DISSERTATION

WEIGHT CHANGE, BODY CONDITION AND BEEF-COW REPRODUCTION

Submitted by

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY RICHARD WARREN WHITMAN ENTITLED WEIGHT CHANGE, BODY CONDITION AND BEEF-COW REPRODUCTION BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

WEIGHT CHANGE, BODY CONDITION AND BEEF COW REPRODUCTION

I. Data compiled on 686 Angus and Hereford cows 2 to 11 years old fed different levels of energy before and after calving were analyzed by the method of least squares to determine the effect of individual weight change and body condition on (1) likelihood of estrus (LOE) 30 to 90 days postpartum and (2) likelihood of pregnancy (LOP) at first breeding. Cows were designated to weight-change groups according to weight gain (G) or loss (L) 120 days before and 90 to 140 days after calving (GG, GL, LG, or LL) and from calving to first breeding (G or L). Cows were also designated to body condition groups (thin, moderate, or good) at calving and first breeding according to visual appraisal and palpated fat cover over the back and ribs. Weight change pre- and post-calving significantly ($P < .01$) affected LOE 40 and 50 days postpartum. Cows gaining weight before calving had a greater LOE 50 days postpartum than cows losing weight before calving ($P < .05$). Likelihood of estrus 60 to 90 days postpartum was significantly affected ($P < .01$) by body condition at calving. For each 10-day interval 60 to 90 days postpartum, LOE increased ($P < .05$) as body condition at calving improved from thin to moderate to good. Neither weight change before breeding nor body condition at first breeding affected LOP ($P > .05$).

II. Studies were conducted to: (1) determine the repeatability of a cow-height measurement and (2) determine the relation of weight-to-height ratio to measurable backfat. Height at the hips was measured to the nearest .1 cm using a steel caliper which swung over the cow and extended downward from a pre-set height to the lumbar vertebrae midway between the tuber coxae. Backfat measurements were taken over the 12th and 13th ribs using an ultrasonic scanner. In three separate studies involving a total of 927 height measurements on 250 cows, repeatability estimates obtained were .86, .81 and .91. In two separate studies involving height and backfat measurements on a total of 120 cows, correlations between weight-to-height ratio and measurable fackfat were .50 and .71.

III. Five hundred sixty Angus and Angus x Hereford cows 6 to 13 years of age were used to determine the relation of pre- and post-calving weight-to-height ratio to likelihood of estrus (LOE) 30 to 90 days postpartum and likelihood of pregnancy (LOP) at first breeding. All cows calved each of the previous three years and were pregnant to Simmental, Simmental x Hereford or Charolais sires. Height of each cow at the hips was measured to the nearest .5 cm and individual weights were taken approximately 120, 90, 60 and 30 days before calving, at first postpartum estrus and at first breeding. Of the pre-calving measurements, weight-to-height ratio (WHR) 60 days before calving most consistently accounted for significant portions ($P < .05$) of variation in LOE 60 to 90 days postpartum. Cows with a higher WHR 60 days before calving had a greater LOE ($P < .05$) at each 10-day interval 60 to 90 days postpartum. Weight-to-height ratio at first estrus accounted for a significant portion ($P < .01$) of the variation in interval from calving to first estrus. Of cows exhibiting estrus by 90 days postpartum (78%), those with a higher WHR at first estrus had a shorter interval from calving to first estrus. Weight-to-height ratio at first breeding was not related to likelihood of pregnancy ($P > .05$).

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CHAPTER I

INTRODUCTION

The ability to predict reproductive performance of beef cows fed different levels of nutrition would allow producers to objectively evaluate production alternatives. By comparing expected performance against projected costs producers could more efficiently utilize feed resources, control production costs and improve reproductive performance.

Earlier studies have shown reproductive performance of beef-cow herds is influenced by level of nutrition. Low levels of nutrition before calving reduce the proportion of cows exhibiting estrus early in the breeding season while low levels of nutrition after calving decrease total pregnancy rates. Insuring adequate levels of nutrition before and after calving can improve overall reproductive performance of beef-cow herds.

Cows differ however, in their response to a given level of nutrition because of differences in age, metabolic size, body condition, milking ability and stage of pregnancy. Changes in body weight and condition reflect these individual differences in maintenance and production requirements. Therefore, reproductive performance of beef-cow herds might be more accurately predicted if the effect of weight change and body condition on postpartum reproductive performance were known.

The objectives of the studies reported here were:

(1) determine the likelihood of estrus and pregnancy in cows gaining or losing weight before and after calving and varying in body condition according to visual scores;

(2) determine the value of a weight-to-height ratio as a measure of body condition in cows; and

(3) determine the likelihood of estrus and pregnancy in cows varying in body condition before and after calving as indicated by a weight-to-height ratio.

CHAPTER II

REVIEW OF LITERATURE

The percent calf crop weaned from cows exposed to breeding varies widely among beef-cow herds (Temple, 1967; Warnick, 1967; Warwick, 1967; Wiltbank *et al.*, 1967). The largest single reduction in potential calf crop occurs when cows fail to become pregnant (Wiltbank, 1961). Likelihood of pregnancy during the breeding season is directly determined by the interval from calving to first estrus and pregnancy rate at breeding (Wiltbank, 1970). Interval from calving to first estrus and pregnancy rate in healthy beef cows mated to fertile bulls is influenced by nutrition, suckling, days postpartum, age and breed.

Nutrition

The effect of nutrition on reproduction has long been recognized (McTurk, 1843) and has been reviewed by Asdell (1949), Reid (1949), Blaxter (1957), Hafez (1959), Reid (1960), Abrams (1962), Wiltbank *et al.* (1965), Tassell (1967), Baker (1969), Lamond (1970) and McClure (1970). These reviews indicate:

(1) failures in reproduction may occur when beef cows receive diets deficient in energy, protein, vitamin A, phosphorus, manganese, copper or cobalt;

(2) most cases of protein, vitamin and mineral deficiencies are confounded with the effects of low energy intake; and

(3) under practical management conditions much of the variation in reproductive performance of beef cows may be accounted for by differences in total energy intake and body condition.

This review will examine the effect of total energy intake and body condition on postpartum reproductive performance of mature beef cows.

Calving percentages vary with amount of available range forage (Walker and Lantow, 1927). Cows grazing ranges with adequate forage weaned 30 percent (Parr and Klemmedson, 1925) and 23 to 40 percent (Osborne, 1960) more calves than cows grazing ranges where forage was scarce. In years following a drought, cows weaned 14 percent (Knox _et al._, 1958), 17 percent (Baker and Quesenberry, 1944) and 46 percent (Carroll and Hoerlein, 1966) fewer calves than after years of normal rainfall.

Calving percentages vary with stocking rate which determines amount of forage available per cow. In the southern great plains the average calf crop weaned from cows on heavily grazed range (12 acres per cow) was 83 percent compared to 90 and 93 percent for cows on moderately (17 acres per cow) and lightly (22 acres per cow) grazed range, respectively (McIlvain, 1958). In Montana, cows on heavily grazed pasture (23.1 acres per cow) weaned a calf crop of 70 percent compared to 89 percent for cows on moderately grazed pasture (30.5 acres per cow) and 90 percent for cows on lightly grazed pasture (38.8 acres per cow) (Marsh et al., 1959).

Amount of forage available varies with season and accounts for much of the variation in reproductive performance of range cows calving during different seasons of the year. Most reports indicate cows calving during summer months have a shorter average interval from calving to first estrus than cows calving during winter months (Thibault et al., 1966; Baker, 1968; Rao and Taylor, 1971). Baker (1968) attributed the shorter interval from calving to first estrus in summer-calving cows to significantly heavier weights at calving resulting from greater availability of forage. The influence of amount of forage available near calving is further indicated by differences noted among cows calving in late spring and early summer. In a three-year study, cows calving during March and April had an average interval from calving to first estrus 28 days (Hereford cows) and 25 days (Angus cows) longer than cows calving during May and June (Warnick, 1955).

When forage is scarce calf-crop percentage may be increased by providing additional feed (Walker and Lantow, 1927; Speth et al., 1962). Cows receiving cottonseed meal and barley at times when forage was scarce weaned 17 percent (Wagnon et al., 1959) and 30 percent (Guilbert and Rochford, 1940) more calves than cows receiving no supplement. Cows fed additional hay and sorghum silage on pasture had calf crops of 100 percent compared to only 20 percent for those cows on pasture alone (Lantow and Snell, 1924). Cows grazing southeastern coastal ranges and receiving 2 pounds of supplement per day weaned a calf crop of 48 percent versus 63 percent for cows receiving 4 pounds per day and 68 percent for cows receiving 6 pounds per day (Foster et al., 1945).

The response to supplemental feeding depends, however, upon cow condition, amount of forage available at time of supplementation and amount of supplement provided. No increase in percent calf crop was obtained in cow herds fed a supplement of cottonseed cake except following winters of heavy snowfall when range forage was scarce and cows calved in poor condition (Black et al., 1938). Supplemental feeding increased calf crops 6 to 10 percent during years of drought but did not improve calf crops in years when adequate forage was available (Knox and Watkins, 1958). Percent calf-crop weaned was not increased by providing additional feed to cows on improved native range or irrigated pasture (Koger et al., 1962; Bellows et al., 1968; Loyacano et al., 1974) and was decreased in cow herds supplemented in excess of needs for extended periods (Pope, 1961; Pinney et al., 1962).

