AN ABSTRACT OF THE THESIS OF

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TITLE: ANALYSIS OF TWO ALTERNATIVE MANAGEMENT SYSTEMS FOR THE PRODUCTION OF FALL BORN BEEF CALVES IN WESTERN OREGON

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Two management systems were evaluated in terms of the effects on calf growth, on calf weight produced per cow per year, and on reproductive performance of fall calving cows. The alternative management systems tested were twin foster calf production and, delayed weaning, production of single suckled calves weaned at the end of the spring forage production season. Fall born calves which were single suckled and weaned at approximately 200 days of age served as controls. An evaluation of the effects of twin fostering on maternal-filial behavior and of the effects of cross suckling on calf growth in early life was also conducted. Delayed weaning was evaluated as a model for the demonstration of the effects of metabolizable protein intake on calf growth.

Calves used in these studies were born during September and October of 1979. Control (C) calves were weaned at approximately 200 days

of age, twin forster (TW) and delayed weaned (DW) single calves were weaned at approximately 291 days of age.

Twin fostering resulted in calves 39 kg lighter at 200 days of age than single suckled calves ($P < .001$). By 291 days after fostering, Holstein and beef twin fosters were not significantly lighter than C calves. At 365 days after fostering, Holstein twin fosters and C calves did not differ significantly in weight, DW singles were heavier than all other groups. At 200, 291 and 365 days after fostering, TW cows had produced 39, 67 and 69% more total calf weight than C cows, respectively. TW cows required 391% more supplement to effect winter weight and body condition changes similar to those of C cows. Fostering, in this study, was not found to effect reproductive performance of cows.

Observations of nursing/suckling activity in the twin foster herd were taken on days 71, 77 and 175 after fostering. Calf growth rates between fostering and day 77 and between days 77 and 175 were compared with percent cross suckling estimated for the appropriate periods. On days 71 and 77, percent cross suckling was 40.8% on day 175 percent cross suckling was 21.3%. The decrease in cross suckling over time was associated with a proportional decrease in suckling frequency and an increase in forage and creep intake by calves. The correlation between percent cross suckling and average daily gain (ADG) was -.73 at day 77. Variability in calf growth declined with age. The high degree of cross suckling observed was probably due to the time lapse between removal of the newborn calf and its replacement with foster calves.

Delayed weaning significantly increased ADG of calves between 200 and 291 days of age ($P < .001$). Steers gained significantly faster than heifers, irrespective of treatment ($P = .02$). DW calves were also significantly heavier at 365 days of age than C calves ($P = .025$). The ability of DW calves to gain faster than C calves between 200 and 291 days of age was likely a result of postruminal digestion of milk. High quality milk protein was suggested to have provided metabolizable protein for the additional gains of DW calves which was not available to calves grazing without access to milk.

Delayed weaning of fall born calves appears to be a sound management practice under western Oregon conditions. The rearing of calves by twin fostering was found to be of questionable feasibility due to the high supplemental feed input required for overwintering of cows rearing foster calves, and also because of the potentially detrimental effects of twin foster calf rearing on reproductive performance of cows.

ANALYSIS OF TWO ALTERNATIVE MANAGEMENT SYSTEMS FOR THE PRODUCTION OF FALL BORN BEEF CALVES IN WESTERN OREGON

by

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ANALYSIS OF TWO ALTERNATIVE MANAGEMENT SYSTEMS FOR THE PRODUCTION OF FALL BORN BEEF CALVES IN WESTERN OREGON

CHAPTER I

INTRODUCTION

In western Oregon, fall calving is thought to be a means of maximizing the efficiency of the cow-calf beef operation on dryland hill pasture (Bedell, 1981). Quantitative data to support this contention, however, are lacking. The trials to be reported in this thesis represent the initial stages of a research program designed to evaluate the effects of various systems and management practices on the efficiency of production of fall born beef calves.

Improved hill pasture land in western Oregon is commonly dominated by mixtures of tall fescue (*Festuca arundinaceae*), perennial ryegrass (*Lolium perenne*) and subterranean clover (*Trifolium subterraneum*) with lesser quantities of various annual grasses, clovers and forbs. Annual dry matter yields of forage on hill pastures in the Willamette valley range from 5000 to 9000 kg/ha. Forage production is, however, very seasonal with over 50 percent of total production occurring between April and June and with virtually no production between July and September (Bedell, 1981). This seasonality of forage production complicates management of hill pastures for the production of beef cattle.

During the winter and spring of 1980, eight managers of fall calving beef operations in western Oregon were interviewed by the author. The intent of the interviews was to gain insight into current management practices and problems facing managers of fall calving beef herds. Information attained from these interviews was used as an aid in the development of research priorities with the fall calving beef herd at OSU.

Two management systems were evaluated in terms of the effects on calf growth, on calf weight produced per cow per year, and on reproductive performance of fall calving cows. In addition to these performance measures it was further intended to evaluate the management systems on the basis of potential costs of production. The management systems were twin foster calf production and production of single suckled calves weaned at the end of the spring forage production season. Fall born calves which were single suckled and weaned from their dams at approximately 200 days of age served as a control.

Twin foster calf production was viewed as a potential means of increasing total calf weight produced per cow through an increase in the number calves weaned per cow per year. Weaning of single suckled calves at nine or ten months of age, delayed weaning, was evaluated as a means of increasing production per cow by increasing individual calf growth rate and calf weight at a given age. As it has been shown that milk production of the dam has a major influence on preweaning calf growth (Jeffrey and Berg, 1971; Jeffrey et al., 1971) dairy x beef crossbred cows genetically capable of a high level of milk production were used in these studies.

Suckling intensity is known to effect the length of the postpartum anestrus interval of the cow (Oxenreider, 1971; Wettemann et al., 1978; La Voie et al., 1981). In an evaluation of twin fostering it was, therefore, considered to be very important to monitor reproductive performance of twin suckled cows.

Fostering of alien calves onto cows immediately after parturition can result in the formation of a strong maternalfilial bond between the cow and her foster calves (Hudson, 1977). If fostering occurs after the cow has had contact with her newborn calf, it is much less successful (M. L. Thonney, unpublished data). In the current trial two calves were fostered per cow within five minutes after parturition. Observations of suckling were taken to evaluate the amount of cross suckling within the foster herd (foster calves nursing cows other than their own foster dam) and the relationship between cross suckling and calf growth rate. Kilgour (1972) found that cross suckling increased the variability of calf growth rates within the foster herd.

In the consideration of delayed weaning, the effect of extended milk intake on calf growth was viewed as a potential model for the demonstration of the effect of metabolizable protein level on protein nutrition of the growing calf. MacRae (1976) postulated that lambs grazing lush green feed, grass-clover pasture, were actually subject to a protein limiting diet. The same is likely to be true for the young calf in a similar environment. Intake of milk, if the esophageal groove functions to cause rumen bypass, in addition to grazed herbage should provide adequate metabolizable protein to sustain higher growth rates of young calves than would be possible from calves grazing without access to milk.

In order to evaluate the management systems described above three trials were conducted and are reported in this thesis. A comparison between twin foster calf production, delayed weaning of single suckled calves and a "traditional" management system is reported in Chapter II. In Chapter III effects of twin fostering on maternal-filial behavior and the resultant effects on suckling activity and calf growth within the foster herd are described. The effects of weaning age, delayed versus traditional, on growth and yearling weight of single suckled calves are reported in Chapter IV. The results reported from the latter study are from the first year of a five year project.

A calendar of production for the fall calving beef herd used in these studies is presented in Figure 1. The reader may wish to refer to this calendar from time to time to avoid confusion of dates ecompassed by varous management practices.

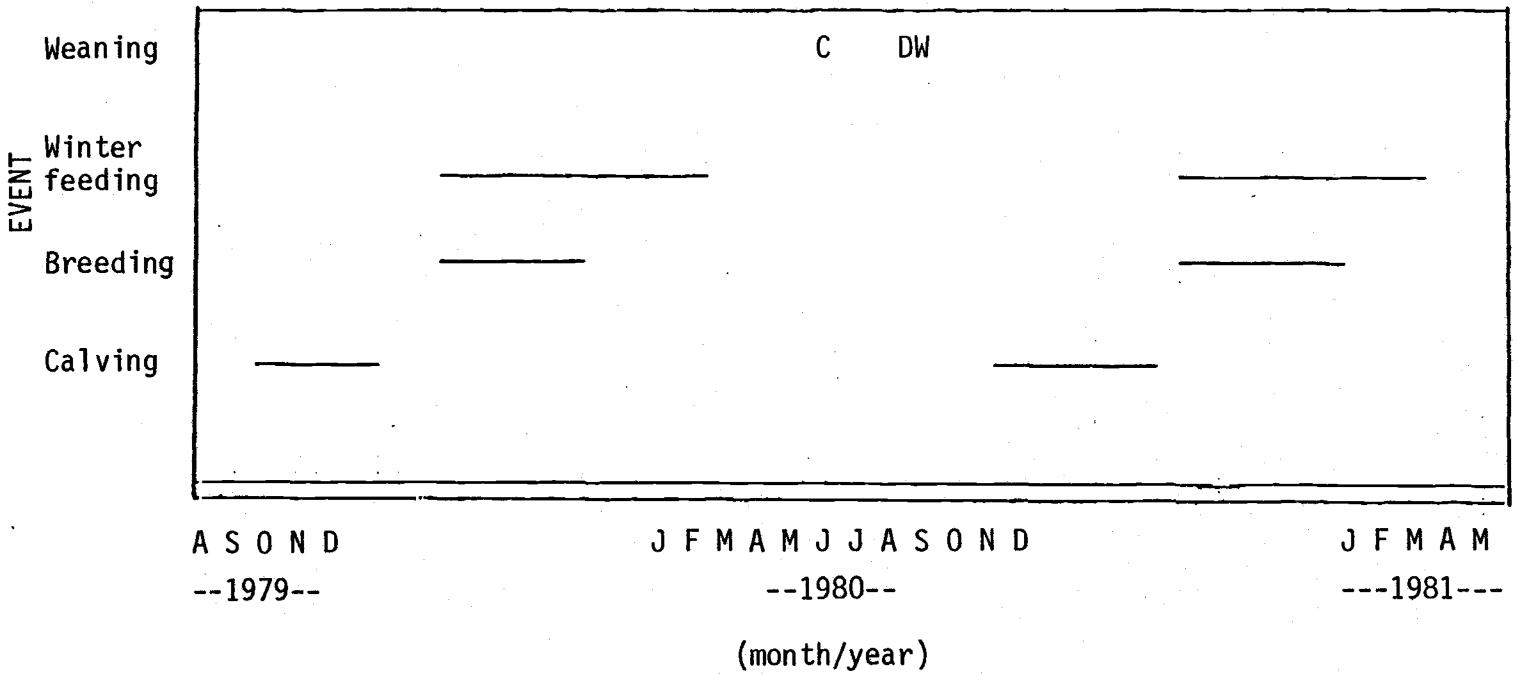

Figure 1. Fall calving production calendar. Dates encompassed by production events are approximate. Weaning dates are given for the control (C) and delayed weaned (DW) treatment groups.

