EFFECT OF TIME OF WEANING ON PERFORMANCE OF YOUNG AND MATURE BEEF COWS AND THEIR CALVES IN A FALL CALVING SYSTEM

By

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Chapter I

Introduction

Fall-calving systems are becoming increasingly more popular as they yield a variety of benefits for producers. Fall-calving allows producers to diversify their operations and increase marketing options. Decreased availability of stocker calves during the spring and summer months results in historically higher prices, presenting a direct economic advantage for fall-born calves. Calving in September and October also removes the risk of calving in inclement weather and reduces calf death loss. Additionally, compared to spring-calving systems, calf birth weights are generally lower for fall-born calves, fall-born heifers reach puberty earlier, and fall-calving provides greater flexibility for weaning and post-weaning management scenarios. Lastly, but not least, the post-partum interval to first estrus is typically shorter in fall-calving cows compared to spring-calving cows.

Changing calving systems requires changes in total management and marketing strategies. Because fall-calving cows are both lactating and gestating during the winter, supplementation costs are presumed greater than for spring-calving cows. Therefore, if fall-calving cows are not managed properly during the pre-partum period to enter the calving season with enough body energy reserves to meet nutritional requirements for lactation and be able to conceive by 85 days post-partum, additional supplementation must be provided. The cost of additional supplementation during this time can dramatically impact profitability of the fall-calving system.

Producers utilizing a fall-calving system have many weaning date options. Fall calves can be weaned from March to early August depending on the calving month and goals of the producer. In Oklahoma, two weaning systems are frequently employed in fall-calving herds. Calves can be weaned at approximately 210 d of age in April (traditional weaning) or at 300 d of age in July (late weaning). Obviously, the reason for weaning calves in July versus April is to produce more pounds of calf, but late weaning may have a negative impact on cow body condition at calving and thus affect fall energy requirements and reproductive performance.

To better understand which weaning system is more profitable and practical, a comprehensive understanding of the effects of time of weaning on cow body condition at calving, cow and calf performance as a result of increased or decreased condition, and subsequent reproductive performance is required.

Additionally, further data is needed regarding calf performance and the economic implications of different marketing and calf management strategies in a fall-calving system.

Chapter II

Review of Literature

Effect of Time of Weaning on Cow Body Condition Score at Calving.

Producers that wean fall-born calves during mid-summer are able to take advantage of abundant, high-quality spring and early-summer forages, resulting in heavier weaning weights. However, this practice may be counter-productive if the extended lactation period detrimentally affects cow body condition at calving. This may result in decreased reproductive performance if nutritional status is not improved through supplementation.

Most research conducted to evaluate the effect of time of weaning on fall-calving cow body condition score (**BCS**) and/or reproductive performance has evaluated early weaning at 6 to 10 weeks of age, or has managed all cows to a BCS of 5.0 before the onset of calving.

Typically, fall-calving cows will enter the calving season in good body condition due to availability of abundant, high-quality forage during late gestation. However, differences in body condition (either inadequate or excessive) at calving can impact supplementation needs and strategies, thus affecting a producer's bottom line.

Fall-calving cows (average weight 533 kg) assigned to a summer-weaning system require 153.9 more Mcal of NE_m for maintenance requirements and 100.5 more Mcal of NE_m for lactation requirements during months 7, 8, and 9 postpartum compared to cows assigned to a spring-weaning system. If grazing range grass in early-summer, spring-weaned cows would be expected to gain 216 lb more than summer-weaned cows during this period (National Research Council, 1996).

Hancock et al. (1985) reported a gain of 0.7 units of condition for cows assigned to a 210 d weaning treatment versus cows assigned to a 285 d weaning treatment (6.7 versus 6.0) at the later weaning date.

In a study by Coffey et al. (2004) fall-calving cows calved at a BCS of 6.7 to 7.0 irrespective of assignment to April or June weaning treatment and cow BW did not differ at calving or breeding across treatments during the 3-year experiment. On average, all treatments groups lost 0.65 units of condition during the post-partum period and entered the breeding season at a BCS of 5.9 to 6.5. Over the three-year study, pregnancy rates averaged greater than 92% for all treatments.

For spring-calving cows assigned to normal weaning at 210 d or late weaning at 270 d and managed to a minimum BCS of 5 one month prior to calving, the difference in total yearly feed cost was $24.92 higher for late weaned cows (Story et al., 2000).

Effect of Body Condition Score at Calving on Reproductive Performance.

When reviewing the effects of cow BCS at calving and rate of BW and condition loss during the post-partum period on reproductive performance, many researchers conclude that pre-partum nutrition is more important than post-partum nutrition in determining the length of the post-partum interval (Dziuk and Bellows, 1983; Richards et al., 1986).

The influence of nutritional status and energy reserves on reproductive performance of beef cows is well recognized (Dunn and Kaltenbach, 1980). The most common method of indicating a cow's nutritional status and energy reserves is the assignment of a body condition score based on visual and/or tactile appraisal (Richard et al., 1986; Houghton et al., 1990). Once assigned a body condition score, cows can then be allocated into like groups for optimal nutritional management (Thompson et al., 1983).

It is generally recognized that cows that calve at a body condition score of 5.0 or greater have sufficient nutrient stores to withstand minimal post-partum weight loss without lengthening the post-partum interval (Dziuk and Bellows, 1983; Richards et al., 1986).

The greater body condition is at parturition, the shorter the interval to first estrus (Richards et al., 1986; Houghton et al., 1990). When evaluating the effect of body condition scores greater than 5.0, Whitman (1975) reported that regardless of pre- and post-partum body weight changes, cows that calved at a body condition score of 7 to 9 were capable of returning to estrus within 60 d after calving.

However, producers should be cautioned to avoid calving cows in an over-conditioned state. While fatter cattle exhibit a shorter interval to estrus, these cattle also exhibit lower pregnancy rates if cows are not decreasing in condition during the post-partum period (Houghton et al., 1990).

Post-Partum Interval/Interval to Pregnancy. The duration of the post-partum interval is a significant indicator of reproductive performance. For cows to conceive during a 45 to 60 d breeding season and maintain a consistent 365 d calving interval, cows should return to first estrus by 60 d post-partum. Cow BCS at calving is an important factor affecting the length of the post-partum interval (**PPI**) and pregnancy rates (Wiltbank et al., 1964; Selk et al., 1988; Lalman et al., 1997). Utilizing a 1 to 5 BCS scale (1=thin condition; 3=moderate condition; 5=fat condition) Houghton et al. (1990) reported that thin cows (BCS $< 3^-$) tend to exhibit an extended PPI that equates to an anestrous interval of 28 to 58 d ($P < 0.10$) longer than that observed by cows in moderate to fleshy condition (BCS $\geq 3^-$) at parturition. These data suggests that in order to maintain a PPI of 60 days or less, cows should be in moderate to nearly moderate condition at calving.

Effect of Rate of Weight/Condition Loss on Reproductive Performance.

Although cows that calve in good, generally regarded as 5.0 or greater on a 1 to 9 scale (1=emaciated; 9=obese), body condition are able to withstand minimal weight changes post-partum and rebreed satisfactorily (Corah et al., 1975; Dzuik and Bellows, 1983; Richards et al., 1986), those cattle that experience severe weight loss during the post-partum period may exhibit suppressed reproductive performance (Wiltbank et al., 1964; Bellows and Short, 1978; Somerville et al., 1979; Cantrell et al., 1981; Hancock et al., 1985; Rakestraw et al., 1986).

In the classic work by Rakestraw and collaborators (1986), cows that lost 3% of their post-partum weight (18 kg) and 8% of initial condition (0.5 units) from calving to breeding and entered the breeding season at 450 kg and BCS of 5.8 exhibited a pregnancy rate of 88%. Those that lost 6% of their post-partum weight (28 kg) and 11.8% of initial condition (0.6 units) and entered the breeding season at 410 kg and BCS of 4.5 exhibited a pregnancy rate of 84%. However, those cattle that lost 17% of their post-partum weight (87 kg) and 23.2% of initial condition (1.45 units), entering the breeding season at 381 kg and BCS of 4.8 recorded a pregnancy rate of only 53%. These data suggest that both body condition score at calving and at breeding are not totally reliable predictors of reproductive performance if cattle experience severe weight and condition loss post-partum. It appears that rate of post-partum weight loss may be more important than condition score at time of calving or breeding.

Similarly, in a study by Cantrell and researchers (1981), fewer fall-calving cows became pregnant that lost 8 percent of body weight during the post-partum period and went from a BCS of 5.5 post-calving to 4.6 at time of breeding (16.4% condition loss) than cows that maintained weight and condition post-partum (82% versus 96%). Hancock et al. (1985) reported that fall-calving cows that lost 4.2% of initial post-calving weight and 0.4 units (6.8%) of condition (from 5.8 to 5.4 at breeding) exhibited a pregnancy rate of 96.2 percent. However, those that lost 8.2% of post-calving weight and 0.9 units (15.5%) of condition exhibited a pregnancy rate of 83.9%, despite entering the breeding season at a BCS of 4.9, which is generally considered adequate for satisfactory reproductive performance.

In contrast, Purvis et al. (1996) reported drastic weight loss of 18.3% of pre-calving weight and 1.8 units (24.7%) of condition (entering the breeding season at BCS of 5.5) for fall-calving cows without suppressing pregnancy rates, indicating that factors other than absolute weight or rate of loss affect reproduction, and that BCS at breeding is also a key indicator/regulator of reproductive performance. These findings are in accordance with the results published by Whitman (1975), indicating that cows that calve at BCS of 7 or greater can withstand significant post-partum losses and still re-breed satisfactorily.

Utilizing spring-calving Angus and cross-bred cows, Richards et al. (1986) observed no difference in post-partum interval despite assignment to differing nutritional treatments (to gain weight, to maintain, to lose and lose/flush prior to and during early breeding). Irrespective of nutritional regime, cows that calved at a condition score of 5.0 or greater returned to estrus earlier than cows that calved at a condition score of 4.0 or less (49 d versus 61 d, $P < 0.01$). Additionally, the interval to pregnancy was not affected by post-partum nutritional management for cows calving at a similar body condition score, but was different for cows calving at 5.0 or greater versus those calving at 4.0 or less (84 d versus 90 d, $P < 0.05$).

Statistically, there is no difference in pregnancy rates between thin cows that continue to lose condition during the post-partum period and fat cows that continue to gain condition (Houghton et al., 1990). Ideally, to not depress reproductive performance and to mitigate the effect on milk production and calf performance, cows should calve in moderate condition and be maintained in such condition throughout the post-partum period.

Pregnancy rates are similar for cows that maintained moderate body condition from parturition to breeding and either thin cows that receive enough energy supplementation to increase body condition or fat cows that are placed on a restricted energy diet to lose condition (Houghton et al., 1990). These data illustrates that cows that calve with moderate or greater amounts of energy reserves are better able to withstand some postpartum weight loss without negatively affecting reproductive performance.

Effect of Weight and Body Condition Score at Calving on Calf Performance.

Milk Production. Milk production plays an important role in calf pre-weaning and weaning performance. Rutledge et al. (1971) reported that 60 % of the variation in 205-d weights of calves could be directly attributed to the dam's milk yield. This finding is similar to the report by Neville (1962) in which 66 % of variation of 8-mo calf weight was accounted for by milk production. A review of classic literature shows the correlation between calf weight gain and cow milk production to be intermediate at approximately 0.55 (Knapp and Black, 1941; Gifford, 1953; Drewry et al., 1959; Neville, 1962; Christian et al., 1965, Melton et al., 1967; Beal et al., 1980).

For cows in moderate condition at time of parturition, body energy reserves, as indicated by BCS, do not influence milk production or pre-weaning and 205-d adjusted weaning weights of calves (Doornbos et al., 1984; Spitzer et al., 1995; DeRouen et al., 1994; Ciccioli et al., 2003). However, calves suckling cows in thin condition at birth or cows that became thin postpartum, were lighter at 105 d (Houghton et al., 1990) and at weaning (Corah et al., 1975) than calves suckling cows in moderate condition. These data indicate that if significant differences in BCS at calving exist, they could be a potential source of variation in milk production and calf weight gain.

Feed intake during lactation has greater influence on milk production and subsequent calf performance than body energy reserves (Perry et al., 1991; Spitzer et al., 1995). Nutrient availability before and during lactation affects the quantity of milk produced (Wiltbank et al., 1962; Totusek et al., 1973). Increased post-partum protein and/or energy supplementation during early lactation will increase milk production (Perry et al., 1991, Marston et al., 1995; Lalman et al., 2000) and pre-weaning calf weights (Gonzalez et al., 1987, 1988). Likewise, postpartum nutrient restriction reduced calf weights at 70 d of age (Perry et al., 1991) and at weaning (Richards et al., 1986; Spitzer et al., 1995). In contrast, Marston et al. (1995) showed that while increased levels of energy during the first 48 d post-partum did increase milk production, it did not increase calf growth in spring-calving primi- and multi-parous cows.

Rutledge and collaborators (1971) demonstrated that while cow weight was not a major factor affecting milk production, heavier cows did give significantly more milk than lighter cows. Additionally, Vaccaro and Dillard (1966) reported a linear effect of dam’s weight on 8-mo calf weight. In contrast, Melton and researchers (1967) identified a correlation that approached significance ($P < 0.06$) between final weight of cow and calf; however, no correlation was identified for cow weight at parturition and total calf gain.

In cows with similar genetic potential for milk production, weight and condition during late gestation and at parturition may influence milk production and subsequent calf performance, although this effect may not be of great magnitude.

