FACTORS INFLUENCING POSTPARTUM REPRODUCTIVE PERFORMANCE OF SANTA GERTRUDIS COWS

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SANTA GERTRUDIS COWS

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PREFACE

The purpose of this study was to evaluate the postpartum reproductive performance of Santa Gertrudis cows under ranch conditions. I would like to extend my thanks to the Santa Gertrudis Breeders International and Dr. Bill Warren of Kingsville, Texas for making this study possible. In addition, I would like to thank Mr. R.P. Marshall, King Ranch, Kingsville, Texas, and Mr. Dennis Alsup, L & L Farms, Decatur, Arkansas, for providing the cows for this study and for their assistance and cooperation in the data collection.

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INTRODUCTION

Each year approximately 25-30% of the beef cows in the United States do not wean a calf, primarily, a result of cows not conceiving during the breeding season. The major factor preventing beef cows from becoming pregnant is postpartum anestrous (Bellows et al., 1979b; Niswender and Wiltbank, 1984). Ovarian inactivity and anestrous are characteristic of the postpartum period and nutritional intake both before and after calving influences the onset of estrus (Dunn et al., 1969; Wettemann et al., 1982). Body weight and condition are influenced by nutritional intake, and changes in these parameters have been demonstrated to be useful indicators of rebreeding performance (Dunn and Kaltenbach, 1980). Production efficiency could be enhanced by the development of management factors which would shorten the postpartum anestrous interval and allow cows to conceive earlier in the breeding period. Cows would calve earlier and wean heavier calves the next year.

Reproductive and nutritional processes differ between breed types of beef cattle (Cartwright, 1980; Frisch and Vercoe, 1978; Randel, 1978; Turner, 1980). Physiological differences have allowed the Brahman-type breeds to adapt to the harsh, droughty, nutritional limited regions of the world.

Differences in the relationships between body weight, body condition and reproductive performance may exist between breed types and should be evaluated in the increasingly popular Brahman-type beef cattle. Therefore, the objectives of this study are: 1) to determine the relationships between body weight and body condition changes during gestation and following calving and 2) to evaluate the influence of body weight and body condition changes and the short term feeding of additional energy after calving on subsequent reproductive performance of Santa Gertrudis cows and calves under ranch conditions.

CHAPTER II

REVIEW OF LITERATURE

History of Santa Gertrudis Cattle

Cattlemen have long recognized the value of crossbreeding, which results in hybrid vigor for growth rate, reproductive, and maternal traits. In the southern regions of the United States, the Brahman-cross has become an increasingly popular beef animal. Turner (1980) indicated that Brahman-cross cattle adapt to environments similar to the way purebred Brahmans adapt and perform better than the Bos taurus parent. The success of such crossbreeding led to the establishment of several new breeds based on percentage Brahman blood. The Santa Gertrudis was one such breed, established in the mid 1900s out of necessity for a beef animal which would more closely match the environmental conditions of south Texas and optimize production.

Observations of Brahman x British cattle in the Gulf Coast region of the United States demonstrated their superiority for production traits compared to the purebred British breeds of cattle. In 1910 a Shorthorn x Brahman bull was donated to the King Ranch and mated to Shorthorn cows.

The resulting offspring from this and other similar matings revealed their superiority for growth and adaptability to the south Texas environment. A decision was then made by King Ranch officials to begin development of a new breed (Parish, 1973). This new breed would combine the growth rate, carcass merit and maternal traits of the Shorthorn with the heat tolerance and insect resistance of the Brahman.

In the initial cross, 52 7/8-Brahman bulls were mated to 2500 purebred Shorthorn females which were divided among eight breeding groups. Two of the 7/8-Brahman bulls, namely Chiltipin and Vinotero, were mated to selected groups of 50 Shorthorn heifers. The best of the following calf crops were retained and crossmated for several generations until a line consisting of approximately 3/8 Brahman x 5/8 Shorthorn had been developed. In 1920, one of the selected matings between Vinotero and a Shorthorn heifer produced a son, Monkey, who eventually became the foundation sire of the breed (Parish, 1973).

The progeny of Monkey were considered far superior to the offspring of other sires and an inbreeding program to Monkey was initiated. Sons and grandsons of Monkey were mated to first and second cross heifers and a system of single and multiple sire herds was set up to assist in selection and to increase numbers. Monkey and selected sons were used in single sire herds while multiple sire herds utilized other sons and grandsons of Monkey (Parish 1973). As a result of vigorous selection, crossmatings and inbreeding, the Santa

Gertrudis breed was developed. This new breed of beef cattle was officially recognized by the United States Department of Agriculture in 1940.

Growth and Development of Brahman-type Cattle

Calf growth and development during the pre- and post-weaning phases are economically important traits in beef production. Differences in growth patterns between breed types are well recognized. Brahman cattle are characteristically slower growing and later maturing than the British breeds of cattle (Frisch and Vercoe, 1978; Turner, 1980). However, heterosis generated in crossing breed types (Brahman x British) generally increases efficiency and rate of growth. Cartwright et al. (1964) observed hybrid vigor among Brahman x Hereford crosses for birth weight, calf survival, weaning weight and postweaning gain.

Preweaning Growth

Growth rate during the preweaning stage and weight at weaning reflect both the genetic potential of the animal and the maternal ability of the dam. Birth weight is the first measurable growth trait. Weight at birth of purebred Brahman calves is similar or slightly less than calves of the British breeds (Ellis et al., 1965; Reynolds et al., 1980). In contrast, birth weights of Brahman-cross and the Brahman-type breeds are generally greater (McCormick et al., 1959; Cobb et al. 1964; Brown et al., 1972; Reynolds et al., 1980) than weights of calves of the British breeds. Ellis et al. (1965) observed that F1 Brahman x Hereford calves were 5.5 kg heavier at birth than purebred Hereford calves. An Oklahoma study (Aaron et al., 1984) revealed that 1/2 Brahman and 1/4 Brahman calves were 1.1 kg and 3.6 kg heavier at birth, respectively, than calves of 0 Brahman (Hereford x Angus, Angus x Hereford) breeding. Willis and Wilson (1974a) studied birth weights of Santa Gertrudis calves over a 14 year period. Factors such as sire, season, sex and year influenced individual birth weights and the average weight at birth was 38.5 kilograms. This is somewhat greater than the 28.6 kg reported by Harricharan et al. (1976) for Santa Gertrudis calves in Guyana.

Calf vigor at birth and survival rate to weaning are important factors affecting production efficiency. Vigor and survivability at birth is greater in Brahman-cross and Brahman-type (Ellis et al., 1965; Peacock et al., 1971; Peacock et al., 1977) compared to straightbred Brahman calves. Turner (1980) characterized straightbred Brahman calves as weak and lacking vigor at birth. Similar observations comparing Brahman, Brangus and Angus calves in Louisiana were made by Reynolds et al. (1980). Calf survival was less for Brahman (73.2%) and Brangus (85.6%) compared to Angus calves (93%). Mahadevan et al. (1972) observed a lower incidence of calf mortality in Santa Gertrudis (21%) compared to Sahiwal (28%) and Brahman (27.1%) cattle in South America.

Growth rate to weaning and subsequent weaning weight is an economically important trait as well as an indicator of mature size. Hybrid vigor generated through Brahman-crosses promotes more rapid weight gain during the preweaning period (Peacock et al., 1956; Damon et al., 1959; Cartwright et al., 1964; Koger et al., 1975) compared to British cattle. Preweaning daily gain for Brahman-sired calves was greater (.77 kg/d) than for calves sired by Angus bulls (.73 kg/d) (DeRouen et al., 1965). In Australia, Lampkin and Kennedy (1965) compared the preweaning growth of Hereford, Brahman-cross and Shorthorn calves under tropical conditions. Weight gains during the preweaning period were .10 kg/d and .09 kg/d greater, respectively, for the Brahman-cross calves than for Hereford or Shorthorn calves. Likewise, Rudder et al. (1975) reported Charolais x Brahman calves gained .28 kg/d more to weaning than purebred Brahman calves.

Preweaning gain from 0-4 months of age for Santa Gertrudis calves in South America was .54 kg/d compared to .46 kg/d and .51 kg/d for Sahiwal and Brahman calves, respectively (Harricharan et al., 1976). Observation of growth rate from 4-8 months of age indicated Santa Gertrudis calves gained .44 kg/d, while Sahiwal and Brahman calves gained .37 kg/d and .38 kg/d, respectively.

Calves of Brahman-type breeding are generally heavier at weaning compared to calves of British breeding (McCormick et al., 1959; Peacock et al., 1960; Peacock et al., 1977).

Weight at weaning was greater for Santa Gertrudis-sired calves in comparison to calves sired by Hereford, Angus or Charolais bulls from Hereford dams (Brown et al., 1972). Santa Gertrudis sired calves gained .8 kg/d and weighed 227 kg at weaning, compared to .76 kg/d and 217 kg, .77 kg/d and 215 kg, .72 kg/d and 205 kg, for Charolais, Angus and Hereford sired calves, respectively.

Kennedy et al. (1971) reported Brahman-cross calves were 28.9 kg and 13.7 kg heavier than Shorthorn x Hereford or Africander-cross calves, respectively, at weaning. Aaron et al. (1984) examined preweaning growth rate among spring-born calves of 1/2, 1/4, or 0 Brahman breeding. Average daily gain to weaning and weight at weaning were greater for 1/2 (.91 kg/d, 229 kg) and 1/4 (.87 kg/d, 217 kg) Brahman calves than for 0 Brahman calves (.84 kg/d, 208 kg). In addition, 1/2 and 1/4 Brahman calves were taller (110.6 cm and 106.7 cm, respectively) than 0 Brahman calves (102.4 cm) at weaning.

Postweaning Growth

Postweaning growth determines age at puberty and influences rate and efficiency of feedlot gain. Growth rate of cattle with some proportion of Brahman breeding appears to be superior through one year of age compared to British breeds of cattle in the southern United States and subtropical regions of the world (Fitzhugh et al., 1969; Rudder et al., 1975; Aaron et al., 1983). Cobb et al. (1964) observed more rapid postweaning growth, and heavier 18 and 30 month weights for Brahman x Angus and Santa Gertrudis heifers compared to Angus, Brahman, and Hereford heifers. Brahman-sired heifers grew more rapidly through two years of age than heifers sired by bulls of the British breeds (Lampkin and Kennedy, 1965) while Santa Gertrudis-sired steers had greater postweaning growth rate than either Brahman or Hereford-sired steers (Lapworth,1976). Brown et al. (1975) demonstrated that steers sired by Santa Gertrudis bulls had more rapid postweaning growth rate and reached a 455 kg slaughter weight at a younger age than calves sired by Angus, Hereford or Charolais bulls from either Angus or Hereford dams.

Greater postweaning weight gain was observed in Brahman-cross and Africander-cross heifers compared to Shorthorn x Hereford heifers in Australia (Kennedy et al., 1971). At 4 months postweaning, Brahman-cross heifers were 7.5 kg and 30.7 kg heavier than Africander-cross and Shorthorn x Hereford heifers, respectively. By 9 months after weaning, Brahman-cross heifers exceeded Africander-cross and Shorthorn x Hereford heifers by 12.0 kg and 50.6 kg, respectively. Similar results were reported with spring-born heifers of 1/2, 1/4 or 0 Brahman breeding in Oklahoma (Aaron et al.,1984). Greater weight gain and yearling weight were observed for the 1/2 (.44 kg/d and 289 kg) and 1/4 (.44 kg/d and 279 kg) Brahman heifers compared to the 0 Brahman heifers (.34 kg/d and 272 kg). In addition, 1/2 and 1/4 Brahman were taller by 6.1 cm and 1.7 cm, respectively, at one year of age compared to 0 Brahman heifers.

Growth rate and age at puberty are related in beef cattle (Wiltbank et al., 1969; Bellows et al., 1965; Laster et al., 1972). Achievement of puberty occurs later in Bos Indicus than in cattle of the Bos Taurus breeds (Howes et al., 1964; Wiltbank, 1978; Turner, 1980). Brahman x Shorthorn heifers reached puberty at an average of 17 months while Brahman heifers required 19.4 months to achieve puberty (Plasse et al., 1968a).

Reynolds et al. (1963) examined the relationship between weight and puberty in a total of 209 Angus, Brahman, F1 Brahman x Angus, Brangus and Africander x Angus heifers over a four year period. Brahman heifers were older (816 d) and heavier (321 kg) at puberty than Angus (433 d, 244 kg), F1 Brahman x Angus (460 d, 303 kg), Brangus (531 d, 290 kg) or Africander x Angus (542 d, 283 kg) heifers. Additionally, 5% of the Brangus and 7% of the Brahman heifers had not reached puberty by 30 months of age.

A Texas study examined growth and puberty in Santa Gertrudis heifers (Shipp et al., 1977). Heifers weighing 233 kg at the beginning of the trial were assigned to target weight groups of either 318 kg or 409 kg by the beginning of breeding. Although actual target weights were not achieved, a greater percentage (79%) of heifers fed to weigh 409 kg than heifers fed to weigh 318 kg (65%) had achieved puberty by the beginning of breeding. However, by day 45 of breeding, 92% of both groups had reached puberty.

Differences Between Brahman-type and British Cattle

Unique differences in physiological function between breed types of cattle exist (Yeates, 1975a; Frisch and Vercoe, 1978; Cartwright, 1980) and have an important influence on production characteristics. Breed adaptability to a specific environmental region relies on these physiological differences. Brahman-type cattle evolved from hot, droughty, parasite infested regions of the world and have been selected to perform under these environmental conditions.

Metabolic Rate and Digestion

Differences in maintenance requirements and digestive capabilities between Brahman and British breed types have been recognized (Frisch and Vercoe, 1978; Turner, 1980). The nutritional uniqueness of the Brahman-type breeds has been suggested to be influenced by body composition, maintenance requirements, patterns of nutrient intake, and digestive function (Cartwright, 1980). A reduced rate of metabolism results in lower metabolic heat production and generally more efficient utilization of available nutrients. Significant differences in blood metabolite concentrations of Brahman and British heifers indicate that basic metabolic differences exist between breed types. Zebu heifers had greater concentrations of glucose, and cholesterol in serum, and blood urea nitrogen, than British heifers under thermoneutral (22.8 C) conditions (Olbrich et al., 1971).

Fasting metabolism is a commonly used index to define the maintenance energy requirements of cattle and most studies agree that the Brahman-type breeds have a lower metabolic rate and therefore lower energy requirements for maintenance (Kibler, 1957; Rodgerson, 1968; Frisch and Vercoe, 1978). An Australian study demonstrated that Brahman cattle had a lower fasting metabolic rate than British cattle (Vercoe, 1970). At a fasted weight of 277 kg, Brahman, Africander, and Hereford x Shorthorn cattle had fasting metabolic values of 5856, 6947, and 6600 Mcal/d, respectively. Similar trends were apparent when metabolic rate was expressed on a per kilogram of fasted weight basis (20.74, 25.54, and 24.09 kcal/kg body weight for Brahman, Africander, and Hereford x Shorthorn, respectively) or on a metabolic body weight ($W^{.75}$) basis (86.74, 102.5, and 97.5 kcal/kg $W^{.75}$ for Brahman, Africander and Hereford x Shorthorn, respectively). This investigator suggested that the reduced fasting metabolism which occured in the Brahman could be explained by either a reduced energy requirement for basal metabolism or more efficient utilization of energy. Reduced maintenance requirements of Brahman -type cattle become invaluable during periods of extremely low nutritional supplies, and survivability in drought-prone areas could be enhanced.

More efficient utilization of low quality forage appears to be the major difference in digestive function between breed types (Ashton, 1962). For example, Brahman steers had greater rumen fermentation rates of organic matter and digested 3% more organic matter than Hereford steers offered similar amounts of the same low quality forage (Phillips, 1961). Vercoe et al. (1972) observed that Brahman-cross and Africander-cross steers maintained consistantly greater dry matter and nitrogen digestibilities than Shorthorn x Hereford steers under both control and heat stress environments. Likewise, Frisch and Vercoe (1977) found that Brahman-cross and Africander cross steers were able to maintain a live weight of at least 10% greater than Hereford x Shorthorn steers on similar fixed levels of low quality roughage.

Greater utilization of low quality forages by Brahman-type cattle could be a function of ruminal digesta retention time. Brahman-cross steers digested a greater proportion of organic matter and cell wall constituents of low quality forage in the rumen compared to Hereford steers (Kennedy et al., 1982). The longer retention time of the digesta in the reticulo-rumen of the Brahman-cross steers was suggested to account for this difference. A longer retention time in the rumen would allow greater utilization of all dietary components.

In contrast, Brahman-type cattle do not appear to adapt well to extremely high energy rations (Turner, 1980). British breeds of beef cattle appear to utilize high energy rations more efficiently than the Brahman and Brahman-type breeds

(Ledger, 1970; Frisch and Vercoe, 1977). Rodgerson et al. (1968) compared feed intake and growth of Hereford and Zebu steers maintained under identical conditions and fed the same high energy diet. Dry matter intake as a percentage of body weight and relative to maintenance requirement was greater for Hereford steers compared to Zebu steers. Additionally, Hereford steers were more than twice as efficient in feed conversion to liveweight gain.

