate (CSR) was the percentage of calves born alive and that survived to weaning (1 = survived, 0 = died before weaning). The calving date (CD) was obtained from the records supplied by the South African Santa Gertrudis Cattle Breeders Society and reported as the average days needed for a FS group to complete a calving cycle where day 0 is considered as the first day of the calving season. Weaning rate is calculated by the number of cows bred divided by the number of cows that weaned a calf (1 = weaned a calf. 0 = did not wean a calf). Production efficiency (KCB) per group was expressed in kilograms of calf weaned per FS group divided by the number of animals bred in each group, while the reproductive efficiency (SANDEX) of each FS group was calculated by means of the following formula:

$$200 - \{(X / Z) \times 100\}.$$

Where X = Age of cow at last calving in days. Z = 913 + (365 x [number of calvings] – 1).

The data on reproductive traits for heifers of different frame size and the productive traits of the claves were analysed separately for the first-parity, second parity, and third and greater-parity cows. Only cows with complete production and reproduction records were included in the analysis. Using a least squares model that included the fixed effects of year of birth, heifer frame size, and their interaction effects, resulted in no significant interactions occurring when the data for hip height of heifers at 18 months of age were analysed. These factors were subsequently deleted from the original model. The data were then re-analysed using the reduced model. Year of birth, heifer frame size were the main effects included in the final model used to evaluate the response variants associated with reproductive traits of the dams and production traits of their calves in first, second, and third and greater parity cows and further included a random error constituent in the model. Analyses for the following reproductive traits of CD, CSR and production traits of BW and WWT included the additional effect of the sex of the calf (SEX). The sex of the calf did not significantly influence CD, CSR, BW and WWT in the small, medium and large frame groups. Thus, sex of the calf was not incorporated in the final model for analysis. All possible two-factor interactions were included in the preliminary analyses. None of the two-factor interactions influenced any of the variables significantly (P>0.21), and were subsequently not incorporated in the original model. Data were analysed by least squares ANOVA using the GLM procedure of SAS (1995) and are presented as least squares means ± SEM.

4.4 RESULTS AND DISCUSSION

The effect of heifer frame size on calving rate was a highly significant ($p < 0.001$) source of variation in second parity cows and a significant ($p < 0.05$) source of variation in the third or greater parity cow groups (Table 4.1). Frame size did not affect first parity cow groups with the small, medium and large frame size having calving percentages in excess of 90%. Similar results with reference to calving rates were reported by Taylor and Swanepoel (1999) in first parity Santa Gertrudis cows. Frame size was not expected to influence CR in first parity cows because the majority of heifers were exposed to breeding at between 18 and 24 months of age, when most of these heifers should have reached puberty. Morris (1980) and Vargas *et al.* (1999) reported similar results in first parity Brahman cattle of different frame sizes. Du Plessis *et al.* (2005) recorded higher heifer pregnancy and calving rates in small framed indigenous cattle compared to a medium sized locally developed breed and the large framed continental breed under arid sub-tropical conditions. Contrary to these results, Steenkamp and Van der Horst, (1974) noted higher reproduction rates in large and medium framed Afrikaner cows compared to small framed cows of this breed on natural pasture. Buttram and Willham (1989) suggested that the interaction between frame size and the nutritional environment indicate that if heifers are to be raised under less than optimal conditions, then smaller cattle, maturing earlier and at lighter weights, are likely to be more desirable. Calving rate of small and medium frame size heifers surpassed ($p < 0.001$) that of the large frame second parity cows by more than 28% (Table 4.1). In a study conducted by Vargas *et al.* (1999) in Brahman cattle the lower calving rate in large frame second parity cows was ascribed to the low calf survival rates of second parity large frame size females. Results from this study indicate that substantially more cows were eliminated due to not producing a calf in the large and medium frame sized second parity groups than that reported by Olson (1994) and Vargas *et al.* (1999) in Brahman cattle. The advantage of higher calving rates in small frame size second parity compared to the large and medium frame size was due to higher pregnancy rates in the small frame size, and not to low calf survival rates or increased incidences of dystocia. Rather, the reduced pregnancy rate observed in the large frame size is probably due to increased body maintenance requirements, although these were not measured and the stresses of lactation experienced under hot and dry extensive pasture conditions being highlighted in the second parity large frame animals. Buttram and Willham (1989) and Olson (1994) in beef cows and Hansen *et al.* (1999) in dairy cows observed that cows with a larger mature size tended to have lower conception rates while lactating with their first calves. The advantage of higher calving rates ($p < 0.05$) for small ($91.5 \pm 3.81\%$) compared to the medium ($84.5 \pm 4.00\%$) and large size ($82.2 \pm 5.30\%$) was also noticeable in the subsequent third and greater parity cow group in the present study. Calving rate improved from $45.4 \pm 6.\ 26\%$ to $82.2 \pm 5.30\%$ in third and greater parity for large frame size cows, resulting in an increase of 36.8% in calving rate. What should be born in mind is that more LF heifers were eliminated as cows due to not conceiving. Thus, the group eventually consisted of a select population of cows that are possibly more fertile than those that have been culled. It appears that frame size does not affect calving rate to the same extent once the cows have reached the third and greater parity group. From the results obtained, it is evident that these cows were able to calve regularly in spite of the apparent negative association between frame size and a stressful environment once they have reached maturity. It is generally accepted that small body size is an adaptive attribute in stressful environments. Therefore, smaller framed animals have higher reproductive rates than large framed animals.