Milk Composition. The degree to which differing milk composition affects calf performance is not well-known. Correlations between percent butterfat and solids are low, however total yields of butterfat and solids are moderately to highly correlated (r = 0.31 to 0.80) with total calf gain (Melton et al., 1967; Totusek et al., 1973; Beal et al., 1980). Contrary results by Rutledge and collaborators (1971) indicate only small and unimportant correlations between milk constituents and calf performance.

The nutrient demands of the mammary gland during early to peak lactation exceed those of the rest of the body, resulting in increased mobilization of body energy reserves and decreased body fat synthesis (Barber et al., 1997). Cows in a positive energy balance have less than 10 % of milk fat arising from mobilization of body fat; however, during early lactation when cows are typically in a negative energy balance, the fatty acids utilized by the mammary gland for production of milk fat arising from body fat increases in direct proportion to the extent of energy deficiency (Bauman and Griinari, 2003). It is practical to infer that fatter cows will be in a greater state of negative energy balance during early lactation due to increased energy requirements, and therefore should have increased levels of circulating non-esterified fatty acids (**NEFA**) available to the mammary gland to produce increased quantities of milk fat when compared to thinner cows. More research is needed to quantify differences between cow BCS in early lactation, state of energy balance and milk composition. Additionally, more data are required to determine if increased milk fat, and subsequent caloric density of milk, is a significant source of variation of calf growth.

Immune Function. Using 26 Angus cows in a 2-yr study, Hough et al. (1990) concluded that colostral concentrations of immunoglobulin G (**IgG**) did not differ between cows fed at 100 % NRC levels and cows fed at 57% NRC levels for protein and energy during the 90 d prior to parturition. Although the researchers discovered that cows fed a restricted diet tended to have increased (8.1 % higher) levels of IgG, their calves exhibited decreased ($P < 0.07$) levels of circulating IgG, suggesting that an unmeasured factor in the colostrum influences absorption of IgG. Similarly, Burton et al. (1984) reported no differences in colostral concentrations of IgG in cows fed a restricted diet, although calves from restricted cows exhibited decreased absorption of IgG.

No differences were observed for serum IgG concentrations in calves born to calves ranging from BCS 4 to 7 at 48 h after birth (Perino et al., 1995), or for serum concentrations and calf production of antibodies against an antigen challenge when cows were managed to BCS ranging from 4 to 6 (Lake et al., 2006). It should be noted that in the trial by Lake et al. (2006) that no differences in absorption is likely due to all cows being fed to meet protein requirements during the third trimester.

It is possible that cow BCS prior to and at calving could have an effect on calf serum immunoglobulin level. Regarding weaning strategies for fall-calving cows, more information is needed regarding length of dry period on colostral and calf serum concentrations of immunoglobulins and how this affects calf pre-weaning growth and performance.

Effect of Time of Weaning on Calf Weaning and Post-Weaning Performance.

In addition to cow herd productivity considerations, choosing a time of weaning strategy should be predicated on the producers post-weaning management/marketing plan. Calves can be assigned to numerous management programs based on producer needs and abilities, calf type, and other producer-specific factors.

Calves may be sold at time of weaning, or if producers opt to retain ownership of their calves, several post-weaning management and marketing options exist. Calves may be placed directly in the feedlot at time of weaning or after a short back-grounding period (calf-fed), or be placed on a grower/stocker program to be placed in the feedlot at 12-16 months of age (yearling-fed).

Before choosing a post-weaning management strategy, producers must understand how their cattle will perform and how it will affect their profitability. Additionally, if retained for the purpose of marketing on a grid, producers need to understand if their management strategy will impact carcass merit.

Normal Weaning versus Late Weaning. If producers intend to market their calves immediately after weaning, later-weaned calves will obviously be heavier than earlier-weaned calves and present a direct economic advantage to producers. Per the 20-yr average, steers weighing 650 lb in July are worth $87.15 more per head than calves weighing 450 lb in April. This value of additional gain equates to $.436/lb (CattleFax).

When comparing late-weaned calves to normal-weaned calves that are retained, grazing forage through June, Coffey et al. (2003) reported that normal-weaned calves still weighed numerically less than their later-weaned contemporaries. Also, April-weaned replacement heifers were 81 lb lighter ($P < 0.05$) than June-weaned heifers at the June weaning date, and remained lighter at the beginning of the breeding season (-96 lb; $P < 0.05$).

In a 5-yr comprehensive evaluation of performance and production economics, Story and collaborators (2000) compared early-weaned (EW; 150 d), normal-weaned (NW; 210 d) and late-weaned (LW; 270 d) spring-born calves. At weaning, each group of steers was placed directly in the feedlot without a prior growing period (calf-fed). At the late-weaning date, NW steers were 139 lb heavier ($P < 0.001$) than LW steers. During the feedlot phase, NW steers exhibited lower DMI and lower ADG. NW steers were on feed for 204 d and LW steers were on feed 154 d. Steers were slaughtered at a common end point of 1 cm back-fat as evaluated by feedlot personnel. However, actual fat depth at slaughter was 1.27 cm for NW and 1.12 cm for LW steers ($P = 0.05$). When compared to LW steers, NW steers yielded heavier carcasses, higher average yield grades, and more carcasses grading USDA Choice or greater. Additionally, net income per steer was $52.07 greater for NW steers than for LW steers. Further, weights of replacement heifers did not differ between weaning dates at weaning or at the beginning of the breeding season. However, total development cost for NW heifers was $42.64 per heifer greater than for LW heifers ($372.06 vs. $329.42; $P < 0.001$).

Yearling-Fed vs. Calf-Fed. The decision to manage cattle as yearlings or calf-feds must first involve an understanding of how the different strategies and breed type (predominantly British or Continental) may affect feedlot performance and carcass characteristics. Data available on each program indicates differences ranging from non-existent to dramatic, which emphasizes the necessity of matching cattle type to production system. Additionally, when reviewing the literature, one must keep in mind that to accurately compare different back-grounding systems through slaughter, one must compare cattle that are fed to an equal fat depth. This is important because as time-on-feed increases, both fat depth and marbling increase.

Evidence indicates that calf-feds are more efficient than yearlings with only small effects on carcass quality, with calves typically having less desirable yield grades and more desirable quality grades (Lancaster et al., 1973; Lunt and Orme, 1987; Dikeman et al., 1995; Huffman et al., 1990). In contrast, some reports indicate that yearlings yield carcasses with higher quality grades (Lardy et al., 1998).

Comparing the effects of allowing calves a 76-d growing period (placed in feedlot and fed a grower ration) versus placing directly on a finishing ration, Lancaster and collaborators (1973) utilized spring-born steers weaned at 205-d of age. Steers placed directly on a finishing ration (calf-fed) were more efficient, requiring less pounds of feed per pound of gain when compared to steers allowed a growing period (yearling-fed), over the entire period from weaning to slaughter. However, average daily gain (**ADG**) did not differ between treatments. Steers were slaughtered at different fat depths (calf-fed = 1.85 vs. yearling-fed = 2.16 cm, $P < 0.01$). No differences were noted for hot carcass weight, ribeye area, KPH fat, or tenderness as evaluated using the Armour tenderometer. However, calf-fed steers exhibited greater marbling and quality grades, but had lower cutability compared to yearling-fed steers.

Lardy et al., (1998) utilized summer-born (calving began June 18) MARC II (¼ Hereford, ¼ Angus, ¼ Gelbvieh, ¼ Simmental) composite steers assigned to a 2 x 2 factorial experiment (early weaned, calf-fed; early weaned, yearlings; normal weaned, calf-fed; normal weaned, yearlings). Due to differences in climate in Nebraska and Oklahoma, the performance of these summer-born calves may be used as an approximate model for what could be expected for fall-born steers in Oklahoma if managed similarly. All groups were back-grounded on dormant, native range prior to initiation of the treatments. At the end of the back-grounding period, steers designated as calf-feds were placed in the feedlot for 181 d. Yearling designated steers grazed native range for 208 d and then placed on feed for 124 d. The researchers detected no interactions between weaning date and steer feeding system. Calf-fed steers were more efficient overall compared to yearling-fed steers, but ADG did not differ between treatments. Steers from each weaning treatment group were slaughtered at the same time, thus no differences were noted for time on feed for early or normal weaned calves or yearlings. Regardless of weaning date, steers managed as yearlings had higher final weights and hot carcass weights, greater dry matter intake and higher quality grades. No differences were recorded for yield grade between treatments. Additionally, no statistical difference in slaughter breakeven price was noted for either management system.

In a 2-yr study utilizing early-weaned (117 ± 23 d of age) spring-born steers, Myers et al. (1999) evaluated the effects of allowing an 82-d pasture growing period followed by high concentrate finishing versus feeding an *ad libitum* finishing diet post-weaning. Steers allowed a growing period were less efficient than calf-fed steers fed a concentrate diet at weaning. For the same period, calf-fed steers posted an ADG of 0.18 kg/d greater than yearling-fed steers. The steers were slaughtered at a similar fat endpoint and no statistical differences between treatments were noted for the carcass traits measured. Also evaluated was the effect of breed type (predominantly British or predominantly Continental) on carcass traits. The researchers recorded heavier hot carcass weights (+ 39.9 kg) for Continental-bred cattle, but observed no other statistical differences in carcass traits.

Hickok et al. (1992) observed spring-born calves weaned at 185 d and managed as calf-feds to be more efficient and faster growing than yearling-fed calves. No significant differences were observed for dressing percentage, marbling, quality grade, or yield grade when evaluated at a constant adjusted fat thickness.

Utilizing cloned Brangus steers, Harris et al. (1997) evaluated performance differences for calf- and yearling-fed production systems fed to a constant age end point (Experiment 1) or constant live weight endpoint (Experiment 2). Calves were weaned at 8 mo of age and randomly assigned to feeding treatment. Calf-fed steers were immediately placed on feed while yearling-fed steers grazed grass or oat pasture for 120 d before beginning the feeding period. In experiment 1, both groups were slaughtered at a constant-age endpoint of 16 mo, resulting in 217 DOF for the calves and 93 DOF for the yearlings. In experiment 2, both groups were slaughtered at a constant live weight endpoint of approximately 530 kg (DOF = 224 for calf-fed steers and 185 d for yearling-fed steers).

Regardless of slaughter endpoint, calf-fed steers produced higher USDA yield grades, higher dressing percentages, and higher marbling scores, but no significant differences in meat palatability. The researchers did not observe significant differences USDA quality grade when steers were slaughtered at similar live weight end points.

Anderson et al. (2005), compared calf-fed steers (211 DOF) and yearlings (90 DOF after approximately 315 d grazing period). Cattle managed as calf-feds had lower ADG and DMI, but were more efficient in converting feed to gain. Yearlings had greater final weights and heavier carcasses, yet displayed decreased marbling scores compared to calves. When evaluating system profitability on a live basis, yearlings had lower breakeven selling prices for weaning and slaughter, lower cost per weaned calf and overall greater profit potential when compared to calf-fed steers.

Allocating fall-born steer calves to three treatments, 1) calf-feds, 2) short-yearlings (4 mo grazing prior to finishing), and 3) long-yearlings (12 mo grazing prior to finishing), Sainz and Paganini (2004) concluded that feedlot ADG was not impacted by prior management. However, ADG tended to increase as back-grounding time increased. Feedlot DMI was also increased as back-grounding time increased and was strongly related to increase in BW. Contrary to many other reports, feed efficiency did not differ among treatment groups. Body weight at slaughter increased with length of the back-grounding period; however, no differences were observed between treatments for longissimus muscle area, marbling score, quality grade, or yield grade.

Brewer et al. (2007) reported that carcasses from calf-fed steers were superior in quality (454.1 vs. 346.1 marbling score; $P < 0.001$) and palatability when compared to yearling-fed carcasses, as evaluated by shear force values and sensory ratings for both USDA Choice and Select steaks. These findings are similar to those reported by Klopfenstein et al. (2000), who indicated that due to increased age at slaughter, steaks from yearling-fed carcasses are less tender than those from calf-feds. However, in both reports, length of the aging period can mitigate carcass palatability differences.

In a review by Gardner and Dolezal (1996), the authors summarized numerous previous studies indicating that yearling cattle must be fed a minimum number of days on a high concentrate diet to not have an adverse effect on carcass palatability. The current industry standard is 130 to 200 d, however it has been reported as lows as 84 d (May et al., 1992). Per the data published by Brewer et al. (2005), it would appear that 84 d is not sufficient to ensure palatability and consumer acceptance.

Conclusions.

Cow-calf producers can significantly impact profitability by controlling feed costs and improving percent calf-crop. Regardless of time of calving or weaning strategy, cows must be managed to calve at a body condition score of 5.0 in order to rebreed by 85 d postpartum. If cows are in thin or decreasing condition, additional supplementation must be provided or cows will exhibit a longer anestrous period and depressed pregnancy rates.

Weaning and post-weaning strategies must be chosen based on the needs and capabilities of individual producers. Weaning fall-born calves at 10 mo of age vs. 7 mo of age will result in heavier calf weights, however the impact on cow BCS and marketing options must be considered by the producer. Cattle type, breed composition, feeding strategy, and marketing strategy all impact the performance of stocker/feeder cattle and thus impact profitability.