Heat Tolerance

Factors such as metabolic rate, sweating, body conformation and respiratory function contribute to superior heat tolerance of the Brahman and Brahman-type breeds of cattle (Bonsma, 1949; Worstell and Brody, 1953; Stewart and Brody, 1954; Vercoe, 1970; Yeates and Partridge, 1975b). Turner (1980) indicated that Brahman cattle were uniquely adapted to hot environments due to coat, hide and hematological attributes, which made them more suitable in maintaining thermal equilibrum necessary for normal physiological function.

The ability to tolerate severe environmental temperatures has a substantial impact on animal growth (Cartwright et al., 1955; Ragsdale et al., 1957; Yeates and Partridge, 1975b, Frisch and Vercoe, 1978). Dale et al. (1959) indicated that heat tolerant Santa Gertrudis heifers grew faster and reached puberty earlier (290 d) under an environmental temperature of

26 C, than less tolerant Shorthorn heifers (440 d). Kellaway et al. (1975) observed similar growth under thermoneutral conditions (20 C) in Friesian and Brahman x Friesian heifers in Australia. However, with increasing temperature and humidity, respiration rate and rectal temperature of Friesian heifers increased while feed intake and liveweight gains decreased. Conversely, Brahman x Friesan heifers responded to increased temperature by much smaller reductions in live-weight gains and feed intake. These results suggest that breed types of cattle respond differently to thermal stress.

Underlying differences in heat tolerance between Bos indicus and Bos taurus cattle appear to be a function of metabolic heat production (Vercoe, 1970). Worstell and Brody (1953) observed that breed differences in heat tolerance were inversely related to metabolic heat production on a per unit body weight and per unit of body surface area basis. When comparing Brahman and Shorthorn cattle, Brahman cattle had the lowest metabolic heat production and the greatest heat tolerance while Shorthorn cattle had the greatest heat production and the lowest heat tolerance. Likewise, Finch et al. (1982) found a negative correlation between metabolic heat production and sweating rate in Brahman, Brahman-cross, and Shorthorn cattle.

Brahman-type cattle are more tolerant to elevated environmental temperatures due to their highly functional skin and better developed sweat and sebaceous glands. The Brahman and Brahman-type breeds have approximately 20% more sweat glands that are closer to the skin surface than the British breeds of cattle (Yeates, 1975a) and therefore are able to lose a greater amount of moisture from the hide by evaporation. Comparison of sweating rates between breed types of cattle have shown that Brahman-type cattle sweat more and sweating generally commences at a higher environmental temperature, thus conserving water for use in more severe heat stress conditions (Johnson, 1970). A greater increase in sweating rate was observed in Brahman x Shorthorn compared to Hereford x Shorthorn steers when environmental temperature exceeded 32 C (Schleger and Turner, 1965).

Body conformation and coat type also appear to contribute to the superior heat tolerance exhibited by the Brahman and Brahman-type breeds. Bonsma (1949) suggested that cattle adapted to the tropical regions of the world are respiratory types, due to their characteristic deep, flat ribbed body shape and well developed dewlap and umbilical folds of skin, which serve to increase surface area and promote heat loss. Coat type and hide characteristics serve as important factors in heat dissapation in cattle (Bonsma, 1949; Stewart and Brody, 1954) since evaporation of sweat from the skin surface and radiation of solar heat are effective methods of cooling. The smooth hair coats with short, primary follicles of the Brahman and Brahman-type breeds are efficient in terms of evaporative cooling (Yeates, 1975a).

Patterns of body fat deposition may also contribute to differences in heat tolerance between breed types. Subcutaneous fat acts as an insulation layer providing a barrier to heat loss. A lesser amount of subcutaneous fat would enhance heat loss and assist in maintaining thermal equilibrum. Brahman cattle deposit a greater amount of fat in the inter-muscular regions of the body rather than subcutaneously as occurs in the British breeds (Ledger, 1959).

Hematological differences which occur between the Brahman type and British breeds of cattle may also be important in their ability to tolerate elevated environmental temperatures and humidity (Olbrich et al., 1971). Brahman cattle have a greater number of red blood cells and more total hemoglobin than Hereford cattle. In addition, venous blood of Brahman cattle has less carbon dioxide than Herefords, implying that Brahman cattle are capable of maintaining lower respiration rates during periods of elevated ambient temperatures (Turner 1980). Brahman cattle have greater erythrocyte numbers under both control (21 C, 65% humidity) and heat stress (32 C, 95% humidity) conditions, and greater concentrations of corpuscular hemoglobin compared to Hereford cattle (Gutierrez-De la et al., 1971).

Insect Resistance

Brahman and Brahman-type breeds appear to be more resistant to insects and pests than cattle of British origin. Bonsma (1949) recognized that cattle which were adapted to the subtropical and tropical regions of the world were less sensitive to infestation with external parasites than imported cattle. The specific mechanisms which are responsible for the greater insect tolerance or resistance of the Brahman and Brahman-type breeds are still uncertain (Cartwright, 1980). Parasite resistance of Brahman and Brahman-type cattle may be due to insect repellant skin secretions, greater muscular control of the skin or a preference for resting and grazing in open areas where insects are less prevalent (Steelman et al., 1973). Yeates (1975a) suggested that the insect resistance of the Brahman and Brahman-type breeds resulted from a better developed subcutaneous muscle layer, leading to superior mobility (twitching) for the removal of insects.

Shorthorn x Brahman cattle are significantly more resistant to tick infestation (Boophilus microplus) than purebred Shorthorns in Australia (Riek et al., 1962). However, skin thickness and concentration of sweat glands were not correlated with degree of tick resistance of these cattle. Brahman-type cattle may develop a superior skin hypersensitivity to the salivary secretions of the tick which promoted the greater resistance. Droughtmaster cattle were able to maintain significantly less tick infestation compared to Hereford cows which had been treated periodically with insecticide (Johnston and Haydock, 1969).

The superior tick and fly resistance of the Brahman and Brahman-type breeds enhances animal performance (Strother et al., 1974). However, it is difficult to assess the direct influence of tick infestation on animal performance, since performance differences may also be confounded by season, nutrition and breed. Turner and Short (1972) observed differential responses in growth rate in Brahman x British, Africander x British and Shorthorn x Hereford cattle resulting from parasite infestation. Periodical worming increased daily weight gain by only 1% in Brahman x British compared to 27% and 30% in Africander x British and Shorthorn x Hereford cattle, respectively. Similarly, when cattle were treated for ticks, daily gain was increased by 46% in Shorthorn x Hereford cattle compared to only 10% and 3% for Africander x British and Brahman x British cattle, respectively.

Brahman-type cattle are superior in mosquito infested areas (Steelman et al., 1976). Daily gains were significantly reduced in Hereford steers prone to mosquito attack but Brahman-cross steers required nearly double the mosquito population as Herefords before a decline in weight gain occurred.

Increasing the percentage of Brahman breeding in cattle also reduces the attractiveness of horn flies (Tugwell et al., 1969). As the percentage of Brahman breeding increased (from 0-75%) an accompanying decrease in fly numbers was indicated, suggesting Brahman-type cattle are either less attractive or more repellant than the British breeds to these pests.

Reproductive Characteristics of Brahman-type Cattle

Puberty

Achievement of puberty at an early age is important for efficient lifetime reproductive and economic performance. Females which reach sexual maturity at an early age can calve by two years of age. To calve by two years of age, females must attain puberty by 14 to 15 months of age. The lack of sexual maturity in 2-year old Brahman heifers was found to be a major factor influencing reproductive efficiency of beef cattle in Florida (Peacock et al., 1976).

Puberty usually occurs at older ages and heavier weights in females of the Brahman and Brahman-type breeds compared to heifers of the British breeds (Reynolds et al., 1963; Cartwright, 1980; Turner, 1980). Brahman females require at least 50 d longer to achieve sexual maturity than Hereford females (Howes et al., 1964). Puberty occurred by 18 months of age and 290 kg in Brangus and Africander-Angus heifers (Reynolds et al., 1971) while Brahman heifers in Florida required 19 to 26 months of age to reach sexual maturity (Plasse et al., 1968a). In contrast, Hereford and Angus heifers achieved puberty by 380 d and 271 kg (Laster et al., 1972).

The proportion of Brahman breeding influences age and weight at puberty. A greater percentage (52%) of 1/4-1/2

Brahman heifers exhibited estrus during the first 21 days of breeding compared to 5/8-3/4 Brahman heifers (16%) of similar body weight (Wiltbank, 1978). Conversely, Aaron et al. (1983) found that 1/4 and 1/2 Brahman heifers of similar weight, reached puberty at a younger age (362 and 360 d, respectively) than either Hereford x Angus or Angus x Hereford heifers (384 d).

Age and weight at puberty have a substantial effect on subsequent reproductive performance in heifers of the Brahman and Brahman-type breeds (Shipp et al., 1977; Shipp et al., 1980; Post, 1984). An increased percentage of Santa Gertrudis x Hereford heifers exhibited estrus and conceived as body weight increased (Wiltbank, 1978). For heifers weighing 182-205, 228-250 or 273-300 kg at the beginning of breeding, 12%, 20% and 77%, respectively, exhibited estrus. In addition, pregnancy rate after 60 days of breeding was 12%, 26% and 88% for heifers in these respective weight groups.

Estrus and Ovulation

Reproductive parameters of the Brahman and Brahman-type breeds differ from those of the British breeds and may contribute to differences in reproductive rate commonly observed between breed-types. Cattle of Brahman-type breeding may exhibit irregular estrous cycles, shorter periods of estrus, and a reduction in the expression of behavioral estrus (Anderson, 1944; Luktuke and Subramanian, 1961). Howes et al.

(1964) concluded that Brahman heifers exhibited fewer signs of estrus and shorter estrual periods than Hereford heifers. Randel (1984) concluded that estrus was shorter, less intense and occurred later in response to an estrogen stimulus in females of primarily Brahman breeding. Furthermore, Brahman-type females had earlier occurring preovulatory surges of luteinizing hormone (LH) and ovulation occurred sooner after estrus than in British females.

Length of the estrous cycle was longer (25 d) and duration of estrus was shorter (4.5 h) for Brahman heifers than for Friesian x Brahman heifers (22 d, 10 h) (Alberro, 1983). Randel (1984) suggested that the biological timing between estrus and ovulation differed between Brahman and British cattle, since the time from standing estrus to ovulation was shorter (18.9 h) in Brahman, than in Brahman x Hereford or Hereford females (29.0 and 28.6 h, respectively).

Anderson (1944) observed greater seasonal changes in sexual activity of Brahman cattle than in British-type cattle. During intervals of increased photoperiod and temperature (summer), sexual activity of Zebu females increased, as indicated by shorter estrous cycles and longer estrual periods. However, during winter months this trend was reversed and sexual activity decreased, as indicated by longer estrous cycles and shorter estrual periods. Plasse et al. (1968a) observed a definite reduction in sexual activity (as indicated by uterine size and tone, and frequency of corpora lutea) of Brahman heifers compared to Brahman x

British heifers during the winter months in Florida. Seasonal flucuations in estrus did not occur in Brahman x British heifers, although a greater incidence of anovulatory estrus and anestrus occurred during winter in the Brahman heifers. Sexual activity of Brahman heifers increased during the spring and reached a maximum during the summer months.

Plasse et al. (1970) observed seasonal influence on the frequency of ovulations without estrus. During periods of cold weather, little behavioral estrus occurred and the occurrance of anovulatory estrus increased. However, during the summer months, the incidence of anovulatory estrus decreased and accounted for 8.4% of all estrous cycles.

Seasonality of reproductive processes in Brahman-type females results from seasonal changes in pituitary and corpora lutea function (Randel, 1984). A decreased incidence of preovulatory surges of LH at estrus occurs during the winter compared to spring and summer in Bos indicus cows. Furthermore, the serum concentrations of LH in early and late spring were elevated in cows compared to values during the winter.

Differences in ovarian physiology and endocrine function between breed types may account for differences in reproductive function. The reproductive tract and ovaries are generally smaller and more difficult to manipulate in Brahman type compared to females of the British breeds (Randel, 1978, Adeyemo, 1980). Additionally, corpora lutea (CL) have been described as smaller and containing less progesterone in the

Brahman and Brahman-type breeds. In comparing Brahman and British x Brahman heifers, corpora lutea were larger and easier to detect in British x Brahman than in Brahman heifers (Plasse et al., 1968a). Randel (1978) reported that corpora lutea of Brahman cows were smaller and more difficult to remove than those from Hereford or Brahman x Hereford females (2.616, 3.836 and 4.211 g, respectively). In addition, total progesterone content of the corpora lutea was less for Brahman and Brahman x Hereford cows (216.9 and 217.7 ug/CL, respectively) than in Hereford cows (334.6 ug/CL).

Smaller corpora lutea may result in reduced luteal function and account for reduced peripheral concentrations of progesterone during the estrous cycle of Brahman and Brahman type females. Systemic concentrations of progesterone in Brahman and Brahman x Hereford females were less than in Hereford females from 2-11 d after estrus. However, from 10 to 4 d before estrus, Brahman and Brahman x Hereford females had greater peripheral concentrations of progesterone than Herefords (Randel, 1978). During the luteal phase of the cycle, White Fulani (Bos indicus) females had reduced concentrations of progesterone in plasma (4.5 ng/ml) when compared to Brown Swiss and Holstein-Friesian (Bos taurus) females (5.0 and 5.2 ng/ml, respectively) (Adeyemo et al., 1980).

The length of the interval from calving to first estrus is an important factor affecting reproductive efficiency. Although nutrition and suckling are known to affect the length of this interval, some studies indicate that breed may also be an important factor (Plasse, 1968b). Results from an Indian study with Harina cattle (Luketuke et al., 1961) reported that first estrus following calving averaged 84.5 d and ranged from 11-390 days. Friesian x Brahman heifers exhibited first estrus sooner (70 d postpartum) than Brahman heifers (110 d postpartum) (Alberro, 1983). A Louisana study (Reynolds et al., 1980) found that a greater proportion of Angus cows (86%) had exhibited estrus compared to Brahman cows (53%) during the first 21 days of breeding.

Reproductive Rate and Gestation

Reproductive rate in Brahman cattle is generally considered to be lower than for the British breeds (Turner, 1980; Franke, 1980). Results from a Florida study indicated that greater pregnancy rates occurred in cows of predominantly British breeding compared to females of predominately Brahman breeding (Warnick et al., 1960). A Louisana study (Turner et al., 1980) observed greater pregnancy rates in Angus dams (84.5%) than in Brahman dams (66.0%) over a three year period. In contrast, other studies suggest that reproductive rate of Brahman females is at least equal to (Turner et al., 1968) or superior (Peacock et al., 1971) to the rate for females of the British breeds. For example, Peacock et al. (1976) found a greater calving rate (89.9%) for straightbred Brahman dams than for either Angus (75.3%) or Charolais

(79.7%) dams under the subtropical conditions of central Florida.

It is evident that accurate comparisons of reproductive performance between breed types is difficult. Cartwright (1980) indicated that in Brahman-type females there is more uncertainty concerning the causes and relationships of reproductive performance than with any other trait. Conflicting reports on reproductive performance are most likely due to differences in climatic, nutritional and location adaptability between breed types. The lower reproductive rates commonly reported for Brahman and Brahman-type breeds may be an inherent ability to adjust to periods of nutritional or climatic stress.

Use of the Brahman breed in crossbreeding programs and in the development of new breeds, such as Santa Gertrudis and Brangus, results in heterosis for reproductive traits and increases overall reproductive performance (Schilling and England, 1968; Peacock et al., 1976; Peacock and Koger, 1980; Reynolds et al., 1979). Turner et al. (1968) demonstrated the effects of hybrid vigor for reproductive performance through crossbreeding using 16 breed-types of dams. Crossbred cows produced 9.6% more calves than straightbred cows under the subtropical conditions of southeastern Louisiana. Calving percentages were greater for Brahman x Hereford, Brahman x Brangus and Brahman x Angus (84.7%, 82.1% and 77.4%, respectively) compared to Angus, Brahman, Brangus and Hereford cows (65.1%, 67.9%, 65.5% and 65.6%, respectively).

Brahman-cross and the Brahman-derived breeds of beef cows generally exhibit better reproductive performance than purebreds under subtropical and tropical climatic conditions (Peacock et al., 1971). Lampkin and Kennedy (1965) observed greater calving rates for Africander x British (77.3%) and Brahman x British (73.8%) females than for British females (56%) in eastern Australia. Similarly, Mahadevan et al. (1972) and Wilson and Wilson (1974b) revealed that overall reproductive performance (calving rate and net calf crop) of Santa Gertrudis cows was greater than for Brahman cows in both South America and Cuba, respectively.

