TECHNIQUES FOR ESTIMATION OF MILK YIELD IN BEEF COWS AND RELATIONSHIPS OF MILK YIELD TO CALF WEIGHT GAIN AND POSTPARTUM REPRODUCTION

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ABSTRACT

Milk production is a primary factor controlling weaning weight of beef calves. The purpose of this experiment was to develop a practical and reliable on-farm method of estimating milk production and to relate estimates of milk production and milk composition to preweaning weight gain of calves. A second objective was to relate milk production to postpartum ovarian activity. Milk production of spring- and fall-calving grade Angus cows was estimated by machine milking (MM; average of 66, 123 and 189 d postpartum) and weigh-suckle-weigh (WSW; average of 50, 95, 136 and 179 d postpartum) techniques following overnight calf removal. Cows and calves were weighed monthly and the postpartum interval to first ovulation following calving was determined. The repeatability of the estimated milk production by MM (.97) was higher (P < .01) than by WSW (.35). The correlation of average WSW and average MM estimates of milk production with preweaning calf gain were high and similar (> .75). Inclusion of milk composition did not improve the multiple correlation of MM-estimated milk production and calf gain. Neither milk production in early lactation (-.06) nor prebreeding weight change (-.07) was correlated with postpartum interval to ovulation. Machine milking was a repeatable method of estimating milk production of beef cows and can be used to evaluate effects of management variables on lactation of beef cows.

(Key Words: Beef Cattle, Lactation, Machine Milking, Weigh-Suckle-Weigh, Weaning Weight, Reproduction.)


Introduction

Milk production is a primary factor controlling weaning weights of calves of similar breed composition (Neville, 1962; Boggs et al., 1980). Calculation and use of expected progeny differences for maternal milk have heightened interest in selection for milk production. This interest has led to questions regarding the consistency of milk production over successive lactations and the relationships between the level of milk production, calf performance, dam's body condition and the reproductive performance of the postpartum, lactating beef cow.

Milk production has been estimated most often by the difference in the weight of a calf before and after suckling (Rutledge et al., 1971; Totusek et al., 1973; Williams et al., 1979). Others have employed hand milking (Hohenboken et al., 1973; Totusek et al., 1973) or machine milking procedures (Gleddie and Berg, 1968; Belcher et al., 1980). Such procedures, particularly those with a controlled suckling period prior to the calf separation as described by Boggs et al. (1980), required repeated, intensive animal handling in which timing is critical. Such procedures are possible with small numbers of animals but are not adaptable to on-farm trials in which larger herds are sampled.
The purpose of this experiment was to develop a practical and reliable method for on-farm estimation of milk production and to assess the relationship of milk production to productivity of beef cows.

**Experimental Procedures**

One hundred twenty-three lactations of 94 grade Angus (A) or Angus and Holstein (H) crossbred cows (43 A, 8 A × H, 35 3/4 A × H, 8 7/8 A × H) that were 2 to 12 yr of age were used to collect data on milk production and its relationship to calf growth and cow productivity. Calvings occurred during the spring (March 19 to May 3; n = 55; Yr 1) or fall (Oct. 2 to Oct. 26; n = 68; Yr 2). Twenty-nine cows used in Yr 1 were used again in Yr 2. Calves were sired by a single Simmental bull in Yr 1 and by one of six Angus bulls in Yr 2.

Spring-calving cows were group-fed a daily diet (as-fed basis) of corn silage (11.9 kg), corn grain (.9 kg), urea (.07 kg) and hay (60:40 orchardgrass:fescue; ad libitum access) prior to calving. This diet was supplemented with an additional 2.3 kg of corn silage plus .9 kg corn grain daily from calving until April 15 when cows were turned out to graze pastures (50:40:10, orchardgrass, fescue, bluegrass) until calves were weaned (Nov. 13). Fall-calving cows were fed corn grain (.9 kg/d) beginning an average of 28 d prior to calving and received a daily diet of corn silage (8.1 kg), corn grain (3.3 kg), urea (.1 kg) and hay (60:40 orchardgrass:fescue; ad libitum access) from calving until calves were weaned (June 12). Cows had constant access to water and trace mineral salt containing 100 ppm selenium. Cows and calves were weighed once within 24 h after calving and at monthly intervals until calves were weaned.