Controlled intake studies have shown that low levels of energy during late pregnancy increase the interval from calving to first estrus and thus reduce the proportion of cows showing estrus early in the breeding season (duToit and Bisschop, 1929; Joubert, 1954; Zimmerman et al., 1961; Wiltbank et al., 1962; Reynolds et al., 1964; Turman et al., 1964; Wiltbank et al., 1964; Wiltbank et al., 1965; Christenson et al., 1967; Hight, 1968; Dunn et al., 1969). This effect is not readily overcome even though cows receive high levels of energy after calving (Wiltbank et al., 1962; Wiltbank et al., 1964; Dunn et al., 1969).

Low levels of energy after calving reduce total pregnancy rate (Wiltbank et al., 1962; Reynolds et al., 1964; Turman et al., 1964; Bellows, 1967; Schilling and England, 1968). The primary effect is a reduction in the total number of cows that exhibit estrus during the breeding season (Wiltbank et al., 1962; Smithson et al., 1963; Wiltbank et al., 1964; Wiltbank et al., 1965; Hight, 1968; Dunn et al., 1969). Pregnancy rate at first breeding may also be depressed but consistent results have not been obtained (Asdell, 1952; Joubert, 1954; Wiltbank et al., 1962; Reynolds et al., 1964; Wiltbank et al., 1964; Wiltbank et al., 1965; Hight, 1968; Dunn et al., 1969).

It is not known how undernutrition delays postpartum estrus in beef cows. Cows restricted in energy intake show reduced follicular growth and ovarian activity (Wiltbank et al., 1964; Oxenreider and

Wagner, 1971). The decrease in ovarian activity may be due to either a lack of gonadotrophin secretion or a decline in ovarian sensitivity. Studies in rats indicate undernutrition decreases circulating levels of gonadotrophins by inhibiting production and/or secretion of gonadotrophin releasing factors from the hypothalamus (Leathem, 1966; Piacsek and Meits, 1967; Negro-Vilar et al., 1971; Ibrahim and Howland, 1972). Limited studies in cycling cows, however, indicate no decline in circulating levels of LH in cows on restricted energy diets and suggest undernutrition may reduce ability of ovarian tissue to respond to LH (Hill et al., 1970; Gombe and Hansel, 1973; Dunn et al., 1974). Further research is needed to clearly identify the endocrine mechanisms involved.

The influence of energy levels can depend upon body condition of cows. McGinty and Ray (1973) found pre-calving nutrition had no effect on interval from calving to first estrus in cows maintained in "excellent condition."

Pregnancy rates have been reported to vary according to body condition of cows prior to the breeding season (Baker, 1968). Hilts (1925) reported a calf crop of 70 percent for cows turned out in good condition compared to 52 percent for those in poor condition. Australian studies indicated 10.6 percent of cows in "poor" condition became pregnant, compared with 36.3 percent of "store" cows, 63.7 percent of "forward store" cows and 88.5 percent of "fat" cows (Donaldson et al., 1967).

Extremely high condition has been implicated as a cause of sterility (Marshall and Peel, 1910). Ovaries from fat sterile cows have been reported as being "smaller than normal" (Quinlin, 1929), having fewer follicles, and containing fatty deposits in and around the ovarian bursa (Marshall and Peel, 1910). Recent studies, however, indicate no difference in pregnancy rate due to fatness (Pinney, 1961; ToTusek, 1961; Wiltbank et al., 1965) and suggest that high condition may result from sterility rather than vice versa.

Suckling

Postpartum estrus in beef cows is delayed by suckling. Average interval from calving to first estrus was from 27 to 54 days longer for cows suckling calves than for non-suckled cows (Graves et al., 1968; Lauderdale et al., 1968; Riesen et al., 1968; Short et al., 1972; England et al., 1973).

The primary effect of suckling is stimulation of mammary tissue which produces a graded response in the onset of estrus. Average interval from calving to first estrus was 46 days for cows milked twice a day, 69 days for cows milked four times per day and 72 days for cows suckling calves (Clapp, 1937). Wiltbank and Cook (1958) found that cows suckling calves exhibited estrus an average of 30 days later than cows milked twice daily. Wagner and Oxenreider (1971) reported average intervals from calving to first estrus of 24, 45 and 52 days for non-lactating, milked and suckled cows, respectively. The mere presence of mammary tissue may delay the onset of estrus as indicated in studies by Short et al. (1972) where interval from calving to first estrus averaged 65 days for suckled cows, 25 days for non-suckled cows and 12 days for cows that were mastectomized.

When energy intake is marginal, suckling and subsequent nutritional stress of lactation may reduce net energy available for reproductive performance. Lactating cows grazing Florida pastures weaned a 63 percent calf crop compared to 84 percent for non-lactating cows (Koger et al., 1962). During a drought year only 28 percent of lactating cows became pregnant compared to 76 percent of those not lactating (Carroll and Hoerlein, 1966). Pregnancy rates of lactating cows in six beef-cattle herds in northern Australia averaged only 36.4 percent for lactating cows compared to 77.5 percent for non-lactating cows (Donaldson et al., 1967). Some studies indicate a possible interaction between nutrition and suckling. Baker (1968) found that if body weights of lactating cows were low there was a high correlation between the length of the suckling period and interval to first estrus. This correlation was not significant, however, when body weights of cows were increased.

It is not known how suckling inhibits estrous activity in cows. The endocrine mechanisms associated with neural stimulation of mammary tissue as well as nutritional stress of milk production are apparently involved. Suckling appears to inhibit estrus and ovulation without significantly inhibiting follicular development. Cows suckling calves did not differ ($P > .05$) from non-suckled cows in follicular activity 30 days postpartum but did have a longer interval from calving to first ovulation (Saiduddin et al., 1968; Wiltbank and Cook, 1968; Oxenreider and Wagner, 1971). Though several studies indicate suckling has no effect on pituitary content of LH (Saiduddin et al., 1968; Wagner et al., 1969; Oxenreider and Wagner, 1971), circulating levels of LH may be reduced. The effects of suckling may be mediated through increased release of oxytocin and/or prolactin (Momongan and Schmidt, 1970; Grosvenor and Mena, 1971; Fell et al., 1971; Tucker, 1971) in response to stimulus of suckling and lactation. Wagner and Oxenreider (1971) suggest that elevated blood levels of progesterone and cortisol from the adrenals in response to the stress of milk removal may also be involved.

Days Postpartum

Interval from calving to first breeding is an important factor in determining likelihood of pregnancy. As indicated in reviews by Casida (1968) and Foote (1971), pregnancy rate at first breeding improves as the number of days since calving increases up to approximately 60 days. Most reduction in fertility occurs less than 35 days postpartum with very few pregnancies resulting from matings less than 20 days postpartum (Lasley and Bogart, 1943; Shannon et al., 1952; Warnick, 1955; Graves et al., 1968; Perkins and Kidder, 1969; Olds and Cooper, 1970; Short et al., 1972).

Pregnancy failure during the early postpartum period appears to be due to lack of fertilization rather than embryonic death. Graves et al. (1968) measured fertility 3 and 38 to 44 days after breeding and found no difference in embryonic mortality between matings early and late in the postpartum period but found fertilization rate was extremely low in matings less than 30 days postpartum. Lowered fertilization rate during the early postpartum period is very likely related to uterine changes occurring after parturition. High counts of lymphocytes, leucocytes and macrophages accompanying the sloughing of cotyledons and removal of placental debris appear to provide a poor environment for successful fertilization (Casida, 1968; Wagner and Hansel, 1969).

Despite a lower pregnancy rate for early matings the economic advantage of early pregnancy and short calving interval dictates cows be bred at the earliest opportunity. Contrary to popular opinion early breeding is not harmful to later reproductive performance. Olds and Cooper (1970) reported no difference in either percent pregnant after 3 services, percent "non-breeders", or percent abortions between cows bred less than or greater than 35 days postpartum. More importantly, after 35 days postpartum calving intervals were shortened by nearly one full day for each day sooner that cows were bred. According to records on 50,000 dairy cows, breeding at 40 instead of 60 days postpartum increased average number of services per conception by only .08 services but shortened average calving interval 15 days (Olds and Cooper, 1970).

Age

Cow age accounts for some of the variation in reproductive performance observed in beef-cow herds. Younger cows nursing calves generally have poorer reproductive performance than older cows nursing calves (Baker and Quesenberry, 1944; Burke, 1954; Wiltbank et al., 1961; Wiltbank and Harvey, 1963; Donaldson et al., 1967). Lower overall pregnancy rates among younger cows are due primarily to a longer average interval from calving to first estrus and consequently a smaller proportion of younger cows exhibiting estrus during the breeding season. Wiltbank (1970) reported intervals of 53.4 days for cows 5 years or older, 60.2 days for 4-year-old cows, 66.8 days for 3-year-old cows and 91.6 days for cows 2 years of age.