CHAPTER II

EFFECTS OF TWIN FOSTER CALF REARING AND DELAYED WEANING ON COW AND CALF PERFORMANCE[1,2]

Summary

The effects of twin foster calf rearing and weaning age on calf weight at 200, 291 and 365 days of age, calf weight produced per cow, and reproductive performance of cows were evaluated using fall born calves. Eleven Holstein x Angus or Holstein x Hereford cows reared 20, Limousin crossbred or Holstein, calves in the twin foster group. Twin fosters were compared with single suckled Limousin crossbred calves weaned at 291 days of age and with single suckled Limousin crossbred calves weaned at 200 days of age. At 200 days twin calves were significantly lighter than single calves. Single suckled calves weaned at 291 days were significantly heavier at 291 and 365 days of age than calves from all other groups. At 291 and 365 days of age, twin foster and single suckled calves which had been weaned at 200 days of age were of similar weight. Calf production per cow at 200 days was increased 39% by twin fostering. At 291 and 365 days of calf age, twin foster dams had yielded 67 and 69% more total calf per cow than single suckled cows weaned at 200 days. Delayed weaning was beneficial on the basis of

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[1]Tech. Paper No. ____, Oregon Agr. Exp. Sta. Contribution to Western Regional Coordinating Committee WRCC-1, The Improvement of Beef Cattle through the Application of Breeding Methods.

[2]Dept. of Anim. Sci.

calf production, cow performance and cost of production. Foster twinning yielded the most calf weight per cow; however, supplemental feed costs and labor required at fostering would severely restrict applicability of this management practice. Twin fostering and delayed weaning did not depress reproductive performance of the cows. The lush spring grass-clover forage appeared to allow cows nursing calves to regain body condition and weight prior to the dry summer period.

Introduction

The cow, in relation to other domestic meat producing animals, has a low reproductive rate. Even under the best management conditions, production of 95 or more weaned calves per 100 cows exposed for breeding is considered exceptional. Twin fetation through embryo transplantation has been examined as one means of increasing reproductive rate and subsequent efficiency of production (Anderson et al., 1978). Fostering of alien calves onto beef or beef x dairy crossbred cows (multiple suckling) has also been studied (Wyatt et al., 1977b; M. L. Thonney, unpublished data). The first reports of calf rearing by multiple suckling involved the use of dairy cows and heifers (Everitt and Phillips, 1971; Carlo and Velez, 1974; Kaiser, 1975; Kaiser and O'Neill, 1975; Hudson, 1977; Moss et al., 1978). In these experiments two, three or four calves were raised per cow.

Management problems associated with multiple suckling include extended postpartum anestrus with a consequent extended calving interval (Carlo and Velez; Kaiser, 1975; Wyatt et al., 1977b). The amount and cost of supplemental feed required to sustain production of the multiple suckled cow is also substantially greater than that required for the single calf cow (Wyatt et al., 1977b).

Results of a survey of western Oregon beef operations conducted in 1980 (Rosecrans, et al., unpublished data) revealed that many managers do not wean fall born calves until June or July. Calves are weaned on the basis of forage availability and quality instead of age. By mid-June a September born calf is approximately nine months of age.

The study reported here was designed to compare twin foster calf rearing and the rearing of single suckled calves weaned at approximately 200 days of age. Traits of interest were calf growth and cow production in terms of reproductive performance, calf weight per cow and changes in winter weight and condition score.

Materials and Methods

Twenty-five, two- and three-year-old Holstein x Angus and Holstein x Hereford cows were used. The cows were bred to Limousin bulls and calved during September and October, 1979. Nine foster dams were chosen at random from the herd of 25. Potential foster dams were isolated when showing initial signs of parturition. Within five minutes after parturition, the cow's own calf was removed and was replaced by two alien calves. Results of a pilot trial conducted earlier indicated that allowing cows to rear their own plus an alien calf resulted in a high number of foster calf rejections. Based on these data, two alien calves were fostered per cow. The newborn calf was fed colostrum and retained for fostering to another cow. The fostered trio was confined to a small pen for 3 to 7 days or until the cow nursed both calves readily. Then they were introduced into the foster herd.

Five cows rearing one calf each were placed with the foster herd for supplementation through breeding. These five cows were not intended to be used as experimental subjects. On the basis of two, eight-hour suckling observation periods on days 71 and 77, however, it was determined that two of the cows were allowing cross suckling by foster calves. Their calves were also observed cross suckling on twin foster dams. These two cows and their calves were kept with the foster herd, while the other three single suckled cows were removed at the end of breeding. With the inclusion of the two cows and their calves, the foster herd consisted of 11 cows raising 20 calves. Eleven of the calves were Holstein bull calves obtained from local dairies; the other nine were progeny of the foster dams and were cross fostered within the herd.

After fostering, single suckled cows were grazed separately from the fostered herd. All cows grazed grass-clover pastures until the start of breeding. Over the winter feeding period, beginning at breeding, the groups were held in lots, two ha in size each. Grass-clover and alfalfa hays were fed at approximately 11 kg/head/day. Fostered cows were supplemented with 3.6 kg rolled barley/head/day, from 15 days prior to breeding until the end of winter feeding for a total of 100 days. Single suckled cows were supplemented with 0.9 kg/hd/day of a 30% CP pelleted protein supplement. Supplementation of fostered cows was imposed at a level calculated to achieve winter weight loss patterns similar to those of single suckled cows. Each group was provided with approximately equal amounts of CP per day. Fostered cows lost more weight between calving and breeding and were, therefore, supplemented earlier in the season. Weight change patterns through the breeding season also necessitated that fostered cows receive supplement later into the season than single suckled cows. All calves had access to a 16% CP creep feed from 16 weeks of age.

Within 48 hours after birth, calves were injected with a solution containing 3 mg sodium selinite and 204 IU vitamin E[3] to protect against white muscle disease, and bull calves were implanted with 36 mg of zeranol[4]. At 182 days after the mean calf birth date all calves were treated for internal parasites with levamisole phosphate[5]. At this time all bull calves were castrated and reimplanted with zeranol[4]. At 196 days (April 15) following parturition eight of the single calves were weaned from their dams. All foster calves and the remaining five single calves were weaned on July 15, 1980, 291 days after calving.

After weaning at 196 days, control weaned single calves (CW) were moved to a pasture as similar as possible to that being grazed by the delayed weaned single (DW) pairs and twin fosters. After 14 days the CW calves were merged with the DW pairs. Trial animals were rotationally grazed on grass-clover pasture through July 15. After July 15

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[3]Burns-Biotec Laboratories, Inc., Omaha, NE 68103
[4]IMC Chemical Group, Inc., Terra Haute, IN 47808
[5]Pittman-Moore, Inc., Washington Crossing, NJ 08560

all calves were moved as one group onto fescue-clover (Festuca arundinacae and Trifolium subterraneum) hay aftermath and remained there until final weights were taken on September 29, 1980. On the hay aftermath, calves were group fed approximately one kg barley/hd/day (IRN. 4-07-939).

Weights of cows and calves and body condition scores of cows were taken periodically throughout the trial. Possible condition scores ranged from one for very thin cows to five for obese cows (Kilkenny, 1978). After CW cows were weaned on April 15, day 200, they were removed from the trial. Calf weights taken on April 15, July 15, and September 29, 1980, were age and sex adjusted to standards of 200, 291, and 365 days for comparison. Calving interval was calculated using actual calving dates. All cows were exposed to 42 days of breeding by artificial insemination followed by a 21-day period with one cleanup bull per group. During artificial insemination, cows were observed for heat twice daily; cows in heat were inseminated each morning.

Probability values for differences between groups in performance traits were computed using a Student's t-test, with the exception of calving percentage, for which Chi square methods were used (Neter and Wasserman, 1974).

Results and Discussion

Cow supplementation resulted in similar winter weight losses for cows rearing single calves or twin foster calves, 21.0% vs. 17.3%, respectively (Table I). The level of supplementation required for fostered cows to sustain winter weight losses similar to those of single calf cows was very high, 299 kg/cow vs. 51 kg/cow, respectively (Table II). Because the total rations were approximately isonitrogenous, the high level of supplementation required by fostered cows only represents additional energy supplied over that supplied to single calf cows. Supplementation also was required for a longer period for fostered cows, 100 days vs. 71 days for singles. This longer period was found to be necessary based on weights and condition scores taken throughout the winter period. Wyatt et al. (1977b) found that cows rearing two calves required 72% more supplement than those rearing singles. In the present study the difference was 391%, though the difference in type of supplement inflated this figure.

At breeding, condition scores of fostered cows were similar to those of single calf cows, 1.6 vs. 1.7, respectively. Kilkenny (1978) suggested that cows with condition scores of 1.7 at breeding would probably have a ±390 day calving interval, while a minimum condition score of 2.5 at breeding has been shown to be necessary for maintenance of a 365 day calving interval. The percentage of fostered cows showing estrus within 60 and 90 days after parturition was not significantly different from that of single calf cows (Table III). In view of the low condition scores of all cows at breeding it is possible that the high level of energy supplied through barley supplementation improved the conception rate at first service of fostered cows, thus the similarity in calving interval between fostered and single calf cows. Also energy supplementation may have increased calving percentage (Table I).

The high level of energy supplementation of fostered cows was probably responsible for the overall reproductive performance and winter weight loss similarities to those of single calf cows. These data are consistent with the conclusions of Kaiser (1975), Wyatt et al. (1977b) and Wettemann et al. (1978) that extended postpartum anestrus of multiple suckled cows is probably due to the high level of suckling stimulus and not to nutritional factors.

Twin fostered cows and DW cows were able to gain in body weight and condition through the spring forage season even though they were nursing calves. At weaning, day 291, body condition was near the target of 2.5 (Table IV) for both groups of cows. The level of body condition attained by mid-July obviated the need to provide supplemental feed through the summer to reach target levels for calving and breeding in the fall. The effects of twin foster calf rearing and delayed weaning of single calves on subsequent reproductive performance of the cows were not evaluated because of subsequent research design.