Calves received no supplemental feed but were allowed to suckle their dams at will except when isolated for an average of 19.9 h (SD = 1.6 h) prior to each estimation of milk production. Water was available ad libitum to calves during separation. Calves averaged 237 d of age (SD = 10 d) at weaning.

At an average of 50, 95, 136 and 179 d postcalving, all calves were isolated from their dams at 1600. Beginning between 0800 and 1300 the following day, each calf was weighed before and after being allowed to suckle its dam to satiety. Suckling periods did not exceed 30 min. Cows and calves were paired in groups of 20 to 23 pairs. Difference between pre- and post-suckling weights was recorded as estimated milk production of the dam. The interval from calf separation to nursing for weigh-suckle-weigh was recorded. During Yr 1 an additional weigh-suckle-weigh measurement was conducted 3 d after the second regularly scheduled procedure. The simple correlation between these two milk production estimates was used to assess precision of the weigh-suckle-weigh procedure.

Twenty-four and 36 cows were selected randomly in Yr 1 and Yr 2, respectively, and milk production was estimated by weighing milk collected by machine milking. Eleven cows used in Yr 1 were used again in Yr 2. At an average of 66, 123 and 189 d postcalving, cows were isolated from their calves at 1600. Beginning between 0800 and 1300 the following day, each cow received 20 IU (i.v.) of oxytocin immediately prior to application of a milking machine. The milking apparatus was removed when milk flow from each quarter ceased. Milk was weighed immediately after collection and the time interval from calf separation to milking was recorded. Fat, solids-not-fat, protein and lactose in samples of milk collected at each milking were determined using standard automated methods5 described by Akers and Thompson (1987). During Yr 1 an additional machine milking measurement was conducted on 12 cows 3 d following the second regularly scheduled procedure. The simple correlation between these two milk production estimates was used to assess precision of the machine milking procedure. Precision of machine milking and the precision of weigh-suckle-weigh estimates of milk production as determined by simple correlation of repeated measures for each procedure taken at a 3-d interval, were compared using the procedures of Snedecor and Cochran (1967).

Blood samples were collected weekly from 20 to 120 d postcalving. Progesterone in blood serum was determined by radioimmunoassay (Beal et al., 1980). If ovulation occurred within 120 d postcalving, the postpartum interval to first ovulation was estimated based on progesterone profiles. Ovulation was defined as

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occurring 1 d following the date of blood collection on which serum progesterone concentration was <1 ng/ml followed by detection of serum progesterone concentrations of >1 ng/ml in blood samples collected for two successive weeks (Wettemann et al., 1972; Beal et al., 1984). Time of first ovulation in cows that failed to ovulate within 120 d postcalving was estimated based on estrous detection. Ovulation was defined as occurring 1 d following detection of behavioral estrus. Cows were not exposed to bulls of breeding age at any time during the experiment.

Milk production estimates, milk composition and calf weaning weight adjusted for calf age, sex and sire within year were analyzed by least squares analysis of variance with cow age, breed (percentage Holstein), year and calving date within year as main effects. Preliminary analysis revealed that the effect of the duration of time that the calf was separated from its dam prior to machine milking or suckling (mean = 19.9 h; SD = 1.6 h) did not significantly effect milk production estimates. Therefore, this variable was not included in the model. This finding is consistent with previous reports that indicate that milk production estimates are influenced less by the interval from separation to milk removal when that interval is 16 h than when it is 4 h (Williams et al., 1979). Residual correlations of adjusted calf weaning weight with milk production and milk composition were determined from this model. The repeatability of milk production across years was estimated as the simple correlation of the average milk production measures of animals with weigh-suckle-weigh (n = 29) or machine milking records (n = 11) in both years.

The value of milk production estimates or calf weaning weights as predictors of a cow’s future performance were compared. Simple or residual correlations (within cow age, breed group) of milk production estimated by machine milking and of calf weaning weight with either previous or subsequent weaning weights were calculated.

All statistical analyses were conducted using the procedures described by SAS (1985).

Results and Discussion

Cows in both years maintained their body weight (Figure 1) and body condition. The average daily gain and average weaning weights of calves, adjusted for age and sex (Figure 1), were similar in Yr 1 (.73 ± .02 kg/d; 206 ± 4.2 kg) and Yr 2 (.73 ± .01 kg/d; 211 ± 3.4 kg).

Milk production estimates for cows that were subjected to both milk estimation procedures (n = 60) are depicted in Figure 2. Average milk production during overnight isolation as estimated by the four weigh-suckle-weigh procedures was 5.2 ± .5 kg. The average weight of milk collected by machine milking was 5.1 ± .2 kg.