Calf survival rate was not affected by heifer frame size in first, second, third and greater parity cow groups (Table 4.1). This is in contrast with results reported by Fitzhugh *et al.* (1973), Cartwright (1974), Vargas *et al.* (1999) and Chase *et al.* (2005) who found that larger cows have lower calf survival rates than smaller framed cows.

Perhaps it was surprising to note that weaning rate was not affected by frame size in first parity cows as represented by the results in Table 4.1. The large cow frame size first parity cows had only a 4% lower weaning rate than small and medium frame size first parity cows. Vargas *et al.* (1999) reported a highly significant difference ($p < 0.001$) in WR, in first parity cows where the small and medium frame size cows out-performed the large frame size cows by 30%. Tawonezvi *et al.* (1988) and Du Plessis *et al.* (2005), noted significant differences between various breed types and frame sized cows and Chase *et al.* (2005) also found that weaning rate was considerably lower for large frame size first- and second-parity cows compared to small and medium frame cows. They attribute the difference in WR to the increased incidences of dystocia and calf mortalities experienced by the large frame cows.

Table 4.1 : Least squares means (±SEM) for calving rate (CR), calf survival rate (CSR), weaning rate (WR) and overall productivity (Sandex) by frame size for parity groups of Santa Gretrudis cattle.

	First-parity		Second-parity		Third and greater-parity	
Frame size	**n**	**%**	**n**	**%**	**n**	**%**
CR (%)						
Small	134	94.0 ± 2.80[a]	115	87.8 ± 6.04[c]	105	91.5 ± 3.81[a]
Medium	498	90.4 ± 4.25[a]	422	84.3 ± 4.35[c]	388	84.5 ± 4.00[b]
Large	198	92.0 ± 3.01[a]	86	45.4 ± 6.26[d]	78	82.2 ± 5.30[b]
CSR (%)						
Small	126	92.8 ± 6.10[a]	91	93.2 ± 4.48[a]	92	93.1 ± 4.56[a]
Medium	456	93.6 ± 4.02[a]	343	91.3 ± 5.12[a]	331	91.8 ± 9.33[a]
Large	166	86.2 ± 8.25[a]	55	87.2 ± 9.87[a]	68	93.0 ± 5.66[a]
WR (%)						
Small	134	84.8 ± 4.33[a]	115	82.9 ± 5.58[c]	105	86.6 ± 5.42[a]
Medium	498	84.0 ± 3.87[a]	422	79.0 ± 4.67[c]	388	89.2 ± 4.20[a]
Large	198	80.6 ± 15.16[a]	86	34.2 ±11.27[d]	78	80.4 ± 5.82[a]
Sandex						
Small	134	94.0 ± 2.80[a]	115	92.0 ± 2.33[c]	105	90.8 ± 3.25[c]
Medium	498	90.4 ± 4.25[a]	422	90.6 ± 2.87[c]	388	87.2 ± 2.82[c]
Large	198	91.5 ± 3.01[a]	86	78.3 ± 5.25[d]	78	73.4 ± 4.52[d]

[a, b] Means with a different superscript letter within a column and trait differ ($p < 0.05$).

[c, d,] Means with a different superscript letter within a column and trait differ ($p < 0.001$).

A possible reason for this could be that cow frame size groups were not matched to similar sized sires in this study as was the case in the study conducted by Vargas *et al.* (1999). Frame size significantly ($p < 0.001$) affected WR of large frame second parity cows. Small and medium frame second parity had weaning rates of 82.9 ± 5.58% and 79.0 ± 4.67% respectively compared to 34.2 ± 11.27% in the large frame size second parity cows. The advantage in WR of the small and medium frame size over the large frame cows is predominantly the result of increased conception rates of the smaller cows. Similar results were reported by Du Plessis *et al.* (2005) in various breeds differing in maturity age, and by Olson (1994) and Vargas *et al.* (1999) in Angus and Brahman large frame cows, respectively. Frame size did not affect WR in third and greater parity cows.