Much of the variation in reproductive performance attributed directly to age of cow may be due to differences in energy intake. In most beef-cow herds young and mature cows are fed together and no provision is made for the additional energy requirements for growth of young cows. Additional requirements for growth combined with stress of lactation and marginal energy intake result in reduced net energy for reproduction. This was evidenced in studies indicating that poorer reproductive performance of young cows was more pronounced in lactating than in non-lactating cows (Koger *et al.*, 1962), and that supplementing young cows increased the number calving by 10 percent while giving no response in older cows (Knox and Watkins, 1958). A three-year study revealed age had no effect on interval from calving to first estrus when cows were provided adequate feed at all times and kept in good physical condition (Warnick, 1955). Controlled-intake studies indicate that when cows are fed according to age the interval from calving to first estrus as well as the proportion cycling 60 to 90 days postpartum are similar for cows 2, 3, and 6 to 10 years of age (Wiltbank *et al.*, 1962; Wiltbank *et al.*, 1964; Dunn *et al.*, 1969).

Breed

Breeds may differ in reproductive performance in a given environment as indicated in reviews by Warnick (1955), Wiltbank *et al.* (1961), England *et al.* (1963), Reynolds (1967) and Baker (1969). Most differences in performance are related to adaptability to climate. Most studies show that cows of European breeding have higher reproductive rates than cattle of Zebu origin except in the hot climates of the southern United States and Australia (Donaldson, 1962; Koger *et al.*, 1962; Reynolds, 1967; Warnick, 1967). When temperature stress is not a factor breed differences may be due to significant differences in mature size or milking ability which play an important role in determining amount of energy available for reproduction. Koger et al. (1962) and England et al. (1963) found that while lactating cows showed wide breed differences in percent calves weaned non-lactating cows performed at similar levels.

Crossbreeding tends to increase while inbreeding tends to decrease reproductive performance of beef cows. Higher calving percentages were reported when cows were bred for crossbred calves than when bred for straightbred calves (Gaines et al., 1961; Niswender et al., 1963; Cundiff et al., 1974). Higher calving percentages were due to higher pregnancy rates at first service, higher pregnancy rates overall as well as increased survival of crossbred calves at birth. On the other hand, lower calving percentages resulting from lower pregnancy rates and increased mortality at birth have been reported when inbreeding of cows increased (Woodward and Clark, 1959; Mares et al., 1961; Rice et al., 1961; Bovard and Priode, 1962; Krehbiel et al., 1969).

Summary

Percent calf crop weaned from cows exposed to breeding varies widely among beef-cow herds. The largest single reduction in calf crop occurs when cows fail to become pregnant. Likelihood of pregnancy during the breeding season is directly influenced by interval from calving to first estrus and pregnancy rate at breeding. Interval from calving to first estrus is generally longer in younger cows, cows suckling calves and cows fed low levels of nutrition prior to calving. Total pregnancy rate is often depressed in cows losing weight or in poor condition during the breeding season; improves as the interval from calving to breeding increases; and is generally higher for crossbred cows or cows bred for crossbred calves.

CHAPTER III

WEIGHT CHANGE, BODY CONDITION AND BEEF-COW REPRODUCTION

Introduction

For most beef-cow herds the greatest improvement in pounds of calf weaned may be obtained by increasing the proportion of cows becoming pregnant early in the breeding season (Morrow and Brinks, 1968; Wiltbank and Faulkner, 1970; Lesmeister et al., 1973). The proportion of cows becoming pregnant early in the breeding season is influenced by level of nutrition. Low levels of nutrition before calving reduce the proportion of cows exhibiting estrus early in the breeding season while low levels of nutrition after calving depress total pregnancy rates (Zimmerman et al., 1961; Wiltbank et al., 1962; Reynolds et al., 1964; Dunn, 1964; Hight, 1968). Cows may differ, however, in their response to a given level of nutrition because of age, size, body condition, milking ability or stage of pregnancy.

The objective of this study was to determine the effect of individual weight change and body condition on likelihood of estrus 30 to 90 days postpartum and likelihood of pregnancy at first service.

Materials and Methods

Data for this study were obtained from five experiments conducted at the Fort Robinson Beef Cattle Research Station, Crawford, Nebraska. Data were compiled on 209 Hereford and 205 Angus first-calf heifers two years of age (Dunn, 1964; Wiltbank et al., unpublished), 66 Hereford and 77 Angus second-calf cows three years of age (Wiltbank et al., unpublished) and 129 pluriparous Hereford cows ranging in age from 5 to 11 years (Wiltbank et al., 1962; Wiltbank et al., 1964). Cows were kept in dry lot and within each experiment were randomly allotted according to age, breed and expected calving date to groups fed different levels of energy before and after calving. Those cows receiving moderate and high levels of energy were group fed while those receiving low levels of energy were fed individually. All cows received protein, minerals and vitamins in excess of NRC recommendations.

Weekly rectal examination of the reproductive tract was initiated 15 to 21 days postpartum and continued until the uterus had involuted (horns returned to approximately "normal" size and consistency) and the cow had shown estrus. Additional examinations were conducted 7 to 13 days after estrus to determine if ovulation had occurred and 35 to 41 days after breeding to diagnose pregnancy.

Checks for estrus began the day after calving and were made with the aid of sterilized bulls painted on the brisket twice daily with a pigmented grease or equipped with a marking harness. Bulls were kept with cows at all times except during feeding. Cows were visually checked twice daily. A cow with grease marks on her rump or standing to be ridden by a bull or another cow was considered to be in heat. Heat dates were verified by palpation records.

Cows were bred at the first estrus after involution of the uterus and not less than 45 days postpartum. The mature cows were hand mated to two or more bulls. The two and three-year-old cows of each breed were bred artificially using semen from a single collection.

For this study, cows were designated to one of four weight-change groups (GG, GL, LG or LL) according to individual weight gain (G) or loss (L) before and after calving. Cows bred were also designated to one of two weight-change groups (G or L) according to weight gain or loss before first breeding. Weight changes were calculated over the longest interval on feed to minimize the effect of rapid weight change occurring near calving and during periods of adjustment to ration changes. Pre-calving weight changes were calculated using weights recorded 120 to 140 days and 1 to 27 days before calving. Post-calving weight changes were calculated using weights recorded 1 to 21 days and 90 to 140 days after calving. Pre-breeding weight changes were calculated using weights recorded 1 to 21 days after calving and within 15 days of first breeding.

Cows were also designated as being in either thin, moderate or good condition at time of calving and at first breeding based upon previously assigned subjective scores. These scores ranged from 1 to 9, indicating low to high condition according to visual appraisal and palpated fat cover over the back and ribs. Because of small numbers in some score groups as well as variation among technicians over years a general classification was adopted. Cows previously scored from 1 to 3, 4 to 6 and 7 to 9 were designated in thin, moderate and good condition, respectively.

Data were analyzed by the method of least squares for unequal subclass numbers (Harvey, 1960). Each cow was assigned an estrous code of 0 (not cycling) or 1 (cycling) for each 10-day interval 30 to 90 days postpartum. Cows bred were assigned a pregnancy code of 0 (open) or 1 (pregnant) at first breeding. Effect of weight change, body condition and two-way interactions were included in the analyses. When significance was indicated by analyses of variance, least-squares means were compared using the Studentized Range test (Snedecor and Cochran, 1967).

Results and Discussion

Average daily weight change before calving for all cows was .03 kg (table 1). The two groups of cows gaining weight before calving gained an average of .37 and .46 kg per day ($P > .05$) while the two groups losing weight lost an average of .37 and .32 kg per day

Table 1. Least-Squares Means and Standard Errors of Condition Score at Calving and Weight Change Before and After Calving.