Cows accepted foster calves and allowed them to nurse; however, a high percent of cross suckling was observed in the foster herd. Cross suckling has been shown to be a problem with calf production by multiple suckling (Hudson, 1977; M. L. Thonney, unpublished data) and commonly results in highly variable growth rates among calves. An analysis of the effects of cross suckling on calf growth within the foster herd and the implications in terms of maternal bonding is presented elsewhere (Rosecrans and Hohenboken, 1981).

A summary of calf weights at birth and at 200, 291 and 365 days of age is presented in Table V. Fostered calves grew at a slower rate between birth and 200 days than did single calves. As a result single calves were 39 kg heavier at 200 days ($P < .001$) than fostered calves. There was no significant difference between 200, 291 or 365 day weights of beef and Holstein fostered calves. Of the 20 calves originally fostered, 19 survived to 200 days of age. One calf died of chronic bronchopneumonia during the winter period. This calf was likely predisposed to bacterial infection by malnutrition. One of the DW dams died several weeks into the DW period. Her calf was subsequently removed from the trial.

At 291 days DW single calves were significantly heavier than C single ($P = .014$), Holstein twin fosters ($P = .018$) and beef twin fosters ($P = .003$). There was no significant difference between weights of the CW singles, Holstein or beef twin fosters ($P > .25$ in all cases). Single calves weaned from their dams at 200 days grew more slowly than all other groups from 200 to 291 days. Growth of DW singles, Holstein and beef twin fosters over the same time period was nearly equal.

After the delayed weaning date, day 291, twin foster calves grew the fastest and DW singles grew the slowest. At 365 days of age DW singles were 29 kg heavier than CW singles ($P = .019$), 33 kg heavier than Holstein twin fosters ($P = .028$) and 39 kg heavier than beef twin fosters ($P = .001$). Holstein twin fosters, beef twin fosters and CW single calves were not significantly different in weight at 365 days ($P > .40$ in all comparisons).

The ability of twin foster calves to outgain single calves between 200 and 365 days of age is most likely due to compensatory gain. Compensatory gain is thought to be due to the ability of an animal to take in more total food and utilize that food more efficiently for gain, after removal of a dietary restriction, than can animals of similar type, age or size which were not previously restricted (Reid and White, 1977). Weights of beef and Holstein twin fosters at 200 days were significantly lower than the genetic potential at 200 days, as evidenced by a comparison of weight between single and twin foster calves. The abundant forage available between April and July plus milk supplied by the foster dams supplied a high quality diet which enabled foster calves to outgrow even the DW singles. Everitt and Jury (1977) found that severe underfeeding of calves in the first 16 weeks of life can decrease mature weight. In the present trial the growth of twin foster calves after 200 days and weights at 365 days indicate that the dietary restriction imposed on foster calves early in life was not severe enough to significantly decrease size at one year of age. The similarity in yearling weights between twin foster calves and CW singles also supports the findings of LeDu et al. (1976a) that the length of time milk is available to the grazing calf influences weight at a given age after weaning more than the amount of milk a calf consumes per day.

A comparison of the effect of treatment on calf weight produced per cow at day 200, 291 and 365 is presented in Figure 1. The high degree of cross suckling observed within the twin foster herd eliminated the possibility of testing the statistical significance of observed differences. No given cow can be said to have supplied milk only to those calves which were fostered to her at parturition. Percent cross suckling by calves wihtin the foster herd was calculated as the number of times a calf suckled alien cows divided by total number of times a calf suckled in a day. Mean percent cross suckling was estimated to be 40.8% on days 71 and 77, and 21.3% on day 175 (Rosecrans and Hohenboken, 1981).

At 200 days, twin fostered cows had produced 278 kg of calf/cow as compared to 195 kg/cow for singles. This reflects a 39% increase in calf weight produced per cow by fostering. At 291 days twin fostered cows had produced 461 kg calf/cow which was 67% and 50% more than that produced by CW single and DW single cows, respectively. At 365 days calf weight per cow for twin fosters was 532 kg or 69% and 55% more than that of CW and DW singles, respectively. Wyatt et al. (1977b) found that cows rearing two calves produced 60% more total calf weight at 240 days than single suckled cows. Anderson et al. (1978) found that cows rearing twin calves, induced by embryo transplantation, produced 46% more calf at 112 days than cows rearing singles.

The differences in calf weight and calf weight per cow that were observed indicate that both delayed weaning of fall calves and twin fostering of calves will increase calf production in the fall calving beef herd. The increase in production per cow was greatest with twin fostering, but supplemental feed input required to sustain production of twin fostered cows was very high. Also a high labor input was required for twin fostering during the calving season, and the purchase price of calves would have to be considered. Weaning calves at nine months instead of 200 days did not increase production costs. Depending upon the relative value of cattle versus supplemental feed and labor, twin foster calf production may or may not be economically feasible. Delayed weaning of fall calves, however, appears to be advantageous irrespective of supplemental feed costs.

TABLE I

Performance of Cows Rearing Single or Twin Foster Calves

	Single cows	Twin foster cows
	(Mean ± SE)	
Fall weight, kg	511 ± 13	496 ± 14
Spring weight, kg	404 ± 8	410 ± ±1
Winter weight loss, %	21.0 ± 1.5	17.3 ± 2.5
Fall condition score	2.5 ± 0.1	2.3 ± 0.2
Condition score at breeding	1.7 ± 0.1	1.6 ± 0.2
Spring condition score	1.6 ± 0.1	1.5 ± 0.1
Winter condition score loss, %	34.4 ± 6.3	33.2 ± 7.6
1979 mean calving date	9-28-79	10-02-79
1980 mean calving date	11-02-80	11-08-80
Calving interval, days	405 ± 6	407 ± 6
Calving percentage	77	90

No significant differences in performance traits were observed.

TABLE II

Supplemental Feed Consumption by Single or Twin Foster Cows

	Single cows	Twin foster cows
Protein supplement[a]/cow, kg	51.0	0
Rolled barley/cow, kg	0	299
Creep feed[b]/calf, kg	44.3	42.7
Creep feed[b]/cow, kg	44.3	73.8
Total supplement feed/cow, kg	95.3	327.8

[a]Protein supplement composed of: 70% barley (IRN. 4-07-939), 25% feather meal (IRN. 5-03-795), 5% molasses (IRN. 4-04-696).

[b]Creep feed composed of: 45% oats (IRN. 4-07-999), 35% barley (IRN. 4-07-939), 15% soybean meal (IRN. 5-04-604), 5% molasses (IRN. 4-04-696).

TABLE III

Percentage of Cows Showing Estrus by 60 and 90 Days Postpartum

	Single cows	Twin foster cows
Cows exhibiting estrus within 60 days postpartum	29	18
Cows exhibiting estrus with 90 days postpartum	57	45

No significant differences observed.

TABLE IV

Weight and Condition Score of Delayed Weaned and Twin Foster Cows at Day 291 (July 15)

	Delayed weaned	Twin foster
	(Mean ± SE)	
Weight, kg	530 ± 19	524 ± 13
Condition score	2.4 ± 0.1	2.4 ± 0.2

TABLE V

Performance of Twin Foster Versus Single Calves

	Twin foster			Single		
	(Mean ± SE)					
	Beef	Holstein	Both	Control weaned	Delayed weaned	Both
(n)	(9)	(10)	(19)	(8)	(5)	(13)
Birth weight, kg	$39^{a} \pm 1$	$43^{a} \pm 2$	41 ± 2	$40^{a} \pm 1$	$41^{a} \pm 1$	41 ± 1
200 d adj. weight, kg	$162^{a} \pm 9$	$160^{a} \pm 9$	161 ± 6	$200^{b} \pm 6$	$200^{b} \pm 10$	200 ± 5
291 d adj. weight, kg	$263^{a} \pm 9$	$270^{a} \pm 12$	267 ± 7	$276^{a} \pm 7$	$307^{b} \pm 8$	288 ± 7
365 d adj. weight, kg	$305^{a} \pm 7$	$310^{a} \pm 7$	308 ± 9	$315^{a} \pm 9$	$344^{b} \pm 5$	326 ± 7

[ab]Means in the same row with different superscripts are different at ($P < .05$). Within the text, exact levels of significance are given, where appropriate.