Bourdon and Brinks (1983) and MacGregor (1997) reported that calving date is an important reproductive trait in beef cattle. Cows that calve late in the calving season often do not return to oestrus before the end of the subsequent breeding season (Vargas *et al.,* 1999). From the results presented in Table 4.2, frame size did not affect day of calving (calving date) in first parity cows, which calved at similar dates in the calving season. A similar trend was found in the mature cows, with no significant difference in CD for the small, medium and large frame size third and greater parity groups.

Table 4.2 : Least squares means (±SEM) for calving day (CD) by frame size for parity groups of Santa Gertrudis cattle.

	First-parity		Second-parity		Third and greater-parity	
Frame size	**n**	**days**	**n**	**Days**	**n**	**days**
Small	126	28.2 ± 3.55[a]	91	38.8 ± 6.12[a]	92	41.5 ± 4.10[a]
Medium	456	27.4 ± 3.10[a]	343	44.6 ± 5.10[a]	331	44.6 ± 4.05[a]
Large	166	33.1 ± 4.86[a]	55	66.0 ± 11.25[b]	68	52.3 ± 6.71[a]

[a, b] Means with a different superscript letter within a column differ ($p < 0.05$).

On average the large frame size cows calved only 7 days later than the small and medium frame size in the third and greater parity group. Notably, a significant effect ($p < 0.05$) of frame size was evident in the second parity with large frame size cows calving on average 25 days later in the calving season than the small and medium frame size cows at the same parity. Cows that calve early in the calving season allow themselves more chances to conceive in a compact breeding season (Evans *et al.,* 2006). Similarly calving date relative to the calving season (early, middle, or late) also can influence production efficiency. For a set weaning date earlier calving cows will wean older and generally heavier calves and use feed more efficiently than later calving cows (Marshall *et al.,* 1990). This can be expected, since Williams (1990) reported that the difference in calving dates of growing young cows is expressed more prominently when animals were under lactational stress. Lactational stress is likely to suppress cyclic ovarian activity and result in a prolonged period of postpartum anoestrus. Short *et al.* (1990) and Vargas *et al.* (1999) reported that first calf heifers had longer postpartum intervals of anoestrus and lower reproductive rates than older cows.

Sex was a significant ($p < 0.05$) source of variation for calf weights at birth and weaning and for pre-weaning average daily gain (Table 4.3). Bull calves were 8.7% heavier than their female counterparts at birth for all parity groups. This is in agreement with results observed in studies by Plasse (1978) and Eriksson *et al.* (2002). Bull calves further outperformed heifers in terms of all traits measured pre-weaning. Similar results were obtained by Lesmeister *et al.* (1973), Rege and Moyo (1993) and MacGregor (1997) under similar environmental conditions in Southern Africa. Bull calves were 7.1% heavier than heifers at weaning and grew 0.1 kg faster to weaning. The significant effect of sex reported in this study is in agreement with reports by Reynolds *et al.* (1982), Tomo *et al.* (1999), Vargas *et al.* (1999) and Ebangi (2000) who found that bull calves are heavier than heifer calves from birth to weaning. Ebangi (2000) ascribed these differences mainly to differences in their endocrinological and physiological functions, together with increased selection pressure for growth rate on bull calves compared to heifers.

Frame size significantly ($p < 0.05$) affected birth weight of calves in the small, medium and large frame size in all parity groups (Table 4.3). The large frame cows consistently produced heavier calves. Calves from cows that had large frames as heifers were on average 7.1 kg heavier at birth than calves of the small frame size in all parity groups. Swali and Wathes (2006) in Holstein-Friesian heifers, Du Plessis *et al.* (2005) in various breeds and Vargas *et al.* (1999) in Brahman cattle found a similar difference with frame size across various parity groups. These results are also in agreement with those reported by Jenkins *et al.* (1991), who found a positive within-breed phenotypic correlation ($r = 0.37$) between BW and adult hip height of the dam. Heavier birth weights are normally associated with later calvings within the calving season. This agrees with the findings on calving date for the different parity groups. Although Gore *et al.* (1994), failed to confirm a relationship between BW and maternal cow frame size, the larger cows tended to produce calves with greater BW than cows of smaller size.

Table 4.3 : Least squares means (±SEM) for calf birth weight (BW), weaning weight (WWT) and pre-weaning average daily gain (P-ADG) and production efficiency per cow group (KCB) and sex of calf (SEX) by frame size for parity groups of Santa Gertrudis cattle.