Longer periods of gestation are commonly observed in Brahman and Brahman-type cows compared to females of the British breeds. Plasse et al. (1968b) revealed that Brahman cows had a longer gestation (292 d) than is commonly reported for the British breeds. Rakha et al. (1971) compared the length of gestation of Angoni, Africander and Hereford cows in Africa. Africander dams had a longer gestation (297 d) than either Angoni or Hereford dams (287 d). Similarly, the lengths of gestation for Brahman x Angus, Brahman and Brahman x Brangus were longer (286.6, 291.1, and 292.1 d, respectively) than for Angus and Brangus cows (280 d, 280 d) in southern Louisana (Reynolds et al., 1980).

Influence of Nutrition on Reproduction

Nutrition is a major factor affecting reproduction in beef cows. Energy intake during the pre- and postpartum periods influences reproductive performance in heifers and cows (Joubert, 1955; Wiltbank et al., 1962; Dunn et al., 1969; Corah et al., 1975; Tervit et al., 1977; Topps, 1977; Dunn and Kaltenbach, 1980). The most critical nutritional period in the beef cow is from 50 d prepartum until 80 d after calving (Corah, 1977; Dunn and Kaltenbach, 1980). If nutrition is inadequate at this time, the cow must mobilize body energy reserves to meet the requirements for maintenance, pregnancy and lactation. Thus, changes in body weight, and more importantly body condition, reflect the nutritional status of the cow. Undernutrition during the prepartum and early postcalving period may depress endocrine function, resulting in delayed estrus and a reduced percentage of cows exhibiting normal estrous cycles early in the breeding season.

Prepartum Nutrition

Nutrient requirements of pregnant beef cows increase substantially during the last third of gestation. During this period, 70-80% of fetal growth occurs and preparation for lactation begins. Decreasing the level of nutrition prior to calving reduces postpartum reproductive performance (Wiltbank et al., 1962; Wiltbank et al., 1964; Corah et al., 1975; Dunn and Kaltenbach, 1980; Garmendia, 1984). Heifers of both beef and dairy breeds reared on a low level of nutrition reached puberty later and had longer postpartum intervals to first estrus (Joubert, 1955). Prepartum energy intake exerted the greatest influence on occurance of estrus in the early post-partum period of yearling heifers (Dunn et al., 1969). By 40 d after calving, 25% of heifers on a high nutritional regime had exhibited estrus compared to only 6% of heifers on the low treatment. At 60 d postpartum, 69% and 44% of the high and low heifers, respectively, had exhibited estrus.

Hereford heifers were assigned a high (100% of NRC) low energy diet (65% of NRC) commencing 100 days prior to calving (Corah et al., 1975). Although level of precalving nutrition did not influence the interval to first estrus, 41% of the high heifers had exhibited estrus by 40 d postpartum compared to only 26% of the low heifers. By the beginning of breeding, 74% of the high heifers and 56% of the low heifers had exhibited estrus.

Bellows and Short (1978) observed similar results with crossbred heifers fed either a high (6.3 kg TDN/d) or low (3.4 kg TDN/d) amounts of energy beginning 90 d prepartum. Postpartum interval to estrus was longer (87 d) for heifers on the low treatment compared to those on the high treatment (66 d). In addition, only 47% of the low heifers had been in estrus while 79% of the high heifers had exhibited estrus by the beginning of the breeding season.

Limiting energy to mature beef cows in late gestation affects postpartum occurance of estrus and pregnancy rate (Wiltbank et al., 1964; Bellows and Short, 1978; Dunn and Kaltenbach, 1980). Fewer Hereford cows (22%), restricted to 4.5 kg TDN/d during the prepartum period and 8.0 kg TDN/d postpartum, had exhibited estrus by 90 d postpartum compared to cows (95%) receiving 9 and 16 kg TDN/d during the pre- and postpartum periods, respectively (Wiltbank et al., 1962). In addition, postpartum interval to estrus was extended and pregnancy rate was decreased in cows on the low nutritional regime. Similar trends were indicated by Bellows and Short (1978) with mature Angus and Hereford cows fed two levels of energy both pre- and postcalving.

Severe prepartum weight loss resulting from undernutrition during the precalving period prolongs the postpartum interval and decreases the percentage of females in estrus by 60 d after parturition (Dunn and Kaltenbach, 1980). Spring calving beef cows which lost 14% of their fall weight by calving had a reduced pregnancy rate (71%) compared to cows fed to maintain weight to calving (85%) (Wettemann et al., 1980). Rasby et al. (1982) found that only 41% of Hereford cows fed to lose weight until calving had expressed estrus by 85 d postpartum, compared to 79% of those which were fed to gain weight beginning 45 d prepartum. Additionally, cows on the restricted diet had reduced pregnancy rate (76%) compared to cows supplemented to maintain their fall weight until calving (95%).

Decreasing the amount of precalving energy intake alters the concentrations of blood metabolites which may affect the endocrine system and alter postpartum reproductive function. Spring calving Hereford cows wintered on submaintenance levels of nutrition and losing weight until calving had reduced plasma glucose and plasma protein concentrations during the prepartum period compared to cows which were fed to either maintain or gain weight prior to parturition (Rasby 1982). In addition, underfed beef cows which lost 13% of their fall weight by calving had greater concentrations of non-esterified fatty acids throughout the prepartum period and at calving compared to cows supplemented to either maintain or gain weight before calving (Garmendia, 1984). These results indicate that cows on a low level of precalving nutrition utilize body energy reserves to meet the requirements for maintenance and fetal growth.

Postpartum Nutrition

Energy intake during the first 80 d after calving has a substantial effect on postpartum reproductive performance. During this time uterine involution occurs, lactation begins and the cow must reinitiate estrous cycles and conceive within 80 d to maintain a 365 d calving interval. Topps (1977) indicated that reduced reproductive performance after calving was due to a combination of undernutrition and the high energy demands of lactation.

Prolonged intervals to first estrus, which result in reduced pregnancy rates, are observed when nutrient intake is limited during the post-calving period (Wiltbank et al., 1962 Oxenreider and Wagner, 1971; Dunn et al., 1980). Wiltbank et al. (1964) restricted Hereford cows to 50% of their recommended energy intake during the prepartum period, then increased energy intake to 75% (low), 100% (moderate) or 150% (high) of NRC recommended amounts postpartum. Cows on the low postpartum treatment had a longer interval to first estrus (73 d) than those on the moderate treatment (49 d). A greater percentage (21%) of cows on the low level of energy failed to exhibit estrus by 70 d after calving than cows on the moderate and high energy treatments (7% and 8%, respectively). In addition, pregnancy rate was enhanced by greater amounts of nutrient intake resulting in 72%, 79% and 92% for low, moderate and high treatments, respectively.

Interval to first estrus was significantly influenced by postpartum nutritional regime in Brangus cows (Rutter and Randel, 1984). Cows on low, medium and high postpartum nutritional treatments exhibited estrus by 57.5, 40.3 and 34.7 d, respectively, after calving. Dunn et al. (1969) concluded that postpartum level of nutrition affected occurance of estrus only late in the postcalving period in Angus and Hereford heifers. By 100 d after calving 81% of heifers on a low level of energy had exhibited estrus compared to 92% and 98% of those on moderate and high levels of energy, respectively. Furthermore, pregnancy rate was significantly influenced by postpartum nutrient intake as 64%, 72% and 87% of heifers on low, moderate and high levels, respectively, conceived.

Cows on a low postcalving nutritional regime and losing weight rapidly prior to and during the breeding period have reduced reproductive performance. Reduced conception rates were observed in postpartum cows fed only 90% of the estimated energy for maintenance compared to cows fed 125% or 175% of maintenance that were maintaining or gaining weight (Somerville et al., 1979).

Fall calving cows were fed to lose approximately 10% of their postcalving weight (low) or to maintain weight (moderate) prior to breeding (Cantrell et al., 1980). Postpartum interval to estrus was prolonged (75 d vs. 54 d) and conception rate was slightly reduced (72% vs. 96%) in the low cows compared to moderate cows. Rakestraw (1984) altered the level of postpartum nutrition in fall calving Hereford cows (fed similarly prepartum) to either maintain weight from calving through breeding (M), lose weight to breeding then maintain weight (LM) or maintain weight to breeding then lose weight during breeding (ML). A longer interval to first estrus (69 d) was observed in LM cows compared to M cows (58 d). Additionally, fewer LM cows exhibited estrus than M and ML cows.

Reproductive response to postpartum level of nutrition may depend upon precalving nutritional regime and subsequent body condition at calving (Bellows and Short, 1978; Dunn and Kaltenbach, 1980; Richards, 1984). Wiltbank et al. (1962)

observed similar intervals (48 and 43 d) to first postpartum estrus in cows fed high levels of prepartum energy and either high or low levels postpartum. Hight (1968) indicated that cows receiving high amounts of energy precalving and either low or high levels of energy postcalving had similar pregnancy rates. High to moderate levels of postcalving energy are essential for cows that are in thin body condition at calving.

Flushing

Flushing is the practice of increasing the plane of nutrition of females for several weeks before and/or during the breeding period in an attempt to improve body energy stores (condition) and/or prevent depletion of body energy reserves. The primary objective of flushing is to improve reproductive performance. Reid (1960) observed that flushing ewes prior to and during breeding increased ovulation rate and percent lamb crop.

The influence of flushing may be dictated by the nutritional status of the female. Reproductive performance was not enhanced by flushing ewes already receiving high levels of nutrition (Reid, 1960). Bellows et al. (1968) fed additional concentrate (3.6 kg/hd/d) to spring calving, lactating beef cows grazing native range, before, during or both before and during the breeding period. No increase in reproductive performance due to flushing was observed, suggesting additional energy was unnecessary when abundant range forage is available. Similar results were obtained by Loyacano et al. (1974) with winter and spring calving beef cows. Flushing with additional energy did not affect percentage of females exhibiting estrus or calving percentage. However, winter weight losses were lowered and spring weight gains were increased in cows receiving additional energy.

A six state regional project (Wettemann et al., 1984) examined the effects of flushing and calf separation on body weight, body condition, reproductive performance and calf weaning weight. A total of 294 cows of Angus, Brangus, Beefmaster, Hereford, Brahman-cross and Santa Gertrudis breeding were used in the study. Flushed cows received an additional 4.5 kg hd/d of energy for four weeks, commencing approximately 30 d after calving. Additional energy did not affect body weight or body condition. Cows which were flushed and separated appeared to have greater ovarian activity during the 56 d breeding period. Conception rate and days to conception were not influenced by treatment, although flushing did improve calf weaning weights.

Flushing for an extended interval may be effective for cows which calve in thin body condition and need rapid weight gain to compensate for losses incurred during the prepartum period. For example, cows which calved in thin body condition (body condition score ≤ 4) and were flushed, commencing 14 d prior to breeding, had similar reproductive performance to cows fed adequately precalving (Richards, 1984).

Influence of Body Weight and Body Condition on Reproduction

Fertility of beef cows is reduced when substantial losses in body weight and condition occur both before and after calving (Wiltbank et al., 1962; Wiltbank et al., 1964; Baker, 1969; Whitman, 1975; Somerville et al., 1979; Rakestraw, 1984). Changes in weight and condition before and after parturition interact to influence the postcalving interval to first estrus (Dunn and Kaltenbach, 1980). The magnitude of change in weight or condition can determine potential rebreeding performance.

Weight change in mature beef cows is highly variable and dependent on nutrition and stage of production. Schake and Riggs (1972) indicated beef cows managed under typical range conditions may experience yearly changes in body weight of 20% or more. Prepartum weight losses indicate that cows are not consuming sufficient energy to meet the demands of maintenance plus fetal and placental growth. Therefore, body energy reserves are utilized to meet these needs.

Occurance of estrus is reduced when weight losses are incurred before and after parturition (Wiltbank et al., 1962; Somerville et al., 1979). Whitman (1975) concluded that body weight changes pre- and post calving significantly influenced the occurrance of estrus by 40-50 d postpartum. Wettemann et al. (1982) demonstrated that the percentage decrease in body weight until calving was correlated to first estrus (r=.58)

These results revealed each 10% loss in precalving weight delayed first estrus by 19 d and conception by 16 days. Likewise, Dunn and Kaltenbach (1980) observed that for each kg of weight loss before calving, the percentage of cows which exhibit estrus by 60 d postpartum decreased by 0.5%.

Since interval to first estrus is prolonged with severe weight loss, fewer cows conceive during the breeding period. Warnick et al. (1967) compared weight loss patterns and pregnancy rates of beef cows in Florida. The lowest pregnancy rate was observed in cows (Brahman and Santa Gertrudis) which lost the most weight before breeding. Schilling and England (1968) indicated weight change before and during breeding significantly affected calving rate in several breeds of beef cows, including Brahman and Brahman-cross. Calving rate was reduced by .123% for each kg of body weight loss prior to breeding.

Conversely, cows maintaining or gaining weight prior to and/or after calving are not mobilizing body tissue, thus the requirements for maintenance, lactation, and fetal growth are achieved through nutrition. Wiltbank et al. (1964) observed greater pregnancy rates in thin cows rapidly gaining weight postpartum than in cows losing weight after calving. Pregnancy rate by 120 d after calving was greatest for cows gaining the most weight postpartum (Dunn et al., 1969). In addition, the occurance of estrus increased and the postpartum interval to estrus was reduced. Whitman (1975) concluded that cows gaining weight before calving had a greater likelihood of exhibiting estrus by 50 d postpartum than cows losing weight precalving. Brahman x Hereford cows which gained weight prior to calving had shorter intervals to first estrus (32 vs. 37 d) compared to cows which lost weight before parturition (Godfrey et al., 1982). Dunn and Kaltenbach (1980) indicated that of cows which maintain body weight before calving, 91% exhibited estrus (r=.76) by 60 d postpartum.

Body condition and changes in condition before and after calving may more accurately reflect energy reserve status of the female, since weight and weight changes include differences in rumen fill and fetal growth. Body condition score estimates the amount of energy reserves (fat) in the animals body. Therefore, changes in body condition indicate alterations in body energy reserves.

Fertility rate is greater for cows calving in moderate to good body condition compared to cows calving in thin body condition (Wiltbank et al., 1964; Baker, 1969; Wettemann et al., 1980). Body condition at calving may be the most important factor influencing early return to estrus and pregnancy rate. Dunn and Kaltenbach (1980) indicated that length of the postpartum interval to first estrus of cows calving in good body condition is unaffected by either pre- or postpartum weight changes. Body condition at calving exerted a greater influence on pregnancy rate than changes in body weight or body condition during late gestation in Hereford range cows (Selk et al., 1985).

Rutter and Randel (1984) observed enhanced pituitary function, thus greater reproductive potential in Brangus cows which maintained good body condition after calving. Whitman (1975) concluded that cows in good body condition at calving will more likely exhibit estrus by 60-90 d postpartum compared to cows which calve in thin body condition. Decrease in body condition before calving is correlated with days to first estrus and days to conception (Wettemann et al., 1982). Specifically, a 20% decrease in body condition score (1=thin, 9=fat) would result in an additional 15 d to first estrus after parturition, compared to cows maintaining body condition. Similarly, only 24% of Santa Gertrudis heifers in thin condition at calving became pregnant during a 60 d breeding period, compared to 87% of heifers in good body condition at calving (Wiltbank et al., 1981). In addition, more heifers (64%) in good body condition were pregnant after 20 d of breeding than thin heifers after 60 d of breeding (24%).

Moderate to good body condition at the start of breeding appears to be necessary for maximal pregnancy rates. Sprott and Wiltbank (1980) concluded that good body condition of Hereford cows at the start of breeding improved pregnancy rate. Ninety percent of cows in good body condition at breeding conceived compared to only 69% of cows in thin body condition at breeding. Cantrell (1980) demonstrated that cows entering the breeding period in good body condition (BCS 5.5) had a shorter interval to first estrus (54 vs. 76 d) and a 12% greater conception rate than cows in thin body condition at breeding (BCS 4.6).

Recent studies have shown that body condition score, body fat percentage (Bellows et al., 1979) and carcass energy content are highly correlated. Wright and Russel (1984) indicated body condition score (1=thin,5=fat) was closely related to actual body composition of nonpregnant, non-lactating cows of beef, beef x dairy and dairy breeds. Within the beef breeds studied, body condition score was more accurate in predicting degree of fatness than live weight. In addition, a 1 unit change in body condition was associated with a change in 2242 MJ of body tissue energy and 100 kilograms of live weight.

Wagner (1985) established a close relationship between body condition score (determined by palpation of fat cover over ribs, vertebra and pins as well as visual observation), carcass fat percentage and total carcass energy content (as determined by chemical composition) of nonpregnant, non-lactating Hereford cows. When carcass components were expressed as a percentage of carcass weight, body condition score accounted for 76% of the variation in live weight, 82% of the variation in carcass fat, and 85% of the variation in total carcass energy content. Dunn et al. (1983) examined the relationship between body condition score, carcass fat and carcass energy content (chemically determined) in 47 suckled, postcalving beef cows. Body condition score was highly correlated with fat cover over the rib (r=.86) and total energy content of the carcass (r=.77).