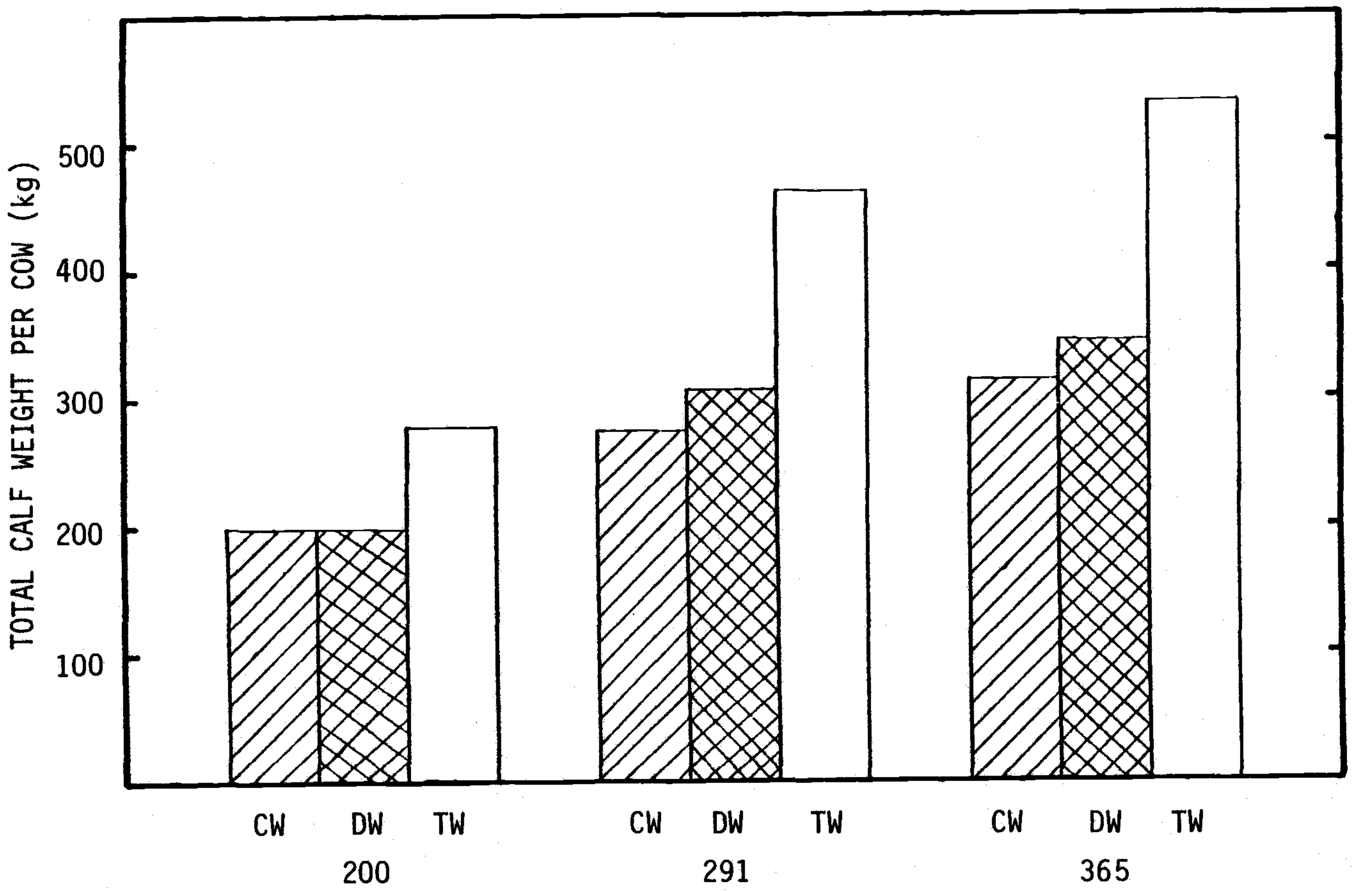

Figure 1. Total calf weight produced per cow. Measurements taken at 200, 291 and 365 days after calving. Comparisons are between cows rearing one calf weaned at 200 days (CW), one calf weaned at 291 days (DW) and twin foster calves weaned at 291 days (TW).

SUCKLING ACTIVITY AND CALF GROWTH IN A FOSTER TWIN BEEF HERD[1,2]

J. G. Rosecrans and W. D. Hohenboken[3]

Summary

Each of nine cows was presented with two alien calves within five minutes of parturition. Each cow's own calf was removed and later fostered to another cow. The foster trio was observed periodically until introduction to the foster herd. The foster herd was observed continuously on days 71, 77 and 175 after the average fostering date. Calf growth rates were recorded from birth through day 77 and from day 77 through day 175.

All cows allowed their foster calves to nurse at the time of introduction to the herd. Behavioral data taken on days 71 and 77 were similar and were summed. Percent cross suckling was high on days 71 and 77 but was less on day 175. Calf growth rates were highly variable to day 77 and were less variable between days 77 and 175. A high negative correlation between percent cross suckling and calf growth rate to day 77 was observed. The decrease in percent cross suckling from day 77 to day 175 was directly proportional to an observed decrease in suckling frequency.

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[1]Technical paper no. 5881, Oregon Agricultural Experiment Station.

[2]Contribution to Western Regional Coordinating Committee WRCC-1, The Improvement of Beef Cattle through the Application of Breeding Methods.

[3]Department of Animal Science

Percent cross suckling was highly variable between calves during all observation periods. The negative relationship between percent cross suckling and calf growth rate was less evident at the latter observation date. This was likely due to increased consumption of forage and creep feed by calves at the latter observation date. Variation between foster pairs for growth rate was not significant. The fostering methods employed apparently disrupted the formation of a specific maternal bond between the cow and her foster calves.

Introduction

The critical period for establishment of the mother-young bond in domestic ruminants occurs soon after parturition (Klopfer and Klopfer, 1968; Klopfer, 1971, Hudson and Mullord, 1977). Hudson (1977) and Thonney (unpublished data) reported that multiple fostering of alien calves onto cows immediately following parturition resulted in the formation of a strong maternal bond, while fostering after the cow had physical contact with her own calf was much less successful. The degree of cross suckling observed within a suckler herd is a good indication of the strength of bonding of cows with foster calves. Quality of the mother-young bond is positively correlated with calf growth rate (Poindron and LeNiendre, 1979). Cross suckling has been shown frequently to result in highly variable growth rates among calves within the suckler herd (Kilgour, 1972; Hudson, 1977; Thonney, unpublished data).

In this study, two calves each were fostered onto beef x dairy crossbred cows within five minutes after parturition. The resultant suckler herd was then observed to evaluate the level of cross suckling allowed at approximately 10 weeks and 25 weeks post-calving. Percentages of cross suckling and calf growth rates were examined to determine the relationship between them. This study was part of a trial to evaluate foster twinning as a means to increase the efficiency of pastoral beef production. A comparison of amount and efficiency of production from the twin suckler herd and a traditional single calf system are presented elsewhere (Rosecrans et al., 1981).

Materials and Methods

Four Holstein x Angus cows and five Holstein x Hereford cows, mated to Limousin bulls to calve in September and October of 1979, were used as foster dams in this trial. Six of the cows were multiparous and three were primiparous. The foster calf group consisted of seven progeny of the foster dams, ten Holstein bull calves and one Holstein x Angus heifer calf. Calf age at the time of fostering ranged from one to 12 days with a mean of 5.5 days. Calf weight at the time of fostering ranged from 36 to 51 kg with a mean of 41 kg.

Fostering procedures

Potential foster dams were removed from the herd and placed in covered 3m x 5m pens immediately prior to parturition. Cows were observed closely in the calving pens. Immediately after parturition, the newborn calf was removed from the pen. On two occasions, however, a dam sniffed or licked her newborn calf before it was removed. Amniotic fluids and expelled placental membranes, when available, were recovered at the time of calf removal. The newborn calf was taken to an adjacent barn and rubbed dry. Two potential foster calves were then rubbed with amniotic fluids and placental membranes. The foster calves were tied so that they could not stand and were placed in the calving pen with the cow. A cow was given two foster calves rather than one foster calf plus her own calf to raise, because results of a previous trial utilizing the latter system indicated that cows readily discriminated between their own and the foster calf. The time elapsed between removal of the newborn calf and its replacement by two potential foster calves was no more than five minutes in all cases. Following the introduction of foster calves to the calving pen, the newborn calf was fed colostrum from a nipple bottle, then placed in a pen with other potential foster calves.

Approximately one hour after introduction of foster calves to the cow, the handler entered the pen and untied the calves so that they could stand. The trio was then observed from a distance. If after one hour both calves had not suckled the foster dam, the cow was haltered and tied and the calves were assisted in locating the udder. One calf was placed on either side of the cow. After both calves had suckled, the cow was untied. This process was repeated later on the day of fostering if either calf was unable to locate the cow's udder and nurse after several attempts. The cow and her foster calves remained in the calving pen for from three to seven days depending upon availability of pasturage. They were then moved to a one ha pasture for one day, then merged into a group of no more than two other foster dams and their calves for two to three days prior to introduction to the herd of foster cows and calves.

Potential foster calves were penned together and fed milk replacer twice daily. Contact with the handler or with other persons was minimized in an attempt to avoid possible imprinting of the calves on humans. The oldest calves in the pen were used first when more than two calves were available for fostering at one time.

Management of the suckler herd

The herd of fostered cows and calves was grazed on grass-clover pasture until commencement of breeding, 45 days after the last fostering. The herd was then placed in a 1.25 ha drylot and was wintered there for the succeeding 119 days, after which they were returned to pasture. In drylot, grass-clover and alfalfa hays were fed. Cows were supplemented with rolled barley for 77 days, beginning 15 days prior to the start of breeding. Calves were creepfed a pelleted mixture of oats, barley, soybean meal and molasses for a 66 day period immediately prior to turnout to pasture in the spring. The calves were weaned on a common date, 286 days after the mean foster date. Cows and calves were weighed periodically throughout the trial.

Behavioral observations

Observations of the newly fostered trio occurred over a one hour period commencing approximately one hour after introduction of foster calves to the calving pen. Behavioral interactions between the cow and foster calves were noted. Each trio was also observed periodically until introduction to the herd, to ascertain if the calves were allowed to suckle by their foster dam.

Observations of suckling activity were taken at an average of 71, 77, and 175 days after fostering. The herd was observed continuously from dawn to darkness on the days specified. All nursing activity was recorded. Generalized responses of cows to nursing attempts by their own foster calves versus alien calves and patterns of approach by calves were also noted.

Results

Upon introduction of foster calves to the calving pen, all cows exhibited some degree of investigative behavior. Most of the cows smelled the foster calves; however, none of the cows licked the foster calves. All calves struggled vigorously when bound by the legs and placed in the calving pen. Once freed of the rope bindings, calves approached the foster cow and exhibited vigorous teat seeking behavior. Although several cows kicked at the calves during their first nursing attempts, cows exhibited little resistance to suckling by the calves. At least one of the foster twins had to be assisted in finding the dam's udder in all cases; calves nursed readily, however, once the udder was located. At the time of introduction to the suckler herd, the foster dam in all cases allowed both of her calves to suckle.

Because observations on day 71 and day 77 were similar, records of suckling activity for the two days were summed and are presented in Figure 1. Of the 18 foster calves, 15 were seen suckling at least one cow other than their own foster dam, and all cows nursed at least two calves in addition to their own. Percent cross suckling by calves, computed as number of times nursed by alien cows divided by total sucklings, ranged from 0 to 87.5% and averaged 40.8%.

In all cases the calf was observed to initiate a suckling bout. It was common to see alien calves approach a cow when one or both of her own foster calves were suckling. Alien calves usually approached and suckled from the rear of the cow or alongside another calf already suckling. It was not uncommon to see four calves suckling a cow at one time. The responses of cows to alien calves were inconcsistent. Some aliens were allowed to nurse alone while others were not. If an alien suckled along with a cow's foster calf, it usually was not rejected. The propensity of a cow to allow cross suckling apparently was affected by the indiscriminate suckling behavior of calves within the herd. Several cows were observed which initially rejected suckling attempts by alien fosters but eventually allowed them to suckle after continual assault by the calves. It appeared that a cow would generally nurse alien calves if a group of calves persisted in attempting to suckle for a period of several minutes or more. Suckling activity on days 71 and 77 was frequent; calves suckled, on the average, 4.5 times per day.

Observations of suckling activity in late lactation (day 175) are presented in Figure 2. Calves suckled, on the average, 2.3 times per day. Calves B1 and C1 did not suckle and cow C was not nursed during that observation period. Calf D1 died of chronic broncho-pneumonia earlier in the trial. The number of times a cow nursed any given alien calf was never greater than one on day 175; on days 71 and 77 this figure was as high as four. Percent cross suckling in late lactation (day 175) ranged from 0 to 100%, with an average of 21.3%, variability between calves for cross suckling was higher than that on days 71 and 77. Of the 17 calves, 11 did not cross suckle and two suckled only alien dams. The reduction in cross suckling from days 71 and 77 to day 175 was proportional to the coincident reduction in suckling frequency per calf, i.e. 48% reduction in cross suckling versus 49% reduction in suckling frequency.