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Chapter III

EFFECT OF TIME OF WEANING IN A FALL-CALVING SYSTEM ON PERFORMANCE OF YOUNG AND MATURE BEEF COWS AND THEIR PROGENY

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Abstract

Predominantly Angus beef cows were used in three consecutive years to determine the effects of time of weaning and cow age class on cow body weight (**BW**) and body condition score (**BCS**), reproductive performance, milk production, and calf performance of fall-calving cows and their progeny. Treatments were arranged in a 2 x 2 factorial with two weaning dates and two age classes (mature cows ≥ 4 yrs and young cows ≤ 3 yrs). Weaning treatments were: (1) normal weaning in mid-April at 210 d of age (NW) and (2) late weaning in mid-July at 300 d of age (LW). Mature cows were heavier than young cows throughout the trial but BCS fluctuations were the same for both young and mature cows. Cow weight and BCS for NW and LW cows were similar at the time of normal weaning; however, at the beginning of the calving season, NW cows were heavier (585 vs. 563 kg; $P < 0.02$) and had greater fat reserves (6.57 vs. 5.95; $P < 0.001$) than LW cows. Postpartum BW and BCS loss was significantly ($P < 0.0001$) greater for NW cows, resulting in similar BW and BCS at the beginning of the breeding season and until April. Time of weaning also affected pre-weaning calf performance. Progeny of

NW cows were 2.3 kg heavier at birth and grew faster prior to weaning, resulting in increased weights (+ 10 kg; $P < 0.05$) at the time of normal weaning. This increase in gain may be partially explained by increased milk production by NW cows (+ 0.59 kg/d as measured in February; $P < 0.05$). When considering only the progeny of cows having previously weaned a calf on the study, due to increased calf weights in April, there were no statistical differences between NW and LW calves in July. Nevertheless, when considering all calves weaned on the trial, late weaning increased calf weights in July, regardless if NW calves were retained during the summer. A cow age class x weaning treatment interaction was detected for pregnancy rate. Pregnancy rates were greater ($P < 0.001$) for LW-Mature cows (98 %) and NW-Young cows (97.8%) compared to LW-Young (88%) and NW-Mature (85.5%) cows. Additionally, LW-Mature cows tended overall to have a shorter interval from calving to conception (71.7 d) compared to the other treatments combinations. These findings indicate that producers may benefit from matching weaning date to cow age class. It appears more advantageous to delay weaning of calves born to dams 4 yr or older, while maintaining normal weaning for dams 3 yr or younger at time of calving. Late-weaning had no detrimental effects for mature cows indicating this practice appears to be a viable alternative weaning option for mature cows.

Key Words: Fall-Calving, Cows, Time of Weaning, Performance

Introduction

Traditional weaning in a fall-calving system occurs in mid-April at approximately 210 d of age; however, due to the availability of high-quality forage during the spring and early summer, a growing trend is to extend lactation and the calf growing period through mid-July (approximately 300 d of age) to increase weaning weights.

This practice would appear to have a positive influence on enterprise profitability due primarily to the heavier weaning weights of older calves. However, for fall-calving cows (average BW of 533 kg) extending lactation increases maintenance requirements by 153.9 Mcal and requires 100.5 additional Mcal for lactation during months 7, 8, and 9 postpartum compared to cows normally-weaned. It is well documented that cow BCS at calving is an important factor affecting the length of the post-partum interval (**PPI**) and pregnancy rates (Wiltbank et al., 1964; Selk et al., 1988). The interval to first estrus is shorter for spring calving cows as BCS at parturition increases (Richards et al., 1986; Houghton et al., 1990). Therefore, increasing energy requirements during the summer may result in thinner conditioned cows at the beginning of the calving season, especially if forage quality or quantity is negatively impacted due to drought or other factors. Additionally, it has been demonstrated that pre-breeding weight and condition loss of fall-calving cows may depress reproductive performance, despite ample energy reserves at calving.

Prior research conducted to evaluate the effect of time of weaning on fall-calving cows has evaluated early weaning at 6 to 10 wk of age, or has managed all cows to the same BCS before the onset of calving. Therefore, the objective of this study was to elucidate the effects of late weaning compared to normal weaning on performance of fall-calving beef cows and their progeny.

Materials and Methods

Experiment 1

In accordance with an approved Oklahoma State University Animal Care and Use Committee protocol, this study was conducted at the Range Cow Research Center, North Range Unit, approximately 16 km west of Stillwater, Oklahoma. Prior to this experiment cows and calves had been managed together as one contemporary group. Treatments were arranged in a 2 x 2 factorial with two weaning dates and two age classes at time of calving (mature cows $\geq$ 4 yr-old and young cows $\leq$ 3 yr-old). In three successive years, (Yr 1 = Apr 2004 to Apr 2005; Yr 2 = Apr 2005 to Apr 2006; Yr 3 = Apr 2006 to Apr 2007) predominantly Angus, fall-calving cows were randomly assigned to one of two weaning date treatments: 1) normal weaning in mid-April at approximately 210 d of age (Treatment = NW), and 2) late weaning in mid-July at approximately 300 d of age (Treatment = LW). Cows were retained in the herd each year (excluding open cows) and remained in the same weaning group as initially assigned. New, pregnant cows were added to the study each spring either as rollovers from a spring-calving herd or as fall-born 2-yr old replacements. The added cows were previously managed with the experimental herd for 10 mo and were equally and randomly assigned to either NW or LW prior to the April weaning date.

Management and Weighing Procedures

Throughout the experiment, cow BW and BCS measurements were recorded after a 16-hr withdrawal from feed and water. Body condition scores (1 = emaciated, 9 = obese; Wagner et al., 1988) were determined by two trained, independent evaluators. Throughout the experiment all cows and calves were managed as contemporaries, grazing the same pastures, receiving the same rate of supplementation, and vaccinated according to the same herd health protocol. The only exception being calf management during the 84 d between weaning dates.

In mid-April (d = 0) cow BW and BCS and calf BW were recorded. Normal-weaned calves were separated from their dams and weaned using a fenceline weaning system (Price et al., 2003). Calves were maintained in drylot for 10 d post-weaning and were given *ad libitum* access to bermudagrass hay and water and received a 20% crude protein supplement at a rate of 1.81kg per hd. On d-10, calves were placed on excellent quality native grass pasture at a stocking rate of approximately 1.22 ha per calf.

Calf BW was recorded for both treatments on d-10 and d-21. In mid-July (d = 84), after a 16-h shrink, cow BW and BCS and calf BW were recorded for both treatments. LW calves were separated from their dams and weaned using the fenceline weaning system and were managed the same as NW calves were post-weaning.

Cow BW and BCS was recorded prior to the beginning of the calving season (late August) and every 2 wk throughout the calving season (only those cows that had calved in the prior period) to determine post-calving BW and BCS. Birth weight of each calf was determined and bull calves castrated within 24 h of birth. Non-shrunk calf BW was subsequently determined at approximately 70, 120, and 150 d of age. Cow BW and BCS was recorded at the beginning (late November) and end (late January) of the breeding season, and at both weaning dates.

Cows were evaluated twice daily for estrus detection for the first 7 d of the breeding season. Cows were artificially inseminated 12 h after detection of standing estrus. Cows not artificially inseminated during this time were treated with 5mg/mL of lutalyse (Pfizer), and twice daily estrus detection was continued for 2 wk. One week after cessation of artificial insemination, three Angus clean-up bulls were turned out for 35 d to constitute a 63 d breeding season. Mature cows were artificially inseminated with semen from either Angus or Charolais bulls and young cows were artificially inseminated with semen from Angus bulls. Cows were pregnancy checked by rectal palpation approximately 80 d after bulls were removed from the breeding pastures. All open cows remained on the study until the July weaning date and were then removed from the study.

Milk Production

In November (yr 2 only, n=22) and February (yrs 1 thru 3, total n=89) and early April (yrs 1 thru 3, total n=87), milk production was estimated using the weigh-suckle-weigh method. Cows were randomly selected from each weaning treatment based on calving date. Number of days postpartum for selected cows was tested to ensure balance between weaning treatments. On d 0 at 1600, cows and calves were corralled and separated. Cows received *ad libitum* access to hay and water while calves were maintained in dry pens. On d 1 at 0800 calves were allowed to nurse until satiety and then separated from their dams. This nursing was to empty the udder and ensure an equal status prior to measuring production. On d 1 at 1600, a treatment was selected randomly to be evaluated first. After all calves were weighed individually, they were reunited with their dams and allowed to nurse to satiety. Once the last calf finished nursing, calves were separated and individually reweighed. This process was then repeated for the second weaning treatment. The difference in final calf weight and initial calf weight was considered milk consumption. This procedure was repeated at 2400 and at 0800 on d 2. The sum of the three weight differences was considered 24 h milk production.

Milk Composition

In yr 3, forty cows were utilized to determine the effects of time of weaning on milk production and composition. Twenty cows from each weaning treatment were randomly assigned to one of two collection periods based on calving date. At an average of 40 d post-partum, cows were brought in at 1500 and calves were separated from cows. At 2300 calves were allowed to nurse to satiety and then separated from their dams. Cows were continually allowed *ad libitum* access to hay and water throughout the collection period. The following morning at 0700, cows were injected intramuscularly with 40 USP units of oxytocin intramuscularly, and were milked using a portable milking machine. After flow ceased, each teat was hand-stripped to ensure complete emptying of each quarter. Milk from the machine milking and the hand-stripped milk were combined, weighed, and thoroughly mixed. A 10-mL sub-sample was immediately collected and preserved using 2-bromo-2-nitropropane-1,3-diol and later shipped to Heart of America DHIA laboratory in Manhattan, Kansas for analysis of butterfat, protein, milk urea nitrogen, lactose, solids-not-fat, and somatic cell count.

Statistical Analyses

Cow was considered the experimental unit. No interactions between year and treatments were detected; therefore, data were pooled across years and analyzed using the MIXED MODEL procedure of SAS (SAS Inst. Inc., Cary, NC). All interactions and covariates remained in the model regardless of significance. Significance was declared when the P-value for the F-statistic was ≤ 0.05.

The model for cow BW and BCS and reproductive performance included weaning treatment and cow age class and the interaction as fixed effects with year considered a random variable. Because, with only one exception, all cows included for milk production were mature cows, the model for milk production included only treatment as a fixed effect and year as a random variable. To analyze milk composition, the model included weaning treatment as a fixed effect and period milked as a random effect.

The model for calf weaning and post-weaning performance (all calves weaned on the study) included weaning treatment, cow age class, and the interaction, breed of sire and sex as fixed effects; calf birth date and calf birth weight were included as covariates and year was treated as a random variable. For analysis of calf pre-weaning performance (only calves born to dams having weaned a calf on the study), the model included weaning treatment, cow age class, and the interaction, calf sex and breed of sire as fixed effects. Again, year was considered a random variable. Least squares means are reported in all tables and overall means in the text represent the simple average of the least square means, except for pregnancy rate which are raw means.

Results for cow BW and BCS include data collected from April 2004 to April 2007. Calving date was analyzed for each treatment using fall 2005 and 2006 calving dates, as the first calving season (2004) was not affected by weaning date, because treatments were not imposed until after the previous breeding season. Interval to pregnancy (calculated as the number of days from calving to conception based on subsequent calving date), date of conception (based on subsequent calving date), and AI conception rate (deviation from AI date threshold pre-determined as 5 d) were calculated using data from the fall 2004 and 2005 breeding seasons and subsequent calving seasons. Days from calving to first AI and pregnancy rate analyses were based on data from the fall 2004, 2005, and 2006 breeding seasons.

Results for calf weaning/post-weaning performance include the weaning and post-weaning weights for *all* 2003, 2004, and 2005 born calves, weaned in 2004, 2005, and 2006, respectively. Results for calf pre-weaning performance include only data collected from calves born in 2004, 2005, and 2006 to cows having previously weaned a calf on the trial. Therefore, numbers of observations, calving dates, and birth weights for pre-weaning and weaning data presented will not be consistent throughout results tables.

Experiment 2

This experiment was also conducted at the Range Cow Research Center, North Range Unit, located approximately 16 km west of Stillwater, Oklahoma in accordance with an approved Oklahoma State University Animal Care and Use Committee protocol. In yr 3, during early lactation, twenty four cows from Exp. 1 were utilized to determine the effects of weaning treatment on hay intake and digestion. Twelve cows from each weaning treatment were randomly assigned to one of two 16-d periods based on calving date. Cows were maintained in 3.7- x 9.1-m outdoor pens and were fed the same type of hay and received the same supplement type and rate as their herd mates.

Each 16-d period consisted of 9 d of adaptation to the pens and hay feeders and 7 d of data collection. Hay intake was measured from d 10 to 17 and fecal grab samples were collected twice daily at 0800 and 1600 to predict fecal output from acid detergent insoluble ash concentration (**ADIA**). Sub-samples of supplement, hay, and orts were dried at 50°C to determine DM. Samples were then ground in a Wiley mill (Model-4, Thomas Scientific, Sweedesboro, NJ) to pass a 1-mm screen before analysis. After grinding, sub-samples were composited by cow within period. Composite samples were then analyzed for NDF, ADF, CP, and ADIA. Neutral detergent fiber and ADF content were determined sequentially using an ANKOM 200 Fiber Analyzer (ANKOM Technology, 2005a,b). Crude protein was determined using a Leco NS-2000 Nitrogen Analyzer (Leco Corporation, St. Joseph, Michigan). Acid detergent insoluble ash was determined as the residue following complete combustion of the ADF residue at 550°C for 8 hr (Van Soest et al., 1991). Apparent DM, OM, and CP digestibility, as well as true NDF and ADF digestibility were calculated for each cow. Additionally, digested DMI (DMI kg/100kg of BW x DM digestibility) and digested OM intake were also calculated for each cow.

Statistical Analysis

Intake and digestibility measurements were analyzed using the MIXED MODEL procedures of SAS. The model included weaning treatment as a fixed effect and period as a random effect. Least squares means are reported in all tables and overall means in the text represent the simple average of the least squares means.