Postpartum Ovarian Function

Varying lengths of anestrous occur during the postpartum period due to inactivity of the ovary. Prolonged intervals delay conception and decrease reproductive efficiency. The inactivity of the ovary is likely due a result of insufficient synthesis and/or secretion of gonadotropins (Wiltbank et al., 1962; Wettemann, 1980; Humphrey et al., 1983) which results in a lack of follicular and luteal development after calving (Casida, 1968; Wettemann et al., 1980).

During gestation, progesterone is the primary steroid secreted by the ovary and concentrations of progesterone are similar to those observed during the luteal phase of the estrous cycle (Donaldson et al., 1970). However, some progesterone secreted by the adrenal gland (Wagner et al., 1969b Wendorf et al., 1983) and placenta may affect reproductive processes. By 2-3 weeks prior to calving, luteal activity decreases and concentrations of progesterone in plasma begin to decline (Henricks et al., 1972; Smith et al., 1973; Corah et al., 1974). At calving, progesterone decreases rapidly to very low concentrations (Ecternkamp et al., 1973; Arije et al., 1974; Smith et al., 1973; Rawlings et al., 1980). Concentrations of progesterone are minimal following parturition (Henricks et al., 1972; Stevenson and Britt, 1979).

During the last three weeks of gestation concentrations of estrogen in plasma originating from the placenta increase rapidly (Ecternkamp et al., 1973; Arije et al., 1974;

Humphrey et al., 1983). A ten-fold increase in plasma estrogens during the month prior to calving has been observed (Smith et al., 1973).

The early postpartum stage is characterized by a period of ovarian inactivity. Corpora lutea of pregnancy regresses and the uterus involutes. Regression of the corpus luteum of pregnancy is complete by 7-18 d postpartum (Oxenreider, 1968; Wagner and Hansel, 1969a). Consequently, concentrations of progesterone and estrogen in plasma remain minimal until first estrus (Smith et al., 1973; Arije et al., 1974; Stevenson and Britt, 1979; Rawlings et al., 1980).

The interval from parturition to first estrus and ovulation is highly variable. Casida (1968) reported postcalving intervals to first estrus of 30-104 d for beef and dairy cows. Other studies report postpartum intervals to first estrus of 46-168 d (Dunn and Kaltenbach, 1980; Randel, 1981). However, the length of this period is dependent upon how quickly the ovary becomes functional following calving. First ovulation after calving may not occur with detectable estrus (Donaldson et al., 1970). Saiduddin et al. (1968) indicated that 46.5% of first ovulations in dairy cows occurred without observable estrus.

Initiation of estrous activity after calving is preceded by follicular growth and development. Growth of follicles increases steadily beginning approximately 10 d after calving (Saiduddin et al., 1968). Wagner and Hansel (1969a) observed an increase in follicle size from 9.6 mm at day 7 to 13.0 mm at day 30 postpartum. With the increase in follicular development, steriod synthesis and secretion increases.

Peripheral progesterone concentrations increase slightly in beef cows at 2-4 d and possibly earlier, before the onset of cyclic ovarian activity (Corah et al., 1974; Rawlings et al., 1980). Arije et al. (1974) observed that concentration of serum progesterone increased steadily from 0.3 ng/ml at 7 d pre-estrus to 2.0 ng/ml at 3 d pre-estrus then decreased to 0.2 ng/ml at estrus. Similarly, Humphrey et al. (1983) observed an increase in progesterone 4.6 d prior to first estrus. The increase in progesterone before estrus may be associated with lutenization of small follicles or ovulation and corpora lutea formation before observable estrus.

Progesterone concentrations increase after ovulation upon formation of the corpus luteum associated with the luteal phase of the estrous cycle (Arije et al., 1974). Progesterone increased from 0.5 ng/ml immediately following estrus to a maximum of 6.1 to 10.2 ng/ml during the luteal phase of the cycle (Stabenfeldt et al., 1969). Concentrations of progesterone then decline upon luteolysis of the corpus luteum near the end of the cycle.

Systemic concentrations of estrogens increase 2 to 3 d prior to the first postpartum estrus and then decline rapidly after estrus (Ecternkamp et al., 1973; Rawlings et al., 1980; Humphrey et al., 1983). Wettemann et al. (1972) observed a rapid increase in blood estrogens 3 d prior to estrus and a maximum value of 9.7 pg/ml occurred at 0.5 d before estrus.

Similar results were reported by Henricks et al. (1972) where estrogens attained a maximum one day prior to estrus and then decreased to minimal concentrations by 2 to 5 h after the end of estrus.

Suckling

Although ovarian inactivity after calving is most likely due to insufficient gonadotropin secretion, suckling also influences the onset of estrous activity after parturition (Graves et al., 1968; Oxenreider, 1968; Donaldson et al., 1970; Radford et al., 1978). Oxenreider et al. (1971) suggested ovarian activity in the postpartum cow is reduced by the nutritional stress of lactation and the sensory stimulation of milk removal.

The frequency and intensity of milk removal from the mammary gland prolongs the interval until the onset of cyclic ovarian activity following calving. Reduced ovarian activity, as indicated by reduced systemic concentrations of progesterone, occur in suckled cows compared to nonsuckled cows. Radford et al. (1978) demonstrated that nonsuckled cows had consistently greater amounts of peripheral progesterone than suckled cows. Furthermore, regular ovarian cycles by 10-33 d postpartum were observed in nonsuckled cows while suckled cows required 14 weeks for resumption of normal estrous cycles. A similar study conducted by LaVoie et al. (1981) demonstrated that systemic progesterone concentrations were reduced in beef cows suckled either ad-libitum (AL) or twice daily (2X) compared to nonsuckled (NS) cows. The interval to first estrus was shorter in NS cows (20 d) compared to AL (38 d) or 2X cows (34 d). These results suggest that suckling has an inhibitory effect on the resumption of estrus following calving.

The length of the anestrous period may be directly related to the intensity of suckling (Edgerton,1980). Wettemann et al. (1978) revealed that beef cows suckling two calves exhibited estrus and ovulated significantly later in the breeding period than cows suckling only one calf. Randel (1981) compared the effects of two suckling regimes (once daily suckling vs. normal suckling) on resumption of reproductive processes in first calf Brahman x Hereford heifers. Treatment began at 30 d postpartum and continued until first estrus. Results indicated suckling of calves only once per day significantly shortened the interval to first estrus (68.9 ± 6.2 d) compared to heifers which were suckled ad-libitum (168.2 ± 6.2 d). Likewise, a 79.8% pregnancy rate in Brahman cows was observed when calves were allowed to suckle only twice daily, compared to 46.3% calves which suckled their dams normally (Bastidas et al., 1984).

Calf removal and early weaning have shown that removal of the inhibitory effect of suckling can initiate ovarian activity and regular estrous cycles. Removal of calves for 48 h (between 50-80 d postpartum) increased the percentage of cows exhibiting estrus by 10 d following treatment (Beck et al., 1979). Lusby et al. (1981) investigated early weaning of calves as a method to stimulate ovarian activity in first-calf beef heifers. Ovarian activity was initiated in 90.3% of the early-weaned heifers compared to only 34.3% of the non-weaned heifers by 85 d postpartum. In addition, a greater conception rate (96.8%) was observed in the early weaned heifers compared to the nonweaned heifers (59.4%). Similarly, Laster et al. (1973) found that early weaning of calves increased the percentage of cows that exhibited estrus and conceived during the first 21 d of the breeding period.

Heat Stress and Fertility

The climatic environment is one of the most influential factors affecting animal productivity. Stress associated with hot, humid environments reduces the productivity and reproductive efficiency of cattle (Bonsma, 1949; Ittner, 1958; Christenson, 1980; Fuquay, 1981). Maintenance of thermal equilibrum by the animal is directly influenced by environmental temperature. Under thermoneutral conditions, heat gain from energy metabolism and solar radiation is balanced by heat loss from blood flow to the skin surface and respiration. The upper critical temperature (UCT) for most domestic livestock is in the range of 24-27 C, although factors such as relative humidity, wind speed and degree of environmental acclimation affect the UCT (Fuquay, 1981). As environmental temperature increases, body temperature approaches the UCT and additional methods of promoting heat loss are implemented such as increased respiratory rate, sweating, and a reduction in energy intake.

Seasonal variation in reproductive efficiency of cattle has been observed in the hot, humid, southern regions of the U.S. (Plasse et al., 1970; Christenson, 1980). Reduced reproductive performance of cattle resulting from increased climatic temperature are well documented (Dunlap et al., 1971; Ingraham et al., 1974; Thatcher, 1974). The relationship between heat stress and reduced fertility in cattle may be due to a combination of increased body temperature, altered endocrine function and reduced energy intake.

Prolonged estrous cycles and a reduction in duration of estrus may contribute to fertility problems encountered during periods of thermal stress. Elevated environmental temperatures and humidity delay puberty, alter estrous cycles and induce anestrous (Branton et al., 1959; Hall et al., 1959; Vincent, 1972; Monty et al., 1974). Gangwar et al. (1965) studied estrous cycles and the intensity of estrus in Holstein heifers exposed to either thermal stress (29-35 C) or control (16-18 C) environmental conditions. Average length of the estrous cycle was longer (21-25 d) for heat stressed heifers than for control heifers (20-21 d). In addition, increased environmental temperature shortened the estrual period (11-14 h) in comparison to control heifers (20 h). Furthermore, intensity of estrus was reduced and 33% of the heat stressed heifers eventually became anestrous. Bond and

McDowell (1972) observed similar results with heat stressed beef heifers. Heifers acclimated to winter temperatures were confined to environmental chambers at 32 C. Respiratory rate and body temperature increased rapidly and heifers eventually became anestrous before acclimating to the change in environmental temperature. Thus it appears that heat stress induced anestrous may be an important reproductive problem.

Increased environmental temperature and subsequent elevated body temperature at and following breeding influence fertility of cows (Gwazdauskas et al., 1973; Thatcher, 1974). Gwazdauskas et al. (1975) reported that the most important factor influencing conception rate was the maximum environmental temperature the day following breeding. Furthermore, as maximum daily temperature after breeding increased from 21 C to 35 C, conception rate declined from 40% to 31%. Likewise, an inverse relationship between temperature, humidity and conception rate was observed by Ingraham et al. (1974). As the temperature-humidity index increased above 70 (prior to breeding) a linear reduction in conception was observed.

Dunlap and Vincent (1971) exposed Hereford heifers to one of two environmental chamber treatments; heat stressed (HS-32.2 C) or control (C-21.1 C) at 65% humidity for 72 h following breeding. Elevated environmental temperature increased the respiratory rate (103 vs. 43 breaths/min) and rectal temperature (40 C vs. 38.5 C) for HS compared to C heifers. None of the heat stressed heifers conceived while 48% of the control heifers conceived. Therefore, even short term exposure to heat stress after breeding may reduce conception rate. Loyacano et al. (1974) investigated the influence of season of breeding on reproductive performance of beef cows. Winter bred cows had greater pregnancy rates than spring bred cows, suggesting that increased environmental temperature may reduce conception rate in spring bred cows.

The physiological mechanisms which result in reduced fertility are still uncertain. Christenson (1980) suggested that elevated environmental temperature may influence reproductive processes by either (1) a direct effect of environmental temperature and humidity resulting in increased body temperature, or (2) an indirect influence of elevated temperature and humidity altering endocrine and uterine function. Elevated environmental temperature could result in increased uterine temperature, providing an unfavorable environment for gametic and embryonic survival. Thatcher (1974) suggested that reduced reproductive performance associated with thermal stress was due to high temperatures acting directly on the developing embryo.

Summary

It is evident that differences in growth and physiological function exist between breed types of beef cattle. Brahman-type cattle are slower growing, later maturing animals which developed unique attributes which allow them to thrive in the hot, droughty, parasite-infested regions of the world. These characteristics prompted the use of the Brahman breed in various crossbreeding schemes. In addition, Brahmans have been used in the development of several new breeds within the last 75 years which could adapt and perform better than the British breeds in the subtropical regions of the United States.

Nutritional regimes before and after calving determine body weight and condition status, and these parameters greatly influence production efficiency in the British breeds of beef cattle. Information is limited on the relationships between nutritional regime, body weight, body condition and reproduction in the Brahman-type breeds of beef cattle. Beef production in the subtropical regions of the United States could become more efficient if proper management schemes were devised for these unique and functional types of cattle.

CHAPTER III

FACTORS INFLUENCING POSTPARTUM REPRODUCTIVE PERFORMANCE OF SANTA GERTRUDIS COWS

Summary

Ninety-eight pregnant (85 to 160 d of gestation), Santa Gertrudis females at two locations were used in 1983-1985 to determine the influence of body weight and body condition changes during gestation and feeding additional energy after calving on reproductive performance. Routine ranch management and feeding procedures were followed except for the feeding of a high energy diet to one half of the cows commencing 14 days prior to the beginning of the breeding period. Cows were weighed and body condition scores were determined at four periods during the study: mid to late gestation, precalving, breeding and at weaning. Blood samples were obtained by puncture of the tail vein near the beginning of breeding. Concentrations of progesterone in serum were quantified and used to determine the percentage of females with ovarian activity. Pregnancy rate was determined by rectal palpation at weaning. The interval from calving to conception was calculated from the subsequent calving date. Calf weights were recorded at birth, near the beginning of breeding and at weaning.

Change in body weight was related to body condition score change in Santa Gertrudis cows. Body weight change accounted for 59% of the variation in body condition score change from midgestation to breeding in experiment 1 and 19% of the variation in body condition score change from late gestation to breeding in experiment 2. Flushing reduced body weight and body condition loss after calving in both experiments, but did not affect reproductive performance (P>.10). Pregnancy rate was not influenced (P>.10) by body weight or body condition changes either before or after calving. The incidence of ovarian activity near the beginning of breeding was not altered (P>.10) by weight or condition loss before or after calving. Precalving weight change influenced (P<.05) the interval from calving to conception in both experiments. Feeding additional energy did not influence (P>.10) calf weights at breeding or adjusted weaning weights.

Introduction

It has been estimated that 25-30% of the beef cows in the United States do not wean a calf each year, primarily a result of cows not conceiving during the breeding period. Postpartum anestrous is the major factor preventing cows from becoming pregnant (Bellows et al., 1979b, Niswender and Wiltbank, 1984). Ovarian inactivity and anestrous are characteristics of the period following calving and nutritional regime before and after calving influences the onset of estrus (Wettemann et al., 1982).

Recent studies have revealed a close relationship between body condition and body energy reserves (Wright and Russel, 1984; Wagner, 1985). The magnitude of change in body condition and body weight are useful indicators of subsequent reproductive performance in beef cows of primarily British breeding (Whitman, 1975; Dunn and Kaltenbach, 1980; Wettemann et al., 1982). Production efficiency could be enhanced by the development of management factors which would shorten the postpartum interval to conception allowing cows to conceive earlier in the breeding season.

Breed type of cattle influences reproduction and nutritional processes (Cartwright 1980, Frisch and Vercoe 1978, Randel 1980, Turner 1980). Brahman and Brahman-type breeds of cattle have physiological differences which allow them to adapt to the hot, droughty regions of the world where nutrient intake is often restricted.

The relationships between body weight, body condition and reproductive performance may differ between breed types of cattle and should be evaluated in the increasingly popular Brahman-type breeds. Management factors could then be developed to maximize reproductive efficiency. The major purpose of this study was to evaluate the relationships between body weight and condition changes in Santa Gertrudis cows and relate these parameters to reproductive performance. A second objective was to determine if feeding additional energy after calving influenced reproductive and calf performance.

Materials and Methods

Experiment 1

Fifty-three, first-calf Santa Gertrudis heifers, approximately 3 years of age, located on the King Ranch in south Texas, were used in this experiment. Heifers calved between December, 1983 and March, 1984 and grazed bluestem pasture during the entire study. Herd management and feeding procedures for the ranch were followed. Drought conditions limited grazing from February until May 1984 and heifers were provided hay and energy supplement (1.5 kg/d) to prevent excessive body weight and condition loss.

Heifers were weighed and body condition score (1=thin, 9=fat) was determined independently by at least two individuals using both visual appraisal and palpation of body surface (Wagner, 1985) at four periods during the experiment: (1) Midgestation (9/20/83), (2) Precalving (12/7/83), (3) Breeding (4/17/84), and (4) Weaning (8/21/84). Exception to this procedure was during the precalving period when management procedures prevented body weights from being taken and body condition scores were visually determined. At the precalving period, one group of heifers was assigned to the control treatment and the second group was designated to receive additional energy supplement (flush). From February 27 to March 26, 1984 (28 d) heifers assigned to the flushed treatment received an additional 5 kg/d (as-fed) of a 20%

crude protein, high energy ration.

The breeding period began March 12, 1984 and ended on August 20, 1984. Two mature Santa Gertrudis bulls of known fertility were used in each treatment group to minimize the influence of bull fertility on reproductive performance. Pregnancy status was determined by rectal palpation at weaning and the interval from calving to conception was calculated by subtracting 283 d from the 1984-1985 calving date.