Item	No.	Before Calving: Total kg	Before Calving: Total %	Before Calving: Daily kg	Before Calving: Daily %	Calving Condition Score	After Calving: Total kg	After Calving: Total %	After Calving: Daily kg	After Calving: Daily %
Overall Mean	676	6.1 ± 2.6	$3.3 \pm .6$	$.03 \pm .03$	$.02 \pm .01$	$4.8 \pm .1$	37.6 ± 4.9	12.8 ± 1.6	$.28 \pm .04$	$.10 \pm .01$
Weight Change										
Gain-Gain	233	44.2 ± 2.3^{a}	$12.4 \pm .6^{a}$	$.37 \pm .03^{a}$	$.10 \pm .01^{a}$	$4.9 \pm .1^{a}$	103.1 ± 4.4^{a}	31.7 ± 1.5^{a}	$.85 \pm .04^{a}$	$.26 \pm .01^{a}$
Gain-Loss	96	57.6 ± 3.9^{a}	$15.1 \pm .9^{b}$	$.46 \pm .05^{a}$	$.12 \pm .01^{a}$	$5.1 \pm .1^{a}$	-38.1 ± 7.4^{b}	-8.2 ± 2.5^{b}	$-.38 \pm .06^{b}$	$-.08 \pm .02^{b}$
Loss-Gain	310	-39.9 ± 4.6^{b}	-7.8 ± 1.1^{c}	$-.37 \pm .06^{b}$	$-.07 \pm .01^{b}$	$4.5 \pm .1^{a}$	115.8 ± 8.9^{a}	34.4 ± 3.0^{a}	$1.02 \pm .08^{a}$	$.30 \pm .03^{a}$
Loss-Loss	37	-37.3 ± 8.0^{b}	-6.6 ± 1.9^{c}	$-.32 \pm .11^{b}$	$-.06 \pm .02^{b}$	$4.8 \pm .2^{a}$	-30.4 ± 15.3^{b}	-6.5 ± 5.1^{b}	$-.38 \pm .13^{b}$	$-.09 \pm .04^{b}$
Body Condition										
Thin	268	4.8 ± 4.2^{a}	2.8 ± 1.0^{a}	$.02 \pm .06^{a}$	$.02 \pm .01^{a}$	$2.4 \pm .1^{a}$	49.1 ± 8.1^{a}	17.7 ± 2.7^{a}	$.35 \pm .07^{a}$	$.13 \pm .02^{a}$
Moderate	358	1.5 ± 1.7^{a}	$2.5 \pm .4^{a}$	$.01 \pm .02^{a}$	$.02 \pm .00^{a}$	$4.9 \pm .0^{b}$	29.1 ± 3.3^{a}	10.3 ± 1.1^{b}	$.22 \pm .03^{a}$	$.08 \pm .01^{b}$
Good	50	12.2 ± 6.2^{a}	4.5 ± 1.5^{a}	$.09 \pm .08^{b}$	$.04 \pm .02^{b}$	$7.1 \pm .2^{c}$	34.7 ± 11.9^{a}	10.5 ± 4.0^{b}	$.27 \pm .10^{a}$	$.09 \pm .03^{b}$
Weight Change X Body Condition										
Gain-Gain										
Thin	45	17.1 ± 4.0^{a}	5.2 ± 1.0^{a}	$.14 \pm .05^{a}$	$.04 \pm .01^{a}$	$2.3 \pm .1^{a}$	121.5 ± 7.7^{a}	42.2 ± 2.6^{a}	$.98 \pm .07^{a}$	$.34 \pm .02^{a}$
Moderate	161	48.2 ± 2.1^{b}	$13.8 \pm .5^{b}$	$.42 \pm .03^{ab}$	$.12 \pm .01^{b}$	$5.1 \pm .1^{ab}$	100.1 ± 4.1^{a}	29.3 ± 1.4^{b}	$.83 \pm .03^{a}$	$.24 \pm .01^{b}$
Good	27	67.3 ± 5.2^{b}	18.3 ± 1.3^{c}	$.56 \pm .07^{b}$	$.15 \pm .01^{b}$	$7.1 \pm .1^{b}$	87.6 ± 10.0^{a}	23.7 ± 3.3^{b}	$.76 \pm .08^{a}$	$.20 \pm .03^{b}$
Gain-Loss										
Thin	9	59.3 ± 9.0^{a}	17.6 ± 2.2^{a}	$.47 \pm .12^{a}$	$.14 \pm .03^{a}$	$2.7 \pm .2^{a}$	-20.3 ± 17.3^{a}	-5.2 ± 5.7^{a}	$-.15 \pm .15^{a}$	$-.04 \pm .05^{a}$
Moderate	70	55.3 ± 3.2^{a}	$15.0 \pm .8^{a}$	$.45 \pm .04^{a}$	$.12 \pm .01^{a}$	$5.3 \pm .1^{a}$	-45.4 ± 6.2^{a}	-10.4 ± 2.1^{a}	$-.41 \pm .05^{a}$	$-.09 \pm .02^{a}$
Good	17	58.2 ± 6.5^{a}	12.7 ± 1.6^{a}	$.47 \pm .09^{a}$	$.10 \pm .02^{a}$	$7.2 \pm .2^{a}$	-48.6 ± 12.6^{a}	-9.1 ± 4.2^{a}	$-.57 \pm .11^{a}$	$-.11 \pm .04^{a}$
Loss-Gain										
Thin	210	-32.2 ± 1.9^{a}	$-6.9 \pm .5^{a}$	$-.28 \pm .02^{a}$	$-.06 \pm .01^{a}$	$2.2 \pm .0^{a}$	122.2 ± 3.6^{a}	41.5 ± 1.2^{a}	$1.03 \pm .03^{a}$	$.35 \pm .01^{a}$
Moderate	96	-50.1 ± 2.8^{a}	$-10.0 \pm .7^{a}$	$-.53 \pm .04^{a}$	$-.10 \pm .01^{a}$	$4.4 \pm .1^{a}$	91.7 ± 5.3^{a}	28.6 ± 1.8^{a}	$.84 \pm .04^{a}$	$.26 \pm .01^{a}$
Good	4	-37.3 ± 13.5^{a}	-6.5 ± 3.3^{a}	$-.31 \pm .18^{a}$	$-.05 \pm .04^{a}$	$7.0 \pm .4^{a}$	133.6 ± 26.0^{a}	33.2 ± 8.6^{a}	$1.20 \pm .22^{a}$	$.30 \pm .07^{a}$
Loss-Loss										
Thin	4	-24.9 ± 13.5^{a}	-4.8 ± 3.3^{a}	$-.23 \pm .18^{a}$	$-.04 \pm .04^{a}$	$2.5 \pm .4^{a}$	-27.1 ± 26.0^{a}	-7.5 ± 8.6^{a}	$-.46 \pm .22^{a}$	$-.12 \pm .07^{a}$
Moderate	31	-47.6 ± 4.8^{a}	-8.6 ± 1.2^{a}	$-.39 \pm .07^{a}$	$-.07 \pm .01^{a}$	$4.8 \pm .1^{a}$	-30.2 ± 9.3^{a}	-6.1 ± 3.1^{a}	$-.36 \pm .08^{a}$	$-.08 \pm .03^{a}$
Good	2	-39.5 ± 19.1^{a}	-6.5 ± 4.5^{a}	$-.35 \pm .26^{a}$	$-.06 \pm .06^{a}$	$7.0 \pm .5^{a}$	-34.0 ± 36.7^{a}	-6.0 ± 12.2^{a}	$-.33 \pm .31^{a}$	$-.06 \pm .10^{a}$

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Note: Figures with different superscripts differ significantly ($P < .05$). Comparisons are within group only.

(P > .05). Cows in good condition at calving made higher (P < .05) daily weight gains before calving (.09 kg per day versus .02 and .01 kg per day) and tended to gain more total weight (P > .05) before calving (12.2 kg versus 4.8 and 1.5 kg) than cows in thin or moderate condition.

Average daily weight change after calving for all cows was .28 kg (table 1). The two groups of cows gaining weight after calving gained an average of .85 and 1.02 kg per day (P > .05) while both groups of cows losing weight after calving lost an average of .38 kg per day. Cows in thin condition at calving made greater (P < .05) changes in percent body weight after calving on a daily (.13 percent versus .08 and .09 percent per day) and total basis (17.7 percent versus 10.3 and 10.5 percent) than cows in moderate or good condition at calving. Similar compensatory postpartum weight gains for cows in poor condition at calving have been reported and largely attributed to increased intake and subsequent gut-fill changes (Tayler, 1959; Lawrence and Pearce, 1964; Hight, 1966).

Average condition score at calving for all cows was 4.8 (table 1). Cows in thin, moderate and good condition at calving differed significantly (P < .05) with average condition scores of 2.4, 4.9 and 7.1, respectively. However, average condition score at calving did not differ (P > .05) among groups of cows either gaining or losing weight before calving. Thus, regardless of weight change prior to calving there were cows in good condition after losing weight and cows in thin condition after gaining weight.

Likelihood of estrus (LOE) 40 and 50 days postpartum was significantly ($P < .01$) affected by weight change before and after calving (table 2). Cows gaining weight before calving and losing weight after calving had a higher ($P < .05$) LOE 40 days postpartum than all other weight-change groups (table 3). Within the gain-loss group, LOE 40 days postpartum increased significantly ($P < .05$) as body condition at calving improved from thin to good. At 50 days postpartum, both groups of cows gaining weight before calving had a higher ($P < .05$) LOE than cows losing weight before calving.

Body condition at calving accounted for a significant ($P < .01$) proportion of the variation in LOE 60 to 90 days postpartum (table 2). For each 10-day interval 60 to 90 days postpartum, LOE increased ($P < .05$) as body condition at calving improved from thin to moderate to good (table 3). Likelihood of estrus 60 days postpartum was .91 for cows in good condition at calving compared to only .61 and .46 for cows in moderate and thin condition, respectively.

Interaction of weight change and body condition also accounted for a significant proportion ($P < .05$) of the variation in LOE 70, 80 and 90 days postpartum (table 2). Most differences were noted among cows losing weight after calving. In all cases, cows in good condition at calving had a higher ($P < .05$) LOE than cows in thin

Table 2. Analyses of Variance for Likelihood of Estrus 30 to 90 Days Postpartum.

Source	d.f.	Days Postpartum 30	40	50	60	70	80	90
		(Mean Squares)						
Weight Change Pre/Post-Calving	3	.0499	1.1845**	1.7452**	.3480	.1160	.0943	.2621*
Body Condition-Calving	2	.0655	.1054	.2170	1.3328**	1.4007**	1.3892**	1.3294**
Weight Change X Body Condition	6	.0317	.1280	.0960	.2719	.4315*	.3136*	.3229**
Remainder	674	.0499	.1366	.2121	.2293	.1810	.1264	.0918

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*P < .05.

**P < .01.

Table 3. Least-Squares Means and Standard Errors of Likelihood of Estrus 30 to 90 Days Postpartum.