Individual calf average daily gains from birth to day 77 and from day 77 to day 175 are presented in Table I. In any given pair of foster twins, the calf which cross suckled least on days 71 and 77 gained more rapidly from fostering to day 77. The correlation between percentage of cross suckling and average daily gain for this period was -.73. A similar correlation between percent cross suckling and average daily gain for the latter period, to day 175, was not calculated because of the high proportion of calves which did not cross suckle. Variability of rate of gain between calves was high in early lactation (CV = 39.8) and decreased in late lactation (CV = 23.9). Analysis of variance for calf gains showed that there was no significant difference among pairs of foster calves for rate of gain. Calf gain from fostering to day 77 and from day 77 to day 175 were 0.49 kg/day versus 0.57 kg/day, respectively. In late lactation the relationship between cross suckling and calf gain decreased relative to that observed earlier in lactation.

Discussion

The fostering methods used in this trial were successful to the extent that all cows allowed their foster calves to nurse. They were not successful in that the level of cross suckling in the herd was much higher than initially expected. It appears that the fostering methods employed resulted in the formation of weak maternal bonds. Cows apparently were not able to discriminate consistently between their own versus alien calves. Foster calves tended to nurse any cow which would allow it. These findings are consistent with those of Kilgour (1972), Hudson (1977) and Thonney (unpublished data) when the cow had contacted her newborn calf prior to its removal and replacement by foster calves. Hudson (1977) found that fostering four calves per cow at birth, when replacement was accomplished immediately following parturition, resulted in a low subsequent incidence of cross suckling within the herd.

Two factors of the fostering methods used were considered most likely to have interfered with formation of the maternal-young bond between cows and calves at fostering. These are the time lapse between birth and removal of a calf and its replacement by alien calves for fostering and calf age at fostering. Inability of fostered cows to produce a sufficient quantity of milk to rear two calves was considered as a possible cause of disintegration of the maternal-young bond over time and cross suckling by calves. Work by Wyatt et al. (1977a) and Wettemann et al. (1978) with Hereford x Holstein crossbred cows has shown that these cows produce 39% to 68% more milk when rearing two calves as opposed to one. In view of this information and measurements of milk production by beef x Holstein cows taken at this station, it is highly unlikely that a deficiency of milk production by the foster cows contributed significantly to disintegration of maternal-young bonds between foster cows and calves. No discernable relationship between calf age at fostering and percent cross suckling was found. This latter finding is consistent with that of Herscher et al. (1963) when fostering lambs to ewes. The five minute time lapse between birth and removal of a calf and its replacement with alien calves for fostering was possibly of sufficient duration to interfere with formation of an effective maternal-young bond between a cow and her two foster calves.

Maternal bonding between a cow and a foster calf is not an "all or none" phenomenon; the possible interactions between a cow and foster calf can be represented as a continuum with complete rejection of the calf at one extreme and adoption of the calf at the other (LeNiendre and Garel, 1977). The high degree of variability between calves for cross suckling observed in this trial shows this well. These data, when compared with those of Hudson (1977) and Thonney (unpublished data), indicate that if a cow is to form a strong maternal-young bond with her foster calves, her own calf must be removed as it is born and the foster calves must be introduced simultaneously.

Poindron and LeNiendre (1979) stated that the quality of a mother-young relationship is positively correlated with calf growth. If percent cross suckling is assumed to be a negative indicator of the quality of mother-young bonding, then the negative correlation between percent cross suckling and calf growth rate presented here is supportive of their findings.

By day 175 as compared to day 77, calves were much more dependent upon creep feed and forage intake than upon milk intake to meet their nutritive needs. This is evidenced by the decrease in suckling frequency and increase in rate of gain. This might explain why variability in rate of gain between calves and the relationship between percentage cross suckling and rate of gain was lower at day 175 than observed earlier.

Calf ID	Cow ID: A	B	C	D	E	F	G	H	I	No. of sucklings	Foster dam suckled (times)	Alien dams suckled	Percent cross suckling	Age fostering days
A1	1	2	1		1	2			1	8	1	5	87.5	6
A2	8				1					9	8	1	11.1	5
B1	5	3			1			1	2	12	3	4	75.0	8
B2		5								5	5	0	0	6
C1			3		1					4	3	1	25	5
C2	1	1	1	2	1	4		1	1	12	1	7	90	4
D1				3		1	1	3	2	10	3	4	70	12
D2		1		5		1				7	5	2	28.6	8
E1			2		2	1				5	2	2	60.0	5
E2			1		4					5	4	1	20.0	5
F1	3			3	1	7			1	15	7	4	53.3	5
F2	1					14				15	14	1	6.7	4
G1		2					10		2	14	10	2	28.6	7
G2							11			11	11	0	0	1
H1		2	2			3		1	2	10	1	4	90	5
H2								6		6	6	0	0	2
I1	1	2		1			1		2	7	2	4	71.4	8
I2								1	5	6	5	1	16.7	4
Times suckled:	20	18	10	14	12	33	23	13	18					
											mean = 40.8			
No. alien calves:	5	6	4	3	6	6	2	4	7					

Figure 1. Suckling activity of cows and foster calves for the sum days 71 and 77

Calf ID	Cow ID A	B	C	D	E	F	G	H	I	No. of sucklings	Foster dam suckled (times)	Alien dams suckled (times)	Percent cross suckling
A1	1									1	1	0	0
A2	2									2	2	0	0
B1										0	0	0	0
B2		2								2	2	0	0
C1										0	0	0	0
C2		1		1						2	0	2	100
D1										--dead--			
D2				2						2	2	0	0
E1					1					1	1	0	0
E2				1	1					2	1	1	50
F1						1				1	1	0	0
F2						4			1	5	4	1	20
G1		1			1		1			3	1	2	67
G2							6			6	6	0	0
H1						1			1	2	0	2	100
H2								3		3	3	0	0
I1						1			3	4	3	1	25
I2									3				
Times suckled:	3	4	0	4	3	7	7	3	8		mean = 21.3		
No. alien calves	0	2	0	2	1	2	0	0	2				

Figure 2. Frequency of suckling activity of cows and foster calves on day 175

TABLE I

Foster Calf Rate of Gain (kg/day)

	Period	
ID	0-77	78-175
A1	0.602	0.766
A2	0.803	0.781
B1	0.290	0.614
B2	0.720	0.724
C1	0.616	0.476
C2	0.324	0.484
D1	0.211	--
D2	0.555	0.522
E1	0.466	0.568
E2	0.617	0.770
F1	0.266	0.492
F2	0.779	0.629
G1	0.441	0.602
G2	0.503	0.278
H1	0.245	0.488
H2	0.535	0.515
I1	0.213	0.446
I2	0.660	0.496
Mean (kg)	0.491	0.568
SE	0.047	0.033
CV (%)	39.8	23.9

CHAPTER III

EFFECTS OF AGE AT WEANING ON GROWTH RATE AND YEARLING WEIGHT OF FALL BORN BEEF CALVES

Summary

The effects of calf age at weaning on growth rate and yearling weight of fall born beef calves were evaluated. By weaning calves in mid-June or early July instead of at 205 days it may be possible to make more efficient use of forage produced during the peak forage production period in western Oregon and to increase individual yearling weights of calves. Calves used in the first year of the study were sired by Limousin bulls and had an average birth date of 18 September 1979. At 200 days after the mean birth date (April 15) calves were allotted to either a control (C) or delayed weaning (DW) treatment. Control calves were weaned on April 15 and the DW calves 91 days later.

Delayed weaning of calves significantly increased gains between 200 days and 365 days of age ($P < 0.001$), steers gained significantly more weight than heifers irrespective of treatment ($P = 0.02$). The treatment effect in both sexes was greater between 200 days and 291 days than between 291 days and 365 days. Calf gains were similar for all groups between 291 days and 365 days. Yearling weights of DW calves were significantly higher than those of controls ($P = 0.025$).

Comparison of the growth rates observed in the current study indicate that the growth advantage of DW calves over control calves

was likely a result of postruminal digestion of milk. High quality milk protein is suggested to have provided metabolizable protein for additional gains which was not available from grazed forage alone. Delayed weaning of fall born calves, under western Oregon conditions, appears to be a sound management practice.

Introduction

A survey of fall calving beef operations in western Oregon conducted in 1980 (Rosecrans et al., unpublished) revealed that all managers interviewed weaned calves at no less than nine months of age. Time of weaning was based on forage quality and availability instead of calf age. Ranchers reported that weaning at approximately nine months (about mid-June) resulted in heavy calves at weaning and did not adversely affect the ability of dams to rebreed in the subsequent season. The objective of this study was to evaluate the effects of weaning fall born calves at 290-300 days of age (delayed weaning) on calf growth and on nutritional factors regulating rate of growth.

Data reported are results of the first year of a five year study and represent trends upon which further work will be based. Of specific interest in the first year of the study were the effects of delayed weaning on calf growth rate during the spring forage season, growth of calves after weaning, e.g. during the summer, and yearling weight of calves.

An increase of forage availability will increase milk production of a cow in late lactation when the cow has been on a restricted energy and protein diet (LeDu et al., 1976a). In western Oregon, forage availability increases rapidly from March through May (Figure 1). A second or "latent" peak in milk production by fall calving cows may occur at this time. A fall born calf will reach 200 days of age during the peak forage growth period. By delaying the weaning of calves until late spring or early summer, when forage growth has ceased, one may be able to promote higher rates of gain, through the combined effects of milk and forage intake, than would be possible with forage intake only. Milk intake by a calf will depress forage intake (Baker et al., 1976); however, with calves 6 months of age or older, the effect of a high level of milk intake on forage intake is minimal (Wyatt et al., 1977). LeDu, et al. (1976a) have shown that the effect of milk intake on calf growth is more of a function of length of time the calf is offered milk than the amount offered per day.

Total metabolizable energy and nitrogen intake are increased when a calf of a given age is suckling and grazing as opposed to grazing only (LeDu and Baker, 1979). It may, therefore, be possible to more efficiently utilize forage in the spring by stocking pastures with cows nursing fall born calves rather than stocking with weaned cows and calves separately. Stocking with cow-calf pairs will direct a higher proportion of the nutrients derived from grazed forage to productive gain by calves and a lower proportion to animal maintenance and relatively unproductive gains (e.g. body fat gain by cows).