One blood sample was obtained from each heifer by puncture of the tail vein near the beginning of the breeding period to determine the proportion of heifers with ovarian luteal activity. Samples were cooled immediately on ice and transported to Stillwater, Oklahoma. Samples were allowed to clot for 24-36 h at 4 C and then centrifuged at 3000x g for 20 minutes. Serum was decanted and stored at -15 C until concentrations of progesterone were determined.

Calves were weighed and identified at birth and remained with their dams on pasture without supplemental grain. Birth weights of all calves were adjusted to a male equivalent by a factor of 1.07 (Hubbard, 1981). Calves were also weighed near the beginning of breeding and at weaning. Actual weaning weights were adjusted for age of dam, sex and age of calf at weaning using Beef Improvement Federation guidelines (Hubbard 1981).

Experiment 2

Forty-five mature, Santa Gertrudis cows located at L&L Farms, in northwest Arkansas, were used in this experiment. Cows calved between March and May 1984 and were maintained on tall fescue pasture from January until September. Cows grazed bermudagrass pasture from September until November. Herd management and feeding procedures for the ranch were followed and cows were offered fescue, orchardgrass or bermudagrass hay when snow or ice covered available winter forage.

Body weights and body condition scores were determined at four periods during the study: (1) Late gestation (1/24/84), (2) Precalving (3/9/84), (3) Breeding (6/6/84), and (4) Weaning (11/27/84). At the precalving period, one group of cows was assigned the control treatment and the other group was designated to receive additional energy supplement (flush). From May 17 to June 15, 1984 (28 d) cows in the flush group received an additional 5 kg/d (as-fed) of a 20% crude protein, high energy ration.

The breeding period began on May 28, 1984 and ended on August 1, 1984. Cows in each group were mated to one mature Santa Gertrudis bull of known fertility. Pregnancy status was determined at weaning by rectal palpation. The interval from calving to conception was determined by subtracting 283 d from the 1985 calving date. Two blood samples were collected from each cow at an 11 d interval near the beginning of breeding (6/7/84 and 6/18/84) and serum was processed and stored as described for experiment 1.

Calves were identified and weighed at birth and remained with their dams until weaning. Calf birth weights were adjusted to a male equivalent by a factor of 1.07 (Hubbard, 1981). A creep ration was offered free choice to all calves from the beginning of breeding until weaning. Calves were weighed near the beginning of breeding and at weaning. Actual weaning weights of calves were adjusted for age of dam, sex and age of calf at weaning as outlined by Beef Improvement Federation (Hubbard, 1981).

Progesterone Analysis

Concentrations of progesterone in serum were quantified by a single antibody, radioimmunoassay (Lusby et al., 1981). A concentration of progesterone greater than or equal to 2 ng/ml in serum was considered to be an indicator of ovarian luteal activity. In Bos taurus cattle, a concentration of greater than 1 ng/ml of plasma has been demonstrated an indicator of luteal activity (Wettemann et al., 1972). Bos indicus cattle may have smaller corpora lutea and lower circulating levels of progesterone than Bos taurus cattle (Randel, 1984). In addition, extra ovarian sources of progesterone may occur (Wagner et al., 1969b; Wendorf et al., 1983) so we chose to be conservative and considered samples with greater than or equal to 2 ng/ml of progesterone to be indicative of luteal activity in Santa Gertrudis females.

Statistical Analyses

Data from experiments 1 and 2 were analyzed separately due to differences in location, environment and management procedures. Means for body weight, weight changes, body condition score, condition score changes, calf weights, calf weight gains, incidence of ovarian activity, pregnancy rate and interval to conception were analyzed using the general linear models least squares analysis of variance procedure with treatment as the main effect. Partial correlation coefficients and regression models were developed to describe the relationships between changes in body weight and body condition score. The model for these analyses included body condition score change, percentage body weight change, age pre- or postpartum of dam, sex of calf and calf gain for each period.

Regression models were developed for the incidence of ovarian activity, pregnancy rate, and the interval from calving to conception. The main effects for these models included body weight, body condition score and changes in body weight and body condition score for each period. For analysis of experiment 2, treatment group was included as a covariate to adjust for differences in body weight.

Results and Discussion

Experiment 1

Body Weight and Body Condition Changes

Body weights, body condition scores (BCS) and changes in these parameters are summarized in table 1. Heifers were in midgestation (85-160 d of pregnancy) at the beginning of the experiment and body weights of flushed (545.9 ± 7.2 kg) and control heifers (540.5 ± 7.0 kg) were similar ($P > .10$). In addition, both groups of heifers were in good body condition at the beginning of the study ($6.50 \pm .07$ and $6.51 \pm .06$, for control and flushed heifers, respectively). Body weights of heifers were not measured at the precalving period, however the increase in body condition score (.44 and .36 units for control and flushed heifers, respectively) would suggest body weight increased from midgestation to precalving. Body condition score of control heifers ($6.94 \pm .04$) was not significantly different from that of flushed heifers ($6.85 \pm .08$) at the precalving period.

During the interval from midgestation to breeding, flushed heifers were fed 5 kg/d of a 20% crude protein, high energy diet for 28 days. The short term feeding of additional energy affected both body weight and body condition changes of the heifers. Flushed heifers lost less ($P < .009$) weight (-49.5 ± 7.1 kg) compared to control heifers (-77.0 ± 7.6 kg)

TABLE 1. BODY WEIGHT AND BODY CONDITION CHANGES OF SANTA GERTRUDIS HEIFERS FROM SEPTEMBER 1983 UNTIL AUGUST 1984 (EXPERIMENT 1)

	Treatment	
Period	Control	Flushed
Weight[a]	Mean[b]	Mean
Midgestation (9/20/83)	545.9±7.2 (25)	540.5±7.0 (28)
Breeding (4/17/84)	468.9±10.7 (25)	493.4±10.6 (27)
Weaning (8/21/84)	475.0±8.9 (25)	486.0±10.6 (28)
Weight Changes		
Midgestation - Breeding	-77.0±7.6 (25)[c]	-49.5±7.1 (27)[d]
Breeding - Weaning	6.0±6.9 (25)	-5.6±3.4 (27)
Body Condition Score		
Midgestation (9/20/83)	6.50±.07 (25)	6.51±.06 (28)
Precalving (12/7/83)	6.94±.04 (25)	6.85±.08 (27)
Breeding (4/17/84)	5.46±.13 (25)[e]	5.81±.14 (27)[f]
Weaning (8/21/84)	5.09±.11 (25)	5.33±.12 (28)
Body Condition Changes		
Midgestation - Precalving	0.44±.07 (25)	0.36±.07 (26)
Precalving - Breeding	-1.48±.13 (25)[e]	-1.00±.14 (26)[f]
Breeding - Weaning	-0.38±.16 (25)	-0.46±.08 (27)

[a] Body weight in kg

[b] Mean±S.E.; ( ) denotes number of observations

[c,d] Means differ p<.05 [e,f] Means differ p<.10

from midgestation until breeding. Control heifers tended ($P>.13$) to be lighter (468.9±10.7 kg) than flushed heifers (493.9± 10.6 kg) near the beginning of breeding. These data are in agreement with a Louisiana study (Loyacano et al., 1974) which found that short term grain feeding significantly increased cow weight gains during spring and decreased weight loss during the winter months.

Changes in body condition were related to weight changes from from midgestation to breeding for heifers on both treatments. Flushed heifers lost less ($P<.09$) body condition (-1.00 units of BCS) compared to control heifers (-1.48 units of BCS) from precalving to breeding. Body condition score was greater ($P<.07$) for flushed heifers (5.81±.14) compared to control heifers (5.46±.13) near the beginning of breeding.

Heifers on both treatments lost body condition from breeding to weaning. Condition loss was slightly less ($P>.10$) for control heifers (-.38 units of BCS) compared to flushed heifers (-.46 units of BCS). However, flushed heifers were in slightly better ($P>.20$) body condition (5.33±.12) than control heifers (5.09±.11) at weaning. Body weight changes were minimal ($P>.13$) for heifers of both treatment groups from breeding to weaning (6.0 kg and -5.6 kg for control and flushed heifers, respectively). Body weights were similar ($P>.20$) for control (475.0±8.9 kg) and flushed heifers (486.0±10.6 kg) at weaning.

Partial correlation coefficients (adjusted for treatment, calf sex, calf gain and age postpartum) for body condi-

TABLE 2. PARTIAL CORRELATION COEFFICIENTS FOR BODY CONDITION SCORE CHANGES AND PERCENTAGE BODY WEIGHT CHANGES OF SANTA GERTRUDIS HEIFERS (EXPERIMENT 1)

Period	r	Prob.[a]
Midgestation to Breeding	.52	.0001
Breeding to Weaning	.42	.002
Midgestation to Weaning	.58	.0001

[a] Significance level (Pr> F)

tion score change and percentage body weight change are presented by period in table 2. Significant correlations for each period would indicate that changes in body condition score were related to body weight changes. The relationship between change in body condition score and body weight change from midgestation to breeding was .52 ($P<.0001$) and from breeding to weaning was .42 ($P<.002$). As would be expected, the greatest relationship between these two parameters ($r=.58$, $P<.0001$) occurred from midgestation to weaning, as the greatest changes in weight and condition occured during this period. A Montana study (Nelsen et al., 1985) found similar positive correlations between visually assigned body condition scores and actual live weight in pregnant, non-lactating Hereford ($r=.61$) and crossbred ($r=.62$) beef cows. Likewise, Wagner (1985) obtained a correlation of .84 between live weight and body condition score for nonpregnant, non-lactating beef cows.

Regression analyses for the influence of percentage body weight change, treatment, sex of calf, calf gain and age postpartum of dam on body condition change are summarized by period in table 3. The regression model was significant in describing body condition score change of heifers for each period of the study and R^2 values indicate that this model accounted for approximately 60%, 44% and 50% of the variation in body condition score change for the periods midgestation to breeding, breeding to weaning and midgestation to weaning, respectively. The primary factor influencing change in body

TABLE 3. REGRESSION ANALYSES FOR INFLUENCE OF PERCENTAGE BODY WEIGHT CHANGE, TREATMENT, CALF SEX, CALF GAIN AND AGE POSTPARTUM ON BODY CONDITION SCORE CHANGE OF SANTA GERTRUDIS HEIFERS (EXPERIMENT 1)

Period	df		Prob.[a]	R^2
Midgestation to Breeding				
Model	5		.0001	.60
body weight change (%)		1	.001	
treatment		1	.73	
calf sex		1	.72	
calf gain		1	.37	
age postpartum		1	.30	
Error	47			
Breeding to Weaning				
Model	5		.0001	.44
body weight change (%)		1	.002	
treatment		1	.92	
calf sex		1	.95	
calf gain		1	.84	
age postpartum		1	.20	
Error	47			
Midgestation to Weaning				
Model	5		.0001	.50
body weight change (%)		1	.0001	
treatment		1	.92	
calf sex		1	.72	
calf gain		1	.39	
age postpartum		1	.52	
Error	47			

[a] Probability of a greater T for the hypothesis, Ho: parameter = 0

condition score was body weight change. For each period of the study, body condition score change was influenced by percentage body weight change. Changes in body condition were not influenced ($P>.20$) by treatment or age postpartum of the dam. In addition, sex of calf and calf gain during each period did not affect ($P>.20$) body condition score change of heifers. In contrast, mature Hereford or Angus cows nursing either bull or steer calves lost significantly more condition than cows nursing heifer calves (Wagner, 1985).

Wright and Russel (1984) found that each 1 unit change in body condition score (1=thin, 5=fat) was associated with a live weight change of 100 kg in Hereford x Friesian, Blue-Grey, Galloway and Luing cows (ranging in live weight from 320 to 720 kg) in Great Britain. Based on the regression coefficient generated by the model in table 14 for the period midgestation to breeding, each 1 unit change in body condition score (1=thin, 9=fat) is associated with a 20% change in live weight (approximately 100 kg for Santa Gertrudis heifers ranging in live weight from 400 - 600 kg). However, the magnitude of the R^2 value would limit the use of this model for prediction purposes to Santa Gertrudis heifers in body condition score of 4 to 7 and ranging in weight from 400 - 600 kilograms.

Reproductive Performance

Reproductive performance of heifers in experiment 1 is summarized in table 4. Regression models used to determine the relationships between body weight, body condition and reproductive performance are summarized in table 5. All heifers were in good body condition at the beginning of the study (table 1) and remained in moderate body condition through weaning. Excellent pregnancy rates were obtained for heifers on both treatments.

Body weight, body condition and changes in weight and condition prior to breeding influence the onset of first postpartum estrus (Whitman, 1975; Dunn and Kaltenbach, 1980). Wettemann et al. (1982) found a 10% decrease in body weight before calving delayed first estrus by 19 days. Heifers on both treatments were similar and in good to moderate body condition both precalving and near the beginning of breeding.

The percentage of heifers with greater than 2 ng/ml progesterone at the time of bleeding (72.0% and 71.4% for control and flushed heifers, respectively) was not influenced ($P>.10$) by treatment. Likewise, absolute body weight and body condition either prepartum or near the beginning of breeding did not influence ($P>.15$) the proportion of heifers with greater than 2 ng/ml of progesterone. Wiltbank et al. (1981) found that only 43% of Santa Gertrudis cows which were in thin body condition at calving exhibited estrus during breeding, compared to 78% of cows which were in moderate body

TABLE 4. REPRODUCTIVE PERFORMANCE OF SANTA GERTRUDIS HEIFERS (EXPERIMENT 1)

Item	Control		Flushed	
	N	Mean [a]	*N*	Mean
Beginning of breeding				
age prepartum	5	20	3	19.4
age postpartum	20	63.2	25	58.4
Age postpartum at time of bleeding	25	82.5±8.1	27	86.1±6.4
(range)		(9 to 133)		(3 to 130)
Percentage of heifers with greater than 2 ng/ml progesterone at time of bleeding	25	72.0±.09	27	71.4±.08
Pregnancy rate (%) [b]	25	100	28	96.4
Age postpartum at beginning of breeding for heifers used to determine the interval from calving to conception	12	35.5±11.7	21	54.0±8.1
Interval from calving [c] to conception	12	78.0±5.5	21	92.5±7.0

[a] Mean±S.E.

[b] Determined by rectal palpation at weaning

[c] Date of conception calculated by subtracting 283 d from 1984-1985 calving date

condition at calving.

Change in body weight ($P<.10$, $R^2 =.05$) and body condition score change ($P<.05$, $R^2 =.08$) from midgestation to breeding influenced the occurrance of greater than 2 ng/ml of progesterone in serum of heifers at the time of bleeding. However, considering only one blood sample was taken and the low R^2 values of these relationships, precise estimates of performance could not be made based on these models. Reduced ovarian activity has been observed in Hereford cows which incurred severe body weight and condition losses prior to breeding (Rakestraw, 1984).

At the beginning of breeding, 5 control heifers and 3 flush heifers had not yet calved and heifers which had calved averaged 85 days postpartum when blood samples were taken. In addition, based on the 1984-1985 calving dates for heifers that calving dates were available, 91% and 60% of heifers on control and flushed treatments, respectively, had conceived by the time blood samples were taken. Although actual ovarian activity near the beginning of breeding was not determined, it appears that a high percentage of heifers on both treatments were experiencing regular ovarian cycles.

The interval from calving to conception was calculated by subtracting 283 d from the 1984-1985 calving date. Calving data was not available for all pregnant heifers. Although not significantly different between treatment groups, the interval to conception was greater for flushed heifers (92.5 ± 7.0 d) compared to control heifers (78 ± 5.5 d). The primary factor

TABLE 5. SUMMARY OF REGRESSION MODELS USED TO DETERMINE RELATIONSHIPS BETWEEN BODY WEIGHT AND BODY CONDITION WITH REPRODUCTIVE PERFORMANCE OF SANTA GERTRUDIS HEIFERS (EXPERIMENT 1)

	Reproductive criteria[a,b]		
Item	Progesterone> than 2ng/ml	Interval to Conception	Pregnancy rate
Body Condition Score			
midgestation	.15 (.04)	.76 (.00)	.14 (.04)
precalving	.96 (.00)	.34 (.02)	.23 (.03)
breeding	.17 (.03)	.20 (.05)	.84 (.00)
Body Condition Change			
midgestation - precalving	.21 (.03)	.61 (.05)	.76 (.00)
midgestation - breeding	.04 (.08)	.21 (.05)	.63 (.00)
breeding - weaning	—	.33 (.03)	.78 (.00)
Body Weight			
midgestation	.49 (.00)	.78 (.00)	.27 (.02)
breeding	.42 (.01)	.15 (.06)	.88 (.00)
Body Weight Change			
midgestation - breeding	.10 (.05)	.05 (.12)	.45 (.01)
breeding - weaning	—	.22 (.05)	.90 (.00)

[a] Significance level (Pr >F)

[b] ( ) R^2 value of model in parentheses

— Data not used in analysis

influencing the interval from calving to conception between treatment groups was age postpartum of heifers at the beginning of breeding. For heifers that calving dates were available, age postpartum was greater for flushed (54.0±8.1 d) compared to control heifers (35.5±11.7 d). Thus, a greater interval from calving to the beginning of breeding for the flushed compared to the control heifers is the probable cause of the greater interval from calving to conception for the flushed heifers. Feeding additional energy following calving did not influence the postpartum interval to conception in a regional project involving 6 breeds of cows (Wettemann et al., 1984).