Results and Discussion

Experiment 1

Pre-partum Cow Weight and BCS. No weaning treatment x cow age class interactions (P = 0.08 to 0.95) were observed for any of the cow weight or BCS data. Therefore, main effects for each will be reported. Cow BW (Table 1) and BCS (Table 3) did not differ between weaning treatments in April. However, similar to findings reported by Hancock and others (1985), the present study illustrates that cows assigned to a normal weaning date gain more BW and BCS during the summer months compared to late-weaned cows. Figure 1 depicts BW changes and Figure 2 illustrates BCS changes of NW and LW cows throughout the year. During the 84 d between weaning dates, NW cows gained 33 kg more ($P < 0.0001$) BW compared to LW cows (118 vs. 85 kg), and were 28 kg heavier and had 0.69 more units of body condition compared to LW cows in July. Normal-weaned cows maintained this advantage in BW and BCS being 23 kg heavier (585 vs. 563 kg, $P < 0.02$) and having 0.62 more units of body condition (6.57 vs. 5.95, $P < 0.0001$) when measured in late August prior to the onset of the calving season. This is in contrast to the study by Coffey et al. (2004) that reported that fall-calving cows calved at a BCS of 6.7 to 7.0 irrespective of assignment to April or June weaning. Also, the present results are not as dramatic as predicted by NRC calculations (National Research Council, 1996), which indicate that spring-weaned cows grazing range grass in early summer would be expected to gain 98 kg more than summer-weaned cows.

The pattern of cow BW change was similar for mature and young cows (Figure 3), with differences ranging from 29 kg at pre-calving to 48 kg in April. As expected, mature cows were heavier ($P < 0.01$) at all points during the production cycle (Table 2). Contrary to expectation, BW changes from April to July were the same for both mature and young cows (102 kg, $P = 0.96$). However, when evaluating changes in BCS for this period (Table 4), more weight gain ($P < 0.05$) was associated with gain in adipose reserves in mature cows compared to young cows. This indicates that although young cow weight gain is similar in absolute amount during the summer months, the distribution of weight is different with more directed to skeletal and muscle growth than to body reserves in young cows.

Post-partum Cow Weight and BCS. Throughout the post-partum period, although both treatments were managed the same nutritionally, rate of BW and BCS loss differed dramatically between treatments ($P < 0.0001$). During the approximate 90 d from the onset of the calving season to the beginning of the breeding season, NW cows lost 9 % of pre-calving BW and 22.9 % of pre-calving body condition, compared to 5.7 % BW loss and 16.1 % condition loss for LW cows (Tables 1 and 3). Post-partum condition loss in the present study is greater than that reported by Coffey et al. (2004), who observed condition loss of 0.65 units (average 9% of pre-calving BCS) for both spring- and summer-weaned cows. At the beginning of the breeding season in late November, BW did not differ between treatments (534 ± 55 kg); however, BCS tended to be greater for NW cows ($P = 0.07$). No differences were observed for cow BW or BCS at the end of the breeding season.

The absolute rate of BW loss post-partum did not differ between cow age classes; however, when expressed as a percentage of BW at pre-calving, young cows lost a greater percentage of BW (8.5% vs. 6.5%; $P = 0.04$). Body condition loss (either as an absolute value or expressed as a percentage) tended ($P = 0.08$) to be greater for young cows than for mature cows (Table 4). Nevertheless, BCS did not differ between age classes throughout the year (Figure 4).

Cow Reproductive Performance. A significant weaning treatment x cow age class interaction was detected for pregnancy rate (Table 12). Young-NW cows had a greater ($P \leq 0.05$) pregnancy rate (97.8%) compared to Young-LW cows (88%) and Mature-NW cows (85.5%). Mature-LW cows exhibited a tendency to have greater pregnancy rates (98%) compared to Young-LW cows (88%; $P = 0.10$) and Mature-NW cows (85.5%; $P = 0.06$). A tendency ($P = 0.07$) for weaning treatment and cow age class to interact was detected for interval to pregnancy. Mature-LW cows had a shorter ($P < 0.05$) interval to pregnancy compared to Young-NW and Mature-NW cows (72 vs. 94 and 88 d, respectively). Mature-LW cows also tended ($P = 0.10$) to have a shorter interval to pregnancy when compared to Young-LW cows (72 vs. 86 d).

Neither weaning treatment of cow age class resulted in differences in calving date, days from calving to the beginning of the breeding season or first AI, date of conception, percentage serviced by AI, AI conception rate, or pregnancy rate.

When evaluating the literature regarding post-partum BW and BCS loss and BCS at the beginning of the breeding season, no consensus is arrived regarding the amount of loss permitted without suppressing reproductive performance. Rakestraw and collaborators (1986) conducted a 3-yr study to determine the effects of three postpartum energy regimes on reproductive performance of fall-calving cows. Their conclusions suggest that significant weight and condition loss postpartum could lead to detrimental reproductive performance, despite adequate energy reserves at calving. These data, along with those presented by Wiltbank et al. (1962) and Dunn et al. (1969) suggest that both body condition score at calving and at breeding are not totally reliable predictors of reproductive performance if cattle experience severe weight and condition loss postpartum.

In contrast to the previous studies and in agreement with the present study, Purvis and Lusby (1996) reported drastic weight loss of 18.3% of pre-calving weight and 24.7% (1.8 units) of condition (entering the breeding season at BCS of 5.5) for fall-calving cows without suppressing pregnancy rates ($P = 0.74$) compared to cows losing only 14.4% of pre-calving weight and 16.4% of condition, indicating that factors other than absolute weight or rate of loss affect reproduction, and that perhaps BCS at breeding is a key indicator/regulator of reproductive performance.

Despite the acceptable pregnancy rate, the interval to pregnancy was longer for NW-Mature cows compared to LW-Mature cows. This longer interval may be due to increased body energy reserves causing decreased DMI during early lactation which results in a longer interval to maximum negative energy balance post-partum (National Research Council, 1996). Because ovulation may be in part controlled by energy balance (Wright et al., 1992), fatter cows will remain in negative energy balance for longer during the post-partum period resulting in a longer anestrous period.

The correlation for days from calving to conception and cow BCS at pre-calving for all observations was 0.08 ($P = 0.53$; $r^2 = 0.0059$).

Milk Production and Composition. Milk production data is presented in Table 11. Milk production did not differ between treatments in November (avg. 53 d post-partum), or in April (avg. 200 d post-partum). However, when evaluated in February (avg. 156 d post-partum), NW cows produced more milk than LW cows (3.7 vs. 3.1 kg/d, $P < 0.05$). In yr 3, milk composition was evaluated and no differences were detected for butterfat, protein, lactose, solids-not-fat, or milk urea nitrogen ($P = 0.41$ to 0.62).

Though not detected in the present study, perhaps due to the small number of observations, differences in milk composition, particularly butter-fat, may be influenced by energy reserves during early lactation. This increase could have a positive influence on caloric content on milk and on subsequent calf weight gain. Although cows in a positive energy balance have less than 10 % of milk fat arising from mobilization of body fat, during early lactation when cows are typically in a negative energy balance, the fatty acids utilized by the mammary gland for production of milk fat arising from body fat increases in direct proportion to the extent of the energy deficiency (Bauman and Griinari, 2003). It is practical to infer that due to increased maintenance energy requirements and perhaps decreased dry matter intake (**DMI**), cows with greater energy reserves are in a more negative energy balance during early lactation, and therefore would have increased levels of circulating non-esterified fatty acids (**NEFA**) available to the mammary gland for the production of milk-fat.

Calf Pre-Weaning Performance. No time of weaning x cow age class interactions were observed for any calf pre-weaning measurement (P = 0.09 to 0.77). Calf birth date and weight did not differ between cow age classes, nor did calf BW differ when measured at the beginning of the calving season. However, cow age did influence calf BW at the end of the breeding season, in March, and in April (Table 8). As expected, progeny of mature cows were heavier than progeny of young cows. When evaluated throughout the 84-d beyond the normal weaning date (Table 9), progeny of mature cows remained heavier; however, by d-94 there were no statistical differences between the progeny of mature and young cows (290 vs. 284 kg, respectively; $P = 0.52$).

Comparing the effects of time of weaning, no difference was observed for birth date; however, calves from NW dams were heavier at birth (36.3 vs. 34.0 kg, $P < 0.01$), but with no apparent differences in dystocia (Table 5). In December (average calf age 75 d), calf BW did not differ. However, in early February (average calf age 127 d), calves from NW dams were 7 kg heavier than calves from LW dams ($P < 0.05$). Over the next 45 d this weight advantage increased to 14 kg ($P < 0.001$), and at the April weaning date calves from NW dams were 10 kg heavier ($P < 0.05$) than LW calves (201 vs. 191 kg).

These results indicate that time of weaning influences pre-weaning calf weight gain by its affect on cow BW and BCS at calving. It appears that greater cow BW and BCS at calving led to increased calf pre-weaning weight gain. This is in contrast to previous reports that state that when considering cows in moderate condition at time of parturition, their body energy reserves, as indicated by BCS, do not influence milk production or pre-weaning and 205-d adjusted weaning weights of calves (Doornbos et al., 1974; Spitzer et al., 1995; DeRouen et al., 1994; Ciccioli et al., 2003).

Nevertheless, as previously noted, NW cows gave more milk when evaluated in February compared to LW cows. The correlation between calf weight gain and cow milk production is intermediate at approximately 0.55 (Knapp and Black, 1941; Gifford, 1953; Drewry et al., 1959; Neville, 1962; Christian et al., 1965; Melton et al., 1967; Beal et al. 1980). Sixty to 66 % of variation in calf weaning weights can be directly attributed to dam's milk yield (Neville, 1962; Rutledge et al., 1971). Therefore, it is conceivable that increased BW and BCS at calving led to increased milk production and greater subsequent calf growth in the present study.

When evaluated following weaning (Table 6), calves born to NW dams having previously weaned a calf on the study remained heavier than calves born to LW dams having previously weaned a calf on the study for the first 21 d after the April weaning date. However, during the cumulative 84 d between weaning dates, calves from LW dams out-gained calves from NW dams (1.16 vs. 0.88 kg/hd^{-d}; $P < 0.0001$) resulting in similar weights at the July weaning date ($P = 0.23$). Coffey et al. (2003) also reported only numerical differences in body weight between April-weaned calves retained and grazing forage through June and their later-weaned contemporaries in June.

Calf Weaning/Post-Weaning Performance. When evaluating *all* calves weaned on the study, cow age class influenced calf BW at weaning and throughout the 84-d following normal weaning (Table 10), with progeny of mature cows out-weighing progeny of young cows throughout.

It has been shown in the previous section that time of previous weaning has an effect on calf weaning and post-weaning weights. However, because new cows and their calves, with no prior influence of treatment, were being added to the study each spring, the overall calf BW at the April weaning date was similar ($P > 0.72$) between treatments when all calves weaned on the trial were included in the analysis (Table 5).

For the first 10 d post-weaning, NW calves had greater ($P < 0.0001$) ADG than LW calves (1.55 vs. 1.12 kg/hd^{-d}). However, LW calves had a greater cumulative (d-0 to d-84) ADG and were significantly ($P < 0.0001$) heavier than NW calves at the July weaning date (288 vs. 268 kg).

Therefore, for calves born to dams with no previous influence of weaning treatment, or when new cows are being added to the herd each year, postponing weaning until 300 d represents a direct economic advantage for producers by increasing marketable pounds of calf.

Experiment 2

Normal-weaned cows had significantly more ($P < 0.001$) energy reserves than LW cows when intake and digestibility were measured (5.5 vs. 4.6). Body composition is believed to affect feed intake (National Research Council, 1987), with over-conditioned cows exhibiting depressed intake. However, no significant influence of time of weaning was observed for any of the intake or digestibility measurements in the present study (Table 13). Fox et al. (1988) reported that a one percent increase in body fat (in the range of 21.3 to 31.5%) would decrease DMI by 2.7 percent. Although NW cows had greater energy reserves than LW cows, at BCS 5.5, NW cows would have approximately 20.75% body fat (National Research Council, 1996), which according to the literature would not be great enough to depress DMI. In the present study, the correlation between BCS and DMI (kg/100kg SBW) was – 0.15 ($P = 0.49$; $r^2 = 0.02$). Although not significant, this correlation does indicate that increased body energy reserves can depress intake.

As previously discussed, NW cows demonstrated an increased interval to pregnancy compared to LW cows. The authors theorized this was due to over-conditioning of NW cows leading to decreased dry matter intake and an increased interval to negative energy nadir during early lactation. Although the intake data from the present study does not fully support this theory, it is important to note that BCS for NW cows during yr 3 (5.5) was less than that observed in yrs 1 and 2 (5.9 and 6.0, data not presented). A cow with BCS 6.0 would be expected to have 22.61% body fat (National Research Council, 1996) and is therefore in the range considered by Fox et al. (1988) to be subject to decreased DMI due to level of conditioning.

Conclusions

Cow BW and BCS are negatively affected by delaying weaning of fall-born calves. Late-weaning results in less weight and condition gain during the late-spring and early-summer months when compared to cows that are weaned normally at 7 mo of age. Thus, NW cows are both heavier and fatter than LW cows at the time of calving. However, despite similar management post-partum, NW cows experienced more drastic weight and condition loss, resulting in both NW and LW cows entering the breeding season at BCS 5.0. The interval from calving to pregnancy was increased for NW cows; however, pregnancy rate did not differ between treatments. No differences in intake or digestibility were detected when evaluated in yr 3. However, in that particular year, due to drought conditions, BCS differences were less between treatments than in previous years. It would be worthwhile to re-visit the effects of cow BCS on intake and digestibility to determine if DMI is, in fact, decreased in fatter cows, which could explain the differences noted in interval to pregnancy.

The detection of a significant interaction between cow age class and weaning date for interval to pregnancy and pregnancy rate indicate that producers may benefit from matching weaning date to cow age class. It appears more advantageous to delay weaning of calves born to dams 4 yr or older, while maintaining normal weaning for dams 3 yr or younger at time of calving.