Item	No.	Days Postpartum						
		30	40	50	60	70	80	90
Overall Mean	686	.08 ± .02	.24 ± .04	.40 ± .04	.66 ± .05	.77 ± .04	.83 ± .03	.86 ± .03
Weight Change								
Pre/Post-Calving								
Gain-Gain	233	.07 ± .02^{ab}	.20 ± .03^{a}	.45 ± .04^{a}	.62 ± .41^{a}	.78 ± .04^{a}	.88 ± .03^{a}	.95 ± .03^{a}
Gain-Loss	96	.12 ± .03^{a}	.48 ± .05^{b}	.71 ± .07^{a}	.78 ± .07^{b}	.85 ± .06^{b}	.85 ± .05^{ab}	.85 ± .04^{ab}
Loss-Gain	320	.10 ± .04^{ab}	.17 ± .06^{a}	.27 ± .08^{b}	.65 ± .08^{a}	.76 ± .07^{a}	.86 ± .06^{a}	.89 ± .05^{a}
Loss-Loss	37	.02 ± .07^{b}	.10 ± .11^{a}	.18 ± .14^{b}	.58 ± .14^{a}	.67 ± .13^{a}	.72 ± .10^{b}	.74 ± .09^{b}
Body Condition at								
Calving								
Thin	272	.03 ± .03^{a}	.19 ± .06^{a}	.34 ± .07^{a}	.46 ± .07^{a}	.55 ± .07^{a}	.62 ± .06^{a}	.66 ± .05^{a}
Moderate	364	.07 ± .01^{ab}	.21 ± .02^{ab}	.45 ± .03^{a}	.61 ± .03^{b}	.79 ± .03^{b}	.88 ± .02^{b}	.92 ± .02^{b}
Good	50	.13 ± .05^{b}	.31 ± .08^{b}	.42 ± .11^{a}	.91 ± .11^{c}	.96 ± .10^{c}	.98 ± .08^{c}	1.00 ± .07^{c}
Weight Change X								
Body Condition								
Gain-Gain								
Thin	45	.02 ± .03^{a}	.09 ± .06^{a}	.33 ± .07^{a}	.47 ± .07^{a}	.62 ± .06^{a}	.78 ± .05^{a}	.89 ± .05^{a}
Moderate	161	.09 ± .02^{a}	.20 ± .03^{ab}	.47 ± .04^{ab}	.69 ± .04^{b}	.86 ± .03^{b}	.93 ± .03^{a}	.98 ± .02^{a}
Good	27	.11 ± .04^{a}	.30 ± .07^{b}	.56 ± .09^{b}	.70 ± .09^{b}	.85 ± .08^{b}	.93 ± .07^{a}	1.00 ± .06^{a}
Gain-Loss								
Thin	9	.11 ± .07^{a}	.33 ± .12^{a}	.56 ± .15^{a}	.67 ± .16^{a}	.67 ± .14^{a}	.67 ± .12^{a}	.67 ± .10^{a}
Moderate	70	.09 ± .03^{a}	.41 ± .04^{ab}	.70 ± .06^{a}	.74 ± .06^{a}	.87 ± .05^{ab}	.89 ± .04^{ab}	.89 ± .04^{b}
Good	17	.18 ± .05^{a}	.71 ± .09^{b}	.88 ± .11^{a}	.94 ± .12^{a}	1.00 ± .10^{b}	1.00 ± .09^{b}	1.00 ± .06^{b}
Loss-Gain								
Thin	214	.00 ± .02^{a}	.08 ± .03^{a}	.22 ± .03^{a}	.45 ± .03^{a}	.65 ± .03^{a}	.78 ± .02^{a}	.83 ± .02^{a}
Moderate	102	.05 ± .02^{ab}	.17 ± .04^{a}	.34 ± .05^{a}	.51 ± .05^{ab}	.64 ± .04^{a}	.80 ± .04^{a}	.85 ± .03^{a}
Good	4	.25 ± .11^{b}	.25 ± .18^{a}	.25 ± .23^{a}	1.00 ± .24^{b}	1.00 ± .21^{b}	1.00 ± .18^{b}	1.00 ± .15^{b}
Loss-Loss								
Thin	4	.00 ± .11^{a}	.25 ± .18^{a}	.25 ± .23^{a}	.25 ± .24^{a}	.25 ± .21^{a}	.25 ± .18^{a}	.25 ± .15^{a}
Moderate	31	.06 ± .04^{a}	.06 ± .07^{a}	.29 ± .08^{a}	.48 ± .09^{ab}	.77 ± .08^{ab}	.90 ± .06^{ab}	.97 ± .05^{b}
Good	2	.00 ± .16^{a}	.00 ± .26^{a}	.00 ± .33^{a}	1.00 ± .34^{b}	1.00 ± .30^{b}	1.00 ± .25^{b}	1.00 ± .21^{b}

Whitman, 1975. Ph.D. Dissertation.

Note: Figures with different superscripts differ significantly ($P < .05$). Comparisons are within group only.

condition (table 3). It would seem that when cows are losing weight after calving their chances of exhibiting estrus 70 to 90 days postpartum are directly related to available body energy reserves.

Average weight change prior to first breeding for all cows was .13 kg per day (table 4). Cows gaining weight prior to breeding gained an average of 1.06 kg per day while those losing weight lost an average of .79 kg per day ($P < .05$). Cows in good condition at first breeding made a greater change from calving to breeding in total percent body weight than did cows in moderate or thin condition ($P < .05$).

Average condition score at first breeding for all cows was 5.0 (table 4). Cows in thin and good condition at breeding differed significantly ($P < .05$) in average condition score but no differences existed ($P > .05$) between cows in thin and moderate condition or moderate and good condition. Average condition score at breeding also did not differ ($P > .05$) for cows gaining or losing weight despite significant differences in weight change prior to breeding.

Neither weight change pre-breeding, body condition at breeding nor interactions of the two variables accounted for a significant ($P > .05$) proportion of the variation in likelihood of pregnancy at first breeding (table 5). Least-squares means shown in table 6 do not differ significantly ($P > .05$) suggesting that once estrus is manifest neither weight change nor body condition affect the likelihood of pregnancy.

Table 4. Least-Squares Means of Condition Score at First Breeding and Weight Change Prior to Breeding.

Item	No.	Total kg	Total %	Daily kg	Daily %	Breeding Condition Score
Overall Mean	627	21.0 ± 2.6	8.3 ± .9	.13 ± .04	.08 ± .01	5.0 ± .1
Weight Change Pre-Breeding						
Gain	496	79.0 ± 2.4^{a}	24.4 ± .8^{a}	1.06 ± .04^{a}	.33 ± .01^{a}	5.1 ± .0^{a}
Loss	131	-37.0 ± 4.7^{b}	-7.7 ± 1.6^{b}	-.79 ± .07^{b}	-.17 ± .02^{b}	5.0 ± .1^{a}
Body Condition Breeding						
Thin	44	12.1 ± 6.0^{a}	4.8 ± 2.0^{a}	.12 ± .09^{a}	.05 ± .03^{a}	2.7 ± .1^{a}
Moderate	453	17.4 ± 2.0^{a}	7.9 ± .7^{a}	.16 ± .03^{a}	.09 ± .01^{a}	5.0 ± .0^{ab}
Good	130	33.4 ± 4.7^{a}	12.4 ± 1.6^{b}	.12 ± .07^{a}	.10 ± .02^{a}	7.3 ± .1^{b}
Weight Change X Body Condition						
Gain						
Thin	32	62.6 ± 6.3^{a}	19.1 ± 2.1^{a}	.84 ± .10^{a}	.25 ± .03^{a}	2.7 ± .1^{a}
Moderate	350	68.7 ± 1.9^{a}	22.7 ± .6^{a}	.95 ± .03^{ab}	.31 ± .01^{a}	5.2 ± .0^{ab}
Good	114	105.6 ± 3.3^{b}	31.3 ± 1.1^{b}	1.38 ± .05^{b}	.41 ± .02^{b}	7.4 ± .1^{b}
Loss						
Thin	12	-38.4 ± 10.2^{a}	-9.5 ± 3.5^{a}	-.59 ± .16^{a}	-.15 ± .05^{a}	2.8 ± .2^{a}
Moderate	103	-33.8 ± 3.5^{a}	-7.0 ± 1.2^{a}	-.64 ± .05^{a}	-.14 ± .02^{a}	4.9 ± .1^{a}
Good	16	-38.9 ± 8.8^{a}	-6.6 ± 3.0^{a}	-1.13 ± .14^{a}	-.21 ± .04^{a}	7.2 ± .2^{a}

Whitman, 1975. Ph.D. Dissertation.

Note: Figures with different superscripts differ significantly ($P < .05$). Comparisons are within group only.

Table 5. Analyses of Variance for Likelihood of Pregnancy at First Breeding.

Source	d. f.	Mean Squares
Weight Change Pre-Breeding	1	.2089
Body Condition Breeding	2	.1380
Weight Change X Body Condition	2	.0918
Remainder	625	.2462

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Table 6. Least-Squares Means and Standard Errors of Likelihood of Pregnancy at First Breeding.