Body condition score at midgestation, precalving or near the beginning of breeding and changes in condition between these periods did not influence ($P>.20$) the interval from calving to conception. Similarly, body condition change during pregnancy in Hereford range cows was not related to the postcalving interval to conception (Selk et al., 1985).

Change in body weight from midgestation to precalving influenced ($P<.05$) the interval from calving to conception. The regression coefficient for this model (table 15) would indicate that for each 10% loss in body weight from midgestation to breeding, the interval from calving to conception would increase by 13 days. However, the low R^2 value (.12) limits the usefulness of this model for prediction purposes. Similarly, each 10% loss in body weight prior to calving was found to delay the interval to conception by 16 days in Hereford cows (Wettemann et al., 1982).

Pregnancy rate for all heifers in this experiment (100% and 96.4% for control and flushed heifers, respectively) was maximal and thus the short term feeding of additional energy during breeding did not influence (P>.20) pregnancy rate. Richards (1984) found that flushing improved reproductive performance of mature beef cows which had incurred severe weight and condition losses prior to calving. The lack of an effect of flushing in this study may be due to the increase in body condition from midgestation to precalving.

Pregnancy rate of heifers was not influenced (P>.10) by body weight, weight changes, body condition, and body condition changes at any time during the experiment (table 5). The failure of these parameters to influence pregnancy rate would likely be expected, as heifers in this study were in good body condition precalving (6.94±.04 and 6.85±.08 for control and flushed heifers, respectively) and moderate body condition at breeding (5.46±.13 and 5.81±.14 for control and flushed heifers, respectively). Moderate to good body condition at the start of breeding was found to be essential for obtaining maximum pregnancy rates of beef cows in south Texas (Sprott et al., 1980).

Although control heifers lost significantly more weight from midgestation to breeding (-77.0 kg vs. -49.5 kg, respectively) and body condition from precalving to breeding (-1.48 vs. -1.00 units of BCS, respectively) than flushed heifers, pregnancy rate was not influenced because the heifers were still in good body condition. Wiltbank et al. (1981) found pregnancy rate in Santa Gertrudis cows in Texas was influenced by precalving body condition. Only 24% of cows which calved in thin body condition became pregnant compared to 87% of cows which calved in good body condition.

Calf Performance

Body weights and weight gains of calves from experiment 1 are presented in table 6. Weight at birth of calves from control heifers (35.4 kg) was slightly greater ($P<.06$) compared to calves from flushed heifers (32.4 kg). Milk production of the dam is the primary factor influencing preweaning calf growth. If nutrient intake of the dam is restricted during the postpartum period, feeding additional energy may increase milk production and enhance preweaning weight gain. However, in this experiment the feeding of additional energy during breeding did not influence calf growth. Weights of calves from control (111.7 kg) and flushed (108 kg) cows were similar ($P>.20$) near the beginning of breeding.

Daily gains to weaning were similar ($P>.05$) between treatments (.92 kg/d for calves from both control and flushed cows). A six state regional study (Wettemann et al., 1984) found that short term feeding of additional energy to beef cows during breeding increased weaning weights. Flushing cows during the breeding period did not influence weight gain to weaning or weaning weight of calves in this study. Actual

TABLE 6. CALF PERFORMANCE[a] (EXPERIMENT 1)

Item	Treatment		
	Control	Flushed	Prob.[b]
No. Calves	25	28	
Birth Weight[c]	35.4±1.3	32.4±0.9	.06
Weight at Breeding	111.7±5.9	108.0±5.4	.65
Actual Weaning Weight	227.1±9.6	227.8±8.0	.95
Adj. 205-day Weight[d]	241.8±7.2	239.8±6.0	.83
Adj. 205-day ADG[d]	0.92±.03	0.92±.03	.91

[a] Weight and weight gains in kg

[b] Significance level (Pr> F)

[c] Birth weight adjusted for sex

[d] BIF guidelines

(227.1 vs. 227.8 kg for control and flushed calves, respectively) and adjusted 205-day weaning weights (241.8 vs. 239.8 kg for control and flushed calves, respectively) were not significantly different. Similarly, Loyacano et al. (1974) found no significant difference between weaning weights of calves from either flushed or non-flushed cows.

Experiment 2

Body Weight and Body Condition Changes

Body weights, body condition scores (BCS) and changes in weight and condition for experiment 2 are summarized in table 7. The unequal number of cows per treatment resulted from the number of cows assigned to each breeding group as specified by procedures for this ranch. In addition, it was not anticipated that a number of the cows on the control treatment would calve late and these animals would need to be excluded from the analysis.

The breeding program at the ranch dictated which cows would be assigned to each breeding pasture and nutritional treatment. This assignment resulted in heavier cows ($P<.03$) on the flush treatment at the beginning of the experiment (648.6 ± 15.1 kg) compared to cows on the control treatment (601.4 kg$\pm$11.9 kg). Both groups of cows were in good body condition at the beginning of the experiment and body condition scores were similar ($P>.20$) for flushed ($6.42 \pm .15$) and

TABLE 7. BODY WEIGHT AND BODY CONDITION CHANGES OF SANTA GERTRUDIS COWS FROM JANUARY 1984 UNTIL NOVEMBER 1984 (EXPERIMENT 2)

	Treatment			
Period	Control		Flushed	
Weight [a]	Mean [b]		Mean	
Late gestation (1/24/84)	601.4±11.9	(17)[c]	648.6±15.1	(28)[d]
Precalving (3/9/84)	602.7±10.8	(17)[c]	641.3±14.0	(28)[d]
Breeding (6/6/84)	570.5±11.1	(16)[c]	618.6±13.2	(28)[d]
Weaning (11/27/84)	565.0±12.6	(17)[e]	599.0±14.7	(28)[f]
Weight Changes				
Late gestation-Precalving	1.3±2.7	(17)[e]	-7.3±3.0	(28)[f]
Precalving - Breeding	-32.2±6.4	(16)	-22.7±4.4	(28)
Breeding - Weaning	-5.5±8.0	(16)	-19.6±5.5	(28)
Body Condition Score				
Late gestation (1/24/84)	6.25±.16	(17)	6.42±.15	(28)
Precalving (3/9/84)	6.10±.19	(17)	6.23±.16	(28)
Breeding (6/6/84)	6.00±.15	(16)	6.11±.17	(28)
Weaning (11/27/84)	6.00±.17	(17)	6.05±.15	(28)
Body Condition Changes				
Late gestation-Precalving	-0.15±.11	(17)	-0.19±.06	(28)
Precalving-Breeding	-0.10±.12	(16)	-0.12±.08	(28)
Breeding - Weaning	0.00±.15	(16)	-0.06±.13	(28)

[a] Body weight in kg

[b] Mean±S.E.; ( ) denotes number of observations

[c,d] Means differ p<.05 [e,f] Means differ p<.10

control cows (6.25±.16).

From late gestation to precalving, weight change was slightly greater ($P<.07$) for cows assigned to the group to be flushed after calving (-7.3 kg) compared to control cows (1.3 kg). If cows are consuming sufficient energy, maternal loss of body weight during pregnancy would be expected to be offset by weight gain resulting from fetal growth. At the precalving period, body weight was greater ($P<.05$) for flushed (641.3±14.0 kg) compared to control cows (602.7±10.8 kg). Minimal changes in body condition occurred from late pregnancy to precalving and precalving body condition score was similar ($P>.20$) between treatment groups (6.10±.19 and 6.23±.16 for control and flushed cows, respectively). Likewise, Wagner (1985) found that winter weight and condition losses under range conditions were greater for heavier weight, fatter conditioned cows compared to thinner, lighter weight cows.

Flushed cows received additional energy supplement during the last two weeks of the period from precalving to breeding. Although not significant, the short term feeding of additional energy reduced ($P>.20$) body weight loss in flushed (-22.7±4.4 kg) compared to control cows (-32.2±6.4 kg). Short term feeding (25 d) of additional energy, beginning on day 25 postpartum, in Africander and Mashona beef cows, compensated for body weight losses incurred prepartum (Holness et al., 1978). Flushed cows were heavier ($P<.02$) than control cows at breeding, 618.6±13.2 kg and 570.5±11.1 kg, respectively.

Changes in body condition followed body weight changes from precalving until breeding. Condition changes of -.10 and -.12 units occurred in control and flushed cows, respectively. Body condition score was similar (P>.20) between treatment groups at breeding (6.00±.15 and 6.11±.17 for control and flushed cows, respectively).

Cows on the flush treatment received additional energy supplement during the first two weeks of the period from breeding to weaning. Feeding of additional energy did not influence (P>.15) change in body weight or body condition. Control cows lost less weight (P>.15; -5.5 kg) compared to flushed cows (-19.6 kg) from the beginning of breeding until weaning. Body weights were greater (P<.10) for flushed cows (599.0±14.7 kg) than for control cows (565.0±12.6 kg) at weaning. Body condition score of control cows did not change (6.00±.17) from breeding to weaning and flushed cows had a slight decrease in body condition (6.05±15).

Partial correlation coefficients (adjusted for treatment, calf gain, calf sex, and age pre- or postpartum of dam) for changes in body condition score and percentage body weight change are presented by period in table 8. Change in condition score throughout the entire study was minimal. The maximum average change in body condition score was -.37, which occurred in flushed cows from late pregnancy until weaning. Body weight and condition change were not correlated (r=.007) from late gestation to precalving. Significant correlations between change in body condition and body weight

TABLE 8. PARTIAL CORRELATION COEFFICIENTS FOR BODY CONDITION SCORE CHANGES AND PERCENTAGE BODY WEIGHT CHANGES OF SANTA GERTRUDIS COWS (EXPERIMENT 2)

Period	r	Prob.[a]
Late Gestation to Precalving	.007	.97
Late Gestation to Breeding	.34	.03
Precalving to Breeding	.35	.02
Breeding to Weaning	.52	.0004
Late Gestation to Weaning	.73	.0001

[a] Significance level (Pr> F)

change occurred from precalving to breeding (r=.35) and from breeding to weaning (r=.52). As would be expected, the greatest correlation between these parameters (r=.73) occurred from late gestation to weaning and the largest changes in both variables occurred during this period. Change in body weight and body condition were highly correlated both prepartum (r=.60) and postpartum (r=.70) in Hereford range cows (Garmendia, 1984).

Regression analyses for the influence of percentage body weight change, treatment, sex of calf, calf gain and age pre- or postpartum of dam on body condition change are summarized by period in table 9. Similar to experiment 1, the primary factor influencing change in body condition score was body weight change. The regression model was significant in describing body condition change of cows for the periods breeding to weaning and late gestation to weaning. The R^2 values would indicate that these models accounted for approximately 37% and 55% of the variation in body condition score change, for the periods breeding to weaning and late gestation to weaning, respectively. For these periods, body condition score change was influenced (P<.01) by percentage change in body weight.

Changes in body condition score were not affected (P>.20) by treatment, sex of calf or age of dam pre- or postpartum during the experiment. Calf weight gain influenced (P<.05) body condition change (P<.05) from the beginning of breeding until weaning. However, this relationship was most likely a

TABLE 9. REGRESSION ANALYSES FOR INFLUENCE OF PERCENTAGE BODY WEIGHT CHANGE, TREATMENT, CALF SEX, CALF GAIN AND AGE POSTPARTUM ON BODY CONDITION SCORE CHANGE OF SANTA GERTRUDIS COWS (EXPERIMENT 2)

Period	df		Prob.[a]	R^2
Late gestation to Precalving				
Model	2		.61	.02
Error	42			
Precalving to Breeding				
Model	5		.33	.13
body weight change (%)		1	.02	
treatment		1	.50	
calf sex		1	.92	
calf gain		1	.56	
age postpartum		1	.53	
Error	39			
Breeding to Weaning				
Model	5		.002	.37
body weight change (%)		1	.0002	
treatment		1	.91	
calf sex		1	.68	
calf gain		1	.05	
age postpartum		1	.67	
Error	39			
Late gestation to Breeding				
Model	5		.12	.19
body weight change (%)		1	.03	
treatment		1	.56	
calf sex		1	.58	
calf gain		1	.44	
age postpartum		1	.71	
Error	39			
Late gestation to Weaning				
Model	5		.001	.55
body weight change (%)		1	.001	
treatment		1	.83	
calf sex		1	.64	
calf gain		1	.40	
Error	40			

[a] Probability of a greater T for the hypothesis, Ho: parameter = 0.

result of the creep ration offered calves rather than maternal influence. The model developed to describe body condition score change was not significant and R^2 values were low, .02, .13 and .19 for the periods late gestation to precalving, precalving to breeding and late gestation to breeding, respectively. Immediate postcalving body weights of cows were not obtained and therefore weight change from precalving to breeding would include weight loss of the calf, fetal membranes and fluids as well as cow weight changes. This may influence the relationship between weight and condition change during these periods. However, only minimal changes in body condition occurred from late pregnancy to breeding and are reflected in the small relationships which were observed. Based on the regression coefficient of the model in table 16, for the period midgestation to weaning, each 1 unit change in body condition score is associated with a 14% change in live weight (approximately 85 kg for Santa Gertrudis cows ranging in weight from 450 - 770 kg). Wagner (1985) observed a 1 unit change in body condition score (1=thin, 9=fat) of nonpregnant, nonlactating Hereford cows was associated with a live weight change of approximately 38 kilograms. However, similar to experiment 1, the low R^2 value, limits the use of this model for prediction purposes to Santa Gertrudis cows in body condition score of 5 to 8, and ranging in live weight from 450 - 770 kilograms.

Reproductive Performance

Reproductive performance of cows in experiment 2 is presented in table 10. Regression models used to determine the relationships between body weight, body condition and reproductive performance of cows are summarized in table 11. Results of reproductive performance for cows in this study are similar to those obtained for heifers in experiment 1.

The proportion of cows with ovarian activity near the beginning of the breeding period was determined by concentrations of progesterone in serum greater than or equal to 2 ng/ml in one of two samples collected at an interval of 11 days. The percentage of cows with ovarian activity near the beginning of breeding was not influenced ($P>.20$) by treatment (88.2% and 82.1% for control and flushed cows, respectively). A regional study involving beef cows in six southern states obtained similar results (Wettemann et al., 1984).

Body condition and condition changes before and after calving did not affect ($P>.20$) the incidence of ovarian activity near the beginning of breeding. This could be expected since changes in body condition from late gestation until breeding were minimal (table 7). Severe condition loss after parturition has been shown to reduce the incidence of ovarian activity at the beginning of the breeding period in fall calving Hereford cows (Rakestraw, 1984).

Body weight loss after calving delays the onset first estrus (Wettemann et al., 1982). Bellows and Short (1978)

TABLE 10. REPRODUCTIVE PERFORMANCE OF SANTA GERTRUDIS COWS (EXPERIMENT 2)

Item	Treatment			
	Control		Flushed	
	N	Mean[a]	N	Mean
Percentage of cows with ovarian activity near the beginning of breeding[b]	17	88.2±.08	28	82.1±.07
Pregnancy rate (%)[c]	12	58.8	19	67.8
Pregnancy rate for cows with ovarian activity near the beginning of breeding (%)	12	66.6	19	82.5
Interval from calving to conception[d]	12	78.5±5.8	19	89.6±4.5

[a] Mean±S.E.

[b] Ovarian activity characterized by concentration of progesterone in serum equal to or exceeding 2 ng/ml

[c] Determined by rectal palpation at weaning

[d] Date of conception calculated by subtracting 283 d from 1985 calving date

found that beef cows gaining body weight and condition before calving had a greater incidence of ovarian activity prior to the beginning of breeding. Results of this study indicated that ovarian activity was related ($P<.07$) to weight loss from precalving to breeding and ovarian function was greater in cows that lost weight (table 17). Ovarian function in Santa Gertrudis cows may not be as sensitive to prebreeding body weight loss as females of the British breeds. Cows in this study experienced weight losses of approximately 4% of their body weight from precalving to breeding. Rakestraw (1984) reported that weight losses of between 6-17% before breeding reduced the incidence of ovarian activity by the beginning of breeding. However, The low R^2 value of this relationship ($R^2 = .08$) would indicate the model should not be used to predict the incidence of ovarian activity in Santa Gertrudis cows based on prebreeding weight change.

The interval from calving to conception was calculated by subtracting 283 d from the 1985 calving date. The interval was slightly shorter ($P>.14$) for control cows (78.5 ± 5.0 d) compared to flushed cows (89.6 ± 4.5 d). Body condition and condition changes did not influence ($P>.20$) the interval to conception. The interval from calving to conception was not influenced by weight or condition loss of Hereford cows either before (82 d) and after breeding (86d) (Rakestraw, 1984).