Additionally, calf pre-weaning growth was affected by the date which the previous calf was weaned. Progeny of NW cows grew faster pre-weaning and were significantly heavier at the time of weaning in April compared to progeny of LW cows. This difference in pre-weaning performance appears to be related to increased milk produced demonstrated by NW cows.

While the impetus for delaying weaning is the gain in calf BW, it appears that when considering only the progeny of cows having weaned at least one calf at the prescribed weaning date, delaying weaning does not have a significant effect on calf weights when compared to NW calves retained to the LW date. Nevertheless, LW calves grow significantly faster during the spring and summer months and are numerically heavier than NW calves in July. With no detection of detrimental effects on performance of mature, late-weaned cows, this research indicates late-weaning provides producers with a viable alternative weaning option for mature cows.

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Table 1. Effect of time of weaning on cow body weight[a] (Exp. 1)

Item	n =	Weaning Treatment[b] LW	NW	SEM[c]	*P*-value[d]
April	305	449	446	8.6	0.55
July	201	528	556	8.3	< 0.001
Pre-calving	196	563	585	15.8	< 0.02
Post-calving	110	534	549	9.7	0.08
Pre-breeding	168	531	536	6.9	0.56
Post-breeding	120	509	508	13.1	0.93
Wt change, April to July	201	+ 85	+ 118	15.4	< 0.001
Wt change, Pre-calving to pre-breeding	168	- 34.2	- 55.4	19.2	< 0.001
Rate of loss, Pre-calving to pre-breeding (kg/d)	168	- 0.38	- 0.62	0.21	< 0.001
% Wt change, Pre-calving to pre-breeding	168	- 5.72	- 9.18	3.13	< 0.001

[a] Cow body weight reported in kg; data included for analysis collected from April 2004 to April 2007.
[b] Weaning treatments: 1) Normal weaning at 210 d of age in April (NW), and 2) Late weaning at 300 d of age in July (LW).
[c] Most conservative SEM.
[d] Probability of a greater F-statistic.

Table 2. Effect of cow age class at time of calving on cow body weight[a] (Exp. 1)

Item	n =	Cow age class[b] Mature	Young	SEM[c]	*P*-value[d]
April	305	472	424	8.5	< 0.0001
July	201	564	519	8.8	< 0.0001
Pre-calving	196	588	559	16.3	< 0.01
Post-calving	110	559	523	9.7	< 0.0001
Pre-breeding	168	555	511	7.6	< 0.0001
Post-breeding	120	528	488	13.2	< 0.0001
Wt change, April to July	201	+ 102	+ 102	15.4	0.96
Wt change, Pre-calving to pre-breeding	168	- 41.3	- 48.5	19.2	0.15
Rate of loss, Pre-calving to pre-breeding (kg/d)	168	- 0.46	- 0.54	0.21	0.15
% Wt change, Pre-calving to pre-breeding	168	- 6.5	- 8.4	3.2	0.04

[a] Cow body weight reported in kg; data included for analysis collected from April 2004 to April 2007.
[b] Cow age class defined as: Mature 4+ yrs, and Young ≤ 3 yrs.
[c] Most conservative SEM.
[d] Probability of a greater F-statistic.

Table 3. Effect of time of weaning on cow BCS[a] (Exp. 1)

Item	n =	Weaning Treatment[b] LW	NW	SEM[c]	*P*-value[d]
April	304	4.55	4.36	0.38	0.41
July	201	5.36	6.05	0.14	< 0.001
Pre-calving	196	5.95	6.57	0.12	< 0.001
Post-calving	111	5.35	5.75	0.13	0.01
Pre-breeding	168	4.95	5.12	0.07	0.08
Post-breeding	120	5.11	5.06	0.11	0.61
Change, April to July	200	+ 1.23	+ 1.88	0.22	< 0.001
Change, Pre-calving to pre-breeding	168	- 1.00	- 1.46	0.16	< 0.001
% BCS change, Pre-calving to pre-breeding	168	-16.10	- 22.9	1.95	< 0.001

[a] Cow BCS (1 = Emaciated, 9 = Obese); data included for analysis collected from April 2004 to April 2007.
[b] Weaning treatments: 1) Normal weaning at 210 d of age in April (NW), and 2) Late weaning at 300 d of age in July (LW).
[c] Most conservative SEM.
[d] Probability of a greater F-statistic.

Table 4. Effect of cow age class at time of calving on cow BCS[a] (Exp. 1)

Item	n =	Cow age class[b]		SEM[c]	*P*-value[d]
		Mature	Young		
April	304	4.48	4.43	0.40	0.82
July	201	5.75	5.65	0.15	0.26
Pre-calving	196	6.22	6.30	0.14	0.41
Post-calving	111	5.64	5.46	0.14	0.19
Pre-breeding	168	5.05	5.02	0.08	0.77
Post-breeding	120	5.07	5.10	0.12	0.78
Change, April to July	200	+ 1.66	+ 1.45	0.21	0.02
Change, Pre-calving to pre-breeding	168	- 1.15	- 1.31	0.16	0.08
% BCS change, Pre-calving to pre-breeding	168	- 18.0	- 20.2	2.0	0.08

[a] Cow BCS (1 = Emaciated, 9 = Obese); data included for analysis collected from April 2004 to April 2007.
[b] Cow age class defined as: Mature 4+ yrs, and Young ≤ 3 yrs.
[c] Most conservative SEM.
[d] Probability of a greater F-statistic.

Table 5. Effect of time of weaning on calf pre-weaning performance[a] (Exp.1)

Item	n =	Weaning Treatment[b] LW	NW	SEM[c]	*P*-value[d]
Birth date, Julian date	155	262	262	2.7	0.90
Birth wt., kg	154	34.0	36.3	0.7	< 0.01
December Wt	121	108	109	2.8	0.82
February Wt	157	140	147	2.7	< 0.05
April Wt	154	191	201	3.5	< 0.05

[a] Calf weights reported as kg; analysis included data from calves born to dams having previously weaned a calf on the study; collected from fall 2004 thru spring 2007.
[b] Weaning treatments: 1) Normal weaning at 210 d of age in April (NW), and 2) Late weaning at 300 d of age in July (LW).
[c] Most conservative SEM.
[d] Probability of a greater F-statistic.

Table 6. Weaning/post-weaning performance of calves born to dams having previously weaned a calf on the study[a]

		Weaning Treatment[b]			
Item	n =	LW	NW	SEM[c]	*P*-value[d]
April Wt (d=0)	77	175	191	5.7	< 0.01
d-10 Wt	77	189	208	7.5	< 0.001
d-21 Wt	77	201	212	11.1	< 0.05
July Wt (d=84)	77	273	266	16.8	0.23
d-94 Wt	77	289	285	7.0	0.71
Wt change, d-0 to d-84	77	+ 98	+ 74	11.8	< 0.0001
d-0 to d-10 ADG, kg/d	77	1.35	1.71	0.21	< 0.001
d-0 to d- 21 ADG, kg/d	77	1.23	0.98	0.29	< 0.0001
d-0 to d-84 ADG, kg/d	77	1.16	0.88	0.14	< 0.0001
d-0 to d-94 ADG, kg/d	30	1.21	1.04	0.04	< 0.01

[a] Calf weights reported as kg; analysis includes data from calves born fall 2004 and 2005
[b] Weaning treatments: 1) Normal weaning at 210 d of age in April (NW), and 2) Late weaning at 300 d of age in July (LW).
[c] Most conservative SEM.
[d] Probability of a greater F-statistic.

Table 7. Effect of time of weaning on calf weaning/post-weaning performance[a] (Exp.1)

Item	n =	Weaning Treatment[b] LW	NW	SEM[c]	*P*-value[d]
April Wt (d=0)	195	189	190	6.7	0.54
d-10 Wt	195	204	208	6.8	< 0.05
d-21 Wt.	194	211	208	6.8	0.43
July Wt (d=84)	194	288	268	12.3	< 0.001
d-94 Wt.	97	291	275	4.8	0.01
Wt change, d-0 to d-84	194	+ 101	+ 79	7.4	< 0.01
d-0 to d-10 ADG, kg/d	195	1.12	1.55	0.13	< 0.001
d-0 to d- 21 ADG, kg/d	194	1.15	0.94	0.17	< 0.001
d-0 to d-84 ADG, kg/d	194	1.20	0.94	0.17	< 0.001
d-0 to d-94 ADG, kg/d	97	1.04	0.87	0.16	< 0.001

[a] Calf weights reported as kg; data included for analysis collected from April 2004 to May 2007.
[b] Weaning treatments included: 1) Normal weaning at 210 d of age in April (NW), and 2) Late weaning at 300 d of age in July (LW).
[c] Most conservative SEM.
[d] Probability of a greater F-statistic.

Table 8. Effect of cow age class on calf pre-weaning performance[a] (Exp.1)

Item	n =	Cow age class[b]		SEM[c]	*P*-value[d]
		Mature	Young		
Birth date, Julian date	155	260	263	3.1	0.25
Birth wt., kg	154	35.6	34.7	0.95	0.34
December Wt	121	109	107	3.7	0.51
February Wt	157	148	138	3.6	0.01
March Wt	83	178	160	5.8	< 0.001
April Wt	154	202	190	4.6	0.009

[a] Calf weights reported as kg; analysis includes data from calves born to dams having previously weaned a calf on the study; collected from fall 2004 thru spring 2007.
[b] Cow age class defined as: Mature 4+ yrs, and Young ≤ 3 yrs.
[c] Most conservative SEM.
[d] Probability of a greater F-statistic.

Table 9. Effect of cow age class on the weaning/post-weaning performance of calves born to dams having previously weaned a calf on the study[a]

		Cow age class[b]			
Item	n =	Mature	Young	SEM[c]	*P*-value[d]
April Wt (d=0)	77	192	174	6.4	< 0.01
d-10 Wt	77	207	191	8.1	< 0.01
d-21 Wt	77	215	198	11.5	< 0.01
July Wt (d=84)	77	276	263	17.2	< 0.05
d-94 Wt	30	290	284	7.0	0.52
d-0 to d-10 ADG, kg/d	77	1.45	1.59	0.22	0.12
d-0 to d- 21 ADG, kg/d	77	1.09	1.13	0.29	0.83
d-0 to d-84 ADG, kg/d	77	1.00	1.04	0.14	0.15
d-0 to d-94 ADG, kg/d	30	1.04	1.18	0.05	0.04

[a] Calf weights reported as kg; analysis includes data from calves born fall 2004 and 2005
[b] Cow age class defined as: Mature 4+ yrs, and Young ≤ 3 yrs.
[c] Most conservative SEM.
[d] Probability of a greater F-statistic.

Table 10. Effect of cow age class on calf weaning/post-weaning performance[a] (Exp.1)

Item	n =	Cow age class[b]		SEM[c]	*P*-value[d]
		Mature	Young		
April Wt (d=0)	195	195	180	7.8	< 0.0001
d-10 Wt	195	209	193	6.9	< 0.0001
d-21 Wt.	194	217	201	6.9	< 0.0001
July Wt (d=84)	194	283	271	12.4	< 0.01
d-94 Wt.	97	289	276	5.4	0.03
Wt change, d-0 to d-84	194	+ 88	+ 91.6	7.5	0.15
d-0 to d-10 ADG, kg/d	195	1.32	1.36	0.13	0.87
d-0 to d- 21 ADG, kg/d	194	1.04	1.04	0.17	0.81
d-0 to d-84 ADG, kg/d	194	1.04	1.05	0.09	0.15
d-0 to d-94 ADG, kg/d	97	0.91	1.00	0.17	0.09

[a] Calf weights reported as kg; data included for analysis collected from April 2004 to May 2007.
[b] Cow age class defined as: Mature 4+ yrs, and Young ≤ 3 yrs.
[c] Most conservative SEM.
[d] Probability of a greater F-statistic.

Table 11. Effect of time of weaning on milk production and composition (Exp.1)

Item	n =	LW	NW	SEM[c]	*P*-value[d]
		Weaning Treatment[b]			
Weigh-suckle-weigh, Yield					
November, kg	22	6.29	6.69	0.54	0.59
February, kg	89	3.13	3.72	0.74	< 0.05
April, kg	87	4.07	3.64	0.55	0.21
Machine Milking					
Yield, kg	40	7.62	7.53	3.31	0.83
Butterfat, %	40	3.68	3.56	0.17	0.58
Protein, %	40	2.85	2.91	0.06	0.51
Lactose, %	40	4.96	5.00	0.05	0.62
SNF, %	40	8.81	8.91	0.10	0.47
MUN, mg/dL	40	7.03	6.41	0.54	0.41
SCC, 10^3 cells/mL	40	305	756	185	0.08

[a] Weaning treatments: 1) Normal weaning at 210 d of age in April (NW), and 2) Late weaning at 300 d of age in July (LW).
[b] Most conservative SEM.
[c] Probability of a greater F-statistic.

Table 12. Reproductive performance for weaning date and cow age combinations.[a]

Item	Treatment Combinations[b]					
	LW-M	LW-Y	NW-M	NW-Y	SEM[c]	P-value[d]
Calving date, Julian dt	262(28)	262(53)	259(34)	259(53)	3.0	0.90
Pregnant, %	97.8(27)	88(51)	85.3(31)	99.8(51)	4.7	0.02
Days, calving to first AI	83.3(6)	78.4(19)	90(9)	81(18)	7.0	0.67
Interval to pregnancy[e]	71.7(7)	85.7(21)	93.5(11)	88.3(29)	5.9	0.07
Date of conception, Julian dt	343(7)	348(23)	348(11)	343(29)	3.8	0.22
Cows serviced by AI, %	67.9(28)	68.8(49)	74.2(31)	58.3(49)	7.8	0.29
Calving interval, change	-4.2(16)	+1.0(10)	+6.8(30)	+24.8(13)	9.4	0.46
BCS, pre-calving	5.87	6.03	6.57	6.57	0.15	0.41
Post-partum BCS loss, %	-14.7	-17.5	-21.4	-22.9	2.1	0.61

[a] Numbers in parenthesis indicate number of observations per cell. For percent pregnant, number is cows exposed.
[b] LW-M = Late-weaned, Mature; LW-Y = Late-weaned, Young; NW-M = Normal-weaned, Mature; NW-Y = Normal-weaned, Young.
[c] Pooled SEM.
[d] Probability of a greater F-statistic.
[e] Days from calving to conception.