	First-parity cows		Second-parity cows		Third or greater-parity cows	
Frame size	**n**	**kg**	**n**	**Kg**	**n**	**kg**
BW (Kg)						
SEX						
Male	381	35.1 ± 0.75[a]	274	37.2 ± 0.68[a]	270	35.3 ± 0.67[a]
Female	267	32.4 ± 0.35[b]	215	33.4 ± 0.89[b]	221	32.9 ± 0.67[b]
Small	126	32.4 ± 0.68[a]	91	34.1 ± 1.05[a]	92	32.8 ± 0.66[a]
Medium	456	35.4 ± 0.61[b]	343	36.4 ± 1.25[b]	331	34.9 ± 0.91[a]
Large	166	37.6 ± 1.43[c]	55	38.6 ± 1.75[b]	68	42.6 ± 1.25[b]
WWT (Kg)						
SEX						
Male	386	238.4 ± 3.75[d]	326	234.8 ± 8.55[a]	228	237.2 ± 8.35[a]
Female	315	222.6 ± 4.10[e]	279	214.2 ± 9.65[b]	187	226.4 ± 7.64[a]
Small	213	210.4 ± 8.65[a]	180	218.9 ± 9.51[a]	114	224.0 ± 9.20[a]
Medium	322	231.2 ± 6.21[b]	387	228.8 ± 11.80[a]	266	229.2 ± 9.60[b]
Large	166	244.0 ± 9.90[c]	38	222.3 ± 13.80[a]	35	232.3 ± 8.10[b]
PADG(Kg)						
SEX						
Male	386	1.06 ± 0.13[a]	344	0.99 ± 0.12[a]	228	1.04 ± 0.16[a]
Female	315	0.910 ± 0.15[b]	279	0.89 ± 0.10[b]	187	0.98 ± 0.14[b]
Small	213	0.83 ± 0.08[a]	180	0.89 ± 0.04[a]	114	0.89 ± 0.05[a]
Medium	322	0.92 ± 0.06[b]	387	0.99 ± 0.04[b]	266	0.94 ± 0.02[b]
Large	166	0.98 ± 0.08[b]	38	0.91 ± 0.05[a]	35	0.97 ± 0.04[b]
KCB(Kg)						
Small	134	161.2 ± 13.45[a]	115	126.2± 17.90[d]	105	152.2 ± 12.26[a]
Medium	498	158.6 ± 11.31[a]	422	123.4± 18.38[d]	388	160.4 ± 14.73[a]
Large	198	136.5 ± 18.64[b]	86	63.1± 14.30[e]	78	164.8 ± 14.92[a]

[a, b, c] Means with a different superscript letter within a column and trait differ ($p < 0.05$).

[d, e,] Means with a different superscript letter within a column and trait differ ($p < 0.001$).

Frame size significantly ($p < 0.05$) affected calf weaning weight in all parity groups except for second parities (Table 4.3). In the second parity cow group, calf weaning weights were not affected by frame size. However, the large frame sized cows weaned lighter calves (222.3 ± 13.80 kg) than the medium (228.8 ± 11.80 kg) frame size, but still heavier than the small (218.9 ± 9.51 kg) frame size. Results obtained by Du Plessis *et al.* (2005) for various breed types of various frame sizes reported higher weaning weights in favour of the large frame breeds. In contrast, Vargas *et al.* (1999) reported no significant difference in calf weaning weights of different cow frame size groups in second parity Brahman cattle, although the large frame size cows tended to produce heavier calf weaning weights compared to small and medium frame size cows. The lighter weaning weights of the large frame dams in the second parity cow groups in this study was probably the result of later calving dates experienced by the large framed animals. Lishman *et al.* (1984) found that early calvers produced heavier calves at weaning in two different climatic regions irrespective of feed supplementation. Morris and Cullen (1988) and Garcia Paloma *et al.* (1992) support the results that heavier weaning weights are due to the age difference between cows calving early and those calving later in the season. The results from this study agree with those reported by MacGregor (1997) and Rege and Moyo (1993) under similar conditions concluded that earlier calving associated with higher fertility would have beneficial effects on growth performance of beef cattle.