The interval from calving to conception was influenced ($p<.06$) by body weight change from precalving to breeding.

TABLE 11. SUMMARY OF REGRESSION MODELS USED TO DETERMINE RELATIONSHIPS BETWEEN BODY WEIGHT AND BODY CONDITION WITH REPRODUCTIVE PERFORMANCE OF SANTA GERTRUDIS COWS (EXPERIMENT 2)

	Reproductive Criteria [a,b]		
Item	Ovarian activity	Interval to Conception	Pregnancy rate
Body Condition Score			
late gestation	.75 (.00)	.52 (.09)	.49 (.02)
precalving	.95 (.00)	.95 (.07)	.73 (.01)
breeding	.57 (.01)	.89 (.07)	.82 (.00)
Body Condition Change			
late gestation - precalving	.44 (.02)	.27 (.19)	.54 (.02)
precalving - breeding	.28 (.03)	.92 (.07)	.83 (.00)
breeding - weaning	—	.48 (.09)	.79 (.01)
Body Weight			
late gestation	.65 (.01)	.64 (.08)	.73 (.01)
precalving	.50 (.02)	.55 (.08)	.79 (.01)
breeding	.16 (.05)	.87 (.07)	.86 (.00)
Body Weight Change			
late gestation - precalving	.32 (.03)	.62 (.08)	.63 (.01)
precalving - breeding	.07 (.08)	.06 (.18)	.73 (.01)
breeding - weaning	—	.36 (.10)	.74 (.01)

[a] Significance level (Pr >F)

[b] ( ) R^2 value of model in parentheses

— Data not used in analysis

The regression coefficient for this model (table 18) indicates that for each 10% loss in body weight from pre-calving to breeding, the interval to conception would increase by 16 days. These findings are similar to those obtained for heifers in experiment 1.

Weight loss from precalving to breeding was reduced slightly in flushed compared to control cows (-22.7 ± 4.4 kg vs. -32.2 ± 6.4, respectively). Pregnancy rate of cows was not influenced ($P > .20$) by treatment, 67.8% and 58.8% for flushed and control cows, respectively. However, when expressed as a percentage of cows with ovarian activity near the beginning of breeding, pregnancy rate was greater for flushed (82.5%) compared to control cows (66.6%). These findings suggest that fertilization failure or early embryonic death may have occurred in those cows which did not receive additional supplement during breeding. Absolute body weight, body condition or changes in weight or condition did not influence ($P > .20$) pregnancy rate (table 11). Cows were in good body condition prior to calving and condition change was minimal from late pregnancy to weaning (-.25 and -.37 for control and flushed cows, respectively). Reduced pregnancy rates have been observed in Brahman and Santa Gertrudis cows which incurred severe weight losses prior to breeding (Warnick et al., 1967). However, absolute body weight or weight changes during late gestation did not influence ($P < .05$) pregnancy rate of Hereford range cows (Selk et al., 1985).

Results of this experiment were similar to those obtained in experiment 1. The minimal changes in body weight and body condition which occurred resulted in little variation between these two parameters, and therefore these factors had limited influence on reproductive performance. The less than optimal pregnancy rates of cows on both treatments of this experiment was of particular interest. Pregnancy rate of cows on both treatments could not be explained by changes in body weight or body condition before or after calving (table 11). In addition, a high percentage of both control and flushed cows were experiencing cyclic ovarian activity near the beginning of breeding (table 10).

Perhaps other environmental factors could have contributed to the less than optimal fertility. Cows in this study grazed tall fescue pasture and were offered fescue, orchardgrass or bermudagrass hay during the winter. It has been suggested that an endophytic fungus (Acremonium coenophailum), which is present in a large percentage of tall fescue, contains alkaloidal toxins which may reduce animal performance. The presence of these alkaloids has been associated with elevated body temperature and altered endocrine function. Either of these factors may influence reproductive processes in cattle.

Calf Performance

Body weights and weight gains of calves from experiment 2 are summarized in table 12. Birth weights of calves from flushed cows were slightly greater ($p<.08$) than for calves from control cows, 40.7 and 37.1 kg, respectively. Calf performance in this experiment was similar to that for calves in experiment 1. Milk production was apparently not influenced by feeding additional energy during breeding, since calf weights at breeding were similar, 112.3 and 117.7 kg for calves from control and flushed cows, respectively.

From the beginning of breeding to weaning, calves on both treatments were offered a free choice creep ration. Daily gain from birth to weaning was slightly greater for calves from flushed cows compared to control cows (1.11 vs. 1.05 kg/d, respectively). Actual weaning weights were greater ($P<.03$) for calves from flushed cows (318.5 kg) compared to calves from control cows (281.1 kg). However, when weights were adjusted to a 205-day equivalent (253.6 vs. 270.4 kg for control and flushed calves, respectively) no significant differences were observed between calves of either treatment group. Although actual milk production was not measured, it appears that if sufficient forage is available and minimal supplement is provided, milk production of Santa Gertrudis cows is not increased by feeding additional energy.

TABLE 12. CALF PERFORMANCE[a] (EXPERIMENT 2)

Item	Treatment		Prob.[b]
	Control	Flushed	
No. Calves	17	28	
Birth Weight[c]	37.1±1.1	40.7±1.4	.08
Weight at Breeding	112.3±7.2	117.7±3.8	.12
Actual Weaning Weight	281.1±4.7	318.5±9.9	.03
Adj. 205-day Weight[d]	253.6±4.6	270.4±5.7	.77
Adj. 205-day ADG[d]	1.05±.17	1.11±.18	.82

[a] Weight and weight gains in kg

[b] Significance level (Pr> F)

[c] Birth weight adjusted for sex

[d] BIF guidelines

Discussion

Relationships between body weight and body condition changes for Santa Gertrudis cows are similar to those previously reported for beef cows of British breeding (Dunn et al., 1983; Wright and Russel, 1984; Wagner, 1985). Changes in body weight were associated with body condition changes from mid to late pregnancy until weaning for Santa Gertrudis cows in both experiments. Location, environment and management procedures were important factors influencing the magnitude of changes in these parameters. For example, heifers in the Texas experiment had greater weight and condition changes than cows in the Arkansas study, and the greater changes were associated with stronger relationships between changes in weight and body condition score.

Data from experiments 1 and 2 were pooled and analyzed to provide more animals and a greater range in body weight and body condition. Partial correlation coefficients (adjusted for location and treatment) for changes in body condition score and percentage body weight change are presented in table 19. Combining data from both experiments resulted in slightly larger correlations for these parameters (r=.66, .59 and .71 for the periods mid-late gestation to breeding, breeding to weaning, and mid-late gestation to weaning, respectively). A regression model was developed to describe change in body condition score and body weight (table 20) using the combined data set. The model included percentage change in body weight, location, and treatment and was significant in describing body condition score change for the three periods of the study. Regression coefficients were similar to those obtained in experiment 2, in which a live weight change of 13-14% was associated with a 1 unit change in body condition score. As would be expected, location (environment) was a significant factor influencing body condition changes of cows for the periods breeding to weaning and mid-late gestation to weaning. Treatment did not influence ($P>.20$) body condition change of cows. Greater variation in both body weight and body condition changes of cows would have permitted the development of prediction models which would describe changes in both weight and condition of cows from thin to fat body condition.

Minimal changes in body weight and body condition and the similarity of the body energy reserves of cows within each herd resulted in little overall variation in these parameters. Although cows in both experiments were provided supplemental energy to prevent excessive weight and condition losses, other factors may be involved in the minimal weight and condition losses which occurred. Differences in maintenance requirements (Vercoe, 1970) and efficiency of nutrient utilization (Ashton, 1962; Vercoe et al., 1972) of Brahman-type cattle may be related to their ability to minimize body weight and body condition changes. Frisch and Vercoe (1977) found that Brahman-cross steers maintained heavier live weights than Hereford x Shorthorn steers on similar amounts of low quality forage. Brahman-type cattle have the ability to rapidly alter metabolic rate to meet the nutrient availibility of a specific environment (Frisch and Vercoe, 1978). Because of the lower maintenance energy requirements of Brahman-type cattle, rate of weight loss may be less under restricted nutritional conditions when compared to the British breeds of beef cows. These breed characteristics could certainly prove advantageous when forage availibility is limited.

Body weight, body condition and changes in weight and condition before and following calving influence rebreeding performance in beef cows of primarily British breeding (Whitman, 1975; Dunn and Kaltenbach, 1980). Considering the management conditions of experiment 1, it appears that good body condition before calving and moderate to good body condition at the beginning of breeding are sufficient to obtain excellent pregnancy rates. However, environmental factors also appear to be important, as cows in experiment 2 remained in good body condition from late pregnancy until weaning and somewhat less than optimal reproductive performance was obtained.

The possible effects of fescue toxicity on reproductive performance of cows in experiment 2 has been discussed earlier in the chapter. Reduced performance has been observed in animals that consume endophyte infected tall fescue. Reduced weight gain, elevated body temperature and accelerated respiration rate occurred in steers which grazed tall fescue compared to steers that grazed orchardgrass or legume-fescue mix pastures (Bond et al., 1984). Likewise, reduced fertility has been observed in cows grazing tall fescue (Hemken et al., 1984). The specific compounds in fescue responsible for the toxicity syndrome have not been isolated and how these compounds influence reproductive performance is unknown (Hemken et al., 1984). A reduction in serum prolactin has been observed in cattle that consumed endophyte infected fescue (Hemken et al., 1984) and the reduction in this hormone may be responsible for the reduction in reproductive performance. In addition, elevated body temperature associated with the fescue toxicity syndrome may reduce fertilization rate or increase the incidence of early embryonic mortality.

When the pregnancy rate of cows in experiment 2 was expressed as a percentage of cows which had ovarian activity near the beginning of breeding, flushed cows had a greater pregnancy rate (82.5%) compared to control cows (66.6%). These data may indicate that feeding an energy supplement during breeding (to dilute the intake of fescue and endophytic toxins) may improve reproductive performance. These results would certainly warrent further investigation into methods of managing cows for optimum reproduction on tall fescue.

The failure of weight and condition loss before breeding to reduce ovarian function in Santa Gertrudis cows was interesting. Precise evaluation of ovarian activity could not be monitered with only one or two blood samples, however, our conservative estimate indicated that a high percentage of cows in each experiment had ovarian luteal activity near the beginning of breeding. Rakestraw (1984) found that severe weight and condition losses after calving reduce the incidence of ovarian activity by the beginning of breeding in Hereford cows. Physiological and endocrinological differences in ovarian function between Brahman-type and British breeds of cows exist (Randel et al., 1978; Randel, 1984). Perhaps these breed differences permit adjustment to the stress of weight and condition change or else the weight losses which occurred were not of sufficient magnitude to influence ovarian function.

Body weight change influenced the interval to conception for Santa Gertrudis cows in both experiments. Previous research has demonstrated that prebreeding weight and condition loss increases the interval from calving to conception in beef cows of primarily British breeding (Whitman, 1975; Wettemann et al., 1982). Weight loss results in a longer interval from calving until the onset of normal estrous cycles. Weight loss before breeding increased the interval from calving to conception for Santa Gertrudis cows in this study. The differences in age postpartum at the beginning of breeding for heifers in experiment 1 could influence these results (table 4). Age postpartum at the beginning of breeding was greater for flushed compared to control heifers. A greater interval from calving to the beginning of breeding would have allowed the flushed heifers a longer period to regain body weight and condition losses from calving.

Considering the high percentage of cows in both experiments that had ovarian activity at the beginning of breeding, the length of the interval from calving to conception may be a result of lack of normal ovulation and luteal development, fertilization failure or early embryonic mortality rather than the failure to exhibit estrus. Smith et al. (1982) reported that fertilization rate may be as low as 80% in Brahman-cross heifers which were maintained on high nutritional regimes. In addition, the influence of heat stress on reproductive performance has been recognized (Thatcher, 1974; Christenson, 1980). Although Brahman-type cattle are more tolerant of increased environmental temperatures, reduced conception rates in beef cattle have been observed under thermal stress conditions (Dunlap and Vincent, 1972).

Results of this study suggest that feeding additional energy after calving (flushing) is unnecessary if Santa Gertrudis cows are in good to moderate body condition at calving and at the beginning of breeding, and sufficient amounts of forage are available. Furthermore, milk production was apparently not increased by flushing cows near the beginning of breeding since calf weight gains and adjusted weaning weights were not significantly influenced by treatment. Similarly, flushing of mature cows has not enhanced reproductive performance (Bellows et al., 1968; Loyacano et al., 1974; Wettemann et al., 1984). Flushing may be beneficial in situations where beef cows must compensate for severe weight and condition losses which occurred before calving (Richards, 1984).

Supplemental feed is a major cost in beef production. If the periods in the production cycle of a beef cow when nutrient requirements are most crucial could be identified, optimum reproductive performance could be obtained. Many of the relationships between nutrition, body energy reserves and postcalving reproductive performance of beef cattle have been identified. However, the influence of breed type on these relationships have not yet been clearly defined.

CHAPTER IV

SUMMARY AND CONCLUSIONS

The purpose of this study was to evaluate the postpartum reproductive performance of Santa Gertrudis cows and heifers under ranch conditions. A total of 98 pregnant (85-160 d of gestation), Santa Gertrudis cows at two locations were used during 1983-1985 to determine the influence of body weight and body condition changes during pregnancy and feeding of additional energy after calving on reproductive performance. Ranch management and feeding procedures were followed except for the feeding of a high energy diet to one half of the cows commencing 14 days prior to the beginning of the breeding period. Cows were weighed and body condition scores were determined at four periods during each experiment: mid to late gestation, precalving, breeding, and weaning. Blood samples were obtained by puncture of the tail vein near the beginning of breeding. Concentrations of progesterone in serum were quantified and used to determine the proportion of females with ovarian activity. Calf weights were recorded at birth, near the beginning of breeding and at weaning.

Changes in body weight were related to body condition score change for Santa Gertrudis cows in both experiments. For all periods of experiment 1, body weight change was correlated with body condition score change. The relationships between these two parameters for cows in experiment 2 was somewhat less, primarily resulting from smaller changes in weight and condition which occurred.

Differences in location, environment conditions and management procedures influenced the magnitude of change in body weight and condition for cows in this study. In experiment 2, only minimal changes in body weight and condition occurred from late pregnancy to weaning. Greater changes in weight and condition occurred for heifers in experiment 1. Body weight change explained 59% of the variation in body condition score change from midgestation to breeding for heifers in experiment 1. For cows in experiment 2, body weight change accounted for only 19% of the variation in body condition score change from late gestation to breeding.

Feeding additional energy after calving (flush treatment) reduced body weight and body condition losses after calving for cows in both experiments but did not influence ($P>.10$) reproductive performance. Similar observations have been made utilizing both spring and fall calving cows (Bellows et al., 1968; Loyacano et al., 1974; Wettemann et al., 1984). Pregnancy rate was not significantly influenced by body weight and body condition changes or feeding additional energy after calving in either experiment. Pregnancy rate was not influenced ($P>.10$) by body weight and body condition change either before or after calving. Prebreeding body weight change influenced ($P<.05$) the interval from calving to conception of cows in both experiments. Ovarian activity was not influenced (P>.05) by body weight change before breeding. Calf weights near the beginning of breeding or adjusted weaning weights were not influenced (P>.10) by feeding additional energy to cows after calving.

Body condition score change was related to body weight change of Santa Gertrudis cows, although the relationships obtained in this study were not as strong as reported for beef cows of British breeding (Wagner, 1985). Body weight and body condition changes were not severe in either experiment and the changes which occurred were not of sufficient magnitude to significantly influence reproductive performance. Reproductive performance of cows and calf performance was not enhanced by feeding additional energy after calving and is unnecessary when cows are maintained on good quality forage and remain in good to moderate body condition from calving through breeding (experiment 1). However, feeding additional energy during breeding, even when cows are in good body condition after calving, may prove beneficial in improving fertility under some environmental conditions (experiment 2).

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APPENDIX

TABLE 13. BODY CONDITION SCORING SYSTEM

Score	Description
1 -	Severely emaciated. Physically weak. All ribs and bond structure easily visible. No external fat present.
2 -	Emaciated, but not physically weak. Muscle tissue severely depleted through shoulders and hindquarters.
3 -	Very thin. No palpable or visible fat on ribs, backbone or in the brisket. Muscles in hindquarter are visible.
4 -	Thin. Ribs, spinus processes and pin bones are easily visible. Muscles in shoulder and hindquarter do not appear depleted.
5 -	Moderate. Little evidence of fat over ribs, tailhead and in the brisket. Last two or three ribs easily visible.
6 -	Good. Smooth appearance throughout. Individual ribs are not visible, palpable fat over pins and tailhead. Some fat deposition in the brisket.
7 -	Very good. Brisket is full, tailhead and pins have protruding deposits of fat. Back appears square due to fat. Definite fat cover over ribs.
8 -	Obese. Back is very square and neck is thick. Brisket is distended and large protruding deposits of fat on tailhead and pins.
9 -	Extremely obese. Description of 8 taken to greater extremes. Heavy deposition of fat in brisket, udder and over ribs.