Table 13. Effect of time of weaning on intake and digestibility (Exp. 2)

Item	n =	Weaning Treatment[a] LW	NW	SEM[b]	*P*-value[c]
BCS	24	4.48	5.50	0.21	< 0.01
Hay Intake[d]	24	3.48	3.47	0.32	0.87
DM Intake[e]	24	2.64	2.63	0.09	0.86
Fecal Output[e]	24	1.17	1.19	0.08	0.85
DM Digestibility, %	24	55.6	54.7	2.8	0.82
NDF Digestibility, %	24	58.8	57.6	2.7	0.76
ADF Digestibility, %	24	59.1	57.7	2.7	0.70
CP Digestibility, %	24	51.1	50.0	3.4	0.80
DMI Digestibility[e]	24	1.48	1.44	0.11	0.76
OM Intake[e]	24	2.50	2.48	0.09	0.85
OM Digestibility, %	24	57.4	56.4	2.7	0.85
Digested DMI[e]	24	1.44	1.40	0.10	0.76

[a] Weaning treatments: 1) Normal weaning at 210 d of age in April (NW), and 2) Late weaning at 300 d of age in July (LW).
[b] Most conservative SEM.
[c] Probability of a greater F-statistic.
[d] kg/100 kg of BW, as-fed basis
[e] kg/100kg of BW, DM-basis

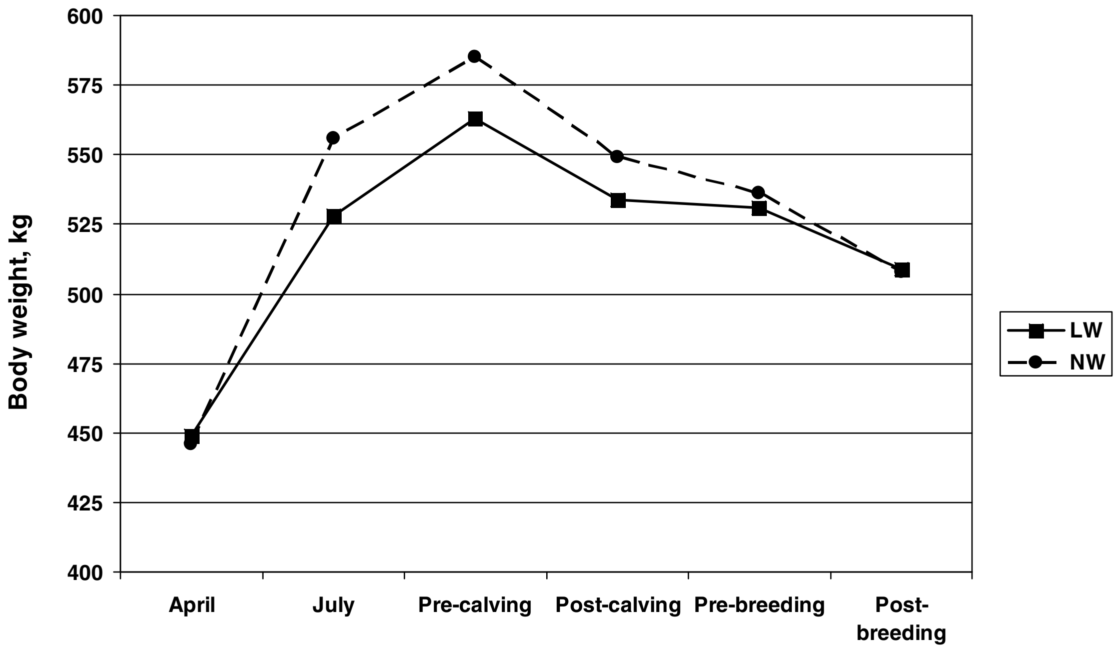

Figure 1. Effect of time of weaning on cow body weight as evaluated throughout the production cycle for cows whose calves were weaned normally at 210 d of age (NW) and cows whose calves were late-weaned at 300 d of age (LW).

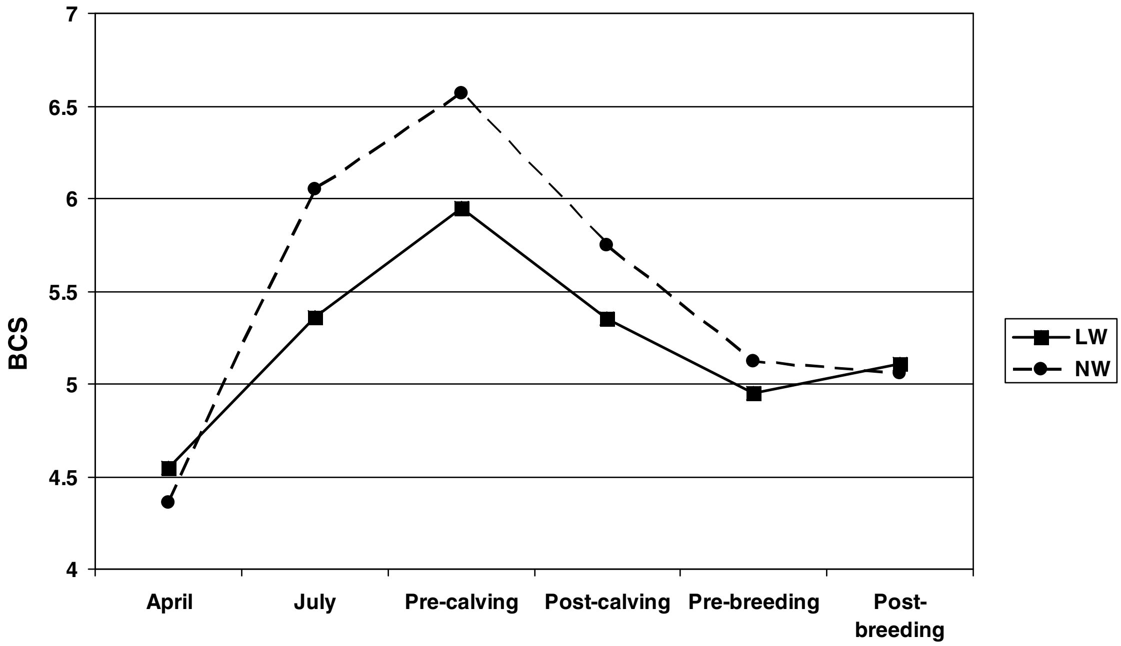

Figure 2. Effects of time of weaning on cow BCS evaluated throughout the production cycle for cows whose calves were weaned normally at 210 d of age (NW) and cows whose calves were weaned at 300 d of age (LW).

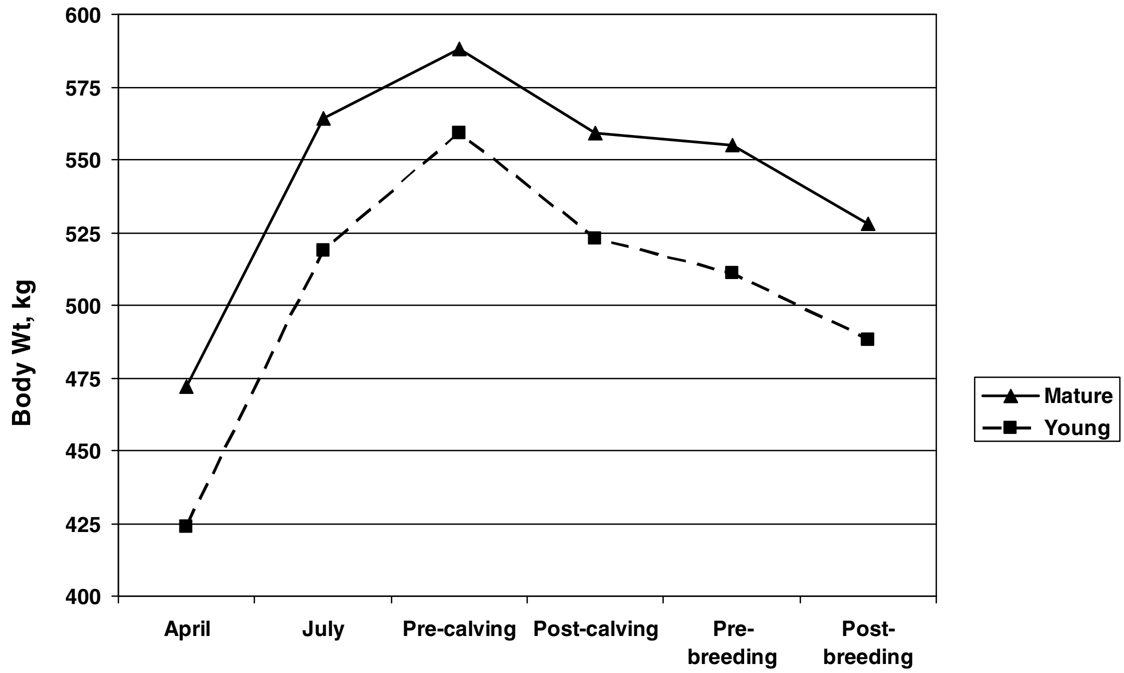

Figure 3. Effect of cow age class at time of calving (Mature 4+ yrs or Young 3 or younger) on body weight changes throughout the production cycle.

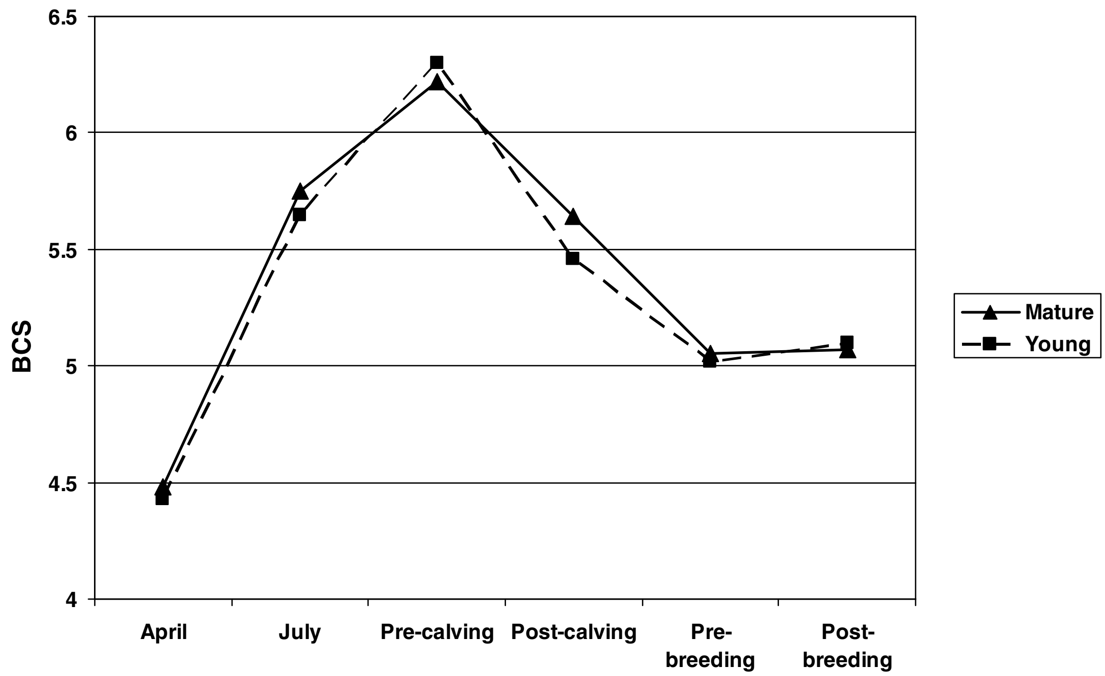

Figure 4. Effect of cow age class at time of calving (Mature 4+ or Young 3 or younger) on cow BCS changes throughout the production cycle.

Chapter IV

COMPARISON OF TWO WEANING DATES AND TWO FINISHING SYSTEMS ON FEEDLOT PERFORMANCE, CARCASS CHARACTERISTICS AND ENTERPRISE PROFITABILITY OF FALL-BORN STEERS

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Abstract

In a two year study 84 fall-born steers of uniform biological type were allotted to a 2 x 2 factorial experiment including two weaning dates (normal-weaned (**NW**) at 210 d of age, or late-weaned (**LW**) at 300 d of age) and two finishing systems (feedlot placement as calf-feds (**CF**) at 310 d of age, or feedlot placement as yearlings (**YF**) at 400 d of age). Treatment combinations were: NW-CF, NW-YF, LW-CF, LW-YF. Steers were slaughtered at a common end point of an estimated 1 cm of backfat. Days on feed averaged 139 for CF and 126 for YF. Late-weaned steers were 13 kg heavier at the time of feedlot entry compared to NW steers. No other differences for time of weaning, nor any interactions between weaning and finishing system were detected. Yearling-fed steers were heavier (+ 34 kg) at time of feedlot placement, had greater DMI and greater ($P < 0.001$) feedlot ADG (than 1.94 vs. 1.81 kg) than CF, resulting in greater final live weights and HCW with corresponding larger REA. No other differences were detected for any carcass traits measured. System economic analysis showed no differences in break-even selling price or system profitability.