Frame size significantly affected ($p < 0.05$) P-ADG in all parity groups (Table 4.3). The lower P-ADG in the large frame second parity group is probably the result of later calving dates which resulted in lighter weaning weights. Except for the second parity cow group the results are consistent with other growth traits evaluated in this study. Morris and Wilton (1976) found a positive phenotypic correlation between milk production and the frame size of the cow. According to Letholu (1983), Dionisio (1989) and Bothma (1993), 50 to 70% of the variation in weaning weight and ADG can be attributed to differences in the milk production of cows. Another explanation for the increased P-ADG of calves from large cows could be the inherent growth pattern of the calves from the large frame cows (Menchaca *et al.,* 1996), and the ability of the fastest gaining calves to consume enough forage to meet their higher nutritional demand for growth (Grings *et al.,* 1996).

Frame size was a significant ($p < 0.001$) source of variation in terms of production performance in the second parity cow group (Table 4.3). Ferrel (1982) found the weight of a calf weaned per cow bred to be more important than calf weaning weight Per se, because production per cow is a function of calving rate, calf survival rate and calf weaning weight. Under the extensive conditions of this study, in the second parity the heifers classified as small (126.2 ± 17.90 kg) and medium frame (123.4 ± 18.38 kg) performed better for this index ($p < 0.001$) than large (63.1 ± 14.30 kg) frame females (Table 4.3).

The impact of cow frame size on the production performance was greater at younger ages while they were still growing than in mature cows in this study. As the large frame size Santa Gertrudis cows matured, they seemed to have overcome the negative effects imposed by size, which was observed at younger ages. Calf survival rates were similar to those of the small frame in all parity groups, but pregnancy rates improved and were comparable to those of smaller frame size in the third and greater parity group. It appears that small framed dams were able to meet their nutrient requirements more effectively during lactation compared to the large cows, in the second parity resulting in higher pregnancy rates.

Frame size was not expected to influence reproduction efficiency of first parity Santa Gertrudis cows in this study. Reproductive efficiency of cows is measured by means of the SANDEX formula, which is a function of the age of the animal in days at calving and the number of calves produced. Heifers in this study were not mated at puberty, but at approximately 20 months of age when the majority had already reached puberty. This is evident from the results of the calving dates reported in first parity cows (Table 4.2). However, in second and third and greater parity cow groups, the small and medium frame size were 13% more efficient ($p < 0.05$) as second parity cows and 15.6% more efficient ($p < 0.05$) as third and greater parity cows, compared to the large frame cows. Carpenter *et al.* (1971) and Du Plessis *et al.* (2005) found that cows with heavier weights at maturity produced heavier calves at birth and such cows had lower reproductive performances. Such animals also tended to have longer calving intervals and produced fewer calves per breeding season.

4.5 CONCLUSION

The results from this study clearly indicate the significant effect of heifer frame size on the subsequent reproductive performance and the pre-weaning growth of the calves, under extensive conditions in the hot and dry climate of Southern Africa. Small and medium frame sized females showed similar reproductive results and significantly out performed large framed animals. Small-framed heifers were generally more fertile compared to medium and large frame heifers as cows in subsequent parities. The results from this study also show that significantly more large framed cows were eliminated from this study due to their inability to produce a calf. The lower conception rates of large frame cows were probably due to higher nutrient requirements for growth and lactation, and not an increased incidence of dystocia as reported by other authors. The reproductive results obtained in this study suggest that a reduction in frame size should be considered when selecting productive animals under extensive hot and dry climatic conditions in Southern Africa. However, it is also evident that a small number of the heifers selected as large frame were able to calve regularly and cope with the interaction between frame size and the nutritional environment a lot better once they have reached maturity.

The heifers selected as medium frame had better production results than the small framed heifers, because their calves grew faster and they weaned heavier calves.

Reproduction rate and calf survival rate are the most important factors that determine the efficiency of the herd. Therefore, management strategies should be adapted to maximize reproduction and calf survival rate, and thus the production efficiency of the herd. Large framed animals produce calves that grow faster under feedlot conditions. However, selecting cattle for the hot and dry climatic regions of Southern Africa, under extensive management conditions and with limited supplementary feeding, the recommended cow frame size should be a medium frame. These animals have similar levels of fertility compared to small framed cows, but with similar or even better growth performances than large framed cows.

4.6 REFERENCES

ANDERSON, P. (1990). Matching cattle type and feedlot performance. Issue 8. www.extension.umn.edu/beef/components/publications/bcmu08.pdf

BALL, L., OTT, R.S., MORTIMER, R.G., AND SIMMONS, J.C. (1983). Manual for breeding soundness of bulls. Society for Theriogenology, Hastings, N.E.

BELLOWS, R.A., AND SHORT, R.E. (1994). Reproductive losses in the beef industry. In: M. J. Field and R. S. Sand (Ed.) Factors Affecting Calf Crop. CRC Press, Boca Raton, FL: ISBN 0-8493-8754-X, pp. 109 - 133.