Milk composition averaged 4.1 ± .07% fat, 8.8 ± .04% solids-not-fat, 4.7 ± .03% lactose and 3.32 ± .02% protein. The actual amounts (percentage x milk weight) of each component present in milk collected by machine milking at 66, 123 and 189 d of lactation are depicted in Figure 3.

Simple correlation (precision) of weights of milk collected by machine milking on two occasions at a 3-d interval without adjustment for cow age and breed was high (R = .97; P < .001). The rank of the 12 animals used for repeated measurements of milk weight was identical for the two milkings. A comparable correlation for repeated weigh-suckle-weigh

![Figure 1](image-url)
estimates was only moderate ($R = .35; P < .01$), and notable re-ranking occurred among animals. Two of the 55 animals changed rank by 10 positions after the second weigh-suckle-weigh procedure. Average change in rank was $3.5 \pm .3$ positions.

The average weigh-suckle-weigh estimate and the average machine milking estimate of milk production in cows sampled by both methods were correlated with each other and similarly were correlated with preweaning weight gains of calves (Table 1). Each individual measure of milk production estimated by machine milking at 66, 123, or 187 d of lactation was highly correlated with calf weight gain. Residual correlations of individual machine milking estimates and preweaning gain were not different ($P > .50$) from the correlation obtained from the average of the three machine milking estimates. Conversely, each correlation between an individual weigh-suckle weigh measure and preweaning gain of the calves was lower ($P < .05$) than the correlation of calf gain with the average of four weigh-suckle-weigh estimates.

Under the conditions of this study, the weigh-suckle-weigh procedure was associated with re-ranking of cows based on repeated estimates of milk production, and the technique produced lower correlations between single milk production estimates and calf gain. These data indicate that the machine milking procedure used in this study was more appropriate for comparing differences in milk production among individual cows and for assessing the relationship between milk production and calf gain from only a single estimate of milk production. When four weigh-suckle-weigh estimates were averaged, the reliability of characterizing milk production of individual animals or the ability to define the relationship between milk yield and calf gain was similar to that from machine milking estimates.

The method of weigh-suckle-weigh used in this experiment was designed for practical, on-farm use. It is less controlled than other methods in which two weigh-suckle-weighs are averaged (Rutledge et al., 1971) or in which cows are uniformly nursed before the weigh-suckle-weigh procedure (Boggs et al. 1980). Intensifying the procedure by averaging measurements or removing and replacing calves at a set interval before the weigh-suckle-weigh isolation period could improve reliability of weigh-suckle-weigh measurements.

The correlation of preweaning calf weight gain and dam's milk production estimated by weigh-suckle-weigh (.76) was within the wide range of .16 (Belcher et al., 1980) to .81 (Neville, 1962) reported by others. Likewise, the correlation of machine milking estimates of milk yield and preweaning gain (.75) was higher than that reported by Belcher et al.
MILK PRODUCTION IN BEEF COWS

TABLE 1. RESIDUAL CORRELATIONS AMONG MILK PRODUCTION ESTIMATES DETERMINED BY MACHINE MILKING (MM) OR WEIGH-SUCKLE-WEIGH (WSW) PROCEDURES AND PREWEANING WEIGHT GAIN OF CALVES

<table>
<thead>
<tr>
<th>Item</th>
<th>Avg MM</th>
<th>MM1</th>
<th>MM2</th>
<th>MM3</th>
<th>Avg WSW</th>
<th>WSW1</th>
<th>WSW2</th>
<th>WSW3</th>
<th>WSW4</th>
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<tbody>
<tr>
<td>Preweaning gain</td>
<td>.75</td>
<td>.70</td>
<td>.73</td>
<td>.74</td>
<td>.76</td>
<td>.44</td>
<td>.34</td>
<td>.24</td>
<td>.40</td>
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<tr>
<td>Avg MM</td>
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<td>.98</td>
<td>.94</td>
<td>.77</td>
<td>.40</td>
<td>.53</td>
<td>.20</td>
<td>.34</td>
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<td>.92</td>
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<td>.74</td>
<td>.34</td>
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<td>.16</td>
<td>.23</td>
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<td>MM2</td>
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<td>.74</td>
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<td>.45</td>
<td>.22</td>
<td>.41</td>
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<td>MM3</td>
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<td>.45</td>
<td>.22</td>
<td>.35</td>
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<tr>
<td>Avg WSW</td>
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<td>.50</td>
<td>.27</td>
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<td>-.22</td>
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*Correlations in excess of .43 are significant (P < .01); correlations in excess of .33 are significant (P < .05).