(Wagner, 1985)

TABLE 14. REGRESSION OF BODY WEIGHT CHANGE (MIDGESTATION TO BREEDING), CALF SEX, CALF GAIN AND AGE POSTPARTUM ON BODY CONDITION SCORE CHANGE OF HEIFERS (EXPERIMENT 1)

Variable	Regression Coefficient	Standard Error	Prob.[a]	R^2
Intercept	-0.33	.61	.58	.60
Body weight change (%)	0.05	.01	.0001	
Treatment				
control	-0.05	.15	.73	
flush	0.00			
Calf sex				
heifer	0.05	.15	.72	
bull	0.00			
Calf gain	-0.001	.001	.37	
Age postpartum	-0.003	.003	.30	

[a] Probability of a greater T for the hypothesis, Ho: parameter = 0.

TABLE 15. REGRESSION OF BODY WEIGHT CHANGE (MIDGESTATION TO BREEDING) ON THE INTERVAL FROM CALVING TO CONCEPTION FOR HEIFERS (EXPERIMENT 1)

Variable	Regression Coefficient	Standard Error	Prob.[a]	R^2
Intercept	77.1	8.0	.0001	.12
Body weight change (%)	-1.3	0.6	.05	

[a] Probability of a greater T for the hypothesis, Ho: parameter = 0.

TABLE 16. REGRESSION OF BODY WEIGHT CHANGE (LATE GESTATION TO WEANING), TREATMENT, CALF SEX AND CALF GAIN ON BODY CONDITION SCORE CHANGE OF COWS (EXPERIMENT 2)

Variable	Regression Coefficient	Standard Error	Prob.[a]	R^2
Intercept	-0.34	1.30	.80	.55
Body weight change (%)	0.07	.01	.0001	
Treatment				
control	0.05	.15	.75	
flush	0.00			
Calf sex				
heifer	-0.05	.16	.73	
bull	0.00			
Calf gain	0.00008	.00008	.33	

[a] Probability of a greater T for the hypothesis, Ho: parameter = 0.

TABLE 17. REGRESSION OF BODY WEIGHT CHANGE (PRECALVING TO BREEDING) ON THE INCIDENCE OF OVARIAN ACTIVITY FOR COWS (EXPERIMENT 2)

Variable	Regression Coefficient	Standard Error	Prob.[a]	R^2
Intercept	.73	.08	.0001	.08
Body weight change (%)	-.03	.01	.07	

[a] Probability of a greater T for the hypothesis, Ho: parameter = 0.

TABLE 18. REGRESSION OF BODY WEIGHT CHANGE (PRECALVING TO BREEDING) ON THE INTERVAL FROM CALVING TO CONCEPTION FOR COWS (EXPERIMENT 2)

Variable	Regression Coefficient	Standard Error	Prob.[a]	R^2
Intercept	83.9	5.3	.0001	.18
Body weight change (%)	-1.6	.8	.06	

[a] Probability of a greater T for the hypothesis, Ho: parameter = 0.

TABLE 19. PARTIAL CORRELATION COEFFICIENTS FOR BODY CONDITION SCORE CHANGES AND PERCENTAGE BODY WEIGHT CHANGES OF SANTA GERTRUDIS COWS AND HEIFERS (EXPERIMENTS 1 AND 2)

Period	r	Prob.[a]
Mid-late gestation to Breeding	.66	.0001
Breeding to Weaning	.59	.0001
Mid-late gestation to Weaning	.71	.0001

[a] Significance level (Pr> F)

TABLE 20. REGRESSION OF BODY WEIGHT CHANGE (MID-LATE GESTATION TO BREEDING), LOCATION AND TREATMENT ON BODY CONDITION SCORE CHANGE OF SANTA GERTRUDIS COWS AND HEIFERS (EXPERIMENTS 1 AND 2)

Model	Regression Coefficient	Standard Error	Prob.[a]	R^2
Mid-late Gestation to Breeding			.0001	.55
Intercept	-0.18	.11	.28	
Body weight change (%)	0.06	.00	.0001	
Location	0.12	.10	.25	
Treatment	0.05	.09	.61	
Breeding to Weaning			.0001	.40
Intercept	-0.40	.08	.0001	
Body weight change (%)	0.07	.01	.0001	
Location	0.55	.10	.0001	
Treatment	-0.08	.11	.48	
Mid-late Gestation to Weaning			.0001	.69
Intercept	-0.45	.11	.0001	
Body weight change (%)	0.06	.00	.0001	
Location	0.60	.10	.0001	
Treatment	0.02	.09	.86	

[a] Probability of a greater T for the hypothesis, Ho: parameter = 0.

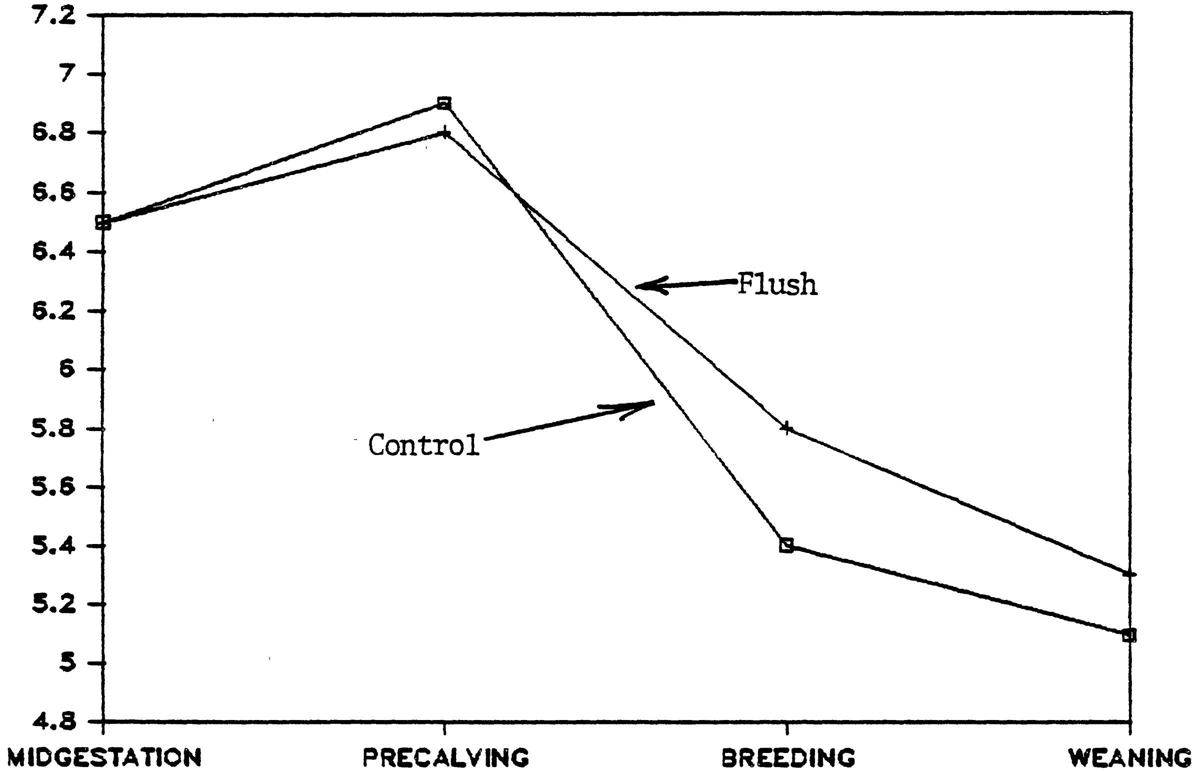

Figure 1. Mean Body Condition Scores of Santa Gertrudis Heifers (Experiment 1)

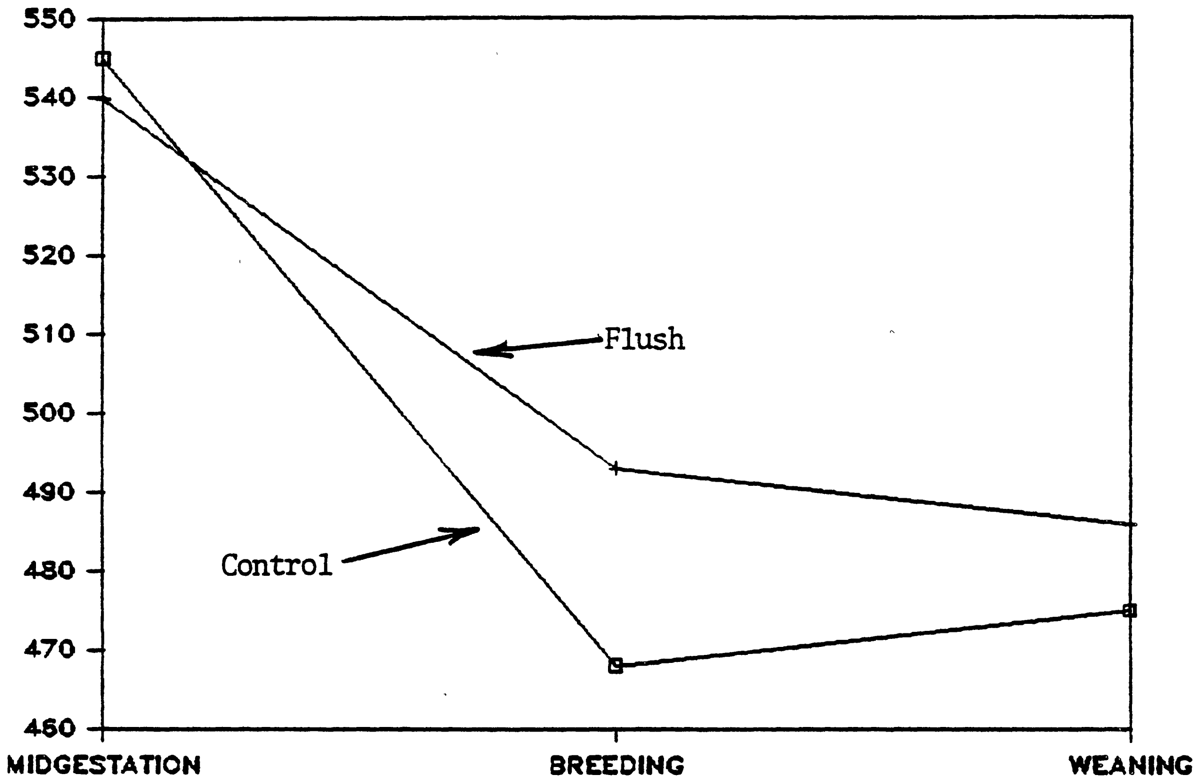

Figure 2. Mean Body Weights (kg) of Santa Gertrudis Heifers (Experiment 1)

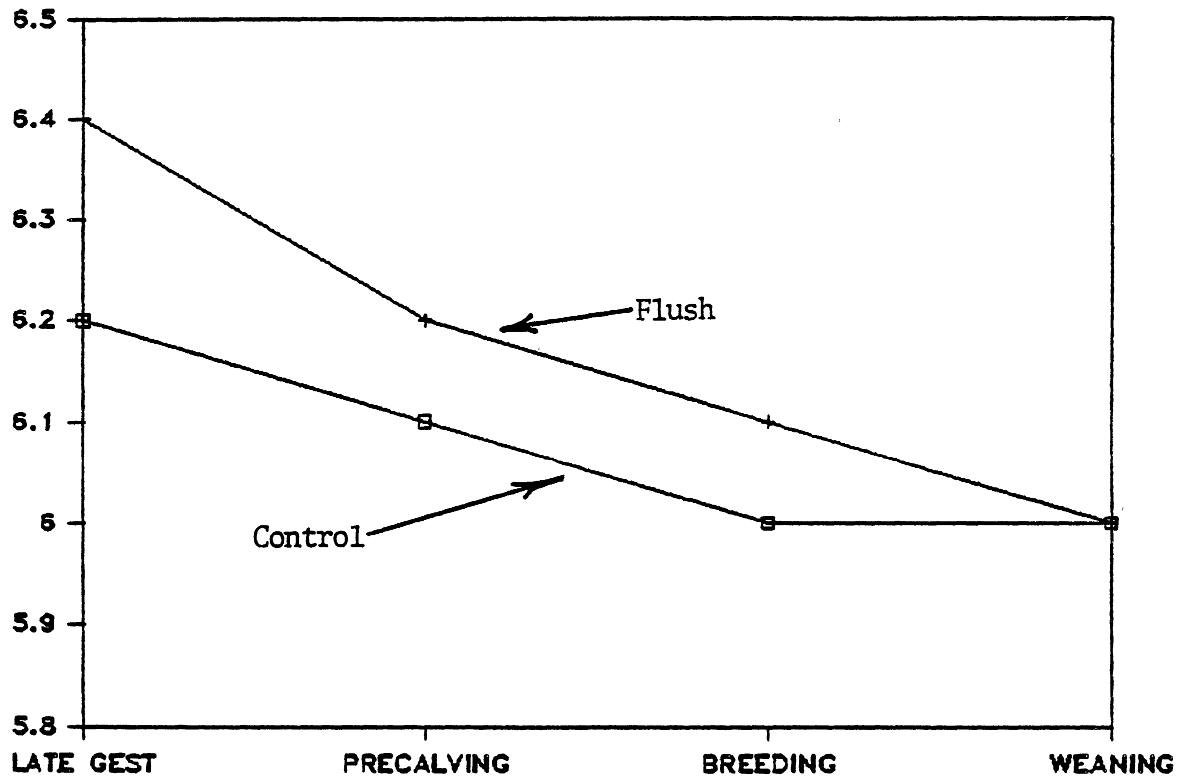

Figure 3. Mean Body Condition Scores of Santa Gertrudis Cows (Experiment 2)

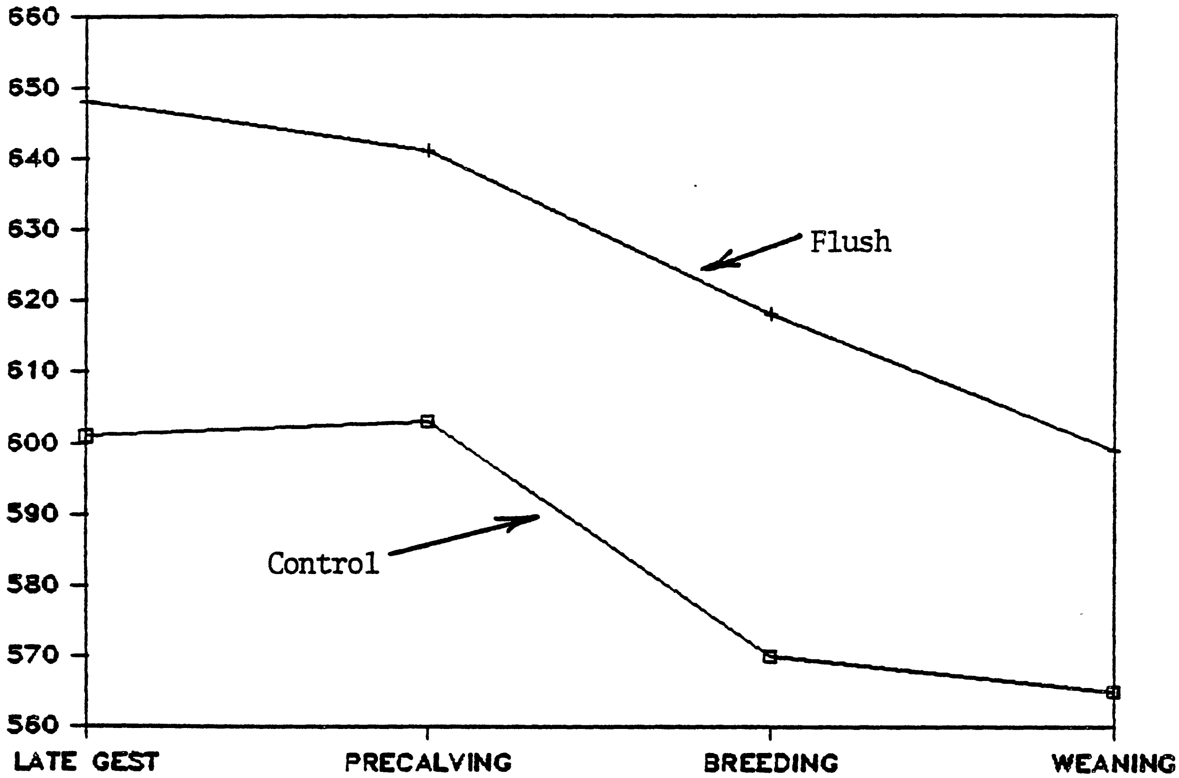

Figure 4. Mean Body Weights (kg) of Santa Gertrudis Cows (Experiment 2)

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