Item	No.	Mean ± S. E.
Overall Mean	631	.56 ± .04
Weight Change Pre-Breeding		
Gain	500	.60 ± .03
Loss	131	.53 ± .07
Body Condition at Breeding		
Thin	45	.61 ± .08
Moderate	455	.57 ± .03
Good	131	.51 ± .07
Weight Change X Body Condition		
Gain		
Thin	33	.64 ± .09
Moderate	352	.58 ± .03
Good	115	.57 ± .05
Loss		
Thin	12	.58 ± .14
Moderate	103	.56 ± .05
Good	16	.44 ± .12

Whitman, 1975. Ph. D. Dissertation.

Note: Means do not differ from one another at the 5% level.

Summary

Data compiled on 686 Angus and Hereford cows 2 to 11 years old fed different levels of energy before and after calving were analyzed by the method of least squares to determine the effect of individual weight change and body condition on (1) likelihood of estrus (LOE) 30 to 90 days postpartum and (2) likelihood of pregnancy (LOP) at first breeding. Cows were designated to weight-change groups according to weight gain (G) or loss (L) 120 days before and 90 to 140 days after calving (GG, GL, LG, or LL) and from calving to first breeding (G or L). Cows were also designated to body condition groups (thin, moderate, or good) at calving and first breeding according to visual appraisal and palpated fat cover over the back and ribs. Weight change pre- and post-calving accounted for a significant portion of the variation in LOE 40 and 50 days postpartum ($P < .01$). The GL group had a greater LOE than GG, LG, or LL groups at 40 days postpartum ($P < .05$). Within GL cows, those in good condition at calving had a greater LOE than those in thin condition ($P < .05$). At 50 days postpartum, both groups of cows gaining weight before calving had a higher ($P < .05$) LOE than cows losing weight before calving. Body condition at calving accounted for a significant portion of the variation in LOE 60 to 90 days postpartum ($P < .01$). For each 10-day interval 60 to 90 days postpartum LOE increased ($P < .05$) as body condition at calving improved from thin

to moderate to good. Neither weight change pre-breeding nor body condition at first breeding affected LOP ($P > .05$).

CHAPTER IV

ESTIMATING BODY CONDITION OF BEEF COWS

Introduction

To control beef production costs and obtain optimum reproductive performance producers must be able to determine levels of nutrition required by individual cows at different stages of the reproductive cycle. Earlier studies have indicated both nutritional requirements and reproductive performance of beef cows vary according to body condition (Hilts, 1925; Wiltbank et al., 1962; Donaldson et al., 1967; Baker, 1968; Klosterman et al., 1968; McGinty and Ray, 1973). Therefore, desired levels of nutrition could best be determined if body condition of cows could be objectively measured. Previous work has indicated a weight-to-height ratio may be a good estimate of body condition (Klosterman et al., 1968).

The objectives of these studies were to: (1) determine the repeatability of a cow-height measurement and (2) determine the relationship between weight-to-height ratio and measurable backfat.

Materials and Methods

Three trials were conducted to obtain estimates of repeatability of a cow-height measurement. Height at the hips was measured to the nearest .1 cm using a steel caliper which swung over the cow and extended downward from a pre-set height to the lumbar vertebrae midway between the tuber coxae. Measurements were taken as cows stood naturally in a straight-sided chute on concrete flooring. In trial 1, 27 yearling Angus heifers were measured by four technicians on each of four occasions. In trial 2, 73 Angus cows, 4 and 6 years of age, were measured by one technician on three separate occasions over a period of 16 months. In trial 3, 150 Hereford cows ranging in age from 3 to 12 years were measured by one technician on two separate occasions 3 months apart. Repeatability estimates for trials 1 and 2 were obtained by calculating the intraclass correlation coefficients of the repeated measurements using the formula:

$$r = \frac{\sigma_c^2}{\sigma_c^2 + \sigma_e^2}$$

where σ_c^2 and σ_e^2 estimate "among" and "within" cow variability, respectively. Components of variance were isolated from analysis of variance for repeated latin squares (trial 1) and one-way analysis of variance for unequal subclasses (trial 2). The estimate of repeatability for trial 3 was the correlation coefficient obtained by simple linear regression analysis (Snedecor and Cochran, 1967).

Two trials were conducted to determine the relationship between weight-to-height ratio and measurable backfat. Height measurements were taken as described earlier. Backfat measurements were taken over the 12th and 13th ribs using an ultrasonic scanner. In trials 4 and 5 respectively, height and backfat measurements were taken 60 and 90 days before calving on 68 mature Angus cows 4 and 6 years of age and 52 Hereford heifers 2 years of age. Correlation coefficients were obtained by simple linear regression analysis (Snedecor and Cochran, 1967).

Results and Discussion

Repeatability estimates of cow-height measurements obtained in trials 1, 2 and 3 are presented in table 1. In trial 1, the average repeatability of four technicians measuring each heifer four times was .86. Repeatability of individual operators ranged from .77 to .87. There was limited variation in height among yearling heifers in trial 1. Therefore, calculated estimates of repeatability do not reflect the closeness of individual measurements. For example, the coefficient of variation (standard deviation expressed as a percentage of the mean) for each set of 16 measurements was 1.0 percent or less for 26 of the 27 heifers and only .9 percent for the overall total of 432 measurements. In trials 2 and 3, repeatability of a single technician measuring mature cows two and three times was .91 and .81, respectively. Coefficients of variation were 3.4 (trial 2) and 3.3 (trial 3) percent.

Correlation coefficients between weight-to-height ratio and measurable backfat were .50 and .71 for trials 4 and 5, respectively (table 2). A higher correlation coefficient was obtained among cows

Table 1. Repeatability Estimates of Cow-Height Measurement.

Trial No.	No. of Animals	No. of Technicians	Measurements Per Cow	Height at Hip Mean ± S.E. cm	C. V. %	R
1	27	4	16	116.2 ± .1	0.9	.86
2	73	1	2 - 3	117.5 ± .3	3.4	.91
3	150	1	2	123.1 ± .3	3.3	.81

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Table 2. Correlation Coefficients Between Backfat and Weight-to-Height Ratio.

Trial No.	No. of Animals	Backfat in mm. Mean ± S.E.	Weight/Height Ratio Mean ± S.E.	r
4	68	6.1 ± .3	432 ± 4	.50
5	52	4.0 ± .3	361 ± 4	.71

Whitman, 1975. Ph.D. Dissertation.

in lower condition as indicated by less measurable backfat and a lower average weight-to-height ratio (trial 5).

Results of these studies indicate: (1) cow height at the hips is a repeatable measurement and (2) weight-to-height ratio can be useful in describing relative condition of mature beef cows.

Summary

Studies were conducted to determine: (1) the repeatability of a cow-height measurement and (2) the relation of weight-to-height ratio to measurable backfat. Height at the hips was measured to the nearest .1 cm using a steel caliper which swung over the cow and extended downward from a pre-set height to the lumbar vertebrae midway between the tuber coxae. Backfat measurements were taken over the 12th and 13th ribs using an ultrasonic scanner. In three separate studies involving a total of 927 height measurements on 250 cows, repeatability estimates obtained were .86, .81 and .91. In two separate studies involving height and backfat measurements on a total of 120 cows, correlations between weight-to-height ratio and measurable backfat were .50 and .71.

CHAPTER V

RELATION OF WEIGHT-TO-HEIGHT RATIO TO POSTPARTUM REPRODUCTIVE PERFORMANCE OF BEEF COWS

Introduction

Earlier studies have indicated that body condition is an important factor in determining reproductive performance of beef cows (Marshall and Peel, 1910; Hilts, 1925; Pinney et al., 1961; ToTusek et al., 1961; Wiltbank et al., 1962; Wiltbank et al., 1964; Donaldson et al., 1967; Baker, 1968; Dunn et al., 1969). Work by Klosterman et al. (1968) has shown that a weight-to-height ratio may be used to indicate body condition of cows.

The objective of this study was to determine the relation of pre- and post-calving weight-to-height ratios to likelihood of estrus 30 to 90 days postpartum and likelihood of pregnancy at first breeding in beef cows suckling calves.

Materials and Methods

Five hundred sixty spring-calving Angus and Angus x Hereford cows ranging in age from 6 to 13 years were used in this study. All cows had calved each of the previous three years and were pregnant to either Simmental, Simmental x Hereford or Charolais sires. Cows grazed corn stalks from late fall until 30 to 60 days before calving when they were moved to native grass pastures and fed 7 to 9 kilograms of good quality alfalfa hay per head per day until the end of the 60-day calving period. When the last cow calved, all cows were moved to irrigated pastures which they grazed on a rotational basis until the end of breeding. During the breeding season cows received 2 to 3 kilograms of ground corn per head per day. Salt and mineral were available free choice at all times.

Prepartum weights were taken at monthly intervals beginning approximately 90 days before the start of calving. On weigh days cows were gathered at first daylight and moved to holding pens without feed or water. To account for possible differences due to time of weighing, the exact time of each weighing was recorded and the relation of weight and time determined by regression analysis. Additional weights were taken at first postpartum estrus and first breeding.

Height of each cow at the hip was measured to the nearest .5 cm using a steel caliper which fastened to the scales and extended from a pre-set height down to the lumbar vertebrae midway between the tuber coxae.