The esophageal groove closes during suckling and directs milk past the rumen and into the abomasum. Digestion of milk in the abomasum and absorption of nutrients in the lower gut would provide the calf with high quality metabolizable protein (MP) and metabolizable energy (ME) to complement protein and energy derived from ruminal fermentation of forage. When comparing the effect of feeding protein supplements in liquid suspension as a suckle to the dry form, total nitrogen (N) retention can be increased by as much as 30% by suckling (Ørskov and Fraser, 1969). Infusion of casein into the abomasum of steers has been found to result in a similar increase in N retention (Johnson et al., 1978).

It is an accepted fact that the ruminant animal has a requirement for MP (Beever and Thomson, 1980). Crude protein level of a given foodstuff is not an accurate indicator of the ability of that feed to meet the MP requirement of a producing animal (Burroughs et al., 1973).

Degradability of the crude protein fraction in the rumen affects the efficiency of utilization for production (Thomas et al., 1979). The protein or N requirement of a ruminant must be defined first in terms of the N requirement of the rumen microbes, and then in terms of the N requirement of the host animal (Sniffen, 1978). Young ruminant animals of a given weight when growing at very high rates, i.e., near their genetic potential, cannot obtain enough MP solely from microbial N, derived from rumen fermentation, to meet the requirements to sustain high growth rates (Burroughs et al., 1973; Ørskov, 1980).

Fresh perennial ryegrass and subterranean clover contain high levels of N (2.5 - 4%) and soluble carbohydrates (Ulyatt and MacRae, 1974). Of the total N present, however, approximately 30% is non-protein nitrogen (NPN) (Rosecrans et al., unpublished data), and more importantly, 70% or more may be degraded in the rumen (Ulyatt et al., 1975). The inability of rumen microbes to capture all of the excess NPN from plant protein degradation in the rumen and convert it to microbial protein which is available to the host animal places the highly productive ruminant in a protein deficient status when grazing such forage.

Delaying the weaning of fall born calves until the end of the spring forage season should provide the calf with a nutritional environment which will more nearly allow expression of genetic potential for growth than by grazing alone of the weaned calf. Forage intake should provide adequate N and carbohydrate for maximum rumen fermentation. Milk intake, if it bypasses the rumen and is digested postruminally, would provide additional high quality protein and additional energy to the calf to sustain a high growth rate. The MP contributed by the bypassed milk protein and the microbial protein from the rumen should complement each other at the cellular level, especially in regards to sulfur containing amino acids (Burroughs et al., 1975). The availability of high quality forage should also allow a cow nursing a calf in the spring to regain the weight and body condition necessary for subsequent rebreeding and lactation in the fall of the year.

Materials and Methods

Twenty-four calves, sired by Limousin bulls, were used in this trial; mean birth date of the calves was September 18, 1979. Of the 24 dams, 19 were either Holstein x Hereford or Holstein x Angus crossbreds, three were Herefords and two were Angus. The winter confinement feeding period of cows and calves ended on January 21, 1980, so that by April 15, cows and calves had been grazing grass-clover pastures for 90 days. On April 15, day 1 of the trial, calves were allotted to either a control (C) treatment or delayed weaning (DW) treatment. Controls were weaned from their dams at this time, while DW calves remained with their dams.

Allotment of individuals among the two treatments was made using restricted randomization. Calves were first grouped by sex. Within sex groupings they were ranked by age and rate of gain (ADG) from birth to April 15. After rankings were made, allotment was conducted so that treatment groups were as uniform as possible in terms of the classification factors used (sex, age, ADG). Characteristics of the resultant treatment groups are listed in Table I.

Mean calf age at the initiation of the trial was 200 days which corresponds closely to the traditional 205 day weaning age. The delayed weaning date occurred on July 15, 91 days after the C date. At the start of the trial it was intended that DW calves be weaned at approximately 100 days after C calves. The actual DW weaning date was determined by forage availability, DW dam weight and body condition change and ADG of DW calves relative to C calves. To facilitate measurement of animal performance near the end of the DW period, weights and condition scores were taken at 14 day intervals instread of the initial 21 day intervals.

After weaning, C calves were grazed on grass-closer pastures similar to those being grazed by the DW pairs. Fourteen days after the C weaning date C calves were merged with the DW pairs and kept with them for the remainder of the trial. After introduction of C calves into the DW group, observations of nursing/suckling activity were taken daily for four days to determine if C calves were cross suckling on DW dams. No cross suckling was observed. During the DW period the trial cattle were rotationally grazed on grass-clover pastures. Rate of rotation was regulated with the objective of maintaining calf ADG at the highest level possible.

After the DW weaning date all calves were moved onto hay aftermath and grazed there until yearling weights were taken on September 29. The stocking rate during this time was at a level that insured adequate forage availability. On the hay aftermath calves were supplemented with 1 kg barley/head/day.

Records of calf birth weights and cow weights and condition at calving at 1979 and 1980 were compared to determine if delayed weaning of calves influenced either variable in the 1980 calving season. All cows were also rectally palpated in April of 1981 to determine if they were pregnant.

Calf growth data were analyzed using a repeated measures design. Treatment (DW vs. C) and sex were considered main effects. Average daily gain was the dependent variable of interest. Period, April 15 to July 15 (period 1) and July 16 to September 29 (period 2), was considered as a subplot factor. Analytical procedure followed the format suggested by Gill and Hafs (1971).

Harvey's (1977) least-squares mixed model analysis of variance computer package was used for the analysis. Yearling weight (YWT) was age adjusted to a 365-day standard and then were analyzed by 2-way analysis of variance. Effects of sex and treatment on ADG and YWT were compared using an F test. Reproductive data from the dams were tested with a student's T test.

Results

One of the cows which was allotted to the DW treatment died early in the trial and her steer calf was subsequently removed from the experiment. Least-squares means and standard errors of ADG from day 200 (April 15) to 365 (September 29) are listed in Table II. Delayed weaning increased ADG of calves by 31% ($P < .001$). Steers grew 12% faster between days 200 and 365 than heifers ($P < .05$).

The effect of DW on ADG was more pronounced with steers than heifers. Delayed weaned steers grew 39% faster than C steers, while DW heifers grew 22% faster than C heifers. The treatment by sex interaction effect on ADG was significant at $P = .09$. Most of the increase in ADG from delayed weaning occurred in period 1, e.g. between the C weaning date and the DW weaning date, for both heifers and steers.

A listing of ADG by period, treatment and sex is given in Table III. During period 1, DW calves grew at a rate of 0.38 kg/day faster than C calves ($P < .001$). The difference between DW and C steers was more pronounced than the difference between DW and C heifers (0.42 kg/day vs. 0.32 kg/day, respectively). In period 2, after the DW weaning date, gains were similar between all groups ($P > .4$).

Reduction in ADG by treatment and sex when comparing period 1 and period 2 is presented graphically in Figure 2. Both DW heifers and steers showed a more pronounced reduction in gains than C calves ($P < .001$). The DW steers, however, maintained a nonsignificantly higher rate of gain in period 2 than C steers. In period 2 C heifers gained faster than DW heifers, though the difference in ADG was very slight (0.04 kg/day). The sex by period interaction was not significant ($P > .13$).

Least-squares means and standard errors of age adjusted yearling weights are listed in Table IV. Delayed weaned calves were significantly heavier as yearling than C calves ($P = .025$). The effect of sex on yearling weight was nonsignificant. Overall, DW calves were 32 kg heavier as yearlings than C calves. DW steers were 41 kg heavier than C steers and DW heifers were 28 kg heavier than C heifers.

Dams of DW calves were able to regain body condition and weight through period 1. At the DW weaning date, dams of DW heifers had a mean weight of 560 kg and a mean condition score of 2.9. At this date, dams of DW steers weighed 495 kg and had a mean condition score of 2.4. In 1980 the target condition score was 2.5. Records of weight and condition scores of C weaned dams were not kept. Control cows were managed by groups to control condition and weight gain through period 1. This was accomplished through alterations in stocking rate.

Mean birth weight of calves born to C dams in the fall of 1980 was 2.0 kg heavier than the mean birth weight of calves born in 1979 to the same dams. For DW dams the increase in birth weight of calves from 1979 to 1980 was 1.5 kg. Delayed weaning of fall calves did not appear to reduce birth weights of calves born in the subsequent year. One cow from each of the treatment groups failed to breed in the 1980-81 breeding season. Apparently delayed weaning did not affect the cows' ability to rebreed the next fall.

Discussion

Response of calves to delayed weaning, in terms of ADG and YWT, was greater than expected. Bailey and Bishop (1972) found that fall born calves weaned at 10 months were 42 kg and 19 kg heavier at ten months than calves weaned at six and eight months, respectively. In a subsequent study by Bailey et al. (1975), it was demonstrated that calves weaned at eight months onto high quality forage were as heavy as yearlings as calves weaned at 10 months. Powell (1975), in a comparison of weaning fall born calves at eight and ten months, found no increase in yearling weight by later weaning. Perks and Turner (1979) compared the effects of weaning spring born calves at 195, 224 and 273 days of age and found no advantage to later weaning of the calf in terms of lifetime ADG.

In comparing the results of the current study with those reported previously, one needs to consider several potentially important differences in environment and management. Bailey's studies (Baily and Bishop, 1972; Bailey et al., 1975) involved the use of Hereford cows and it was reported that milk production dropped to very low levels (0.5 kg/day) by nine months post-calving. In the studies by Powell (1975), Bailey and Bishop (19752) and Bailey et al. (1975), comparisons were made between weaning at eight and ten months of age. By eight months of age the calves were between 200 and 250 kg in weight. Therefore, the calves may have been approaching the weight at which microbial N could meet their N needs for growth, for calves that have only a moderate potential for rate of growth. With these considerations in mind, it is then not surprising that calves weaned at eight months onto high quality, abundant forage performed as well as those not weaned until 10 months of age. Perks and Turner (1979) studied spring calving Hereford x Frisien cows. The lack of response in their study was likely due to a deficiency of forage quality and quantity in late lactation that would sustain milk yields at a level to attain maximum potential growth rates of the later weaned calves. Calves grazing dry forage may tend to use milk as a replacement for, rather than an addition to, forage intake.

The maximum ADG that was observed in the current study occurred between 200 and 224 days of age. During this time period, DW steers gained 1.8 kg/day and C steers gained 1.52 kg/day while DW heifers and C heifers gained 1.42 and 1.25 kg/day, respectively. During the subsequent 67 days prior to the DW weaning date, gains declined with the greatest decline being shown by C heifers and the least decline by DW steers. The high ADG of DW calves relative to C calves is likely due to additional MP and metabolizable energy ME supplied via milk consumption. The main effect on growth is likely to have been due to additional MP available for protein accretion by the animal. Because 85 to 91% of the protein in milk is degraded in the rumen, (Burroughs et al., 1975; Beever and Thomson, 1980), only post-ruminal digestion of the milk could have influenced ADG to the magnitude observed.