Key Words: Fall-Calving, Weaning Date, Finishing System, Feedlot, Carcass, Profitability

Introduction

In the Southern Great Plains, fall-calving systems provide producers with numerous weaning and post-weaning management options and decisions. Calves can be weaned at a traditional age of around 7 mo in April or May, which generally corresponds to mild weather conditions, high quality forage availability, and high calf prices. Alternatively, some managers in this region have chosen to extend lactation through the spring and early summer and delay weaning until 10 to 11 mo of age. The primary benefit of this strategy is to increase weaning weight and gross revenue with little change in labor inputs. In the companion paper (Hudson et al., 2007), it has been shown that calves weaned in April and provided excellent quality forage, gained approximately 23 kg less during the spring grazing period compared to nursing calves regardless of previous cow management.

The current ethanol boom has increased competition for feed grains between the fuel and livestock industries, resulting in increased costs and decreased returns for traditional beef cattle finishing systems. This growing trend of grain to fuel is increasing interest in, and encouraging use of, longer grazing periods prior to feedlot finishing. This approach results in more pounds of calf weight gain at a lower price prior to finishing compared to "calf-fed" systems with little to no post-weaning grazing.

Previous reports have demonstrated excellent late-summer performance when stocker calves are grazing native range and receiving and protein supplement (DelCurto et al., 1990a, b; Hannah et al., 1991; Lalman et al., 2004). Therefore, late-summer grazing with protein supplementation could be an important component of an efficient beef production system given current market conditions.

From a systems context, it is important to understand the influence of time of weaning and production system (summer grazing or "yearling" vs. "calf-fed") on post-weaning grazing and feedlot performance. Similarly, it is imperative to understand the impact of these management options on carcass characteristics and overall system profitability. Therefore, the purpose of this study was to determine the effects of time of weaning and finishing system on feedlot performance, carcass characteristics, and enterprise profitability of fall-born steers.

Materials and Methods

This study was conducted at the Range Cow Research Center, North Range Unit, approximately 16 km west of Stillwater, Oklahoma and at the Willard Sparks Beef Research Center (**WSBRC**), Stillwater, Oklahoma in accordance with an Oklahoma State University Animal Care and Use Committee approved protocol. In two successive years (Yr 1, n = 32; Yr 2, n = 52), fall-born steers of uniform biological type (Yr 1, predominantly Angus; Yr 2, Angus and ½ Angus x ½ Charolais) from the Oklahoma State University Range Cow research herd were stratified by age and BW to ensure groups were similar and were then randomly allotted to a 2 x 2 factorial experiment to evaluate the effects of time of weaning and finishing system on feedlot performance, carcass characteristics, and enterprise profitability.

Steers are the progeny of cows previously assigned to one of two weaning dates: 1) normal weaning (**NW**) in mid-April at approximately 210 d of age, and 2) late weaning (**LW**) in mid-July at approximately 300 d of age. After weaning in July (d = 0), steers were randomly assigned to two finishing systems: 1) feedlot placement in late July or early August at average calf age of 310 d (**CF**), and 2) feedlot placement in October at average calf age 400 d (**YF**).

On d 0, steers were weighed after a 16 hr withdrawal from food and water, dewormed based on individual BW with Ivomec Plus® (Merial, Duluth, GA), and implanted with Component E-S with Tylan (200 mg progesterone and 20 mg estradiol benzoate; VetLife, Overland Park, KS). Calf-fed steers were transported to the WSBRC, assigned to pens based on arrival BW, and placed on an 18-d step-up program followed by a high-concentrate finishing diet. On d 54, CF steers were re-implanted with Revalor-S (120 mg trenbolone acetate and 24 mg estradiol benzoate; Intervet, Millsboro, DE).

Yearlings remained at the Range Cow Research Center grazing native range with abundant forage at a stocking rate of approximately 0.47 ha/hd. On Mondays, Wednesdays, and Fridays, YF steers received 1.06 kg of a 40% CP cottonseed meal-based supplement (equivalent to 0.454 $kg \cdot hd^{-1} \cdot d^{-1}$) in a feeding barn equipped with individual stanchions to ensure precise and consistent supplement consumption. On d 84, steers weights were recorded after a 16-hr withdrawal from feed and water, and steers were shipped to WSBRC. Upon arrival at the feedlot, steers were dewormed based on actual BW with Ivomec Plus® (Merial, Duluth, GA), re-implanted with Revalor-S (120 mg trenbolone acetate and 24 mg estradiol benzoate; Intervet, Millsboro, DE), and allotted to pens based on arrival BW. Yearlings were placed on the same 18-d step-up program as CF, followed by high-concentrate finishing. Steers in both groups remained on a high concentrate diet until experienced feedlot personnel estimated 12^{th} rib back fat thickness to be 1 cm. Steers were slaughtered at a commercial packing plant and carcass data collected by the same trained technicians for both groups.

Economic Analysis

Actual LS means for initial and final weights, ADG, and DMI were used in conjunction with 10 yrs of historical prices to determine the break-even selling price and profitability of each system. Steers were priced into the post-weaning phase using the mean steer weight of each group according to USDA weighted average pricing for Oklahoma in August (http://www.ams.usda.gov/lsmnpubs). Table 4 details fixed prices used for the analysis. Interest charged varied and was input as the average prime rate during the specified period. The feedlot ration cost was estimated based on the average corn price for the specified period (Cattlefax, 2007). Initial feedlot price for yearlings was set as the breakeven selling price off of pasture, as calculated using the OSU Stocker Planner (http://www.ansi.okstate.edu/software/). Selling price for both groups was based on USDA weighted average live pricing for Select/Choice (35-65) price spreads for the month sold in Texas and Oklahoma (http://www.ams.usda.gov/lsmnpubs). Initial and final weights, ADG, and DMI used for the analysis were based on actual LS means observed for each group in the study. The break-even selling price and profit/loss were determined for each system using the OSU Feedlot Performance Program and the OSU Breakeven Feedlot Calculator (http://www.ansi.okstate.edu/software/).

Statistical Analysis

Grazing performance for the yearlings, feedlot performance for both YF and CF steers (excluding DMI and gain:feed), and carcass data were analyzed using steer as the experimental unit. Dry matter intake and feed efficiency were calculated on a pen basis. Data were analyzed using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The model for grazing performance included weaning treatment as a fixed effect with breed of sire as a covariate and year as a random effect. The model for feedlot weight and gain and carcass characteristics included weaning treatment and system as fixed effects and a term for the interaction. Breed of sire was included as a covariate and year was considered a random effect. The model for DMI, feed efficiency, and economics included system as a fixed effect and year as random effect. All interactions and covariates remained in the model regardless of significance. Significance was declared when the P-value for the F-statistic was ≤ 0.05.

Results

Time of Weaning Effects and Grazing Performance. Figure 1 depicts time of weaning and feedlot entry and corresponding steer BW. Grazing performance during the 84-d grazing period is presented in Table 1. Time of weaning did not influence performance during the grazing period ($P = 0.30$ to 0.95). Yearlings weighed 285 ± 31.7 kg at the beginning of the grazing period and gained 44.4 ± 8.2 kg for an ADG of 0.53 ± 0.1 kg. On average, yearlings were 400 d of age and weighed 331 kg at time of feedlot entry.

When analyzed across both finishing systems, late-weaned steers were 13 kg heavier ($P < 0.001$) than NW steers (321 vs. 308 kg) at initial feedlot entry (data not presented). However, no other differences were observed for time of weaning throughout the experiment. Additionally, no significant interactions between time of weaning and finishing system were detected for feedlot performance or carcass characteristics. Therefore, only main effects of finishing system will be reported in the following tables.

Feedlot Performance and Carcass Charactersistics. Table 2 summarizes growth performance for the feedlot phase. Averaged across both years, DOF was 139 d for CF and 126 d for YF. Yearlings were 34 kg heavier upon feedlot entry than were CF steers. Due to increased DMI and greater ADG ($P < 0.001$), YF steers were also heavier at the time of slaughter (569 vs. 546 kg; $P < 0.0001$).

Carcass data are presented in Table 3. Both groups were slaughtered when 12th rib backfat was estimated to be 1 cm. Actual backfat thickness was 1.20 and 1.22 cm for CF and YF, respectively. Dressing percent, marbling, and YG were not influenced by finishing system. However, due to increased initial weights and greater ADG, final weights were greater for YF steers. Increased final weights resulted in YF steers having greater HCW (355 vs. 334 kg; $P < 0.0001$) with corresponding larger ($P = 0.01$) REA.

Economics. System profitability and break-even selling price data are presented in Table 5. System did not influence break-even selling price or overall profitability. It is important to note the large standard errors associated with this analysis, particularly profit/loss. Figure 2 illustrates the price of corn for each year and the 10-yr profitability for each system, as well as a forecast for future performance based on current corn prices.

Discussion

Grazing Phase. In the present study, grazing phase ADG was 1.22 kg for the first period, but due to decreasing quality and availability of standing forage, decreased dramatically over the next 56 d of the grazing period despite protein supplementation. These results are similar to those previously reported by others. Average daily gain has been observed as low as zero (Harris et al., 1997), but more typically ranges from 0.53 to 0.93 kg/d for winter and spring/summer grazing, respectively (Anderson et al., 2005).

The length of the grazing period also ranges dramatically in the published literature, from as few as 76 d (Lancaster et al., 1973) to as many as 365 d (Sainz and Paganini, 2004). Typically, restricted energy intake during the grazing period results in more aggressive DM consumption and compensatory gain in the feedlot (Coleman et al., 1993; Sainz et al., 1995).

Feedlot Phase. The increased daily gain for yearlings compared to calf-feds during the finishing phase of the present study (+0.13 kg) is similar to that reported by others who have grazed yearlings for a similar period of time. Myers et al. (1999) compared calf-feds to yearlings allowed an 81 d grazing period and reported increased ADG of +0.12 kg for yearlings during the feedlot phase. Likewise, Lunt and Orme (1987) compared weanling vs. yearling heifers and reported an increase in feedlot daily gain of +0.15 kg for yearling heifers.

Further, the literature indicates that as the length of the growing period increases, feedlot ADG tends to increase, likely as a compensatory gain mechanism due to greater nutrient restriction. Harris et al. (1997) reported increased feedlot ADG of +0.37 kg for steers grazing forage for 120 d prior to feedlot entry. For fall-born steers also restricted for 120 d, Sainz and Paganini (2004) reported increased daily gain of +0.22 kg; for fall-born steers grazing for 1 yr prior to finishing, they reported an increase in ADG of +0.32

kg. Additionally, Anderson et al. (2005) reported an ADG increase of +0.45 kg for spring-born steers grazing forage for 315 d prior to finishing.

In contrast, some reports indicate no differences in feedlot ADG for yearlings and calf-feds (Lancaster et al., 1973; Hickok et al., 1992; Lardy et al., 1998).

The DMI increase of 1.3 kg per day for YF steers in the current study concurs with the literature for steers provided a shorter back-grounding period. Previous results indicate that, like feedlot ADG, DMI tends to increase as the length of the back-grounding period increases. For YF steers subjected to shorter grazing periods (81 to 120 d), daily DMI differences range from 1.09 to 1.75 kg more than CF (Myers et al., 1999; Sainz and Paganini, 2004). For steers restricted for longer periods of time (210 to 365 d), DMI was 3.84 to 5.4 kg more for YF compared to CF. These data support the findings of others (Fox et al., 1972; Mader et al., 1989) who reported that restricting intake for a period of time prior to finishing increases feed intake in the feedlot. Collectively, these studies provide weight for the role of DMI in the compensatory gain phenomenon.

Regarding feed efficiency, many (Lancaster et al., 1973; Hickok et al., 1992; Lardy et al., 1998; Myers et al., 1999; Anderson et al., 2005) have reported improvements in efficiency of 0.04 to 0.19 kg less feed per kg of BW gain for calf-fed cattle. Only one study reported no differences in efficiency (Sainz and Paganini, 2005).

Carcass Characteristics. Many have perceived that yearlings yield carcasses with greater quality grades compared to calf-feds due to increased maturity at slaughter (Thompson and O'Mary, 1983). Although much concern has been expressed regarding the ability of calf-feds to grade due to reaching slaughter weight at an earlier point on the growth curve relative to yearlings, many publications indicate that *yearling* systems may yield carcasses with *less* desirable quality grades and palatability (Lancaster et al., 1973; Harris et al., 1997; Anderson et al., 2005; Brewer et al., 2007). Due to typically heavier initial weights and increased ADG during the finishing phase, yearlings reach slaughter weight with fewer DOF compared to calf-feds. As summarized by Owens et al. (1995), the protein:fat ratio increases as mature size increases, therefore, yearlings accrete less fat during the finishing period relative to calf-feds.

Many papers illustrate decreased marbling scores and/or quality grades for yearlings (Lunt and Orme, 1987; Anderson et al., 2005; Brewer et al., 2007). Yet others indicate no differences in any carcass traits evaluated (Myers et al., 1999; Sainz and Paganini, 2004). Nevertheless, numerous papers concur that yearling-fed systems yield more favorable yield grades (Lancaster et al., 1973; Lunt and Orme, 1987; Harris et al., 1997; Anderson et al., 2005) and larger REA (Anderson et al., 2005; Brewer et al., 2007).

In a review of factors affecting carcass characteristics, Gardner and Dolezal (1996) concluded that yearling cattle must be fed a high concentrate diet for a minimum number of days to minimize the risk of unfavorable or unacceptable carcass palatability. It has been reported by May et al. (1992) that as few as 84 DOF is sufficient to ensure acceptable carcass attributes. However, the recent report by Brewer et al. (2007) found that 91 d was not sufficient to ensure low risk probabilities of tough steaks and to allow for acceptable sensory ratings.