Cows were checked for estrus twice daily beginning 20 days after the first cow calved. A cow standing to be ridden by another cow was considered to be in estrus. Cows in estrus were marked with paint and removed from the pasture for breeding and weighing 6 to 30 hours later. Breeding began 40 days after the last cow calved and continued for 60 days. Cows were bred artificially by two technicians using semen from a single sire (American Breeders Service, Chianina bull 24604). Pregnancy was determined by rectal palpation of the reproductive tract 50 to 110 days post breeding.

Data were analyzed by the method of least squares for unequal subclass numbers (Harvey, 1960). Prepartum weights were designated to appropriate intervals of 30, 60, 90 and 120 days, plus or minus 15 days. Original prepartum weights were used in all calculations after regression analyses indicated no effect due to time of weighing ($P > .05$). Weight-to-height ratios were calculated using the formula: $(Wt_{kg}/Ht_{cm}) \times 100$. Each cow was assigned an estrous code of 0 (not cycling) or 1 (cycling) for each 10-day interval 30 to 90 days postpartum. Cows bred were assigned a pregnancy code of 0 (open) or 1 (pregnant) at first breeding. Weight-to-height ratios and weight change pre- and post-calving were analyzed using a model that included the effects of breed of cow, sex of calf, sire of calf and date of calving. Likelihood of estrus 30 to 90 days postpartum was analyzed separately for each prepartum interval using a model that included the effects of breed of cow, sex of calf, sire of calf, respective two-way interactions, calving date and the appropriate prepartum weight-to-height ratio. Among cows exhibiting estrus, interval from calving to first estrus was analyzed using a similar model including the effect of weight-to-height ratio at first estrus.

Likelihood of pregnancy at first breeding was analyzed using a model that included the effects of breed of cow, sex of calf, sire of calf, technician, days since calving and weight-to-height ratio at first breeding. The effect of cow age was not included in these analyses because exact age of each cow was not known. All cows included in these analyses calved without difficulty and suckled their calf from calving through breeding.

Results and Discussion

Least-squares means of weight-to-height ratios and weight change before and after calving are shown in tables 1 and 2. Average weight-to-height ratio (WHR) before calving increased from 356 at 120 days prepartum to 373 at 30 days prepartum (table 1). During this period cows gained an average of .28 kg per day (table 2). Cows that calved in the latter part of the 60-day calving period tended to gain less weight ($P < .01$) before calving and have lower ($P < .01$) WHR values 15 to 45 days prepartum than earlier calving cows. WHR values 120, 90, 60 and 30 days prepartum tended to be higher ($P < .05$) for cows pregnant with bull calves than for cows pregnant with heifer calves. Neither WHR at first postpartum estrus nor WHR at first breeding were significantly affected ($P > .05$) by differences in breed of cow, sex of calf, sire of calf or date of calving. Average daily weight gain from calving to first estrus was .39 kg per day. Later calving cows tended to gain more weight after calving ($P < .01$),

Table 1. Least-Squares Means of Weight-to-Height Ratios Prior to Calving, at First Postpartum Estrus and at First Breeding.

	120 Days Prepartum		90 Days Prepartum		60 Days Prepartum		30 Days Prepartum		First Estrus		First Breeding	
Item	No.	Mean ± S. E.	No.	Mean ± S. E.	No.	Mean ± S. E.	No.	Mean ± S. E.	No.	Mean ± S. E.	No.	Mean ± S. E.
Overall Mean	443	356 ± 2	371	350 ± 2	325	371 ± 3	232	373 ± 4	482	356 ± 2	495	355 ± 2
Breed												
Angus	343	353 ± 3	274	346 ± 3	242	368 ± 4	170	371 ± 6	363	353 ± 4	372	352 ± 3
Angus/Hereford	100	359 ± 3	97	353 ± 3	83	375 ± 3	62	374 ± 4	119	360 ± 3	123	357 ± 3
Sex of Calf												
Male	229	361 ± 3**	194	353 ± 3*	180	376 ± 3*	125	379 ± 5*	242	358 ± 3	250	358 ± 3
Female	214	351 ± 3	177	346 ± 3	145	367 ± 4	107	366 ± 5	240	354 ± 3	245	351 ± 3
Sire of Calf												
Simmental/ Hereford	152	357 ± 3	87	352 ± 3	78	374 ± 4	50	377 ± 5	138	358 ± 3	138	358 ± 3
Simmental	238	356 ± 3	247	353 ± 2	213	366 ± 2	164	371 ± 3	303	355 ± 2	312	354 ± 2
Charolais	53	354 ± 5	37	344 ± 6	34	375 ± 8	18	370 ± 11	41	356 ± 6	45	353 ± 6
Calving Date												
Linear Regr. Coef.		----		----		----		-1.15 ± .34**		0.18 ± .35		----
Correlation Coef.		----		----		----		-.13		-.16		----

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*P < .05.

**P < .01.

Table 2. Least-Squares Means of Weight Change Before and After Calving[1].

		Before Calving				After Calving			
		Total		Daily		Total		Daily	
Item	No.	kg	%	kg	%	kg	%	kg	%
Overall Mean	208	22.7 ± 2.6	2.5 ± .3	.28 ± .03	.03 ± .01	29.2 ± 3.2	3.5 ± .4	.39 ± .04	.05 ± .01
Breed									
Angus	151	23.2 ± 4.3	2.6 ± .5	.28 ± .05	.03 ± .01	32.0 ± 5.1	3.9 ± .6	.42 ± .07	.05 ± .01
Angus/Hereford	57	22.2 ± 3.0	2.4 ± .3	.27 ± .04	.03 ± .01	26.3 ± 3.6	3.1 ± .4	.36 ± .05	.04 ± .01
Calf Sex									
Male	111	23.3 ± 3.1	2.5 ± .4	.28 ± .04	.03 ± .01	21.7 ± 3.8	2.6 ± .4	.29 ± .05	.03 ± .01
Female	97	22.1 ± 3.6	2.5 ± .4	.27 ± .04	.03 ± .01	36.7 ± 4.4**	4.5 ± .5**	.49 ± .06**	.06 ± .01**
Sire of Calf									
Simmental/ Hereford	43	23.0 ± 3.5	2.5 ± .4	.29 ± .04	.03 ± .01	20.9 ± 4.2	2.4 ± .5	.29 ± .06	.03 ± .01
Simmental	149	19.9 ± 2.2	2.2 ± .2	.24 ± .03	.03 ± .01	29.3 ± 2.6	3.6 ± .3	.38 ± .04	.05 ± .01
Charolais	16	25.2 ± 7.1	2.7 ± .8	.30 ± .09	.03 ± .01	37.3 ± 8.6	4.6 ± 1.0	.51 ± .12	.06 ± .01
Calving Date Regression	208	-.44 ± .26	-.04 ± .03	-.009 ± .003**	-.001 ± .001**	.17 ± .32**	.02 ± .04**	.004 ± .004**	.001 ± .001**

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[1]Calculations based on weights recorded an average of 30 and 120 days before calving and at first postpartum estrus or breeding.

**P < .01.

possible reflecting differences in available forage during respective 90-day postpartum periods for cows calving in March versus early May. Cows suckling heifer calves also made higher weight gains from calving to first estrus ($P < .01$) than cows suckling bull calves. There was, however, no significant difference ($P > .05$) in reproductive performance due to sex of calf.

Analyses of variance and least-squares means for likelihood of estrus (LOE) 30 to 90 days postpartum are presented in tables 3 and 4. Because of the small proportion of cows exhibiting estrus by 30, 40 and 50 days postpartum, no meaningful conclusions can be drawn for these intervals. By 60 and 70 days after calving only 15 and 34 percent of the cows were cycling (table 4). These values are approximately 10 percent below those reported for cows on low levels of energy before and after calving (Wiltbank et al., 1962; Wiltbank et al., 1964; Dunn et al., 1969). Cows calving in the latter part of the 60-day calving period and making higher post-calving weight gains tended to have a greater ($P < .01$) LOE 60 and 70 days postpartum than earlier calving cows that gained less weight after calving. Weight-to-height ratio approximately 60 days before calving was significantly related to LOE 60 and 70 days postpartum ($P < .05$) as well as LOE 80 and 90 days postpartum ($P < .01$). For each 10-day interval 60 to 90 days postpartum, LOE became greater as WHR increased. As WHR 60 days prepartum increased by a value of 10, LOE 60, 70, 80

Table 3. Analyses of Variance for Likelihood of Estrus 30 to 90 Days Postpartum.