BOTHMA, A.J. (1993). Comparison of the Government Nguni studs in Venda. M.Sc thesis, University of Pretoria.

BOURDON, R.M., AND BRINKS, J.S. (1983). Calving date versus calving interval as a reproductive measure in beef cattle. *J. Anim. Sci.* 57 (6), pp. 1412 - 1421.

BROWN, J.E., BROWN, C.J., AND BUTTS, W.T. (1972a). A discussion of the genetic aspects of weight, mature weight and rate of maturing in Hereford and Angus cattle. *J. Anim. Sci*. 34, pp. 525 - 537.

BROWN, J.E., BROWN, C.J. AND BUTTS, W.T. (1972b). Relationships among weights, gain and earliness of maturing in Hereford and Angus females. *J. Anim. Sci.* 35, pp. 507 - 517.

BUTTRAM, S.T., AND WILLHAM, R.L. (1989). Size and management effects on reproduction in first-, second- and third-parity beef cows. *J. Anim. Sci.* 67, pp. 2191 - 2196.

CARPENTER, J.A., FITZHUGH, H.A., BROWN, J.E., AND CROUCH, E.K. (1971). Relationship among growth curve parameters and measures of productivity in beef cows. *Beef cattle research in Texas, 1971*, Tex. Agric. Exp. Sta., Tex. A. and M. Univ., College Station, Texas. pp. 41 - 43.

CARPENTER, J.A., FITZHUGH, H.A., CARTWRIGHT, T.C., AND THOMAS, R.C. (1972a). Relationship between performance and mature size of beef cows. *Beef Cattle research in Texas, 1972,* Tex. Agric. Exp. Sta., Tex. A. and M. Univ., College Station, Texas. pp. 23 – 27.

CARPENTER, J.A., FITZHUGH, H.A., CARTWRIGHT, T.C., AND THOMAS, R.C. (1972b). Relationship between performance and mature size of beef cows. *Beef Cattle research in Texas, 1972*, Tex. Agric. Exp. Sta., Tex. A. and M. Univ., College Station, Texas. pp. 27 - 30.

CARTWRIGHT, T.C. (1974). Efficiency of production and cow size. *Report of proc. of the beef improvement federation*, Denver, Colorado April 1974. pp. 26 - 31.

CHASE, C.C., RILEY, D.G., OLSON, T.A., AND COLEMAN, S.W. (2005). Evaluation of Brahman and tropically adapted Bos taurus breeds in the humid subtropics. American Society of Animal Science Southern Section Meeting, LittleRock,Arkansas.27.http://www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=177032

DIONISIO, A.C. (1989). Evaluation of growth and reproductive performance of Nguni and Afrikaner cattle in Chobela Research Station – Mozambique. M.Sc thesis, Agricultural University of Norway.

DU PLESSIS, I., HOFFMAN, L.C., AND CALITZ, F. J (2005). Influence of reproduction traits and pre-weaning growth rate on herd efficiency of different beef breed types in an arid sub-tropical environment. *S. Afr. J. Anim. Sci.* 35, pp. 89 - 98.

EBANGI, A.L. (2000). Genetic improvement of beef cattle in a tropical environment with special reference to the Gudali and Wakwa breed in Cameroon. Ph.D thesis, University Orange Free State.

ERIKSSON, S., NÄSHOLM, A., JOHANSSON, K., AND PHILIPSSON, J. (2002). Sex-specific genetic parameters for field recorded birth weight of beef calves. *Proceedings of the 7th World Congress on Genetics Applied to Livestock Production.* CDROM communication no 02-25.

EVANS, R.D., WALLACE, M., GARRICK, D.J., DILLON, P., BERRY, D.P., AND OLORI, V. (2006). Effects of calving age, breed fraction and month of calving on calving interval and survival across parities in Irish spring-calving dairy cows. *Livestock Science*. 100 (2-3), pp. 216 – 230.

FERRELL, C.L. (1982). Effects of post weaning rate of gain on onset of puberty and productive performance of heifers of different breeds. *J. Anim. Sci.* 55, pp.1272 - 1283.

FITZHUGH, H.A., MIQUEL, M.C., AND THOMAS, R.C. (1973). Canonial analysis of beef cow weight and productivity. *J. Anim. Sci.* 37, pp 233 - 245.

GARCIA PALOMA, J.A., ALBERIO, R., MIQUEL, M.C., GRONDONA, M.O., CARILLO, J., AND SCHIERSMANN, G. (1992). Effect of calving date on lifetime productivity of cows in a winter calving Aberdeen Angus herd. *Anim. Prod.* 55, pp. 177 - 189.