In the report by Brewer et al. (2007), carcasses from calf-fed steers were superior in quality (454.1 vs. 346.1 marbling score; $P < 0.001$) and palatability when compared to yearling-fed carcasses, as evaluated by shear force values and sensory ratings for both USDA Choice and Select steaks. These findings are similar to those reported by Klopfenstein et al. (2000), who indicated that due to increased age at slaughter, steaks from yearling-fed carcasses are less tender than those from calf-feds. However, in both reports, the researchers concurred that increasing the length of the carcass aging period can mitigate carcass palatability differences, with 14 d improving tenderness significantly over aging for 7 d.

Utilizing cloned Brangus steers to evaluate differences for calf-feds and yearlings, Harris et al. (1997) reported no differences in meat palatability after aging 14 d, regardless if steers were slaughtered at a constant-age endpoint of 16 mo or at a common live weight endpoint of 530 kg (DOF = 224 for CF and 185 d for YF) after 14 d of aging. Additionally, no differences in palatability or tenderness were detected by Lancaster and collaborators (1973), by Lunt and Orme (1987), who allowed a 7 d aging period prior to evaluation. Similarly, Myers et al. (1999) allowed a 14 d aging period prior to evaluation and reported no differences in carcass palatability for CF or YF steers.

Economics. Similar to the findings of the present study, the differences in break-even selling price and system profitability are frequently numerically different, with YF having a lesser break-even price and increased overall profitability. In the system analysis by Anderson et al. (2005), YF steers had a lower break-even selling price (P = 0.03) and tended to be more profitable compared to CF steers.

Conclusions

When determining the most appropriate time of weaning and finishing system, one must consider cattle breed and type, forage availability for back-grounding, and financial ramifications. The decision to place cattle directly into the feedlot as calf-feds or allow a grazing period prior to finishing is predicated on understanding how each strategy may affect feedlot performance, carcass characteristics, and profitability.

The present study indicates that with the exception of initial feedlot weight, time of weaning of fall-born steers of British x Continental breeding does not influence feedlot and carcass characteristics. Likewise, time of weaning does not interact with finishing system. Similar to many of the published reports, the current study illustrates that yearling-fed steers are less efficient in converting feed to gain in the feedlot, but are more aggressive eaters, consuming more DM and gaining weight more rapidly. Consequently, final weights and carcasses were heavier for YF steers than for CF steers. This increase in weight translates to increased ribeye area and, in many cases, improved cutability.

The length of the back-grounding period and the degree of nutrient restriction are often greater determinants of feedlot performance and carcass traits. In the present study, when allowed an 84-d grazing period with a protein supplement, many of the differences in carcass characteristics were moderated, with only differences in HCW and REA observed. When evaluated on an economic basis, there appears to be no difference in break-even selling price or system profitability. However, one must consider that the previous 10 years have been highly variable, making it difficult to determine true differences, yet this period is more indicative of potential differences compared to the 20 yr evaluation due to differences inherent in the current market vs. the historical market.

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Table 1. Performance of yearling-fed steers weaned at two different dates grazing native range and receiving a protein supplement[a]

	Weaning Treatment[bc]	
Item	LW	NW
Initial wt, d=0	294	289
d 28 wt	328	323
d 56 wt	338	334
Final wt, d=84	338	332
Wt gain, d-0 to d-28	33.4	34.7
Wt gain, d-28 to d-56	10.1	10.3
Wt gain, d-58 to d-84	0.25	-1.8
Cumulative gain, d-0 to d-84	44.0	43.9

[a] Weights are least squares means, expressed in kg.
[b] Weaning treatments included: 1) Normal weaning at 210 d of age in April (NW), and 2) Late weaning at 300 d of age in July (LW).
[c] Rows without superscripts do not differ.

Table 2. Effects of growing/finishing system on steer feedlot performance[a]

Item	System CF	YF	SEM[c]	*P*-value[d]
Age at feedlot entry, d	313	400	10.8	< 0.0001
Initial wt, kg	297	331	13.4	< 0.0001
Final wt, kg	546	569	5.7	< 0.01
DOF	139	126	10.6	< 0.0001
ADG, kg/d	1.81	1.94	0.10	< 0.001
Dry matter intake and feed efficiency[b]				
DMI, kg/d	10.6	11.9	0.22	< 0.0001
Gain:Feed	0.0812	0.0781	0.004	0.16

[a] Steer weight reported as kg. Experimental unit is individual steer.
[b] Experimental unit is pen for DMI and feed efficiency.
[c] Most conservative SEM.
[d] Probability of a greater F-statistic.

Table 3. Effect of growing/finishing system on carcass characteristics[a]

Item	System		SEM[b]	*P*-value[c]
	CF	YF		
Live wt, kg	554	587	8.39	< 0.001
Final shrunk wt, kg	532	563	8.08	< 0.001
Dressing percent	62.6	63.1	0.60	0.29
HCW, kg	334	355	4.72	< 0.001
Marbling score[d]	437	416	2.53	0.21
12^{th} rib backfat, cm	1.20	1.22	0.097	0.81
REA, cm^2	84.54	88.48	2.32	0.01
YG	2.75	2.78	0.09	0.78

[a] Experimental unit is individual steer.
[b] Most conservative SEM.
[c] Probability of a greater F-statistic.
[d] Marbling score: small = 400-499.

Table 4. Fixed inputs used for economic comparison of two finishing systems

	System	
Item	CF	YF
Freight	$3/loaded mile	$3/loaded mile
Medical	$12	$10 grazing; $7.50 feedlot
Yardage	$0.35/hd	$0.35/hd
Pasture	---	$0.55/kg gain
Death loss	2 %	2 % grazing; 1 % feedlot
Equity	$100	$100

Table 5. Breakeven selling price and profit/loss of steers assigned to two finishing systems

	System			
Item	CF	YF	SEM[a]	*P*-value[b]
Breakeven selling price, $/0.45kg	0.73	0.72	0.22	0.17
Profit/loss, live basis, per steer	45.42	60.95	28.64	0.62

[a] Most conservative SEM.
[b] Probability of a greater F-statistic.

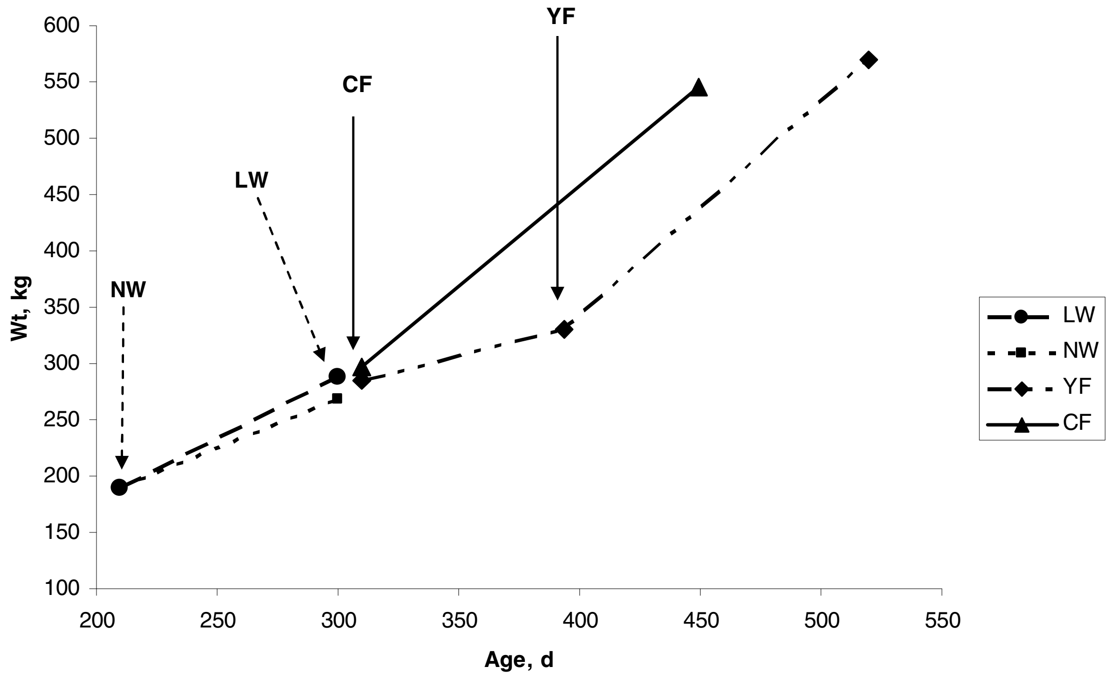

Figure 1. Growth curves throughout the experiment. The dashed arrows indicate time of weaning for normal-weaned (NW) and late-weaned (LW) calves. The solid arrows indicate the beginning of the feedlot phase for the calf-fed (CF) and yearling-fed (YF) cattle.

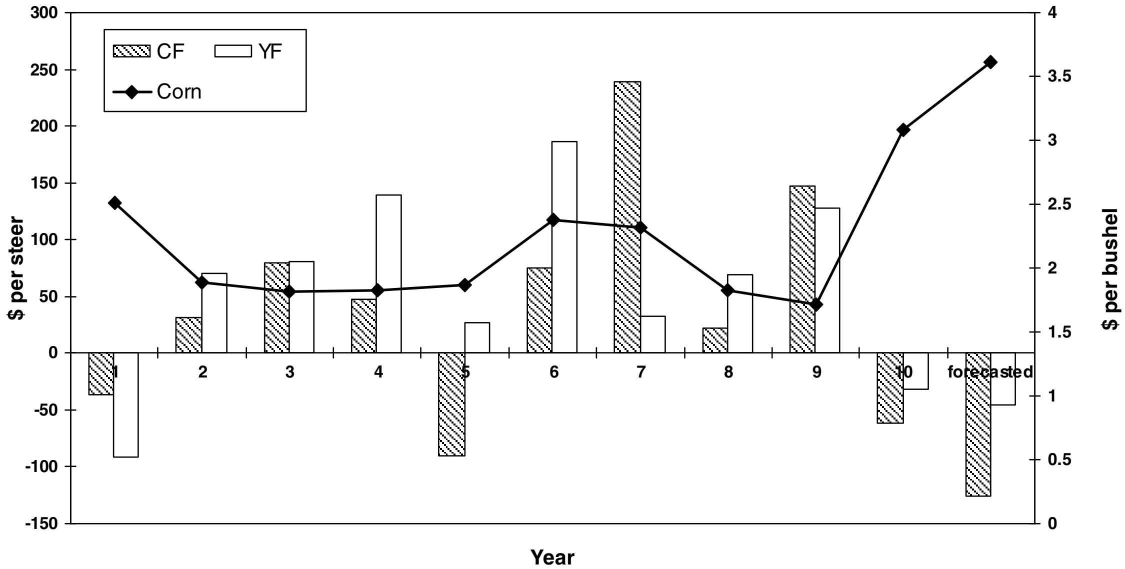

Figure 2. Comparison of profit/loss for steers assigned to two finishing systems overlaid with corresponding price of corn.

VITA

Melissa Dale Hudson

Candidate for the Degree of

Master of Science

Thesis: EFFECT OF TIME OF WEANING ON PERFORMANCE OF YOUNG AND MATURE BEEF COWS AND THEIR CALVES IN A FALL CALVING SYSTEM

Major Field: Animal Science

Biographical:

Personal Data: Born in Talihina, Oklahoma, April 28, 1977, the daughter of Monte and Kathy Glenn. Married Rick D. Hudson August 5, 2000 and have one son, Gabriel Zane, born January 11, 2003.

Education: Graduated from Wilburton High School, Wilburton, Oklahoma in May, 1995; attended Eastern Oklahoma State College in Wilburton for one year as a member of the senior livestock judging team; transferred to Oklahoma State University, Stillwater, Oklahoma and completed a B.S. in Animal Science and a minor in Agricultural Economics in December, 1998; completed requirements for the Master of Science Degree at Oklahoma State University in July, 2007.

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Name: Melissa Dale Hudson Date of Degree: July, 2007

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: EFFECT OF TIME OF WEANING ON PERFORMANCE OF YOUNG AND MATURE BEEF COWS AND THEIR CALVES IN A FALL CALVING SYSTEM

Pages in Study: 94 Candidate for the Degree of Master of Science

Major Field: Animal Science

Scope and Method of Study: Predominantly Angus beef cows were used in three consecutive years to determine the effects of time of weaning and cow age class on cow body weight and body condition score, reproductive performance, milk production, and calf performance of fall-calving cows and their progeny. Treatments were arranged in a 2 x 2 factorial with two weaning dates and two age classes (mature cows ≥ 4 yrs and young cows ≤ 3 yrs). Weaning treatments were: (1) normal weaning in mid-April at 210 d of age (NW) and (2) late weaning in mid-July at 300 d of age (LW).

Findings and Conclusions: Time of weaning influenced cow body weight and body condition score. At the beginning of the calving season, NW cows were heavier and had greater fat reserves than LW cows. Postpartum BW and BCS loss was significantly greater for NW cows, resulting in similar BW and BCS at the beginning of the breeding season and until April. Progeny of NW cows were 2.3 kg heavier at birth and grew faster prior to weaning, resulting in increased weights (+ 10 kg) at the time of normal weaning. When considering all calves weaned on the trial, late weaning increased calf weights in July, regardless if NW calves were retained during the summer. These findings indicate that producers may benefit from matching weaning date to cow age class. It appears more advantageous to delay weaning of calves born to dams 4 yr or older, while maintaining normal weaning for dams 3 yr or younger at time of calving. Late-weaning had no detrimental effects for mature cows indicating this practice appears to be a viable alternative weaning options.

ADVISER'S APPROVAL: Dr. David L. Lalman