Source	d. f.	Days Postpartum						
		30	40	50	60	70	80	90
		(Mean Squares)						
Breed (A)	1	.00	.00	.00	.32	.77*	.31	.42
Calf Sex (B)	1	.00	.03*	.00	.04	.00	.10	.01
Calf Sire (C)	2	.00	.01	.00	.00	.09	.50	.19
A X B	1	.00	.00	.02	.28	.30	.83	.02
A X C	2	.00	.02	.01	.03	.05	.77*	.55
B X C	2	.00	.02	.01	.23	.13	.16	.00
Calving Date Linear	1	.00	.05**	.05	.75**	1.05**	.14	.04
WHR 120 - Linear	1	.00	.01	.07	.21	1.35**	1.39*	.16
Remainder	422	.00	.01	.03	.10	.20	.23	.19
Breed (A)	1	.00	.02	.04	.30*	.08	.08	.05
Calf Sex (B)	1	.00	.01	.01	.01	.27	.07	.08
Calf Sire (C)	2	.00	.02	.05	.01	.02	.02	.18
A X B	1	.00	.01	.06	.18	.44	1.08*	.06
A X C	2	.00	.01	.02	.07	.01	.35	.28
B X C	2	.00	.01	.01	.23*	.35	.28	.04
Calving Date Linear	1	.00	.03*	.07	1.19**	2.22**	.67	.00
WHR 90 - Linear	1	.00	.03*	.03	.25	.36	.21	.19
Remainder	350	.00	.01	.03	.00	.16	.23	.23

Table 3. (Continued)

Source	d. f.	Days Postpartum 30	40	50	60	70	80	90
		(Mean Squares)						
Breed (A)	1	.00	.03*	.08	.18	.05	.06	.15
Calf Sex (B)	1	.00	.01	.01	.08	.51	.00	.13
Calf Sire (C)	2	.00	.02	.08	.13	.09	.03	.03
A X B	1	.00	.01	.12*	.04	.24	.50	.00
A X C	2	.00	.02	.02	.03	.02	.77	.43
B X C	2	.00	.01	.03	.24*	.42	.48	.05
Calving Date Linear	1	.00	.03*	.03	.84**	1.46**	.72	.15
WHR 60 - Linear	1	.00	.02*	.02	.43*	.81*	2.50**	1.86**
Remainder	304	.00	.01	.03	.08	.16	.23	.20
Breed (A)	1	.00	.02*	.04	.00	.01	.00	.03
Calf Sex (B)	1	.00	.01	.03	.09	.52	.15	.63
Calf Sire (C)	2	.00	.01*	.03	.01	.02	.18	.27
A X B	1	.00	.00	.02	.03	.18	.31	.11
A X C	2	.00	.01*	.02	.01	.07	.43	.33
B X C	2	.00	.00	.02	.11	.39	.00	.10
Calving Date Linear	1	.00	.03**	.09*	.83**	1.08**	.35	.08
WHR 30 - Linear	1	.00	.01	.02	.05	.06	.69	.63
Remainder	211	.00	.00	.02	.08	.15	.23	.21

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*P < .05.

**P < .01.

Table 4. Least-Squares Means and Standard Errors of Likelihood of Estrus 30 to 90 Days Postpartum.

		Days Postpartum						
Item	No.	30	40	50	60	70	80	90
Overall Mean	560	0 ± 0	.01 ± .01	.05 ± .01	.15 ± .02	.34 ± .03	.60 ± .04	.78 ± .03
Breed								
Angus	430	0 ± 0	.02 ± .01	.05 ± .02	.14 ± .03	.31 ± .05	.57 ± .05	.75 ± .05
Angus/Hereford	130	0 ± 0	.01 ± .01	.05 ± .02	.17 ± .03	.36 ± .04	.62 ± .05	.82 ± .04
Sex of Calf								
Male	285	0 ± 0	.00 ± .01	.05 ± .02	.15 ± .03	.36 ± .04	.58 ± .05	.77 ± .04
Female	275	0 ± 0	.02 ± .01	.04 ± .02	.16 ± .03	.32 ± .04	.61 ± .05	.79 ± .04
Sire of Calf								
Simmental/ Hereford	158	0 ± 0	.01 ± .01	.03 ± .02	.13 ± .03	.34 ± .04	.58 ± .05	.76 ± .04
Simmental	349	0 ± 0	.00 ± .01	.03 ± .01	.13 ± .02	.24 ± .03*	.50 ± .04*	.70 ± .03*
Charolais	53	0 ± 0	.02 ± .01	.07 ± .03	.22 ± .06	.43 ± .08*	.72 ± .09*	.88 ± .08*
Calving Date								
Linear Regr.	325	---	.0026 ± .0012*	.0028 ± .0028	.0149 ± .0045**	.0196 ± .0064**	.0137 ± .0077	.0063 ± .0073
Correlation		---	.10	.16	.22	.23	.12	.11
WHR - 60								
Linear Regr.	325	---	.0005 ± .0002*	.0005 ± .0006	.0021 ± .0009*	.0029 ± .0013*	.0051 ± .0016**	.0044 ± .0015**
Correlation		---	.12	.10	.18	.17	.16	.15

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*P < .05.

**P < .01.

and 90 days postpartum improved by 2, 3, 5 and 4 percent, respectively (table 4). On the other hand, WHR approximately 30 days before calving was not significantly related to LOE either 60, 70, 80 or 90 days postpartum. Weight-to-height ratio 15 to 45 days prepartum may not have been significantly related to LOE because weight changes occurring near calving primarily reflect growth of fetus and accumulation of fluids rather than real changes in body condition.

Analyses of variance and least-squares means for days from calving to first estrus are presented in tables 5 and 6. Average interval from calving to first estrus for cows cycling by 90 days postpartum (78 percent) was 79 days (table 6). Cows with a higher WHR at first estrus tended to have a shorter interval ($P < .01$) from calving to first estrus than cows with a lower WHR. As WHR at first estrus increased by 10, average interval from calving to first estrus was shortened by 1.3 days. Later calving cows which gained more weight after calving also tended to have a shorter ($P < .05$) postpartum estrus interval than earlier calving cows.

Analyses of variance and least-squares means for likelihood of pregnancy at first breeding are presented in tables 7 and 8. Neither breed of cow, sex or sire of calf, AI technician, days from calving to breeding nor WHR at breeding accounted for a significant proportion of the variation in likelihood of pregnancy at first breeding. Average pregnancy rate at first service for all cows was 60 percent.

Table 5. Analyses of Variance for Days from Calving to First Postpartum Estrus.

Source	d. f.	Mean Squares
Breed (A)	1	358.5
Calf Sex (B)	1	2.0
Calf Sire (C)	2	135.2
A X B	1	476.3
A X C	2	304.3
B X C	2	399.7
Calving Date Linear	1	858.3*
WHR - Estrus Linear	1	3653.8**
Remainder	461	199.6

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*P < .05.

**P < .01.

Table 6. Least-Squares Means of Days from Calving to First Postpartum Estrus.

Item	No.	Mean ± S. E.
Overall Mean	482	79 ± 1
Breed		
Angus	363	80 ± 2
Angus/Hereford	119	77 ± 1
Sex of Calf		
Male	242	79 ± 1
Female	240	79 ± 2
Sire of Calf		
Simmental/Hereford	138	78 ± 1
Simmental	303	80 ± 1
Charolais	41	78 ± 3
Calving Date Linear	482	
Regression		-.35 ± .17*
Correlation		-.30
WHR - First Estrus Linear	482	
Regression		-.13 ± .03**
Correlation		-.26

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*P < .05.

**P < .01.

Table 7. Analyses of Variance for Likelihood of Pregnancy at First Breeding.

Source	d. f.	Mean Squares
Breed (A)	1	.3468
Calf Sex (B)	1	.1644
Calf Sire (C)	2	.7750
Technician (D)	1	.4744
A X B	1	.9505
A X C	2	.0675
A X D	1	.0003
B X C	2	.4996
B X D	1	.5537
C X D	2	.5588
Days Postpartum	1	.0001
WHR - Breeding	1	.0850
Remainder	502	.5416

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Table 8. Least-Squares Means of Likelihood of Pregnancy at First Breeding.

Item	No.	Mean $\pm$ S. E.
Overall Mean	525	.60 $\pm$ .06
Breed		
Angus	396	.56 $\pm$ .09
Angus/Hereford	129	.64 $\pm$ .07
Sex of Calf		
Male	271	.58 $\pm$ .07
Female	254	.63 $\pm$ .08
Sire of Calf		
Simmental/Hereford	148	.50 $\pm$ .08
Simmental	328	.66 $\pm$ .06
Charolais	49	.65 $\pm$ .16
AI Technician		
Tech 1	205	.65 $\pm$ .09
Tech 2	320	.55 $\pm$ .06

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Summary

Five hundred sixty Angus and Angus x Hereford cows 6 to 13 years of age were used to determine the relation of pre- and post-calving weight-to-height ratios to likelihood of estrus (LOE) 30 to 90 days postpartum and likelihood of pregnancy (LOP) at first breeding. All cows calved each of the previous three years and were pregnant to Simmental, Simmental x Hereford or Charolais sires. Height of each cow at the hips was measured to the nearest .5 cm and individual weights were taken approximately 120, 90, 60 and 30 days before calving, at first postpartum estrus and at first breeding. Of the pre-calving measurements, weight-to-height ratio (WHR) 60 days before calving most consistently accounted for significant portions ($P < .05$) of the variation in LOE 60 to 90 days postpartum. Cows with a higher WHR 60 days before calving had a greater LOE ($P < .05$) at each 10-day interval 60 to 90 days postpartum. Weight-to-height ratio at first estrus accounted for a significant portion ($P < .01$) of the variation in interval from calving to first estrus. Of cows exhibiting estrus by 90 days postpartum (78 percent) those with a higher WHR at first estrus had a shorter interval from calving to first estrus. Weight-to-height ratio at first breeding was not related to likelihood of pregnancy ($P > .05$).

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