Supplying a high quality protein concentrate in a suckle to lambs eating a barley urea diet has been shown to increase food intake by 10-15% (Ørskov et al., 1973). At higher levels the post-ruminally digested protein supplement further increased ADG and efficiency of feed conversion without increasing food intake. Similar effects have been reported with light weight cattle by Thomas et al. (1979) and by Lindsay and Davies (1981) when supplying supplemental protein sources which were resistant to degradation in the rumen but were available to the animal via digestion in the abomasum and absorption from the lower gut.

Milk intake has been shown to increase total ME intake of grazing calves (LeDu and Baker, 1979) and also to buffer growing calves against the negative effects of low forage availability (Baker and Barker, 1978). When fat or lactose is digested in the rumen, voluntary forage intake (VFI) and forage digestibility are depressed (Bailey and Ørskov, 1974). The net effect post-ruminal digestion of fat and lactose is to increase total energy intake with little or no effect on VFI or forage digestibility. Barnes et al. (1978) found that when rearing calves with high growth potential (Charolais x Holstein) on dams which produced either "moderate" or "high" levels of milk, increased milk intake did not significantly decrease VFI of calves that were 6 months of age or older. It was also found that the higher milk level increased calf weight at 240 days but did not influence fatness of the calf. This information provides further evidence that the milk ingested by DW calves was digested postruminally.

It appears that the growth response to delayed weaning observed in this trial was likely due to an increase in total ME and MP intake. The actual biological mechanisms underlying observed responses are not clear at this point and require further examination. The effects of stocking rate and yearly variations in forage production on animal response merit considerable interest from a management standpoint. Proposed techniques for evaluation of hypotheses that the esophageal groove functions to cause rumen bypass of suckled milk in calves approaching maturity and also that MP from milk are the major mechanisms leading to increased growth are presented elsewhere. Hopefully an adequate hypothetical model has been presented to which further research may be addressed.

Delayed weaning of fall born calves under western Oregon conditions can be viewed as an example of one means by which a stockman can control nutrition to more fully realize the genetic potential of calves for growth. At the same time, forage utilization for beef cattle may be increased. With further understanding of the biological interrelationships involved, it will be possible to continue to improve the efficiency of production both in biological and economic terms.

TABLE I

Characteristics of Treatment Groups on April 15

Item	Steers		Heifers	
	DW	C	DW	C
n	4	5	7	7
Age, days	195	195	209	205
ADG[a], kg	0.75	0.78	0.70	0.71
WT, kg	189	194	186	185

[a]ADG from birth to April 15

TABLE II

Least-squares Means and Standard Errors for Overall (days 200 to 365) Average Daily Gain (kg)

		Treatment		
		DW	C	Mean
Sex	H	0.79 ±.03	0.64 ±.03	0.71[a] ±.02
	S	0.93 ±.04	0.67 ±.03	0.80[b] ±.01
Mean		0.86[c] ±.02	0.66[d] ±.02	0.76 ±.02

[ab](Means differ significantly at $P < .05$)

[cd](means differ significantly at $P < .001$)

TABLE III

Least-squares Means and Standard Errors for Average Daily Gain (kg) by Period

(A) Period 1 (200 to 291 days)

		Treatment		
		DW	C	Mean
Sex	H	1.13 ±.04	0.81 ±.04	0.97 ±.03
Sex	S	1.31 ±.05	0.89 ±.05	1.10 ±.03
Mean		1.23 ±.03	0.85 ±.03	1.04 ±.02

(B) Period 2 (291 to 365 days)

		Treatment		
		DW	C	Mean
Sex	H	0.44 ±.04	0.48 ±.04	0.46 ±.03
Sex	S	0.54 ±.05	0.45 ±.05	0.49 ±.03
Mean		0.49 ±.03	0.46 ±.03	0.48 ±.02

TABLE IV

Least-squares Means and Standard Errors
for Adjusted Yearling Weight (kg)

		Treatment		
		DW	C	Mean
Sex	H	323 ±8.4	295 ±12.5	309 ±8.2
	S	349 ±25.6	308 ±12.4	326 ±14.2
Mean		332[a] ±10.7	300[b] ±8.8	316 ±7.5

[ab](Means differ significantly at $P < .05$)

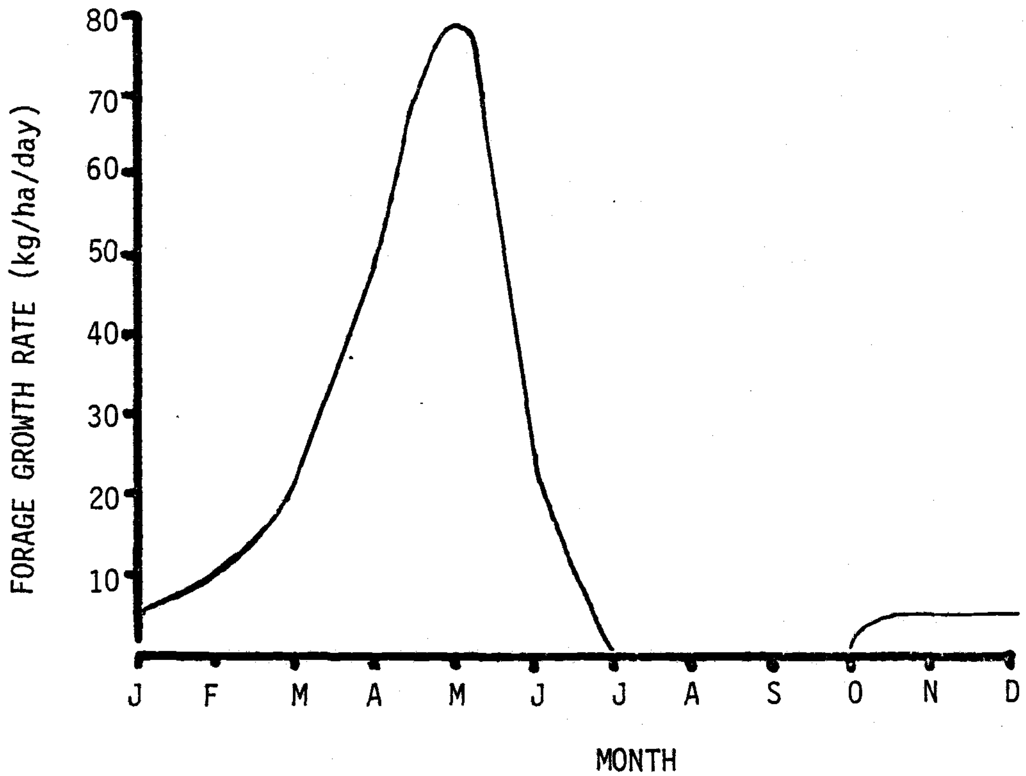

Figure 1. Forage growth curve for western Oregon dryland hill pasture.

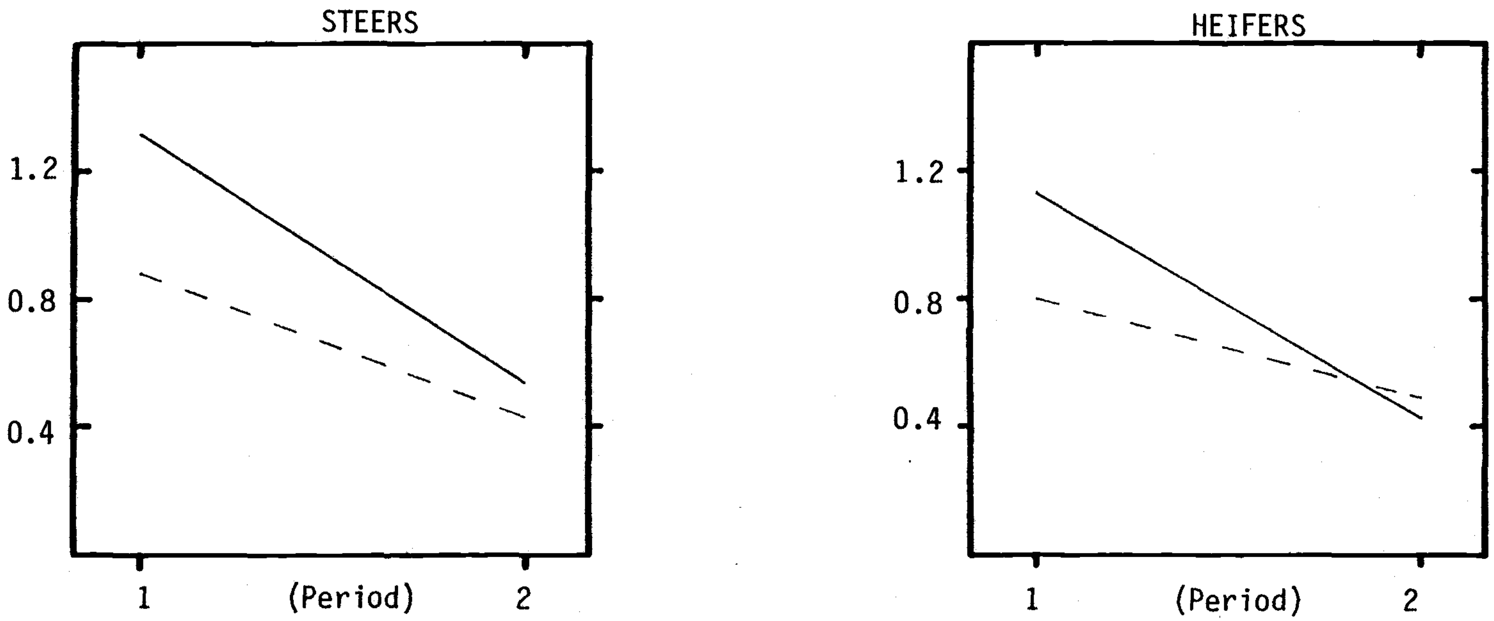

Figure 2. Reduction in rate of calf gain from period 1 to period 2. Control calves are indicated by the broken lines (-------), delayed weaned calves by the solid lines (———).

CHAPTER IV

GENERAL DISCUSSION

Fall Calving Management

Of the two alternative management systems evaluated, weaning of fall born calves in coordination with decreased forage production in late spring, delayed weaning, appears to be the most feasible. Calf production per cow was significantly increased over that of the more traditional system of weaning calves at about 200 days of age, without any apparent increase in the cost of production or detrimental effect on the reproductive efficiency of the cow. Production of twin fostered calves was shown to increase production per cow over either method of single calf production. The supplemental feed input and extended calving interval inherent with twin fostering, however, leads one to seriously question its feasibility.