GORE, M.T., YOUNG, R.B., CLAEYS, M.C., CHROMIAK, J.A., RAHE, C.H., MARPLE, D.N., HOUGH, J.D., GRIFFIN, J.L., AND MULVANEY, D.R. (1994). Growth and development of bovine fetuses and neonates representing three genotypes. *J. Anim. Sci.* 72, pp. 2307 - 2318.

GRINGS, E.E., SHORT, R.E., MCNEIL, M.D., HAFERKAMP, M.R., AND ADAMS, D.C. (1996). Efficiency of production in cattle of two growth potentials on Northern Great Plains rangelands during spring summer grazing. *J. Anim. Sci.* 74, pp. 2317 - 2326.

HANSEN, L.B., COLE, J.B., MARX, G.D., AND SEYKORA, A.J. (1999). Productive life and reasons for disposal of Holstein cows selected for large versus small body size. *Journal of Dairy Science.* 82 (4), pp. 795 - 801.

JENKINS, T.G., AND FERRELL, C. (2003). Beef cow efficiency: Characterization and efficient use of resources in beef production systems. http://www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=154403

JENKINS, T.G., KAPS, M., CUNDIFF, L.V., AND FERRELL, G.L. (1991). Evaluation of between- and within-breed variation in measures of weight-age relationships. *J. Anim. Sci.* 69, pp. 3118 - 3128.

KLOSTERMAN, E.W., SANSFORD, L.G., AND PARKER, C.F. (1968). Effect of cow size and condition and ration protein content upon maintenance requirements of mature beef cows. *J. Anim. Sci.* 27, pp. 242 - 246.

KRESS, D.D., HAUSER, E.R., AND CHAPMAN, A.B. (1969). Efficiency of production and cow size in beef cattle. *J. Anim. Sci.* 29, pp. 373 - 383.

LETHOLU, L.L. (1983). Review of Tswana breed cattle. *Proceedings of the expert committee on animal genetic resources in Africa*, Bulawayo, Zimbabwe.

LESMEISTER, J.L., BURFENING, P.J., AND BLACKWELL, R.L. (1973). Date of first calving in beef cows and subsequent calf production. *J. Anim. Sci.* 36 (1), pp. 24 – 36.

LISHMAN, A.W., LYLE, A.D., SMITH, V.W., AND BOTHA, W.A. (1984). Conception rate of beef cows and growth of suckling calves as influenced by date of calving and supplementary feeding. *S. Afr. J. Anim. Sci.* 14, pp.10 - 17.

LLEWELLYN, L.M (2003). Range cow nutrient requirements during production periods. Annual report Grassland section. North Dakota State University.http://0www.ag.ndsu.nodak.edu.innopac.up.ac.za/dickinso/research/2002/range02b.htm

LONG, C.R., CARTWRIGHT, T.C., AND FITZHUGH, H.A. (1975). Systems analysis of sources of genetic and environmental variation in efficiency of beef production: cow size and herd management. *J. Amin. Sci.* 40 (3), pp. 409 - 421.

LUO, M.F., BOETTCHER, P.J., SCHAEFFER, L.R., AND DEKKERS J.C.M. (2002). Estimation of genetic parameters of calving ease in first and second parities of Canadian Holsteins using Bayesian methods. *Livestock. Prod. Sci.* 74, pp.175 -184.

MACGREGOR, R.G. (1997). Evaluation of methods of measuring reproduction and production in beef cows. Ph.D thesis, University of Pretoria.

MARSHALL, D.M., MINQIANG, W., AND FREKING, B.A. (1990). Relative calving date of first-calf heifers as related to production efficiency and subsequent reproductive performance. *J. Anim. Sci.* 68, pp.1812 - 1817.

MENCHACA, M.A., CHASE, C.C. JR., OLSON, T.A., AND HAMMOND, A.C. (1996). Evaluation of growth curves of Brahman cattle of various frame sizes. *J. Anim. Sci.* 74, pp. 2140 - 2151.

MONTEIRO, L.S. (1969). The relative size of calf and dam and the frequency of calving difficulties. *Anim. Prod.* 11, pp. 293 - 306.

MORRIS, C.A., AND CULLEN, N.G. (1988). Oestrus and reproductive performance of early and late calving beef cows. *N.Z.J. of Agric. Res.* 31, pp. 395 - 411.

MORRIS, C.A., AND WILTON, J.W. (1977). The influence of body size on the economic efficiency of cows: *A Review. Anim. Breed. Abst.* 45, pp. 139 - 153.