Milk composition adjusted for cow age, breed and year was partitioned into four components: fat, lactose, protein and fluid (milk weight minus fat, lactose and protein). The residual correlations among the averages of these components and the residual correlations of each component with preweaning calf gain were high (Table 2). Total quantities of protein and lactose were correlated closely with the variation in the fluid portion and all three measures were highly correlated with calf gain. Milk fat was less closely related to variation in the fluid portion, but it remained highly correlated with calf gain. Fluid level was included as a covariate in the statistical model to determine whether fat content explained differences in calf gain independent of variation in the fluid portion. The partial

TABLE 2. RESIDUAL CORRELATIONS AMONG AVERAGE FAT, PROTEIN (PRO), LACTOSE (LAC) AND FLUID COMPONENTS OF MILK AND PREWEANING WEIGHT GAIN OF CALVES

<table>
<thead>
<tr>
<th>Item</th>
<th>FLUID</th>
<th>PRO</th>
<th>LAC</th>
<th>FAT</th>
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<tbody>
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<td>Preweaning gain</td>
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<td>.77</td>
<td>.72</td>
<td>.70</td>
</tr>
<tr>
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<tr>
<td>LAC</td>
<td>.69</td>
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</table>

*Correlation for FAT, PRO and LAC (component percentage x milk weight) was averaged for milk collected at 66, 123 and 179 d postcalving; fluid component was calculated as difference (milk weight minus other components).
correlation of fat content and calf gain in that model. 26 (P < .15), indicated that including measures of fat content did not enhance the ability to explain differences in calf gain. Other investigators have reached similar con-
clusions (Rutledge et al., 1971; Totusek et al., 1973).

The precision of the machine milking procedure, the consistency of milk production as estimated by machine milking in successive lactations and the strong relationship of estimated milk production and calf gain raised the possibility that milk production measured by machine milking might be a better indicator than weaning records of their previous calves of differences among cows in expected calf gain. To evaluate this possibility, we compared the within-age and breed group correlation of estimates of milk production in the current lactation and adjusted calf weaning weights in a previous or subsequent year (.35 P < .07, n = 29) with the within-group correlation of adjusted weaning weights in adjacent years (.29, P < .14 , n = 29). Comparable simple correlations, without age or breed adjustments, were .43 (P < .07) and .47 (P < .01) for the two relationships, respectively. The similarity of both the within-group and simple correlations suggests that recording machine milking estimates of milk production would be comparable to, but no better than, the use of previous calf weaning weights in predicting the weaning weights of subsequent calves raised by individual beef cows.

Postpartum intervals to first ovulation varied from 9 to 143 d. Postpartum interval was 23 d shorter in Yr 2 (43 ± 4 d; fall calving) than in Yr 1 (63 ± 4 d; spring calving). The partial correlations of postpartum interval with the amount of milk collected by machine milking at an average of 66 d postcalving (-.06; P < .70) did not indicate that cows that produced more milk experienced longer postpartum intervals. Postpartum weight change prior to breeding also was not correlated with postpartum interval (-.11; P < .43). Within breed and cow age group, the correlation of milk collected and weight change during the first 2 mo of lactation (-.17) was not significant; however, the simple correlation of weight change and milk collected (-.31), without regard to breed composition of the cows, was significant. These relationships indicate that cows in this herd that produced more milk tended to lose more weight (or to gain less weight) than lower-producing cows. Despite that relationship, neither the degree of weight change nor the amount of milk produced was related to the timing of the first ovulation postcalving.

Implications

In addition to verifying the importance of milk production in determining calf weaning weights, these data suggest that milk production is highly repeatable and that in adequately nourished cows the trait can be selected for without decreasing reproductive efficiency due to delayed postpartum estrus. Machine milking was more repeatable than the weigh-suckle-weigh procedure. The machine milking procedure can be utilized to investigate the relationship between maternal milk estimates of current genetic evaluation programs and actual levels of milk production. Furthermore, this method of estimating milk production in individual cows can serve as the basis for investigating the effects of changes in management on lactating ability of beef cows.

Literature Cited


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