Results of the behavioral evaluation of the effects of twin fostering indicate that the labor required to accomplish fostering was essentially wasted. Cows and foster calves failed to form strong maternal-young bonds. If one wishes to rear more than one calf per cow in a herd situation and wishes to minimize variability in calf growth rates, then fostering should be accomplished immediately at parturition. This could be facilitated through the use of a pharmacological agent to induce parturition. The probability of successful fostering would be greatly increased and labor required reduced under the situation where the manager has more control over calving.

The relative ability of the beef cow to produce milk is known to have a large influence on preweaning growth rate and weaning weight of the beef calf. Calf growth rates observed in this study, particularly between 200 and 291 days of age, indicate, however, that the ability of the cow to maintain some level of milk production late in the preweaning period (persistency of the lactation curve) may be more important in terms of weaning weight of the calf than the amount of milk produced at peak lactation. It is considered a common practice to select and breed beef cows to maximize milk production within the limits imposed by feed resources. Under the conditions of fall calving, improvement in weaning weight of calves through selection for maternal performance may, however, be a reflection of the persistency of lactation more so than the amount of milk produced at peak lactation. The beneficial effects of infusing dairy breeding into the beef cow, then, may be due to an ability of the dairy cow to produce more milk later in lactation and the relative inability of beef cows to do so.

Calf Nutrition and Growth

The gain response associated with delayed weaning indicates that a rethinking is needed of the association between nutrient intake and growth of the young ruminant. Energy and crude protein levels of lush immature forages, measued by traditional methods of evaluation, should be in excess of what the calf can utilize for maintenance and growth. Milk intake, however, was shown to increase rate of gain, by 22% in heifers and 39% in steers, over that of calves grazing without access to milk. It is proposed, then, that the response of calves to milk intake reflects an inability of microbial protein to meet the calf's requirements for a high rate of growth. Milk, when it bypasses the rumen, would provide the calf with additional MP to complement the microbial protein from ruminal digestion. The net effect is that forage intake should maximize rumen fermentation potential through an abundance of soluble carbohydrates and nitrogenous compounds while milk intake provides additional MP available directly to the calf. The complementation, in terms of microbial protein from ruminal digestion of forage and protein from postruminal digestion of milk, would, upon absorption from the small intestine, provide a high quality mixture of metabolizable amino acids to the calf. The calf is then provided with a nutritional environment that more nearly allows the expression of its genetic potential for growth. That environment cannot and would not be provided by the singular intake of grazed forages or milk alone. A combination of forage and milk is necessary to attain maximum production.

In order to prove that MP intake was the operant factor in the growth response to delayed weaning, it will be necessary to prove that suckled milk, in a 9-month old calf does in fact bypass the rumen. It will also be necessary to prove that milk ingested in such a manner leads to increases in nitrogen utilization.

A pilot trial was conducted to evaluate a proposed procedure for testing the above hypothesis. Glucose was used as a tracer to determine if the esophageal groove functioned to cause rumen bypass of ingesta. If digested in the rumen, glucose would be rapidly degraded and converted to volatile fatty acids. Hence, blood glucose levels would not change in response to glucose intake. If, however, glucose were digested in the abomasum, indicating rumen bypass, then a rapid rise in blood glucose would be observed. Glucose passes undegraded from the abomasum into the duodenum from where it is absorbed directly into the blood stream (Reik, 1954; Pritchard and Hennessy, 1981). A nitrogen balance trial, comparing the quantity of nitrogen ingested with that excreted, was conducted concurrently with the tracer study.

In the pilot trial, 2-month-old one Holstein bull calf was used. It was fed a basal diet containing approximately 74% TDN and 11% CP at a rate of 2.7% of body weight per day (2.5 kg/day). Milk was fed at 0.69 kg/day. A swithcback trial was conducted during which the calf received the entire diet in the dried form and suckled water from a bottle for seventeen days. It then received the milk as a suckle for the next seventeen days. A nitrogen balance trial was conducted, for each of the periods described. The calf was fed for ten days prior to data collection in each period to insure adjustment to the diet. It was then placed in a metabolism crate for a seven day collection period to allow measurement of nitrogen retention. Glucose was administered either with the dry feed or as a suckle, at one g glucose/kg body weight. Collection of blood at 30 minute intervals from 0 to 180 minutes after feeding allowed measurement of changes of blood glucose levels in response to method of feeding.

Feed, feces, urine and orts were analyzed by the Kjeldahl method (AOAC, 1975) for nitrogen content. Blood samples were centrifuged and the plasma removed, frozen and later analyzed for glucose. Plasma glucose content was determined colorimetrically using an o-toluidine reagent[1].

The results obtained indicate that glucose administration is a useful tracer for the measurement of esophageal groove function. As expected a rapid peak in blood glucose occurred within 60 to 120 minutes after feeding when glucose was administered in a suckle. When glucose was administered in the dry form no significant response in blood glucose was observed. Nitrogen retention was not affected by route of milk intake. This was unexpected because the milk was bypassing the rumen when suckled. The results of the nitrogen balance study do not necessarily indicate that nitrogen retention is not affected by route of milk intake. Studies with larger numbers of animals are needed before conclusions can be drawn as to the effect of route of milk intake on nitrogen retention.

[1]Pierce Chemical Co., Rockford, ILL 61110

CHAPTER V

PROPOSED RESEARCH

The Effect of Bypass Protein on the Grazing Calf

A definitive evaluation of the effect of MP on calf growth is needed to form reliable conclusions as to the actual mechanisms of response to delayed weaning. Intensive laboratory and field studies would be required to evaluate this aspect of calf nutrition. Calves between 200 and 300 days of age should be used. In an intensive study one could measure nitrogen retention in calves fed diets identical except for the form in which protein is offered. Diets high in energy content and low in total protein content in relation to the requirements of the calves used would insure accuracy of determination. The procedures outlined for the pilot study described in the general discussion would work well for collection of these data. In addition, the use of duodenal reentrant cannulas would allow further measurement of the amount and amino acid content of protein reaching the small intestine. This would provide a direct measure of qualitative and quantitative differences in protein available to the animal as influenced by feeding method.

An evaluation of the effect of dietary bypass protein on growth of calves grazing lush forage could be added as a third and fourth treatment to the present design of the delayed weaning study. Calves weaned at 200 days of age and provided with a supplement high in bypass protein could then be compared to calves weaned at 200 days and not supplemented. If bypass protein is an important effector of the gain response to delayed weaning, then the supplemented weaned calves should show a response similar to that of the delayed weaned calves. The addition of a fourth treatment, supplementation with a highly degradable protein source, would enhance interpretation even further. Proteins supplemented should be chosen on the basis of their having an amino acid content as similar to milk as possible. This would eliminate any effect of amino acid deficiency on observed response. To insure uniformity between bypass and degradable protein sources it would be advisable to choose a highly degradable protein source and treat it with heat or formalin to prevent rumen degradation. The untreated form could be used as the degradable protein source.

Stocking Rate and Net Efficiency of Production

An evaluation of the effect of stocking rate on production per hectare is needed to improve management recommendations for fall calving. Without such an evaluation it will not be possible to determine if delayed weaning has any effect on the efficiency of meat production. It is further suggested that the total feed input required to produce a slaughter calf be measured to evaluate the net efficiency of production as influenced by weaning age of the calf.

It is possible that weaning of fall born calves at 200 days of age would allow one to produce more total meat per acre than when weaning at 290 to 300 days. However, if one considers the total amount of time and feed required to produce a marketable slaughter animal then delayed weaning is likely to be the more efficient system. Delayed weaned calves are significantly heavier at 300 and 365 days of age than control weaned calves and thereby could go to the feedlot sooner and possibly be fed for a shorter time to reach slaugher grade.

Bedell (1981) suggests that grazing both cattle and sheep would optimize forage utilization for meat production on hill pastures. During the second year of the delayed weaning study, in progress at this time, sheep have followed the cow herd in the pasture rotation. This has allowed a faster rotation of the cow herd. Forage conditions at the Berry Creek ranch have definitely been improved with the addition of sheep to the system. At this time the sheep are owned and cared for by a private cooperator; and, therefore, collection of data from the sheep flock has not been possible. It would be preferable to use university owned sheep in this system so that management could be controlled as desired and data collection would be possible. From one year's experience, it appears that under the dual grazing at Berry Creek with pastures managed primarily to benefit the cattle, that the production of lambs for market in June is possible. Collection of data on both sheep and cattle would provide a much better estimate of production per hectare than is possible under the current situation.

Foster Calf Production

In the evaluation of twin foster calf production it was found that even though cows and foster calves failed to form permanent maternal-young bonds it was possible to produce more calf weight per cow with fostering than with single suckling. It was suggested that the failure of cows and calves to bond was due, primarily, to the foster calves not being presented during the critical period for establishment of a permanent maternal-young bond in the postparturient cow. The critical period for attachment in the cow appears to occur immediately after parturition and to be of very short duration.

The indepth study of maternal behavior in cattle is a relatively new field. The results obtained in the foster twinning study demonstrate how important behavioral alteration can be in terms of calf performance. Klopfer (1971) discussed research conducted in his laboratory which was aimed at identifying the hormonal changes which occur at parturition that prepare the dam for attachment to its newborn progeny. If a hormone or specific combination of hormones can be identified that provide the basis for maternal acceptance of young and could be produced for exogenous administration, then the fostering of calves onto cows would be a much more feasible management practice. Another alternative in the rearing of several calves per cow that merits interest, is the elimination of maternal-young bonding completely. Under this situation, cows would be restrained in an alley and calves would have free access to suckle. This process has been tried in New Zealand, with calves being nursed one or two times daily, with some success. The labor required under such a system would be substantially greater than that required for the rearing of single suckled calves, however, total production per cow might offset the cost of labor. Calf growth rates under restricted access suckling have been found to be less variable than with twin fostering (R. Kilgour, personal communication).

There are many interesting factors which can and do influence the production of fall born beef calves in western Oregon. Topics of interest cover a spectrum of research areas from forage production and management, animal nutrition and physiology to animal breeding and genetics. Integrated research addressed to all of these areas will be required to continue to improve the efficiency and profitability of production. A potential byproduct of this research will be the greater understanding of the biological factors which can be manipulated to effect the efficiency of sustained production of ruminant livestock for use as human food in a productive and somewhat complex ecosystem.

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