MORRIS, C.A. (1980). A review of relationships between aspects of reproduction in beef heifers and their lifetime production. 2. Associations with relative calving date and with dystocia. *Anim. Breed.* Abstr. 40(11), pp. 753 - 767.

MORRIS, C.A., AND WILTON, J.W. (1976). Influence of body size on the biological efficiency of cows: A review. *Can. J. Anim. Sci.* 56, pp. 613 - 647.

OLSON, T.A. (1993). Reproductive efficiency of cows of different sizes. 42nd Annual Florida Beef Cattle Short Course Proceedings; Gainesville, FL. University of Florida (Gainesville): Animal Science Department. p 103: http://0www.animal.ufl.edu.innopac.up.ac.za/extension/beef/documents/SHORT93/OLSON.HTM#sub1

OLSON, T.A. (1994). The effect of cow size on reproduction. In: Factors affecting calf crop. Edited by Fields, M.J. and Sand, R.S. Butterworths. ISBN 0-8493-8754-X. Chapter 17, pp. 243 – 261.

PLASSE, D. (1978). Aspectos de crecimiento del *Bos indicus* en el Tropico Americano. *World Rev. Anim. Prod.* 14(4), pp. 29 - 48.

REGE, J.E.O., AND MOYO, S. (1993). Effect of birth date on growth performance of calves of seasonally bred range cattle. *J. Anim. Breed. Genet.* 110, pp. 209 - 224.

REYNOLDS, W.L., DE ROUEN, T.M., AND KOONE, L.K. (1982). Pre-weaning growth rate and weaning traits of Angus, Zebus and Zebu-cross cattle. *J. Anim. Sci.* 54, pp. 241 – 247.

REYNOLDS, W.L., DEROUEN, T.M., MOIN, S., AND KOONCE, K.L. (1980). Factors influencing gestation length, birth weight and calf survival of Angus, Zebu and Zebu cross beef cattle. *J. Anim. Sci*. 51, pp. 860 - 867.

SAS. (1995). SAS/STAT* User's Guide (Release 6.03). SAS Inst., Inc., Cary, NC.

SHORT, R.E., BELLOWS, R.A., STAIGMILLER, R.B., BERARDINELLI, J.G., AND CUSTER, E.E. (1990). Physiological mechanisms controlling anestrus and infertility in postpartum beef cattle. *J. Anim. Sci.* 68, pp. 799 - 816.

STEENKAMP, J.D.J., AND VAN DER HORST, C. (1974). The relationship between size and efficiency in the beef cow. *S. Afri. J. Anim. Sci.* 4, pp. 81 - 91.

STEINBOCK, L.A., NÄSHOLM, B., BERGLUND, K., JOHANSSON, C., AND PHILIPSSON, J. (2003). Genetic effects on stillbirth and calving difficulty in Swedish Holsteins at first and second calving. *J. Dairy Sci.* 86, pp. 2228 – 2235.

SWALI, A., AND WATHES, D.C. (2006). Influence of the dam and sire on size at birth and subsequent growth, milk production and fertility in dairy heifers. *Theriogenology.* 66, pp. 1173 – 1184.

TAYLOR, G.J., AND SWANEPOEL, F.J.C. (1999). Selecting for fertility in tropical and sub-tropical environments. Beef Cattle Production Information Workshop. Univ. of the Orange Free State, Dept. Animal Science. Hooglandpers. ISBN 0-86886-547-8.

TAWONEZVI, H.P.R., WARD, H.K., TRAIL, J.C.M., AND LIGHT, D. (1988). Evaluation of beef breeds for rangeland weaner production in Zimbabwe. *Anim. Prod.* 47, pp. 361 - 367.

TOMO, P.S.M., TAWAH, C.L., SWANEPOEL, F.J.C., AND HOOGENBOEZEM, J.M. (1999). Production characteristics of Angoni cattle in Mozambique: 1. Non-genetic influences on pre- and post-weaning growth. *Tropic. Sci.* 39, pp.187 – 193.

VARGAS, C.A., OLSON, T.A., CHASE, C.C. JR., HAMMOND, A.C., AND ELZO, M.A. (1999). Influence of frame size and body condition score on performance of Brahman cattle, *J. Anim. Sci.* 77, pp. 3140 - 3149.

WELLER, J. I., MISZTAL, I., AND GIANOLA, D. (1988). Genetic analysis of dystocia and calf mortality in Israeli-Holsteins by threshold and linear models. *J. Dairy. Sci*. 71, pp. 2491 – 2501.

WILLIAMS, G.L. (1990). Suckling as a regulator of postpartum rebreeding in cattle: A review. *J. Anim. Sci*. 68, pp. 831 - 852.